12th International Scientific Conference

Energy and Climate Change

PROCEEDINGS

organized by

Energy Policy and Development Centre (KEPA)

National and Kapodistrian University of Athens

2019

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Prof. Dimitrios MAVRAKIS

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6th Green Energy Investments Forum

9 October 2019, Athens – Greece
"Kostis Palamas", Akadimias 48 and Sina street

12TH International Scientific Conference on Energy and Climate Change

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CHAIR	**H.E. Amb. Traian CHEBELEU** Deputy Secretary General, BSEC-PERMIS
	Prof. Dimitrios MAVRAKIS Director of KEPA, National and Kapodistrian University of Athens (NKUA)
	Welcome
	Prof. Dimitrios MAVRAKIS Director of KEPA
SPEAKERS	**Mr. Adonis GEORGIADIS** Minister of Development & Investments
	Mr. Kostas FRAGOGIANNIS Deputy Minister for Economic Diplomacy and Openness, MFA
	H.E. Amb. Michael CHRISTIDES Secretary General, BSEC – PERMIS
	H.E. Amb. Juha PYYKKO Ambassador of Finland to Hellenic Republic *Finland's Presidency of the Council of the EU*
	Mr. Ramu DAMODARAN Chief of United Nations Academic Impact (UNAI)
10:30	*Coffee break*
10:45	**SESSION B: POLICY MAKERS**
	Prof. Asaf HAJIYEV Secretary General, PABSEC
	H.E. Amb. Anatol VANGHELI Ambassador at the Embassy of Moldova to the Hellenic Republic
	Mr. Charilaos ALEXOPOULOS Chairman-in-Office of the BSEC Business Council
	Prof. Dimitrios MAVRAKIS Director of KEPA
12:15	*Coffee break*

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12:30 **SESSION C: POLICY AND MARKET STAKEHOLDERS**

Mr. Georgios PATOULIS
Regional Governor of Attica

Mr. Andreas EFTHIMIOU
Mayor of Moschatou - Tavrou

Mr. Theofanis STATHIS
Mayor of Mouzaki

Video – Energy school in Mouzaki, Greece

Video – Shimokawa and SDGs, Japan

Mr. Guillaume Le BRIS
Associate Director/Sustainable Infrastructure Group, EBRD

Mr. Harris DAMASKOS
Principle Banker/Athens RO, EBRD

Mr. Roman MATKIWSKY
Director for Energy and Infrastructure, BSTDB

Mrs. Theodora ANTONAKAKI
The Bank of Greece

Mrs. Mavica ILIOU
Director, Piraeus Bank Group

Mrs. Marina KOTSORIDI
Manager, Piraeus Bank Group

Dr. Sotiris KAPELLOS
Energy Group of Hellenic-German Commercial and Industrial Chamber

15:30 *Networking cocktail reception*

16:30 **END OF FORUM**

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Scientific Sessions

10 October 2019, Athens – Greece
"Kostis Palamas", Akadimias 48 and Sina street

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09:00	*Registration*
9:30	**SESSION A: ENVIRONMENT – CLIMATE CHANGE**
CHAIR	Prof. Milton A. TYPAS, National and Kapodistrian University of Athens - Greece Prof. Andonaq Londo LAMANI, Polytechnic University of Tirana – Albania Video for Prof. Krzysztof WARMUZINSKI
SPEAKERS	**"Greening the Blue - Challenges and solutions in the energy sustainability shift in the maritime sector"** by Prof. Thor Ø. JENSEN, University of Bergen - Norway **"Applying Computable General Equilibrium Modelling to the Circular Economy"** by Dr. Hans KREMERS, ModlEcon S.à.r.l.-S, Esch-zur-Alzette - Luxembourg **"Citizens' perceptions in participating in recycling and circular processes"** by Dr. Eleftheria ALEXANDRI, Hellenic Open University – Greece **"CSP business models and value chain mapping: Insights from the CSP industry"** by Mr. George VASILEIOU, University of PIRAEUS-Greece **"Risk Governance in Public Sector - led transitions: The case of electrification of ferries in Norway"** by Prof. Tom SKAUGE, Western Norway University of Applied Sciences-Norway
11:30	*Coffee break*
11:45	**SESSION B: ENVIRONMENT – CLIMATE CHANGE**
CHAIR	Prof. Katherine M. PAPPAS, National and Kapodistrian University of Athens – Greece Prof. George PAPAGEORGIOU, EUC Research Centre – Cyprus
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Scientific Sessions

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"A survey of attitudes towards environmental and energy problems, impacts and policies",
by Prof. John A. PARAVANTIS, University of Piraeus – Greece

"Estimation of the resilience of urban parks in Athens»
by Dr. Eleftheria ALEXANDRI, Hellenic Open University – Greece

"Megacities, energy and climate change"
by Mr. Panagiotis D. TASIOS, National and Kapodistrian University of Athens – Greece

"Development prospects of the Hellenic natural gas market"
by Mr. I. NTROUKAS, National and Kapodistrian University of Athens – Greece

13:45 Light lunch

14:30 SESSION C: ENERGY EFFICIENCY

CHAIR
Prof. George HALKOS, University of Thessaly – Greece
Prof. Tom SKAUGE, Western Norway University of Applied Sciences - Norway

SPEAKERS

"Assessing Strategies for Cultivating an Energy Efficiency Culture"
by Prof. George PAPAGEORGIOU, EUC Research Centre – Cyprus

"Design tool for thermal energy storage in buildings"
by Dr. Nikolaos STATHOPOULOS, National Centre of Scientific Research "Demokritos" - Greece

"Multicriteria Analysis on the Energy Upgrade of a Cultural Heritage Building"
by Dr. Eleftheria ALEXANDRI, Hellenic Open University – Greece

"A case study of the energy refurbishment of a public building: Assessment of the current situation and evaluation of retrofit solutions"
by Mr. Andreas KYRIAKIDIS, University of Cyprus -Cyprus

"Computational Investigation to the Design Method of Centrifugal Fan Volute with the Aim of Increasing Energy Efficiency"
by Mr. Ardit GJETA Polytechnic University of Tirana- Albania

"The role of behavioral barriers in the natural gas penetration for the building sector"
by Dr. Popi KONIDARI, National and Kapodistrian University of Athens – Greece

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16:30	**SESSION D: RENEWABLE ENERGY SOURCES**
CHAIR	Prof. Evangelos DIALYNAS, National Technical University of Athens – Greece
	Prof. Thor Ø. JENSEN, University of Bergen – Norway
SPEAKERS	**"Towards non-carbon energy production: Technical and environmental assessment of enhanced strategies in CO_2 purification for geothermal power plant"** by Mrs. Andrea HERNÁNDEZ PEDRERO, Instituto Universitario de Investigación CIRCE – (Fundación CIRCE - Universidad de Zaragoza) - Spain
	"The application of ArcGIS for assessing the potential of solar energy in urban area: The case of Vranje" by Mr. Boban PAVLOVIC, University of Belgrade – Serbia
	"Generation of Photovoltaic output power forecast using artificial neural networks" by Mr. Abderrazzak ELAMIM, HASSAN II University - Morocco
	"The RES Auctions in Greece 2016-2019. Results and perspectives" by Dr. Dionysios PAPACHRISTOU, Regulatory Authority for Energy - Greece
	"The Renewable Energy Dimension of Energy Security" by Mrs. Nicole KONTOULIS, University of Piraeus – Greece
18:30	**End of Scientific Sessions**

Brokerage Event

11 October 2019, Athens – Greece
"Kostis Palamas", Akadimias 48 and Sina street

12TH INTERNATIONAL SCIENTIFIC CONFERENCE ON ENERGY AND CLIMATE CHANGE

AGENDA

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9:30	**SESSION A: FUNDING OPPORTUNITIES**
CHAIR	Prof. Andonaq Londo LAMANI, Polytechnic University of Tirana – Albania Prof. Constantinos KARAGIANNOPOULOS, National Technical University of Athens – Greece
SPEAKERS	**"HORIZON 2020 Open calls for "Climate Action""** by Mrs. Christiana SIAMBEKOU, PRAXI Network – Greece
	"HORIZON 2020 Open calls for Energy" by Mr. George MEGAS, National Documentation Centre (EKT/NHRF) – Greece
	"Youth Contest "Clean Energy in the combat for climate change" by Mrs. Vivian KLEIDERI, Association of Phycists - Greece
	"Energy school of Municipality Mouzaki" by Mr. Evangelos KATSAROS, Municipality of Mouzaki - Greece
	"Young Energy Europe" by Mr. Vasileios SAKKAS, Hellenic – German Commercial and Industrial Chamber - Greece
	"Building Energy Efficiency – Impact of Building Automation, Controls and Management" by Michos KIRIAKOS, Elemsi - Greece
	"DevelopmentAid. Connecting you to the world of business opportunities" by Mr. Sergiu CASU, Developmentaid – International organization
11:30	*Coffee break*
11:45	**SESSION B: PROJECTS**
CHAIR	Prof. Argiro DIMOUDI, University of Thrace – Greece Prof. Athanasios DAGOUMAS, University of Piraeus – Greece
SPEAKERS	**"From the Renewable Energy Islands - Tilos project, to 'Green' Ports and Ships"** by Mr. Panagiotis KTENIDIS, University of West Attica - Greece

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Brokerage Event

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"Climate change impact on Water Resources Management in remote islands using Hybrid Renewable Energy Systems"
by Dr. Elissavet FELONI, National Polytechnical University of Athens - Greece

"Renewable Energy Business Models for realizing the competitive advantage of renewable energy"
by Neda MUZHO, Vrije Universiteit Brussel and University of National and World Economy - Bulgaria

"Zero Energy Hospitals - The prospects for energy upgrade of hospital buildings in the Balkan region"
by Prof. Argiro DIMOUDI, University of Thrace – Greece

"ZERO – PLUS: Planning & Implementation of monitoring for the ZERO-PLUS Settlements – Lessons learned"
by Prof. Margarita ASSIMAKOPOULOU, National and Kapodistrian University of Athens - Greece

"Start-up of a network of PAR stations over mainland Spain and its applications"
by Mr. Francisco FERRERA-COBOS, CIEMAT - Spain

"Energy Efficiency on Greek islands buildings: the cases of HAPPEN and STEPPING"
by Mr. Stavros APOSTOLOU, Aegean Energy and Environment Agency – Greece

"Towards clean, affordable and reliable energy in insulated areas: the cases of SMILE and INSULAE projects on Greek islands"
by Mr. Petros MARKOPOULOS, Network of Sustainable Greek Islands (DAFNI) - Greece

"The "B-EU EFFICIENT" Proposal"
by Dr. Popi KONIDARI, National and Kapodistrian University of Athens - Greece

"Networking for H2020"
by Dr. Popi KONIDARI, National and Kapodistrian University of Athens - Greece

15:30 **END OF CONFERENCE**

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List of participants

A/A	Title	First Name	Last Name	Organization
1	Dr.	Eleftheria	Alexandri	Hellenic Open University
2	Mr.	Charilaos	Alexopoulos	BSEC Business Council
3	Mr.	Georgios	Andreakos	University of Patras, Hellas
4	Mrs.	Theodora	Antonakaki	The Bank of Greece
5	Dr.	Eleftherios	Antonopoulos	Ministry of Environment and Energy, Department of International and European Activities, Hellas
6	Mr.	Stavros	Apostolou	Aegean Energy and Environment Agency, Hellas
7	Prof.	Margarita	Assimakopoulos	National and Kapodistrian University of Athens, Departments of Physics, Hellas
8	Prof.	Evangelos	Baltas	National Technical University of Athens, Hellas
9	Mrs.	Artemis	Bertiou	Envinow, Hellas
10	Mr.	Loukas	Biniaris	National Technical University of Athens, Hellas
11	Mr.	Sergiu	Casu	DevelopmentAid, Moldova
12	Amb.	Traian	Chebeleu	Black Sea Economic Cooperation-PERMIS
13	Amb.	Michael	Christides	Black Sea Economic Cooperation-PERMIS
14	Prof.	Athanasios	Dagoumas	University of Piraeus, Hellas
15	Mr.	Harris	Damaskos	EBRD, Hellas
16	Mr.	Ramu	Damodaran	United Nations Academic Impact, U.S.A
17	Prof.	Evangelos	Dialynas	National Technical University of Athens, Hellas
18	Prof.	Argiro	Dimoudi	University of Thrace, Hellas
19	Mr.	Giannis	Dolas	Euronews, Hellas
20	Mr.	Vasilios	Dourmas	Univerisity of Patras, Hellas
21	Mr.	Andreas	Efthimiou	Municipality of Moschato-Tavros, Hellas
22	Mr.	Christos	Elias	GAIAOSE, Hellas
23	Dr.	Elissavet	Feloni	National Technical University of Athens, Hellas
24	Mr.	Francisco	Ferrera-Cobos	CIEMAT, Spain

25	Mr.	Kostas	Fragogiannis	Ministry of Foreign Affairs, Hellas
26	Mr.	Adonis	Georgiadis	Ministry of Development & Investments, Hellas
27	Mr.	Ardit	Gjeta	Polytechnic University of Tirana, Albania
28	Mr.	Konstantinos	Glinis	National Technical University of Athens, Hellas
29	Prof.	Asaf	Hajiyev	PABSEC, Turkey
30	Prof.	George	Halkos	University of Thessaly, Hellas
31	Mrs.	Andrea	Hernandez Pedrero	CIRCE, Spain
32	Amb.	Ardiana	Hobdary	Embassy of Albania in Hellenic Republic
33	Mrs.	Michaila	Hrevusova	Embassy of Slovakia in Hellenic Republic
34	Mrs.	Mavica	Iliou	Piraeus Bank Group, Hellas
35	Prof.	Thor Øivind	Jensen	University of Bergen, Norway
36	Mr.	Christos	Kalantzis	National Technical University of Athens, Hellas
37	Mr.	Alekos	Kalofolias	Greek-Chinese Society for Development & Cooperation, Hellas
38	Dr.	Sotiris	Kapellos	Hellenic-German Commercial & Industrial Chamber, Hellas
39	Prof.	Constantinos	Karagiannopoulos	National Technical University of Athens, Hellas
40	Mr.	Evangelos	Katsaros	Municipality of Mouzaki, Hellas
41	Prof.	Nabhan	Khayata	Rhein Main University of Applied Sciences, Germany
42	Mrs.	Vivian	Kleideri	Association of Phycists, Hellas
43	Dr.	Popi	Konidari	National and Kapodistrian University of Athens, Energy Policy and Development Centre (KEPA)
44	Mr.	George	Kontaxis	Municipality of Mouzaki, Hellas
45	Mrs.	Nicole	Kontoulis	University of Piraeus, Hellas
46	Mrs.	Marina	Kotsoridi	Piraeus Bank Group, Hellas
47	Mr.	Georgios	Kotsos	Hellenic Parliament
48	Dr.	Hans	Kremers	ModlEcon S.a.r.l.e, Luxembourg
49	Mr.	Panagiotis	Ktenidis	University of West Attica, Hellas
50	Mr.	Andreas	Kyriakidis	University of Cyprus
51	Mr.	Theodosis	Labrinos	National Technical University of Athens, Hellas

52	Mr.	Aristoklis	Lagos	National Technical University of Athens, Hellas
53	Prof.	Andonaq	Lamani	Polytechnic University of Tirana, Albania
54	Dr.	Luis	Lamani	Polytechnic University of Tirana, Albania
55	Mr.	Stamatis	Laskaris	Eclectic Consulting Trading Services P.C., Hellas
56	Mr.	Guillaume	Le Bris	EBRD, Hellas
57	Mr.	Theodoros	Liagas	National Technical University of Athens, Hellas
58	Dr.	Miltiadis	Makrygiannis	PABSEC, Turkey
59	Mr.	Kostantinos	Maniatopoulos	F. Director General, Energy E.C.
60	Mr.	Aimilios	Margaritis	Eclectic Consulting Trading Services P.C., Hellas
61	Mr.	Petros	Markopoulos	Network of Sustainable Greek islands (DAFNI)
62	Mr.	Roman	Matkiwsky	BSTDB, Hellas
63	Ms.	Aliki-Nefeli	Mavraki	National and Kapodistrian University of Athens, Energy Policy and Development Centre (KEPA)
64	Ms.	Eleni-Danai	Mavraki	Aegean Energy and Environment Agency, Hellas
65	Prof.	Dimitrios	Mavrakis	National and Kapodistrian University of Athens, Energy Policy and Development Centre (KEPA)
66	Dr.	Stavros	Mavroudeas	Environmental & Energy Advisors (Envena), Hellas
67	Mr.	George	Megas	National Documentation Centre, Hellas
68	Mr.	Kyriakos	Michos	Electrical & Mechanical System Integration (ELEMSI), Hellas
69	Mrs.	Vasiliki	Mitropoulou	Association of Phycists, Hellas
70	Mr.	Igor	Mityakov	Embassy of Russia in Hellenic Republic
71	Mr.	Poluchronis	Mpairactaris	Prefecture of Attica, Hellas
72	Ms.	Neda	Muzho	Vrije Universiteit Brussel and University of National and World Economy, Bulgaria
73	Mr.	Ioannis	Ntroukas	National and Kapodistrian University of Athens, Energy Policy and Development Centre (KEPA)
74	Dr.	Dionysios	Papachristou	Regulatory Authority for Energy (RAE), Hellas
75	Prof.	George	Papageorgiou	European University Cyprus Research Centre

76	Mr.	Christos	Papageorgiou	Association of Phycists, Hellas
77	Mr.	Abraham	Papakirillou	CFA Society Greece
78	Prof.	Katherine	Pappas	National and Kapodistrian University of Athens, Department of Biology, Hellas
79	Prof.	John	Paravantis	University of Piraeus, Hellas
80	Mrs.	Jenny	Passari	National and Kapodistrian University of Athens, Energy Policy and Development Centre (KEPA)
81	Mr.	Boban	Pavlovic	Univerisity of Belgrade, Serbia
82	Mrs.	Katanuon	Porvaznikova	Embassy of Slovakia in Hellenic Republic
83	Amb.	Juha	Pyykkö	Embassy of Finland in Hellenic Republic
84	Mr.	Michele	Rizzo	Politecnico Di Milano, Italy
85	Mrs.	Vasiliki	Roussou	Bank of Greece
86	Mr.	Vassilis	Sakas	Hellenic-German Commercial & Industrial Chamber, Hellas
87	Mrs.	Maria	Saliari	National and Kapodistrian University of Athens, Departments of Physics, Hellas
88	Mr.	Aleksandr	Sargsyan	Embassy of Armenia in Hellenic Republic
89	Mr.	George	Shoshitashvili	Embassy of Georgia in Hellenic Republic
90	Mrs.	Christiana	Siambekou	PRAXI Network, Hellas
91	Mr.	Konstantinos	Sirogiannis	National Technical University of Athens, Hellas
92	Prof.	Tom	Skauge	Western Norway University of Applied Sciences, Norway
93	Mr.	Theofanis	Stathis	Municipality of Mouzaki, Hellas
94	Mr.	Dimitrios	Stamatelopoulos	Electrical & Mechanical System Integration (ELEMSI), Hellas
95	Dr.	Nikolaos	Stathopoulos	National Centre of Scientifc Research "Demokritos", Hellas
96	Mr.	Panagiotis	Tasios	National and Kapodistrian University of Athens, Hellas
97	Mrs.	Eleni	Theodorakopoulou	Electrical & Mechanical System Integration (ELEMSI), Hellas
98	Mrs.	Symela	Touchtidou	Euronews, Hellas

99	Mr.	Konstantinos	Tsinnas	National Technical University of Athens, Hellas
100	Mrs.	Anastasia	Tsolaki	GAIAOSE, Hellas
101	Mr.	Apostolos	Tsorakis	Ministry of Foreign Affairs, Hellas
102	Prof.	Milton A.	Typas	National and Kapodistrian University of Athens, Department of Biology, Hellas
103	Amb.	Anatol	Vangheli	Embassy of Moldova in Hellenic Republic
104	Mr.	George	Vasileiou	University of Piraeus, Hellas
105	Mr.	Periklis	Vrachamis	National Technical University of Athens, Hellas

DAY 1: 6TH GREEN ENERGY INVESTMENTS FORUM

Session A: Policy makers

Welcome address for the 6th Green Energy Investments Forum by Prof. Dimitrios MAVRAKIS

Director of KEPA, National and Kapodistrian University of Athens, Hellas

Your Excellences,

Distinguished participants,

Dear Colleagues and postgraduate students,

It is with great pleasure and honor to welcome you at the opening of the 6th Green Energy Investments Forum that is jointly organized with PERMIS, the International Secretariat of the Black Sea Economic Cooperation Organization and coincides with the 12th Annual Scientific Conference on "Energy and Climate Change".

The Forum has been established with the aim to promote and facilitate green investments among the BSEC – MS.

This year, we enjoy the honor of the participation of the Minister of Development and Investments *Mr. Spyridon Adonis Georgiadis*, the Deputy Minister of the Hellenic Ministry of Foreign Affairs *Mr. Kostas Fragogiannis*, the Secretary-General of PERMIS, Ambassador *Michael Christides*, the Chief of United Nations Academic Impact *Mr. Ramu Damodaran*, from the UN headquarters in New York, the Secretary-General of the Parliamentary Assembly of the Black Sea Countries *Professor Asaf Hajiyev*, the Deputy Secretary-General of PERMIS Ambassador *Traian Chebeleu*, the Ambassador of Moldova *Anatol Vangheli*, the Regional Governor of Attiki Mr. Georgios Patoulis, the Mayors of Moschato – Tavros Mr. *Andreas Efthymiou* and of Mouzaki Mr. *Theofanis Stathis*, distinguished representatives from the European Development and Reconstruction Bank *Mr. Guillaume Le Bris* and *Mr. Harris Damaskos, Mr. Roman Matkiwsky* from the Black Sea Trade and Development Bank, *Ms. Theodora Antonakaki* from the Bank of Greece and *Mrs. Mavika Iliou* from the Bank of Piraeus.

The 6th Forum, responding to the call of the UN Secretary-General, aims to contribute in the efforts to increase our ambition on Climate Change actions. It defines a turning point in our orientation targeting the promotion and development of green and bankable project proposals based on a "Structured Policy Dialogue". This process will allow end-users to participate in the green transformation of their economies and benefit from the financing instruments of multilateral banks and international green funds.

The Forum aims to raise these issues among policy makers, representatives of multilateral financing institutions, market stakeholders, representatives of local societies and end-users during this first day.

We will discuss scientific issues in the frame of the 12th annual scientific conference tomorrow. Distinguished scientists participate in this international event presenting the outcomes of their scientific research. The brokerage event of the third day offers the opportunity to exchange views and proposals for concrete cooperation.

Our activities are financially supported, exclusively, by our sponsors the "Hellenic Petroleum", the Alpha Bank, the "Elemsi" and the GAI OSE, to whom we express our deep gratitude and the registration fees of the participants.

Finally, allow me to express my sincere gratitude to Dr. Popi Konidari and Mrs Jenny Passari for their devoted and remarkable efforts to organize this event.

The current session is chaired by his Excellency the Deputy Secretary-General of PERMIS Ambassador *Traian Chebeleu*, a devoted promoter of regional cooperation and inspired supporter of the green energy transition of the economies of the BSEC - MS.

Short CV

Prof. Dimitrios Mavrakis is the Director of KEPA, the UNAI hub for SDG7; coordinator of the "BSEC – Green Energy Network" focused on Renewable Energy Sources (RES) and Energy Efficiency (EE) for scientists, market stakeholders, and policy makers, from the countries of BSEC under the supervision of BSEC – PERMIS; coordinator of PROMITHEASnet, the Energy and Climate Change Policy Network, consisted of academic institutes from S.E. Europe, Black Sea and Central Asia; Chief editor of the "Energy View of the BSEC countries"; Chief editor of the "Euro-Asian Journal of Sustainable Energy Development Policy"; Editor of the worldwide disseminated "PROMITHEAS newsletter"; Chairman of the annual international scientific conference on "Energy and Climate Change" (12th year); Initiator of the European Energy Community. <u>Current activities:</u> promotion of regional cooperation on Climate Change Policy issues among academic institutions, governmental authorities and market stakeholders from the countries of EU and the BSEC; knowledge transfer about climate change, EE, RES, development of scenarios for mitigation/adaptation, looking-forward energy modelling; organization of the Green Energy Investments Fora within the BSEC region; participation in the BSEC Working Group on energy; coordinator of FP6, FP7 and H2020 projects. He was appointed by EC as member of the Advisory Groups on Energy (AGE) of E.C. for FP6 and FP7.

Opening speech
Mr. Spyridon - Adonis GEORGIADIS,
Minister of Development & Investments, Greece

Ladies and Gentlemen,

I welcome you to Greece and this conference,

Initially, I would like to emphasize that the current Greek government, especially Prime Minister *Mr. Kyriakos MITSOTAKIS*, is very much engaged in the combat against climate change.

We believe that humanity has to deal with this issue and stop pretending that everything proceeds as usual.

We have to find ways to be proactive. It is not an easy task, and not a matter for one single government or one state individually.

It is an issue that concerns the survival of humanity as a whole.

Unfortunately, we are not even close to achieving the targets we have set for the reduction of CO_2 emissions. The fact is that we are deviating badly from their accomplishment.

For what it concerns the Greek side, there are already announcements about the undertaken and planned actions.

Recently, our Prime Minister has emphasized, during his speech at the UN, in New York that we must do much more and act with bigger speed forward, in decarbonizing our energy sector.

Our ambition is to close all the lignite-fired power stations by 2028 since lignite is considered as the dirtiest coal, with high emission factors.

This is not an easy task for Greece, given that its energy sector is currently dependent on lignite. So, it is an enormous change and it implies a huge effort, but we are very ambitious in achieving it.

We have already launched tenders concerning renewable energy and natural gas plants and we are going to do even more in the future. We are determined to do as much as possible.

We have already discussed with the European Union about extra funding, especially for regions of Greece at Western Macedonia and at Megalopolis in Peloponnesus. These are regions whose local economies depend totally on lignite. Therefore, we have to find ways to assist them in transforming into a new kind of economy.

Be aware that it is not only the Greek government but also the Greek people that support such actions. I think that the vast majority is very sensitive on these matters and this majority of people is supporting us in the effort to fight with the rest of the nations for this really big challenge that we are dealing with.

We must not allow, just for the sake of the current type of global economy to jeopardize the survival of humanity, of flora and fauna and finally of this beautiful planet.

Whatever we are going to do, we have to do it very quickly.

Ladies and Gentlemen,

We are very happy to be with you at this conference about “Energy and Climate Change”.

You have our full support.

Thank you again for visiting our country and welcome.

Short CV

Mr. Spyridon – Adonis Georgiadis is a graduate of the Department of History and Archeology of the Philosophy School of the National and Kapodistrian University of Athens. In 1993 he undertook the management of the publications "GEORGIADIS - LIBRARY OF GREEKS". In 1994 he founded the Center for Free Studies "HELLENIC EDUCATION". He was elected as a Member of the Parliament in the elections of 2007 and 2009 under the political party of Laos. In February 2012, he joined the political party of New Democracy, resigning from his parliamentary position. He was elected with the New Democracy Party in the 2012 and 2015 national elections. In 2011 he was Deputy Minister of Shipping in the Government of Mr. Loukas Papadimou and in 2013 Minister of Health in the Government of Mr. Antonis Samaras. On January 18, 2016, he was appointed by the decision of Mr. Kyriakos Mitsotakis, the President of the New Democracy party, as one of the two Vice-Presidents of the party to supervise the parliamentary work of the party. On July 9, 2019, Mr. Georgiades was sworn as Minister of Development and Investments in the government of Mr. Kyriakos Mitsotakis.

Intervention points
Mr. Kostas FRAGOGIANNIS,

Deputy Minister for Economic Diplomacy and Openess,
Ministry of Foreign Affairs, Greece

Distinguished Guests,

Ladies and Gentlemen,

It is with great pleasure that I welcome you to Athens for the 6th Green Energy Investments Forum.

After a decade in which the words investment, economic growth and employment carried with them a negative charge in every discussion concerning Greek economic activity, I am pleased to stand before you and support that, at this moment, a new investment friendly, favourable wind, is blowing across the country. A strong political, economic and social momentum is formed, pushing us "forward", to a position long deserved by our country and its real substance.

Greece is reclaiming its position in the world business map as a country of extroversion and investment, with all national and institutional efforts spent in the service of this cause.

In this timing, with this determination, with the signs of climate change now plain for all to see, our government is called on to deliver on **a dual promise**:

Promote growth and investment; while at the same time take measures to confront climate change that could possibly affect, not only our efforts for business growth, but even current economic activity.

The truth is that a lot of people believe economic development and environmental protection are mutually excluding concepts.

Yet, in my opinion as Deputy Minister responsible for Economic Diplomacy and Openness, with a 30 years' experience in large-scale foreign investment, this dual goal is not only achievable, but Greece can become a case in point of the aforementioned fact/claim.

In the next few minutes, I will explain how green energy investment can actually serve both economic growth and protect the environment in Greece and the means employed by this government to achieve this.

With 19,000 kilometers of coastline and more than 100 inhabited islands, Greece is not only a country of great natural wealth, but its economic future is linked to its ability to protect its unique environment.

Climate change consequences in the form of aggravated weather phenomena and rising sea level, will have a detrimental effect to almost every facet of economic activity, from agriculture, to tourism, to infrastructure.

At the same time, we enjoy a privileged position at the energy and trade crossroads of Europe and Asia. With natural gas reserves reshaping the energy landscape of Eastern Mediterranean, Greece is developing rapidly into an energy and transit hub.

We have a vested interest, therefore, to both tackling climate change and promoting energy investment to achieve sustainable economic growth.

Taking into consideration the added benefit of Greek favourable climate conditions allowing for the development of green energy resources (solar, wind etc.), **promoting green investment does not only make sense, but will allow us to enjoy the best of both worlds.**

What are the means by which we aim to promote in concrete, tangible way green energy investments?

Step 1. By revising the Greek energy mix, phasing out the lignite share to the benefit of clean energy sources, we create Green Energy investment space.

This will be reflected, in the specific targets set and ambitious policies declared, in our **revised Energy and Climate National Plan**, as underlined by the Greek Prime Minister before the UN Summit for Climate Change.

Namely,

- the increase of the current 2030 RES target in the Greek energy mix from 31% to 35%.
- A more ambitious target respectively set for energy efficiency.
- And most importantly, our declared decision to phase out the lignite share in electricity production by 2028!

Our reasoning rests on the fact that **market will follow the RES investment opportunities created by replacing the lignite share in the energy mix with renewable resources and natural gas**. Raising the clean energy share in our energy mix creates ample energy space to be covered by green investment.

Step. 2. The **availability of funds and the processing time**, for an investment to take place, are key prerequisites for attracting investment, green or otherwise.

A nexus of policies that involve national and **EU investment financing tools offered, and bureaucratic hurdles regarding the issuance of permits, removed**, are consequently employed:

- Strengthening of the banking sector to support green investment,
- Making use of EU financial instruments from EIB, EBRD,
- and the future Just Transition Fund, set up to assist EU countries in their transition towards decarbonization,

Whereas,

- The digitalization (electronic applications) of the administrative issuance of investment permits will simplify and speed up administrative procedures.
- And the adoption of new environmental regulation terms will also accelerate investment processing times.

Ladies and gentlemen,

In the beginning of my speech I claimed green **energy policies are not incompatible to economic growth**, and most importantly Greek economic growth.

I rest my case on the fact that:

- **RES investment does not exclude small scale energy producers** that see in the increase of RES targets' an extra incentive to invest.

  While,

- the increase in **energy efficiency targets is a policy measure that will deliver a great deal of added value to local communities**.

  The energy upgrade of public and private buildings will support SME's and benefit local contractors, functioning as an economic multiplier to local communities.

- Our supporting policies towards natural gas as a transition fuel during the phasing out of lignite, **create investment opportunities in LNG terminals and corresponding infrastructures, but also in new transmission and distribution gas networks.**

Indeed, the recently upgraded **Revythousa LNG station** and the planed **LNG terminal in Alexandroupolis constitute an investment in themselves**, with the IGB pipeline connecting to Alexandroupolis' LNG station delivering natural gas to Eastern Europe.

In fact**, LNG distribution and transfer entails investment opportunities, in both shipping and transfer routes**, to the point of possibly creating **LNG refueling stations in Mediterranean ports** in the near future for vessels operating on LNG.

- Within 2020, the **National Plan for electromobility** will be formulated with special provisions for recharging stations for electric vehicles, beginning with the new buses in service in Athens and Thessaloniki.
- **Waste management** will be tackled within the next three years, with new investments of modern waste management and energy exploitation in cooperation with the private sector.

The non-mutually excluding concept of economic development and environmental protection is actually proven by the **series of green investments already enunciated.**

1. The interministerial Committee for Strategic Investment will approve the new Solar Electricity production Project by use of mineral salt in Crete. This is a green investment of €250mil., which will cover 10% of energy demand in Crete and will add 500 new jobs.
2. The development of 16 electricity production stations from RES (11 Solar, 5 Wind) in Serres and Voiotia, with a total budget of €172mil. has already been approved as has
3. the investment project of 12 Solar stations in Thessaly and Central Greece with a total budget €214mil.
4. The €300mil. investment project of electricity production by use of natural gas in Voiotia officially launched by the Greek PM the week before.

Greece emerges as a viable and credible transit country to European markets by adding more energy sources and routes. Our dedicated efforts on green energy investment are evident in all EU energy developments.[1]

Our natural wealth is part of our cultural legacy. The natural environment formulates in a considerable, if not critical way, the economic, social, even political parameters of a country, as it affects, the perspective of the citizens that live and grow within it.

In this framework, the emblematic example of the **island of Tilos, the first green and energy independent island in Greece**, shows the road ahead.

The era of mass investment, without regard for the natural environment has proven as counterproductive for long term profit, as cost inefficient, as proven by the benefits enjoyed by both businesses and countries that respected their natural wealth.

As we remain fully committed to the Paris Climate Agreement and UN Agenda for 2030 with 17 SDGs, Greece embodies the unique combination of culture, nature and opportunity.

The 2020 High Level Summit in Athens for the protection of cultural and environmental legacy from climate change will signify our comprehensive world outlook.

This is the time to reposition Greece in the world economic map and reclaim economic growth with respect to our environment and cultural legacy.

Thank you.

[1] Regarding the natural gas, we refer to the underground warehouse in Kavala; the right for construction and use of it, is under the Competition of the Hellenic Republic Asset Development Fund (TAIDEP). For electricity we mean small storage projects (batteries) that will take place at isolated grids and mainly at the planned TERNA pump in Amphilochia. Kavala and Amphilochia will be tomorrow in the new list of common interest EU projects the so-called PCIs (in the current list for the period 2017-2019, only Amphilochia is included).

Short CV

Kostas Fragogiannis was born in 1959, in Kavala, where he completed his basic education. After graduating from the British Institute of Marketing (HND), he continued his studies in the U.S., earning a BS in Business Administration and an MBA in International Management & Computer Systems from the University of San Francisco.

For over 30 years, he has held senior executive positions in major companies and groups, such as Emporiki Bank, Interbank, Delta, the Vasilakis Group, Ant1, the Viohalco Group, Vivartia, and the Chipita Group, where he was also a founding member of the Group’s international operations 24 years ago. Before assuming his duties as Deputy Minister of Foreign Affairs for Economic Diplomacy and Openness, he was the Development Manager of the Chipita Group, contributing significantly to the further growth and development of the Group's international operations.

Having successfully handled development projects worth hundreds of millions of euros throughout the world, he has gained invaluable experience in negotiating with organizations in countries where he has overseen investments. Through his role in the development and internationalization of companies, he has contributed to the creation of thousands of jobs, while also creating considerable added value in each country where he has been active. He has led a total of 18 productive investment projects in 16 countries, 9 investment consortiums, 5 buyouts and, finally, the founding of multiple commercial enterprises in dozens of countries.

Through his many years of international experience, he has gained a full and up-to-date perspective on what is required to effectively attract foreign investments and to promote exports and growth in the international economy.

Speech of Amb. Michael CHRISTIDES

BSEC PERMIS Secretary General

Ladies and gentlemen,

First of all, I would like to thank and congratulate the organizers. I would also like to thank the participants – especially the Ministers who participate for the first time and the other high-level representatives of the administration (national and regional). Their presence is the unmistakable proof that the effects of the BSEC- GEN and KEPA activities are meeting with the interest of more stakeholders.

This is the 12th Annual Scientific Conference (they started in 2008, under the auspices of BSEC).

The annual "Green Energy Investment Forum" was inaugurated in 2016 and we are already hosting its 6th edition. Not all of them were hosted in Greece – one took place in Turkey and another in Bulgaria.

We believe that the above efforts of all concerned, together with the activities of the relevant BSEC Working Group, offer a valuable vehicle in the wider Black Sea region for addressing the growing negative impact of Climate Change.

After so many years, we gained experience in organizing similar events; this Forum in Athens is perhaps the most "mature" in what concerns its preparation and the participation of stakeholders, Government representatives, policy makers, businessmen, IFI (bankers) etc.

We all know that these are issues we have to handle together, with systematic and well-structured cooperation: natural disasters provoked by Climate Change do not recognize neither do they respect national boundaries; we are all together sitting in our small globe's ship!

The BSEC Organization is here. It has thanks to KEPA and GEN accumulated valuable experience. Today it even comes forward with concrete projects of regional scope; our Member States have only to decide how better to take advantage and benefit from what "our" Organization has to offer.

Information Technology (IT) and Innovation for addressing these issues has also progressed enormously. It can give a decisive hand in our efforts to mitigate the effects of Climate Change.

So, allow me to conclude with an appeal to our Member States to show a greater "sense of ownership" towards the BSEC Organization and to try, in a coordinated way, to take advantage of the experience and work already achieved by GEN and KEPA.

Through this experience we can elaborate and finalize concrete projects, which will attract the interest of IFIs and, subsequently, that of the private sector. The sector of Energy could thus set the perfect example of tangible cooperation among the BSEC Member States, an example that hopefully will find followers also in other sectors of public life.

Short CV

Ambassador Michael B. CHRISTIDES is the Secretary General of the Permanent International Secretariat (PERMIS) of the Organization of the Black Sea Economic Cooperation (BSEC), headquartered in Istanbul, Turkey. Born in Thessaloniki, Greece in 1949, Ambassador CHRISTIDES joined the Hellenic MFA in 1976 as first in his Class and served with distinction until his retirement in August 2014. Among other assignments he served as Ambassador of Greece to Bulgaria, to Turkey and to Argentina and held senior posts in the Hellenic MFA. After his retirement Ambassador CHRISTIDES was elected by the BSEC Council of Ministers of Foreign Affairs as Secretary General of the BSEC PERMIS, assuming his duties on 1 July 2015. Following the unanimous endorsement by all BSEC Member States, the same Council of Ministers of Foreign Affairs reappointed on 15 December 2017 Ambassador CHRISTIDES for a second three-year term-in-office, as of 1 July 2018.

Intervention by Amb. Juha PYYKKÖ

Ambassador of Finland to Greece

Ladies and Gentlemen,

I'm sincerely sorry that the visit to Athens today of the Permanent State Secretary of the Ministry of Foreign Affairs of Finland is preventing me from attending this event and addressing myself the selective audience.

I heartedly wish that the Forum's works would bear fruit as to the necessary investments, which would promote the transition to low-carbon economies, as well as to achievement of the 7th Sustainable Development Goal.

Juha Pyykkö, Ambassador of Finland

(the speech was read to the participants)

Excellencies, Ladies and Gentlemen,

I would like to start by thanking the organizers of this event for their kind invitation to me to make an intervention on EU and Finnish green investment policies as a representative of the country, Finland, currently holding the Presidency of the Council of the European Union.

I will make brief points on four important issues, namely, generally on our fight against climate change; energy efficiency in buildings; the importance of switch to less emitting fuels; and finally on labour needs in the energy sector.

Ladies and Gentlemen,

the programme of the Government of Finland outlines that Finland will strive for climate neutrality by 2035. The goal is very ambitious. This target was set in June 2019 and our Government is currently analyzing scenarios for the future. The share of renewable energy is currently some 40 percent in our energy mix while the share of clean electricity, meaning renewables and nuclear, is around 80 percent.

The 2035 climate neutrality target will require new emission reduction measures and intensification of existing ones. These will be evaluated and outlined in the climate and energy strategy and other planning documents that are being worked out by the Finnish Government.

The Government currently coordinates industrial low-carbon roadmaps that will be developed in cooperation with the industry, in line with the new climate action. Sectoral roadmaps will help to ensure that any new emission reduction efforts that target the industry can be planned to be effective while still being realistic in terms of competitiveness. Finnish industry organizations are actively involved in the work.

Finland also advances the EU discussion on long-term climate vision. It is crucial that the EU climate vision will be ambitious based on the Commission's proposal of climate neutrality by 2050.

Ladies and Gentlemen,

buildings and construction consume half of the world's natural resources and about 40 percent of the world's energy. The sector accounts for about one third of global greenhouse gas emissions, as population growth, urbanization and rising sea levels further increase the need for construction.

To achieve our climate objectives, we must reduce the emissions from buildings and construction, and in the 2050s the sector should be completely carbon neutral. Energy efficiency will continue to be important, but we must also reduce emissions in new areas, especially in the manufacturing and recycling of construction materials.

There is an important EU regulation on near zero energy buildings which is important for efficient energy usage in new buildings. However, our building stock is renewed at a rate of just over one percent a year, although the rate of renewal of course varies depending on the country or the region. This is why significant energy-saving measures need to be applied to existing buildings, as well. In order to truly reduce the environmental impact of buildings, the most important and challenging task is to improve the energy performance of existing buildings.

One example of this effort is our carbon footprint-based approach on buildings. In Finland, the Ministry of the Environment has developed a methodology for assessing the carbon footprint of buildings. The methodology aims to facilitate the calculation of the climate impact of construction and covers the entire life cycle of a building, from the manufacture of construction materials to transportation and site operations, operation and repair, and end-of-life demolition.

The first version of the assessment method will be tested in construction projects during this fall season. During the testing period, the method is intended to be used for carbon footprint assessment of new buildings and large-scale renovations. After testing, the method is to be updated. The assessment method is based on the European Commission's Level (s) method and EN standards.

Ladies and Gentlemen,

addressing climate crisis necessitates a switch to less greenhouse gas emitting fuels. In Finland, the share of renewable energy is already around 40 percent of energy consumption, and as implied earlier, we are aiming at fully decarbonizing our energy system in the 2030s.

Currently modern bioenergy production is our stronghold in Finland with special expertise in usage of challenging bio and waste fuels as well as maximizing the electricity output from biomass energy production. Bioenergy is a clean local option in many parts of the world.

Raising share of variable renewable energy such as wind and solar power is a challenge to electricity grid stability. To ensure grid stability, there is a need for back-up power based on oil and gas engine capacity. In this context, for example gas engines can be good clean solutions to ensure the grid stability and to produce reliable energy on islands, as well.

In Finland we have built small import LNG terminals. Those help to clean our maritime transport and certain industrial processes. LNG can also be a fuel for electricity production on islands. For example, the island of Åland in Finland aims at being an island using 100 percent of renewables.

Ladies and Gentlemen,

the race for skilled professionals is intensifying in the labor market. Changes in business and restructuring in the energy sector give rise to the need for new professionals. In addition to increasing understanding of energy matters among the youth, we need young talents to work in companies. New attitudes and thinking create sustainable innovations enabling transition towards climate neutrality in the energy sector.

Consequently, there is a strong interest in the energy sector to attract new workforce - but not any kind of workforce. Renewable energy jobs are typically those that require higher levels of education and skills. According to the International Renewable Energy Agency (IRENA), jobs in the renewable energy sector will grow from the current 11 million to about 17 million by 2030. Thus, it is crucial for the energy sector to make the sector visible and attractive so that young talented women and men want to work in there.

In Finland, we have put a lot of effort into increasing equality in the work in the energy sector. We have also sought to highlight the importance of equality in other international contexts. We are an active participant in the IEA's Clean Energy, Education and Empowerment Partnership, and joined the Equal by 30 campaign last year. These initiatives promote equal opportunities in energy business.

Thank you for your attention.

Speech from Mr. Ramu DAMODARAN

Chief of United Nations Academic Impact,

Deputy Director for Partnership and Public Engagement in the United Nations Department of Public Information's Outreach Division

Thank you very much Mr. Chairman, thank you Prof. Mavrakis, my gratitude on behalf of the United Nations to the Energy Policy and Development Centre of the NKUA in Greece; you have been a very valuable supporter and a motivator of the United Nations Academic Impact, of our 1300 universities, and also of UN causes carried forward by so many of our distinguished friends. To everyone associated with the organization of this important conference, particularly Prof. Mavrakis and Dr. Konidari, my deepest appreciation and gratitude.

You have really built into the Centre the ability to compress both the challenge and the promise of energy and, in particular, to defeat the threat of climate change. That defeat is necessary, it is essential, and we are very grateful.

I am myself not a scientist, but my years at the United Nations, and as a global citizen if I may so dare to make the claim, have made clear the imperative of science in the resolution of problems that are summarily categorized as social, or economic, or even political. Science sustains what is at the heart of the United Nations, a set of values, and it is some of these that I will try to link to what we will discuss today. The value of truth, the value of energy going beyond the physical dimensions of energy to energy as a driving force and, above all, the premise of nations, states and governments which reflects the value of selfhood and self-determination. And the value of imagination in bringing these together, the inter-governmental and the global that goes beyond that collective norm, a value cherished and ably addressed by civil society and scholars and researchers like yourselves.

Just last week, on the second of October, the world commemorated the 150th birth anniversary of Mahatma Gandhi; I mention this because, as we remember him, we remember the one lesson that he left behind, the lesson of the absolute undeniable nature of truth. Once you accept the truth then that changes everything around it, but where the problem lies is in exercising the persuasion to allow the acknowledgement and acceptance of the truth. It is this acceptance that this series of international conferences has sought, based on core truths you identified and highlighted twelve years ago, but it remains necessary to rearticulate and to reaffirm it because there are hesitations and there are

doubters. And what this conference really brings together is the reason that must be called to play and the excellence individual investigation and research command, bringing the energy of science, in a very literal sense, to the realization of truth.

We meet today on the edges of a sea whose "turquoise coast "Mark Antony gave to Cleopatra as a wedding gift. A sea where Orpheus could compose music which, it was said, could move rocks. A sea where Jason and the Argonauts went in quest of the Golden Fleece. A sea where God, a little tired after creating the world, stopped to have supper and scattered crumbs from the food he was eating upon the earth. A sea, which over two centuries, saw many battles and yet the sea which harbored peace on two distinct occasions, in 1856 when the nations of Black Sea came together in unity and at the end of the Second World War, in Yalta , where Churchill, Roosevelt and Stalin got together to begin thinking about the new world which United Nations represents today.

So, we have, if you will, in the promise of that sea the sense of that truth because no matter what happens in it or even of what was once considered a myth. The idea of the lost city of Atlantis , long regarded as mythology , until 24 years ago it was proved to be possibly correct when scientists in the United States determined that is was very possible that a break in the Bosporus led to the complete submerging of an entire city, the hitherto mythical city of Atlantis. Which brings to mind the concept of "Polis" the idea of a city, a city both national and in its way international, like the city of Korinth which grew into the region of Korinthia, constantly expanding in geography and in unified political control.

History, and legend, are a glorious mixture of promise and hope; of ideas that were seared in the imagination and then realized the assertion of fact. Think of Prometheus who, at the very fundamental level, took the power of fire and energy from those who hoarded it and made it popularly accessible to the world at large. That heritage is with us today, a heritage that goes to the essence of the attributes Socrates saw essential in the city State, or nation, or, to extend the imagination, in united nations, qualities of wisdom, courage, justice and integrity. Think of those qualities and bring them to the Nations today, to a United Nations that fosters these with the intellectual leadership of women and men like you.

That leadership is, if I may venture to suggest, sustained by a very simple truth. That this earth has enough resources, enough energy, enough promise to the needs of its citizens. What we need to achieve targets is government action, the action of the financial and banking sector, as we will be discussing over the next three days, the involvement of citizens, and we at the United Nations working with institutions like KEPA and the skills and talents you command.

Think of what UN is doing in Albania in the area of small and medium enterprises, with a focus on youth involved, making certain that the young people and generation who are now in college receive a relevant and purposeful education ; public spending on education in Albania, in the last two years has increased dramatically precisely because of this.

Look at Azerbaijan where the State Oil Company of Azerbaijan, SOCAR, which is really known for harnessing conventional fuels, has turned around and is now leading innovation in Baku and other parts of Azerbaijan to allow cars driving on solar energy on the road.

Look at Georgia where the government and a European Union programme has started an initiative on waste, trying to contain its dimensions in this increasingly electronic age

Look at the Republic of Moldova which is working with the United Nations and the European Union to increase the renewable energy potential, starting in the streets of Chisinau and other parts of that lovely country, generating access to clean and sustainable energy to the population of the capital and other towns as well.

Look at the Russian Federation and its focus on energy efficiency in building management and construction.

Look at Turkey, where national legislation supports refugee education.

Look at Bulgaria where consumption of energy and renewable resources increased by nearly 10% in the first ten months of the year 2017.

And, of course, look at Greece, the promise of a fossil fuel free future, its ambitions articulated earlier this morning for 2021, its determination to define national statistics for energy and environment to be adopted by the end of this year.

Look at Romania where a large number of universities have introduced a new pattern of programmes in the areas of sustainable development, including through management and polytechnical education, leading again from individual futures to the future of the community and the nation.

Look at Ukraine, whose the energy development is committed to generate 25& of the country's energy from renewable sources before the year 2039.

I am suggesting all of these as instances to show what this great organization of cooperation, and the countries that constitute it, and by their governments, often working with the United Nations, and with civil society and scholars like yourselves can achieve, because you *know the truth.* And you have to persuade politicians, financers, bankers of the truth that you have discerned, that is at once both your destination and the road to that destination.

At the United Nations, as you probably know, we are extremely fond of acronyms. Allow me, in conclusion, to suggest one that can be summarized by the letters of the alphabet that constitute this great city of Athens.

Accepting Truth Helps Energise Nation States. ATHENS.

Yes. Nation states can be energized if we accept truth and truth will be constant, whichever way you look at it.

Today is – as some of you may know - a curious day in the calendar, the 9th of October, 2019.

When you write that date, it reads 9 10 2019. If you reverse those numbers, if you read it backwards, it will still be 9 10 2019. The same left to right or right to left.

That is what truth is. No matter which way you look at it, it will remain the truth. But there will be people who refuse to accept because somewhere in their minds is the struggle between what reason suggests is true and hope tries to believe is false.

You can change that. You are changing it. Looking around this room, the words of Homer resonate in the mind. “I know not what the future holds, I know who holds the future.”

For that, we are in your debt. Thank you.

Short CV

Mr. Ramu Damodaran is Deputy Director for Partnership and Public Engagement in the United Nations Department of Public Information’s Outreach Division and is chief of the United Nations Academic Impact initiative, which aligns institutions of higher learning and research with the objectives of the United Nations and the States and peoples who constitute it. He is also the current secretary of the United Nations Committee on Information. His earlier posts with the Organization have included the Departments of Peacekeeping and Special Political Questions, as well as the Executive Office of the Secretary-General. Ramu Damodaran has been a member of the Indian Foreign Service, where he was promoted to the rank of Ambassador, and where he served as Executive Assistant to the Prime Minister of India as well as in the diplomatic missions in Moscow and to the United Nations, and in a range of national governmental ministries.

Session B: Policy makers

Speech of Prof. Asaf HALIYEV

Secretary General of PABSEC

Dear participants,

I am very pleased and honoured to participate to the Sixth Green Energy Investments Forum, that takes place in the frame of the 12th Annual International Conference on "Energy and Climate Change". It really offers a great opportunity to discuss and be informed about developing projects and ways of investments that will assist the economies of the BSEC Member States to acquire a more "green" identity.

The Parliamentary Assembly of the Black Sea Economic Cooperation (PABSEC) has always been placing emphasis to the issues of Climate change, Green economy, Renewable energy and Environmental protection by discussing and adopting several Reports and Recommendations during the last years.

The Black Sea region is one of the main suppliers of energy to the world markets. Therefore, energy plays an important role in the economic development of this region. The development of infrastructure aimed at increasing oil and gas transportation and transit routes confirms the strategic importance of the Black Sea region in the field of energy and as a link connecting Europe and Asia. The Black Sea region is an integral part of the global energy market and is of strategic importance in the future development of energy relations.

I would like to underline the great importance of several energy pipe-lines as Baku-Tbilisi-Ceyhan (oil from Caspian Sea is delivered to the world market), recently built South Gas Corridor (TANAP and TAP) (gas from Caspian Sea is delivered to the European market) and Turkish Stream, where gas from Russia will be delivered to the European market. Despite the fact that Black Sea region is reach in energy resources, the issue of green energy is very important for the region; Firstly, it is necessary to protect environment and create more clean conditions for people who live in the region; Secondly, we have to think about future of our planet. We must not wear out our nature since it constitutes our debt for the next generation. At the same time a high level of IT allows to develop green energy issues.

In our Assembly, it has been stressed that developing a competitive regional energy market, by means of investments in the energy infrastructure, with the view to increase energy security, interconnectivity and further diversify energy sources and routes, is the priority task for the BSEC. Towards this end it is necessary to take gradual steps to materialize the vision of transforming the BSEC region into a model for clean energy by the year 2050 and to encourage cooperation among the Member States to define a Green Energy Strategy with the view to promoting renewable energy sources, clean technologies and energy efficiency.

Over recent years, the BSEC member states actively pursue the development of new energy policy that aims to ensure the energy security, the welfare and security of all citizens and the effective functioning and development of the economy, continued energy access at affordable prices with due account to the environmental challenges, and address the issues of sustainable development. The countries of the Black Sea region are introducing new technologies and largely investing in the development of the alternative energy market.

The Parliamentary Assembly of the Black Sea Economic Cooperation attaches great importance to the protection and preservation of the environment for the present and future generations, aiming at achieving the sustainable development in the BSEC Member States.

The PABSEC recognizes the need for close cooperation among the BSEC Member States in identifying and analysing the causes and the growing impact of global climate change in the Black Sea region. Exchange of information in this crucial area of environmental protection would be a useful contribution to both regional cooperation and the national environmental policies of the Member States.

Moreover, PABSEC acknowledges that governments play a critical role in creating appropriate frameworks to incentivize financial and capital markets to fund projects aimed at minimizing the harmful impact of global climate change. Such projects should optimize energy efficiency, promote renewable energy sources, and protect the industrial sectors most vulnerable to climate change: agriculture, tourism, forestry, water resources, and waste management. National, regional, and local public authorities must have the competence to identify priority environmental investments and help project owners, in particular the utilities sector, to implement viable environmental investment projects.

Furthermore, national parliaments should accelerate the process of improving the legislative framework in the context of the formation of a favourable investment climate for the development of renewable energy sources and support the creation of legal and institutional frameworks to take advantage of new opportunities for environmental financing, such as local financial markets, financing mechanisms related to activities to reduce greenhouse gas emissions, and debt-for environment swap.

Today in order to take effective measures towards decreasing the climate change affects in the world, it is necessary for strong international cooperation within the international framework. Cooperation at the trans-national, regional and local levels is of significant essence for efficient and effective address to the issue of climate change. The BSEC states along with the international organisations and civil society must engage in a constructive dialogue which yields tangible results.

Speech of Mr. Anatol VANGHELI

Ambassador of the Republic of Moldova to the Hellenic Republic

Dear Secretary General,
Dear Deputy Secretary-General,
Dear organizers of the event,
Dear participants,
Excellences Ambassadors,
Representatives of state and academic institutions,
Ladies and Gentlemen,

I would like to thank you for the invitation to participate at present Conference, at its 12th edition and to congratulate the organizers. This event, beside its importance both for diplomatic and scientific world, confirmed by your attendance today, gives us the possibility of addressing an important subject – climate change, which is not anymore treated like a national issue. The energy and climate change subjects found a honorable place both on countries and regional and international organizations agenda. The fact that last month, the United Nation General Assembly, in the presence of more than 100 leaders, started with a major climate change summit, is an eloquent example in that regard.

As many of you here today will address the subject from the country perspective, I would like to point out that for the Republic of Moldova, the promotion of the use of green energy continues to be a priority and the actions taken in this regard by the Government are in accordance with the legislation of European Union and international standards. It is important to specify that if on other subjects, Governments can have different opinions or views, on green energy and on combating the negative impacts of climate change it stays the same. For the Republic of Moldova, the use of green energy means has multiples implications – it is ecological friendly, also a way of diversification of energy supply paths, which means more security and creates premises for a sustainable economic development of the country. In this regard, state energy policy from renewable sources continue to be implemented through local, sectorial and state programs, along with the contribution of foreign donors and investors, which is further encouraged.

Having said that, I would like to thank the organizers for the invitation to participate and wish you success in debating new incentives to the development and use of green energy, both at legislative and executive levels, in our countries and in whole region, based on the best practices. Let me express the hope that today event, as the previous one which I had the pleasure to be part of, will provide a platform to exchange views, experience and best practices among BSEC member states.

Thank you.

Speech of Mr. Charilaos ALEXOPOULOS

Chairman- in – Office of the BSEC Business Council

Your Excellency Minister, Mr. Georgiadis,

Your Excellency Deputy Minister, Mr. Fragogiannis,

Your Excellency Ambassador, Mr. Christides,

Your Excellency Prof. Hajiyev,

Your Excellencies Ambassador Pyyka and Ambassador Vangheli,

Honorable Mr. Damodaran,

Honorable Mayors,

Distinguished speakers and guests,

Ladies and Gentlemen,

Please allow me to first greet and thank Professor Mavrakis for the invitation extended to me as the Representative and Chairman-in-Office of the Business Council of BSEC for the period July – December 2019. It is a great honor to be among such distinguished personalities in such an important event.

Thank you Professor Mavrakis for giving us the opportunity to make known the presence and the functions of a body which, although being by one of the oldest in the context of the Black Sea Economic Cooperation –actually it was established in 1992 - receives such a small publicity and attention relative to the other related Organizations.

Having the accreditation of their Governments' appointment, the members of the Business Council have the privilege and the duty to represent and connect the business world of the 12 countries that comprise the Organization. The representatives of Albania, Armenia, Azerbaijan, Bulgaria, Georgia, Greece, Moldova, Romania, Russia, Serbia, Turkey and Ukraine aim to promote business cooperation and regional integration in the Wider Black Sea Area, as well as to secure their businesses' integration into the global business system. Through lobbying and acting for the continuous improvement of the business environment throughout the Black Sea region, the BSEC Business Council aims to help local business people to attract foreign investment in their countries.

The statutory provisions of the Business Council of BSEC describe in a clean way its mission, thus establishing the context and the guidelines of a regional cooperation among the Chambers of Commerce and Industry and other official Organizations of the Black Sea Region business communities. These are summarized in:

(i) Lobbying and acting for the continuous improvement of the business and investment environment throughout the BSEC region, which will both benefit local business people and help attract foreign investors;

(ii) Acting as a catalyst and ensure the involvement of the business communities in the BSEC process;

(iii) Providing a platform for a dialogue between the private and public sectors and for joint reviews of business needs, opportunities, challenges and other issues;

(iv) Catalysing the process of Public Private Partnership (PPP) in the BSEC region;

(v) Facilitating, through trade conferences, business fora, fairs, exhibitions, sectoral meetings and through the Internet, etc., regional and global trade, the establishment of joint ventures and other strategic partnerships, the exchange of experiences and know-how, as well as other forms of cooperation among business people, thus contributing to the increase of economic interdependence within the BSEC region;

(vi) Actively helping attract Foreign Direct Investment in the Black Sea Region by providing, through targeted promotion, investment fora, international conferences, fairs and exhibitions, road shows and special Internet sites a showcase for the region's strengths and opportunities, resources, products, know-how and human talent to the rest of the world;

(vii) Helping enhance the competitiveness of SMEs through management training, marketing training, assistance in developing e-business as well as through other technical assistance programs;

(viii) Helping SMEs take advantage of the globalisation process by giving them export training and information on foreign market opportunities as well as by helping them network with foreign customers, suppliers and sub-contractors;

(ix) Facilitate the networking of business people with Universities and Research Institutes, as well as with other business people, both within and outside the Black Sea Region, in order to help them identify innovation opportunities;

(x) Developing joint projects of cooperation, by paying equal attention both to the end result and to the actual process of working together;

(xi) Helping with the building of new business institutions in the Region, such as national and regional sectoral associations, and provide assistance to existing institutions so they can improve their effectiveness in serving their own business constituencies;

(xii) Fostering better mutual understanding of the Region's national and business cultures and help pave the way for a more effective intercultural business communication and cooperation;

(xiii) Collecting and disseminating statistical data and information on business conditions and business opportunities in the Black Sea Region;

Ladies and Gentlemen,

Please do not be overwhelmed by the enumeration of all the above activities. These do not form any achievements yet. But they actually form a good, solid basis for achieving the aim. And the aim is so clean as the Green Energy that in our days looks an inevitable "must". For the sake of our planet, for the sake of our nations, … lastly, for the sake of our businesses.

Thank you for your attention.

Short CV

Mr. Alexopoulos was born in Thessaloniki on September 28, 1966. He graduated from the High School of the German School of Thessaloniki in 1984 and in 1990 he obtained the Masters in Mechanical Engineering from the Aristotle University of Thessaloniki. In 1991 he got the title of MBA from the Business School of City University of London.

He was a shareholder and manager of the Elementary School "Philippos Alexandros SA" and the company of technical consultants DOMOPLAN LTD. Shareholder and member of the Board of Directors of hotel chain DOMOTEL SA. Currently he is a shareholder and member of the Board of Directors of the general contractor DOMOTECHNIKI SA, as well as of the two subsidiaries that the company operates in Sarajevo and Skopje.

He was President of the Association of Alumni of the German School of Thessaloniki and President of the female volleyball team of Epicuros Polichnis (A1 National). He is a member of the Board of Directors of the Federation of Industries of Greece (FIG) and of the Thessaloniki Chamber of Commerce and Industry (TCCI), having served as 2nd Vice President in both Organizations. Today he is a member of the Board of Directors of Thessaloniki Tourism Promotion and Marketing Agency.

He is a member of the Business Council of the international organization BSEC (Black Sea Economic Cooperation Organization) and Chairman of the National Committee of Greece. Since March 2014 he is the Honorary Consul General of Japan in Thessaloniki.

He is married to psychologist Lara Soues, having two children, a daughter and a son.

Fostering Green Energy Investments

Prof. Dimitrios Mavrakis
BSEC – GEN Coordinator, UNAI Hub SDG7

The melt of ice and permafrost land in the arctic, the opening of the north arctic maritime route from the Sea of Barents to the Pacific Ocean, the successive hurricanes in Caribbean Sea and the Gulf of Mexico, the wildfires in the eternal Siberian forests, the floods and fires in Europe and in Asia occurs in parallel with the ongoing debate over the occurring or not of the Climate Change and the emerging failure to achieve the set goals during the UNFCCC COP 20 in Lima, in 2014.

It has taken almost half a century to our societies, starting from the conference in Stockholm in 1972, to conclude that humanity should set as goals for its survival, to keep the increase of the mean atmospheric temperature up to the year 2100 below the 2^{o}C or even if possible below the 1.5^{o}C.

During the COP 21 in 2015, the parties of UNFCCC have signed the Paris Agreement that included their Intended National Contributions (INDCs), to accomplish the set goals in Lima.

In addition, the Green Climate Fund was established as the financing instrument to support countries, with developing and underdeveloped economies, to implement their commitments.

Those INDCs were expected to allow achieving the set goals, provided that until 2020 it would have been achieved the peaking of GHG emissions.

One year later in 2016, the parties ratified the Agreement and transformed their INDCs into conditional and non-conditional NDCs.

Conditional NDCs expressed the reservation of the signatory parties to fulfill their commitments under the precondition of receiving the necessary external financing support.

Apart from the global euphoria disseminated by the media, it was obvious that Paris agreement, as the outcome of hard negotiations between the rich and the poor of the planet, have had not the potential to put the global economy in the declared 2^{o}C and 1.5^{o}C trajectories.

Even the proudly announced commitment of the developed economies to allocate initially, through the Green Climate Fund, one hundred billion US dollars a year to 2020 to developing or under-development economies was not realized apart from an initial contribution below the amount of the $100 billion.

Official Reports circulated by the United Nations Environment Programme has shown that NDCs, even fully implemented, cover only one-third of the emissions reduction needed for staying well 2^{o}C. In addition, ratified NDCs are not binding the signatories as a matter of international law. There is not a mechanism to force a country to set a target by date and no enforcement exists if a set target is not met.

Now in the eve of 2020 it has been announced that we fail to accomplish the GHG emissions' peaking and we continue increasing the CO_2 atmospheric concentration.

According to a communication of the Global Carbon Budget last year, the percentage change of carbon emissions since 2000 in China has increased by 208%, in India by 155%, in all other countries by 53% and only in US and EU have decreased by 10% and 16%, respectively.

For a better understanding of the situation it is worth mentioning that during the past 400.000 years up to the mid-18th century, the CO_2 concentration in the air fluctuated below the 280ppm. Following a recent announcement of NASA, the CO_2 concentration in August 2019 has reached the 412 ppm, up about 4ppm from the same time last year.

For those not familiar with the ppm as a measurement unit, allow me to clarify that 1ppm is equal to 2.13 $GtCO_2e$ with 1$GtCO_2e$ corresponding to annual emissions on the transportation sector in the EU, including air transports.

With the current value of 412 ppm and the 450 ppm as the high limit of atmospheric concentration of CO_2 for the 2°C up to 2100, it is clear that we are losing the set goals for good.

It is in this base that the Intergovernmental Panel on Climate Change has had warned last October 2018 that we consume fast, the remaining carbon budget we can emit in the atmosphere.

The ugly reality is that apart from the scenarios we develop for the evolution of current policies, the implementation of unconditional or conditional NDCs until 2030, the forecasts are that we will overpass the all-time budget to remain below the 1.5°C and we will be quite close to overpass the 2°C level before 2050.

An irreversible process is in progress leading to the destructive increases around the 3°C or even higher.

Regardless of nice speeches, luxurious international conferences or angry demonstrations of young people, the answer to the threat of Climate Change is the fast transformation of our fossil fuels based global economy into a zero carbon-emitting green economy.

On the other hand, we know, we have to know that the reality is different. The occurring green transition is slow, the allocated funds insufficient, and most important the attitudes and behaviors of our policy leaders less ambitious comparing to the challenges we face as humanity.

We have not the luxury behaving like the giraffes, hiding our heads in the poisoned sand of irresponsibility.

It is now the time to listen the continuous warnings of the Secretary – General of the United Nations that *"it is absolutely essential that countries commit themselves to increase what was promised in Paris because what was promised in Paris is not enough and what was promised in Paris is not even being implemented at the present moment ... We need more ambition; we need a stronger commitment."*

It is thus now the time for commitments and action and this is the aim of the current Forum.

The Energy Policy and Development Center in its dual capacity as coordinator of the BSEC Green Energy network and as the global UNAI Hub for the SDG7 responding to the call of the UN SG have worked for almost one year outlining a number of initiatives with ideas that can be transformed into bankable investment proposals with the active involvement of end-users, local municipalities and market stakeholders including multilateral banks.

We propose the following investment initiatives relevant to SDG7 with the aim to increase the ambition among our local societies to combat climate change.

The initiatives target the development of project – proposals on:

1. *Energy Efficiency in buildings of the public and private sector, up to the level of Smart Zero Energy – SZEB, combining "Smart Building – Smart Finance" procedures*. This puts emphasis on implementing existing technologies leading to Zero Energy consuming buildings and the introduction of smart technologies leading to decentralized energy solutions with RES and virtual networking playing a decisive role.
2. *Energy Poverty by aggregating energy-poor end-users in Energy Communities and transforming them into energy prosumers, combining "Smart Buildings – Smart Finance" procedures*.

   Apart from its social dimension, resolving Energy poverty in a sustainable perspective contributes to the reduction of GHG emissions and what is also important contributes to normalize the operation of their national electricity markets. Aggregating poor energy consumers in legal entities like the Energy Communities with the active involvement of their municipalities is the crucial starting line for this initiative.

3. *Increase the penetration rate of Natural Gas and RES in local markets, in close cooperation with Regional Governors, Mayors and private investors.* This includes both the expansion

of already existing networks and the construction of new in cities so far not interconnected to the main network.

Behavioral barriers and bureaucratic obstacles are the main obstacles that should be overcome to accelerate the expansion of existing networks. On the other hand, the interconnection of a number of new cities with the main network necessitates a well-planned project that will transform initial wishes into reality. Regions and municipalities can play a decisive role in facilitating the implementation of the necessary works, attracting private investors and most important motivating local end-users to benefit from NG.

4. *Development and networking of Small Scale LNG installations in remote areas of the mainland and of the islands.* Small Scale LNG installations will prove to be the necessary bridging solution, in the perspective of the zero-emitting society of 2050. It is an expensive solution if it will not be developed from a network perspective. On the other hand, it fits very well to the existing needs of the Greek Islands if it will be properly designed. Again the cooperative role of local societies will be decisive.
5. *LNG introduction in maritime transportation (IMO 2020, IMO 2050), heavy road transport, off-grid power generation, plus local consumers*: IMO has undertaken the commitment for gradual zero CO_2 emissions up to 2050. The use of less emitting LNG technologies as a bridge to the final goal is a necessity. We don't know what will be the technologies for the global fleet but the solution has to be found in the coming decade if new carriers are expected to be launched in the big shipyards.
6. *Electrification of short-medium maritime transportation routes.* This is a technology already in use for short-medium distances, quite friendly for ferryboats in short routes in Greece, provided that the costs can be acceptable. We have already a relevant project under development in Greece. More details will be presented in the sessions of the third day and we consider that the optimum combination could be based on energy community producing and storing electricity from RES or wastes.
7. *Deployment of a Youth Contest on SDG7*, targeting the familiarization of youth, their families and societies with the concepts and the associated activities of SDG7.This concerns an initiative that we already promote through the Hellenic Association of Greek Physicists and local municipalities. It is an initiative that aspires to expand in the countries of the BSEC and globally.

We also propose a clear and structured process for the transformation of ideas based on these initiatives into projects. We name it as "Structured Policy Dialogue" and it includes the gradual engagement of all necessary actors up the final operational stage, including MRV procedures. Further to that and based on the BSEC – Green Energy Network, in close cooperation with the Permanent International Secretariat of BSEC we plan to incorporate relevant projects from the BSEC - MS into International Cooperative Initiatives (ICIs) in the frame of the Non-State National and Sub-national Actors (NSA) functioning under the UNFCCC with the assistance of UNAI in the headquarters of the United Nations in N.Y.

We invite potential partners to participate in the efforts to develop and implement Green Energy projects to join the UNAI Hub SDG7 Society.

We already work together with colleagues and municipalities from Albania, Bulgaria, Serbia, Italy and Great Britain, Japan, Moldova, Russian Federation, Romania and Armenia while we already have made the first steps of cooperation with the Municipality of Moschato - Tavros and we are in the process of exchanging ideas with the Region of Attiki and the municipalities of Muzaki and hopefully with the Municipality of Piraeus.

Based on our experience, so far, we understand that the implementation of our proposals seems to be as "mission impossible" but if we can motivate you to cooperate, we can change it to "mission possible".

It is for this reason that we make an appeal to all of you to follow the UN-SG call to increase your ambition by providing concrete and effective political and economic support to our initiatives. We especially invite Regional Governors and Mayors, to lead in the efforts to motivate their societies, through the proposed actions, and participate in the global efforts to accelerate the green transformation of our economies.

Follow us and register in the UNAI Hub SDG7 society in the frame of the BSEC – GEN.

Follow us and participate actively by developing and implementing bankable green energy investments in sub-national levels and aggregate them in International Cooperative Initiatives under the UNFCCC through the BSEC activities.

Session C: Policy and market stakeholders

Policies of the Municipality of Moschato – Tavros for the decrease of carbon imprint and the use of renewable energy sources

Andreas EFTHIMIOU
Mayor of Moschatou - Tavrou

Good morning

It is a great honor for me to be here among you and share my thoughts with you, the most experts in energy and climate change issues.

First of all, let me introduce myself.

I am Andreas Efthimiou, the Mayor of Municipality of Moschato – Tavros. I have a Master's Degree in "Physiscs" and Diploma in "Hydraulic Engineering" with a Master's Degree in "Development and Environment" and I work at the Civil Aviation Authority too.

The municipality of Moschato – Tavros came from the join of two municipalities in 2011, the Municipality of Moschato and the Municipality of Tavros. Two cities with completely different urban planning, social and cultural characteristics.

A municipality of a total 5,24 square kilometers which is situated between Athens and Piraeus and on its south side has a coastal front extended for 1 km. The uses of the area are mostly for residence purposes as long as for productive activities and service provisions mainly at the city of Tavros. The population of the city is about 42.000 thousand people but they actually live and work more than 60.000 (sixty) people.

Many great cultural institutions (Michael Cacoyannis Foundations, Hellenic Cosmos Cultural Centre, Athens Festival) are also based in the region as long as three University Foundations (Institution Of Fine Arts, Harokopio University, Athens University of Applied Sciences).

In the city area and mainly in Tavros there are a lot of old refugee block of flats and worker apartment buildings. Due to the oldness of the buildings and the residents' low standard of living as a result of the high percentage of unemployment, the issue of energy poverty becomes particularly intense.

In the context of its environmental policy, energy saving and confrontation of the environmental change phenomenon the Municipality of Moschato – Tavros applies a series of policies and actions among which is the participation of the municipality in the Mayors Sustainable Energy Action Plan, which in summary includes monitoring of the the performance of Sustainable Energy Action Plan (SEAP) implementation of the Municipality of Moschato - Tavros. This report is submitted four years after the submission of the SEAP by the Municipality of Moschato - Tavros at the Office of the Covenant of Mayors and refers to the achievements in the period from 2014 to 2017. This report provides an overview on the calculation of energy consumption and CO2 (carbon dioxide) emissions in Moschato – Tavros Municipality, as well as on the progress of the list of the related actions proposed in the SEAP.

As reflected in the results presented in this report, the percentage of CO_2 (carbon dioxide) emission's reduction in the Municipality of Moschato - Tavros has exceeded the target set in the SEAP (Sustainable Energy Action Plan) and is equal to 20% of the 2009 emissions by 2020.

The replacement of diesel boilers with higher efficiency boilers and the installation of natural gas boilers justify the reduction in the consumption of heating oil as well as the significant increase in natural gas consumption for heating purposes. Moreover, the improvements due to the thermal insulation of residential buildings and their overall energy upgrade through the "Saving at Home" (call implemented by NSRF) is likely to have played a major role on the overall improvements achieved in the residential sector in terms of energy consumption and CO_2 emissions.

The large-scale installation of photovoltaic cells, which are also contributing to the local power generation, has a major impact on the achievement of the CO_2 reduction target. The installed solar power capacity in 2017 is about 27 times larger than in the reference year. The Municipality promoted these actions, as it proceeded in the installation of six (6) units in five (5) schools and in the Indoor Gym of the Municipality of Moschato – Tavros, approximately 100 kwp power.

Based on the above data, the savings in energy consumption are extremely important and are accompanied by an equally significant reduction in CO_2 emissions of 51%, which exceeds the target set by the Municipality of Moschato - Tavros in the SEAP (Sustainable Energy Action Plan).

In the near future the Municipality's planning includes

1) Replacement of the municipal lighting with low consumption lamps (LED).

2) Expansion of the natural gas network at the whole city and connection of all the municipal buildings (schools etc).

3) Continuation of the energy upgrade program for the municipal buildings (schools, athletic facilities etc).

4) Continuation of the photovoltaics installation. Until now they have been installed 100kwp.

5) Citizen's environmental training, especially at the students.

6) Promotion of the circular economy and more green spots creation.

The biggest problem however is that of energy poverty which affects thousands of the inhabitants.

For the confrontation of the problem the municipality is orientated in the establishment of energy communities in cooperation with Energy Policy and Development Centre of the National and Kapodistrian University of Athens, the private sector and others.

We are planning

1) Cooperation with companies for the inhabitant's houses insulation.

2) Expansion of the photovoltaic systems for the provision of free electric power.

3) Expansion of the natural gas network (Study of the Energy Policy and Development Centre).

4) Competition among the University and Institutions for the study and construction of a ZEB nursery school in cooperation with the Institute of Passive Building.

5) Educational programs for the students on issues of saving energy, environmental protection and actions in order to be approached the levels of a ZEB school.

For all the above there has been established cooperation with the Energy Policy and Development Centre of the National and Kapodistrian University of Athens, the Hellenic Physical Society, the Department of Mechanical Energy of the University of Western Macedonia (UOWM), the National Technical University of Athens and other scientific institutions.

Many thanks to Mr. Ramu Damodaran and my professor Mr. Dimitrios Mavrakis.

Thank you.

Short CV

Born in 1958, he studied Physics at the University of Athens and holds a Master's Degree in "Telecommunications and Automation". He is a qualified Civil Engineer with a postgraduate diploma in the sector of "Environment and Development" from the National Technical University of Athens.

He has a long and successful career in the private sector, as a professor at Public Institutes of Professional Training and a cooperative partner at the National Technical University of Athens. At present he is an air traffic controller at the Civil Aviation Service. He has been elected as a city councilor since 1987, serving for several years from all the responsible posts of the municipal authority. He was elected Mayor in the Municipality of Moschato – Tavros in 2011, 2014 and 2019.

Energy School in Mouzaki

Mr. Theofanis STATHIS, Mayor of Mouzaki, Greece


NORTH SIDE
10 _1ο Σχολείου Μουζακίου 07-10-2019 για ομιλια Δημάρχου Μουζακιου
Φάνη Στάθη


NORTH SIDE
10 _1ο Σχολείου Μουζακίου 07-10-2019 για ομιλια Δημάρχου Μουζακιου
Φάνη Στάθη


SOLAR PANELS WITH VACUUM TUBES FOR HOT WATER
AND HEATING
10 _1ο Σχολείου Μουζακίου 07-10-2019 για ομιλια Δημάρχου Μουζακιου
Φάνη Στάθη


EAST SIDE


SQUARE FOOTAGE OF THE
BASEMENT =977.76 m2


SQUARE FOOTAGE OF THE
BASEMENT =977.76 m2


SQUARE FOOTAGE OF THE
1ST FLOOR =701,49 m2
10 _1ο Σχολείου Μουζακίου 07-10-2019 για ομιλια Δημάρχου Μουζακιου
Φάνη Στάθη


NORTH SIDE
10 _1ο Σχολείου Μουζακίου 07-10-2019 για ομιλια Δημάρχου Μουζακιου
Φάνη Στάθη


90% HEAT RECOVERY SYSTEM VENTILATION
10 _1ο Σχολείου Μουζακίου 07-10-2019 για ομιλια Δημάρχου Μουζακιου
Φάνη Στάθη


UWindows: 1.40-1.80 W/m2K
1st Mouzaki Elementary School: UWindows 0.07-1.2 0 W / m2K


URoofs: 0.15-0.30 W/m2K
1st Mouzaki Elementary School: URoofs0.10-0.20 W / m2K
10 _1ο Σχολείου Μουζακίου 07-10-2019 για ομιλια Δημάρχου Μουζακιου
Φάνη Στάθη


10 _1ο Σχολείου Μουζακίου 07-10-2019 για ομιλια Δημάρχου Μουζακιου
Φάνη Στάθη

SDGs, Shimokawa, and Me - Shimokawa Town's effort in achieving SDGs

Hitomi SHIMIZU,

Shimokawa SDGs Ambassador,

Shimokawa Town Hall, Hokkaido - Keio University, Japan.

Abstract

In this presentation, Shimokawa Town, Hokkaido shares our attempt in achieving Sustainable Development Goals (SDGs). As a town that suffered from many social issues, we tackled the depopulation by making "Cyclical Forest Management System" that led to implementing SDGs.

As first in line in contributing on SDGs, we propose our unique efforts in actually implementing SDGs by developing the "Shimokawa Vision 2030": Shimokawa version SDGs, with residents in the lead and putting it in the future vision of the 6th Comprehensive Plan. Furthermore, we focus on our success on thriving "Shimokawa's Challenge" by cooperating with various stakeholders and gradually inviting residents to take grass-root movements (G17). We wrap up the presentation by sharing the effective usage of SDGs as a tool.

Keywords: SDGs, local government, residents, partnership, implementation.

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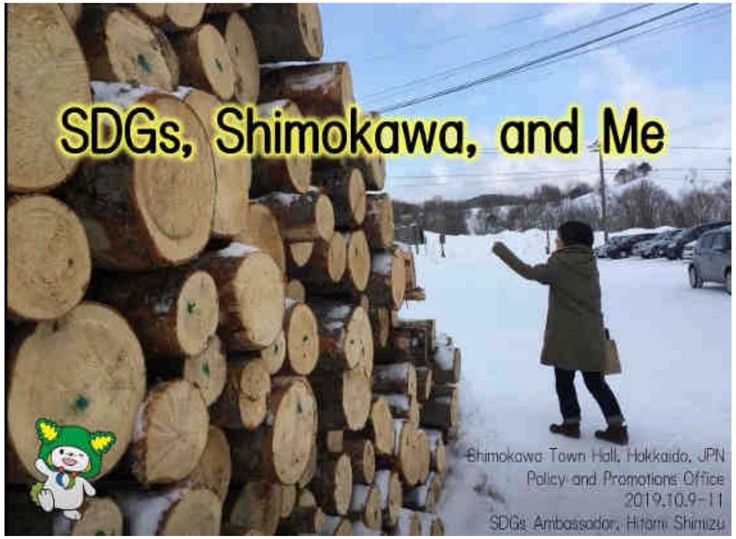
Shimokawa Town Promotion Department. (Seen: 9/29/2019). 仕事をつくる・始める, Tanoshimo Web Page. https://shimokawa-life.info/shimokawabears/

Short CV

Hitomi Shimizu studies in the Graduate School of Media and Governance at Keio University. Born in the countryside: Nagano, Japan, raised in Tennessee, US, she has more than five local fields to implement SDGs in, and strives to Think Globally, Act Locally. As the SDGs Ambassador of Shimokawa Town, Hokkaido, she is working inside the town for half a year to promote SDGs, also promoting what Shimokawa is doing to achieve the Goals, and as well as researching the main reasons for local governments to achieve and adopt SDGs. She also actively invites youth to take action on sustainability in SDGs-SWY; a youth group.

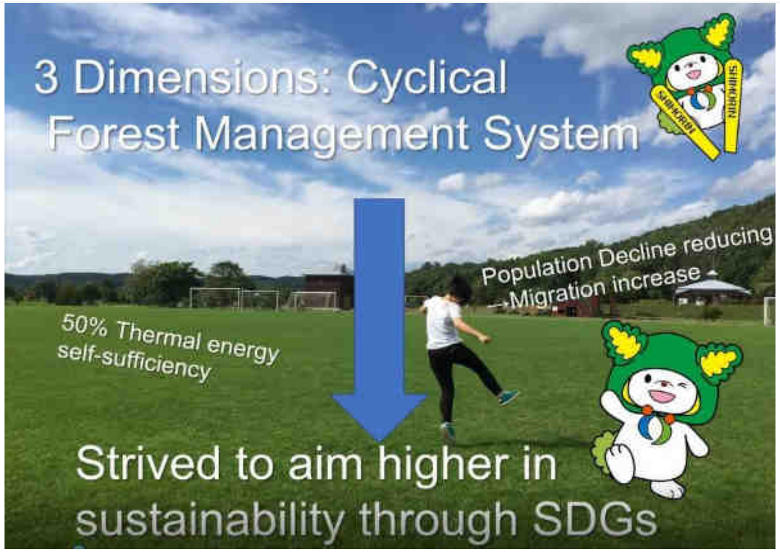

SDGs, Shimokawa, and Me
Shimokawa Town Hall, Hokkaido, JPN
Policy and Promotions Office
2019.10.9-11
SDGs Ambassador, Hitomi Shimizu


Today's Agenda
About Us!
ackground
SDGs Now
To Leave no one Behind
Benefits
Enjoy!

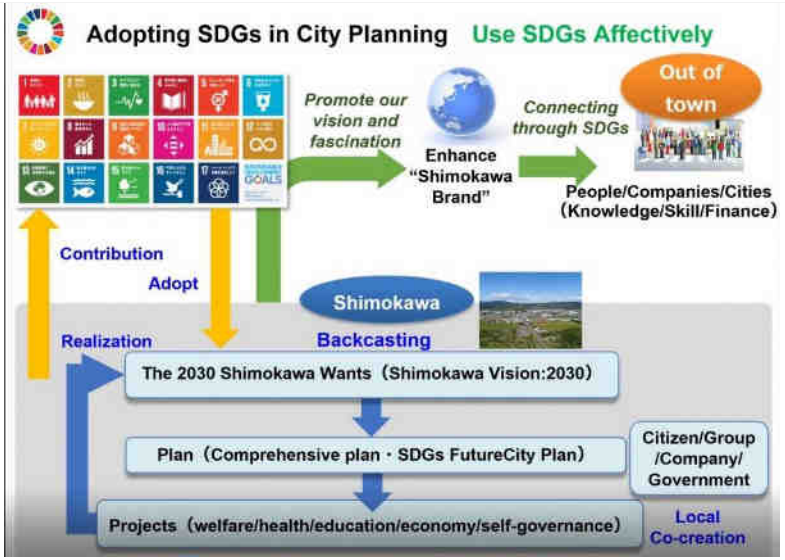

Shimokawa
Population : approx. 3,300
area : 644.2㎢(Same as Tokyo)
Woods : 569.8㎢(88% of the land)
Climate : Summer+30℃ Winter△30℃
Temp. difference 65℃
We're Here!
Ski Jump
(No.1 town of the number of Olympic medals in Japan)
Woody Biomass Energy
Forestry
Mine Closure
Depopulation
Railway Abolished

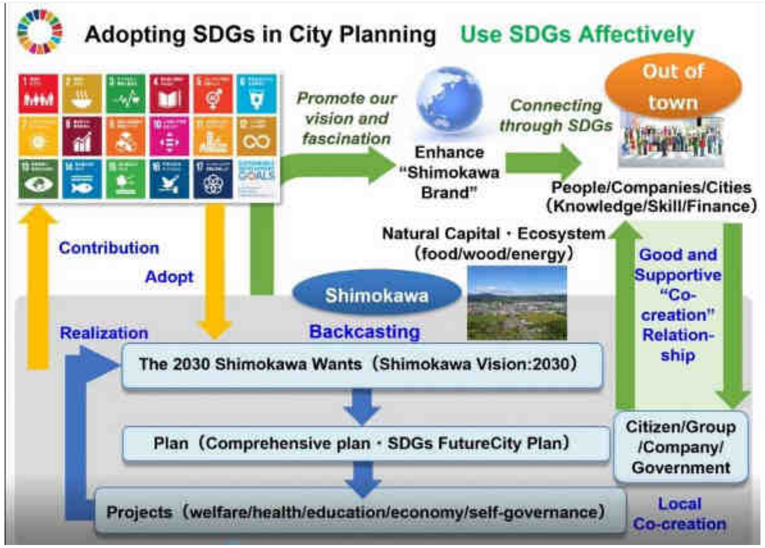

Today's Agenda
About Us!
Background
SDGs Now
To Leave no one Behind
Benefits
Enjoy!


Social × Economy × Environment = Integrated Approach
NEEDS
Cyclical Forest Management System
Brushwood
Wood Chip Manufacturing facility
Energy Independence
Zero Emission wood-processing
plant→grow→cut→ (plant50ha× cut after 60 years)
FSC Certified Wood
Parenting Support
Reduced energy cost used for parenting support governance.
Compact Town
Forest Service Industry
Carbon Offset Credit
Forest Environment Education
Forest Therapy
[Regeneration] Ichinohashi Bio Village


3 Dimensions: Cyclical Forest Management System
Population Decline reducing →Migration increase
50% Thermal energy self-sufficiency
Strived to aim higher in sustainability through SDGs


Today's Agenda
About Us!
Background
SDGs Now
To Leave no one Behind
Benefits
Enjoy!


Adopting SDGs in City Planning
Use SDGs Affectively
Promote our vision and fascination
Enhance "Shimokawa Brand"
Connecting through SDGs
Out of town
People/Companies/Cities (Knowledge/Skill/Finance)
Contribution
Adopt
Realization
Shimokawa
Backcasting
The 2030 Shimokawa Wants (Shimokawa Vision:2030)
Plan (Comprehensive plan · SDGs FutureCity Plan)
Citizen/Group /Company/ Government
Projects (welfare/health/education/economy/self-governance)
Local Co-creation


Adopting SDGs in City Planning
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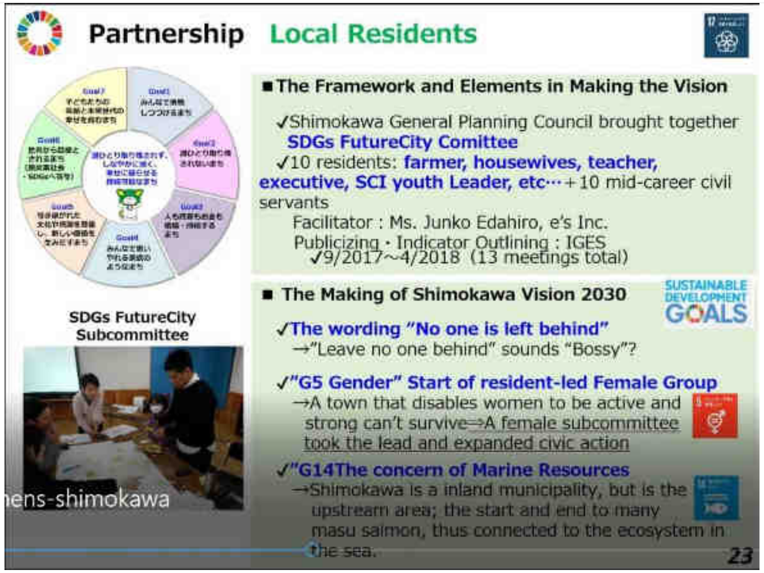
Out of town
Enhance "Shimokawa Brand"
People/Companies/Cities (Knowledge/Skill/Finance)
Natural Capital · Ecosystem (food/wood/energy)
Contribution
Adopt
Shimokawa
Realization
Backcasting
Good and Supportive "Co-creation" Relation-ship
The 2030 Shimokawa Wants (Shimokawa Vision:2030)
Plan (Comprehensive plan · SDGs FutureCity Plan)
Citizen/Group /Company/ Government
Projects (welfare/health/education/economy/self-governance)
Local Co-creation

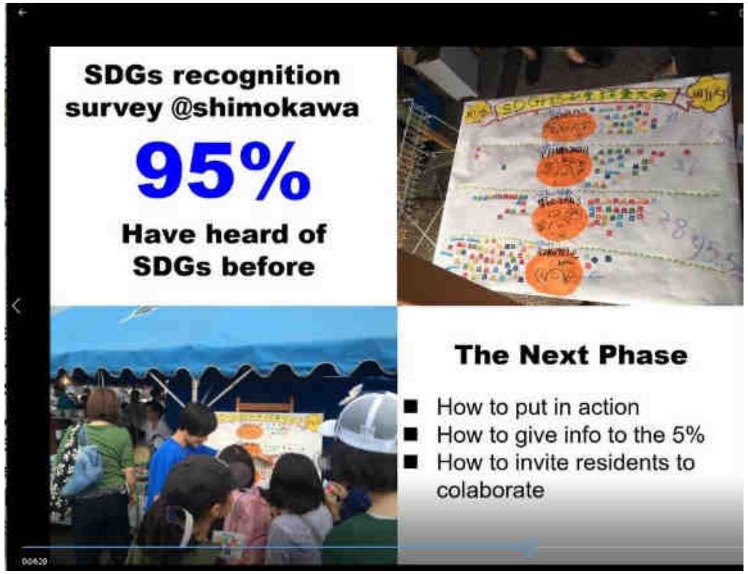

The 2030 Shimokawa Wants
Shimokawa Vision 2030
2018.4.23
Local residents taking the lead in formulating the Vision
Point 1
Goal7 Where children's smile and well-being of the future generation is nurtured
Goal1 A town where everyone can keep challenging
Putting Shimokawa Vision in the "Ideal Future" of Shimokawa's 6th comprehensive plan.
Point2
Goal6 A "global role-model" town (decarbonized society/ SDGs contribution)
A sustainable town that is strong and resilient, where people can live happily and no one is left behind
Goal2 A town where no one is left behind
Goal5 Where culture and resource is cherished, and new value is created
Goal4 Where everyone is family, considerate and warm
Goal3 Where people, resources, money can circulate and sustain
Point3
Develop SDGs Indicators to measure progress
Point4
Inside out stakeholder's cooperation to achieve the Shimokawa Vision


Partnership
Local Residents
■The Framework and Elements in Making the Vision
✓Shimokawa General Planning Council brought together SDGs FutureCity Comittee
✓10 residents: farmer, housewives, teacher, executive, SCI youth Leader, etc…+10 mid-career civil servants
Facilitator : Ms. Junko Edahiro, e's Inc.
Publicizing · Indicator Outlining : IGES
✓9/2017~4/2018 (13 meetings total)
■ The Making of Shimokawa Vision 2030
✓The wording "No one is left behind"
→"Leave no one behind" sounds "Bossy"?
✓"G5 Gender" Start of resident-led Female Group
→A town that disables women to be active and strong can't survive⇒A female subcommittee took the lead and expanded civic action
✓"G14The concern of Marine Resources
→Shimokawa is a inland municipality, but is the upstream area; the start and end to many masu salmon, thus connected to the ecosystem in the sea.
SDGs FutureCity Subcommittee
SUSTAINABLE DEVELOPMENT GOALS
23


Shimokawa Bears ~ Inviting Start-ups
■Shimokawa invites start-ups that agree to SDGs and can relate to one of the "Shimokawa Vision"'s Goal. Calling every year.
(Shimokawa Town Promotions)
SUSTAINABLE DEVELOPMENT GOALS
Goal1 A town where everyone can keep challenging
example) revive a once gone festival etc.
Goal2 A town where no one is left behind
ex) elderly living supporting business / new education service etc.
Goal3 Where people, resources, money can circulate and sustain
ex) Promote local for local(food) / Shimokawa original local money/projects to promote young people to come etc.
人も資源もお金も循環・持続するまち
http://shimokawa-life.info/shimokawabears/


Today's Agenda
About Us!
Background
SDGs Now
To Leave no one Behind
Benefits
Enjoy!


しもかわSDGsマップ
4 0 PLaces Approx
5 9 Goals
Map making Workshop
Make a map that shows how much SDGs is related to our everyday life to give better understanding in the GLOBAL GOALS and promote grass-root actions.
この地図について
SDGsって？


SDGs recognition survey @shimokawa
95%
Have heard of SDGs before
The Next Phase
How to put in action
How to give info to the 5%
How to invite residents to colaborate


Usage of SDGs
Using SDGs as a tool for city planning/ regional revitalization.
→"Realizing a Sustainable Community" and expanding worldwide→Achieve SDGs
①Checklist
New issues revealed by looking back at the community from the 17 perspectives.
②Backcasting
A radical city planning for the realization of the "Goal" from the present state.
③Branding
Through the framework of SDGs, we deliver our visions and actions to promote our brand.
FRaU
④Partnership
Good relations in various fields.
New schemes born from cooperation agreements.


References
Shimokawa Town
the Sustainable Development Goals Report
2018
Institute for Global Environment Strategies
IGES
■References
Shimokawa SDGs Report 2018
(Voluntary Local Review)
https://www.iges.or.jp/jp/sdgs/report.html
29

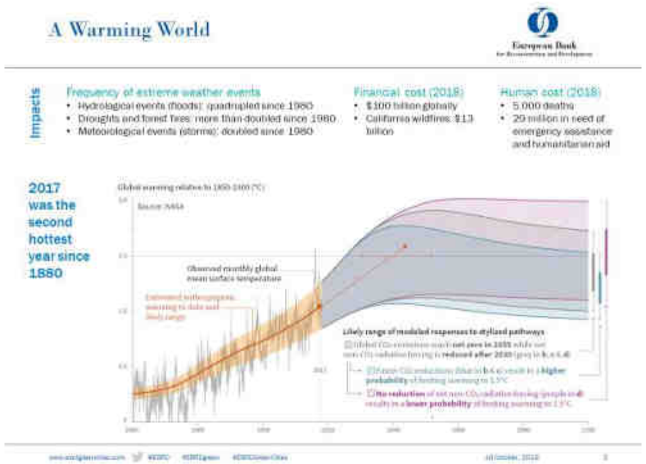

No one will be left behind


Everyone will take part


Everyone will take part
What can we do?
ens-shimokawa

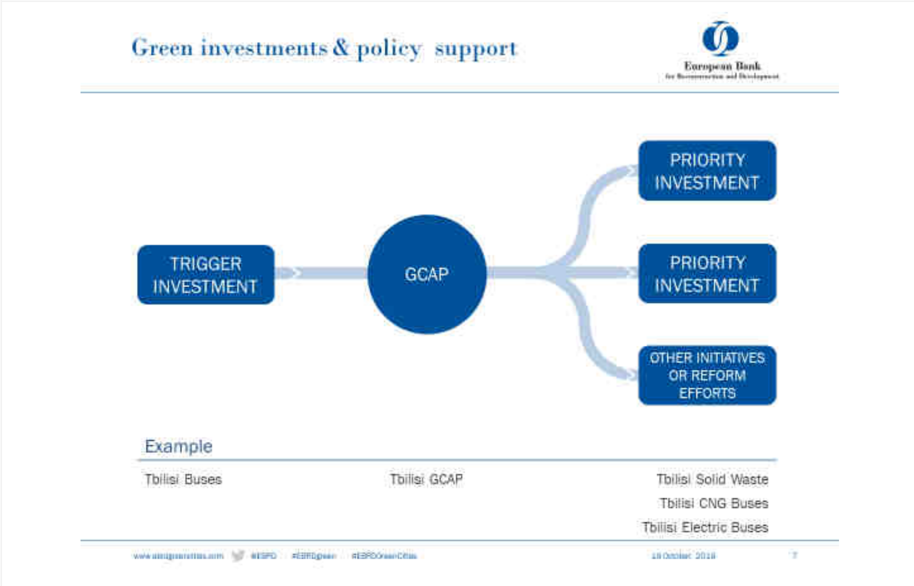
Green Cities

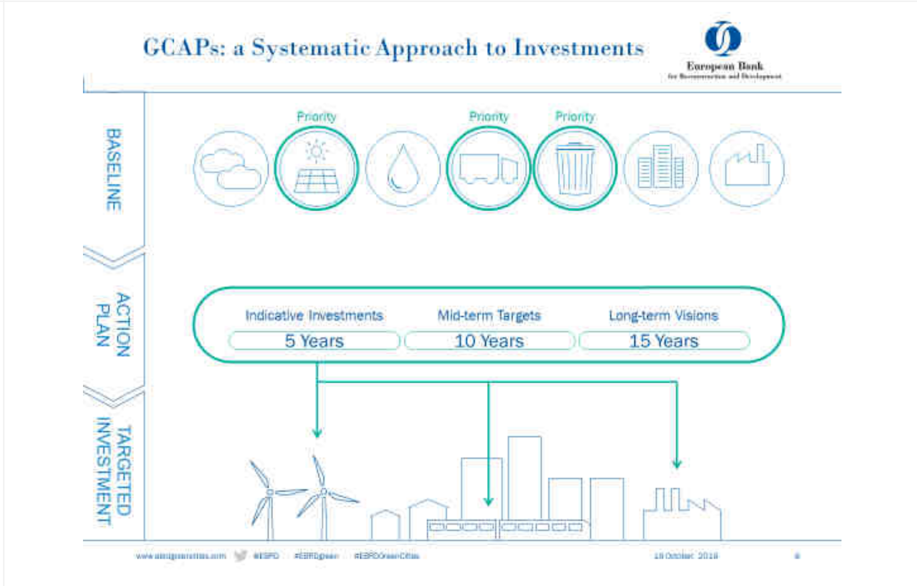
Mr. Guillaume Le BRIS, Associate Director/ Sustainable Infrastructure Group, EBRD




EBRD Green Cities
European Bank for Reconstruction and Development
€1 billion framework to support cities to identify, benchmark, prioritise and invest in Green City measures to improve urban environmental performance through:
Delivery of strategy and policy support
Green City Action Plans (GCAP)
Policy dialogue
Facilitating and stimulating Green City infrastructure investments
Urban Transport
District Energy
Solid Waste
Renewable Energy
Water & Wastewater
Building Energy Efficiency
Street Lighting
Climate Change Resilience
Building capacity of city administrators and key stakeholders


Eligibility Criteria
European Bank
In order to become a part of EBRD Green Cities, cities must meet the following criteria:
1 Located in EBRD's Countries of Operation
2 Population ≥ 100,000
3 Conduct a Green City Action Plan
4 Initiate 'Trigger' Infrastructure Project
In one of the following sectors:
• Solid Waste
• Water & Wastewater
• Urban Transport
• District Heating
• Public Building Energy Efficiency
• Renewable Energy
• Climate Change Resilience
• Street Lighting
5 Projects must target a 20% reduction in GHG emissions, energy or resource consumption, or pollution


Green investments & policy support
European Bank for Reconstruction and Development
TRIGGER INVESTMENT
GCAP
PRIORITY INVESTMENT
PRIORITY INVESTMENT
OTHER INITIATIVES OR REFORM EFFORTS
Example
Tbilisi Buses
Tbilisi GCAP
Tbilisi Solid Waste
Tbilisi CNG Buses
Tbilisi Electric Buses


GCAPs: a Systematic Approach to Investments
European Bank for Reconstruction and Development
BASELINE
ACTION PLAN
TARGETED INVESTMENT
Priority
Priority
Priority
Indicative Investments
5 Years
Mid-term Targets
10 Years
Long-term Visions
15 Years

GCAPs – a systematic approach

European Bank for Reconstruction and Development

Initial Policy Review

	month	Stage	Description
BASELINE	1–3	Indicator Assessment	35 indicators Baseline assessment of climate performance
	4–6	Climate Change Priorities	Agree which indicators identify the priority climate change challenges
ACTION PLAN	7–9	Visions & Indicative Actions	Articulate a city's future development goals and select measures to address challenges and realise visions
	10–12	Green City Action Plan	Formal approval affirming local commitment to implement and secure resources for GCAP

Green City Infrastructure Investments

European Bank for Reconstruction and Development

Financing Options

Sovereign-backed loans	Municipal loans or utility loans guaranteed by municipality	Quasi corporate utility loans	Loans to PPP/ private companies
Central Government	Municipality	Utility Company	Private Company

Investment Size

€ 2 million to € 150 million

Ex: Batumi Bus, Georgia

European Bank for Reconstruction and Development

EBRD Finance €5.5 million

Supporting the City of Batumi to improve and modernise bus operations through the purchase of a new bus fleet of 10 electric and 20 diesel buses.

- First electric bus project for the Bank
- GCAP preparation
- Procurement support
- Corporate development and stakeholder participation programmes

Supported by an E5P grant of € 1.5 million

Ex: Chisinau Public Buildings, Moldova

European Bank for Reconstruction and Development

EBRD Finance €10 million

GHG Reduced 4,000 ton CO_2 eq / yr

Supporting the City of Chisinau in the renovation of up to 120 buildings, covering kindergartens, schools and hospitals.

- GCAP covenanted
- Utilising Energy Performance Contracts where savings will offset costs
- 2nd public buildings investment for EBRD

Supported by an E5P grant of € 5 million & EIB co-financing of € 10 million

Ex: Varna Climate Resilience Infra Project, Bulgaria

European Bank for Reconstruction and Development

EBRD Finance € 10.16 million

Supporting the City of Varna for urban infrastructure upgrade, including roads, parking zone and electric vehicle charging stations

- GCAP preparation
- Upgrade will increase roads' flood resilience and reduce air pollution.
- All investments will have a positive environmental effect including by employing EU standards, reducing pollution and greenhouse gas emissions or improving resource efficiency

Ex: Izmir Metro Project II, Turkey

European Bank for Reconstruction and Development

EBRD Finance	€ 80 million
GHG Reduced	16,500 ton CO_2 eq / yr

7.2km extension to the existing 19km Light Rail Transit system and the construction of seven new stations.

- Reduce motorisation and congestion, air and noise pollution, and traffic accidents.
- Enhance the interconnectivity of the existing metro system with the commuter rail system ("IZBAN") to increase access from suburban areas to the centre of the City.

Public Outreach

European Bank for Reconstruction and Development

Stakeholder Engagement Workshops

European Bank for Reconstruction and Development

GCAPs hold at least 3 stakeholder workshops at key milestones to ensure the outputs reflect the city's and its citizens' visions.

Stakeholder include:

- Local city officials
- CSOs
- Utility companies
- Universities
- International organisations
- Community groups

Green Cities Impact

Since Nov 2016, under EBRD Green Cities:

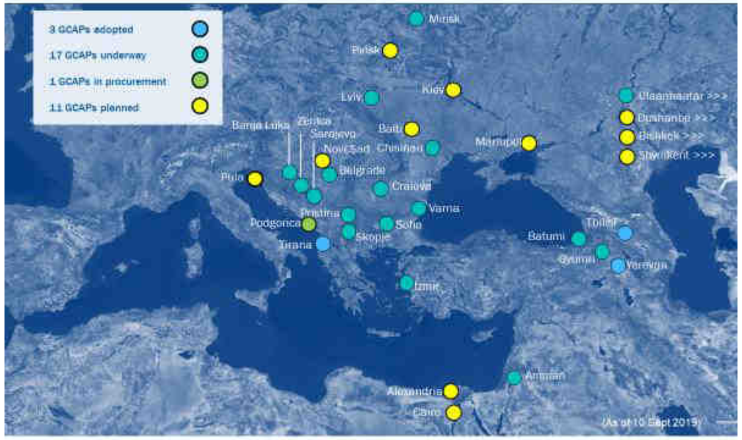
32 cities have joined EBRD Green Cities

€ 350 million invested in sustainable infrastructure

€ 1 billion in EBRD & donor finance mobilised

372 $\frac{\text{k tonnes } CO_2}{\text{year}}$ reduced = **80,000 cars**

Green Cities



Contacts

For all further enquiries, please contact:

Guillaume Le Bris
Sustainable Infrastructure Group – Athens
lebrisg@ebrd.com

Harris Damaskos
Sustainable Infrastructure Group – Athens
damaskoh@ebrd.com

Promoting Cooperation & Development in the Black Sea Region

ROMAN MATKIWSKY

Director Energy & Infrastructure

Black Sea Trade & Development Bank

Short CV

Roman Matkiwsky is responsible for the Energy & Infrastructure portfolio at the Black Sea Trade & Development Bank. With over 20 years of experience at Macquarie Capital, Skanska Infrastructure Development, Société Générale Emerging Europe Asset Management, and the European Bank for Reconstruction and Development (EBRD); Roman brings a strong track record of both corporate / project finance as well as private equity / infrastructure investment.

Born in Canada of Ukrainian and Polish parents, Roman is fluent in several languages (Ukrainian, Polish, with a good comprehension of French, Italian, and Russian). After taking a Bachelor of Commerce degree at the University of Toronto, he became a Chartered Financial Analyst, which he followed with an MBA at Ivey Business School at the University of Western Ontario. In Canada he embarked on his banking career at the Royal Bank of Canada.

Roman is married with two children, and is an avid lover of sports (cycling, tennis and sailing), international affairs and art.

Black Sea Trade & Development Bank

Black Sea Trade and Development Bank

Promoting Cooperation & Development in the Black Sea Region

October 2019

Black Sea Trade & Development Bank

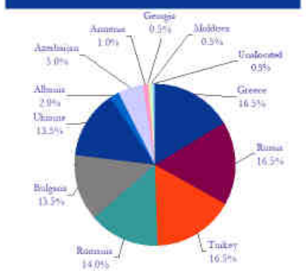
The Black Sea Trade and Development Bank: Who We Are & What We Do

2

Black Sea Trade & Development Bank

Diverse Group of Shareholders – *Credit Ratings*

Shareholders



Shareholder Credit Ratings (as of 31st August 2019)

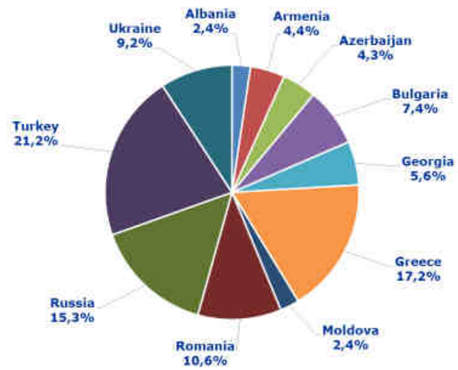
Country	Moody's	S&P	Fitch
Albania	B1	B+	NR
Armenia	Ba3	NR	B+
Azerbaijan	Ba2	BB+	BB+
Bulgaria	Baa2	BBB-	BBB
Georgia	Ba2	BB-	BB
Greece	B1	B+	BB-
Moldova	B3	NR	NR
Romania	Baa3	BBB-	BBB-
Russia	Baa3	BBB-	BBB
Turkey	B1	B+	BB-
Ukraine	Caa1	B-	B

3

Black Sea Trade & Development Bank

Board of Directors Approved Loan & Equity Portfolio

– spread amongst 11 countries (as at 30th June 2019)



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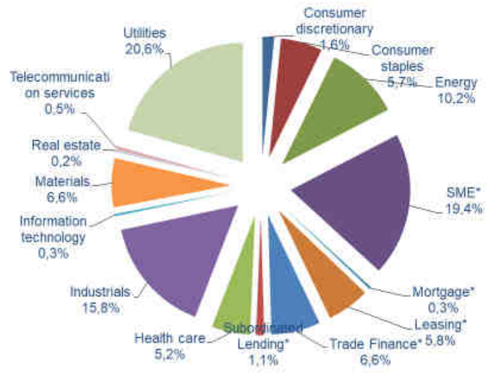
***Loan Portfolio (Outstandings)** split between targeted end user sectors (as at 30th June 2019)*



***Lending through Financial Institutions**

5

BSTDB offers a range of investment products which align with its regional development mandate

Mandate	Foster economic growth and regional cooperation through financing projects and trade activities and providing financial services to public and private entities in the Black Sea Region
Target borrowers & projects	• Public and private companies with operations in one or more of the Member States • Transaction benefits Member State/s and has development impact • Economically sustainable / financially viable so Band participation will be profitable and the undertaking will prove sustainable beyond BSTDB's involvement • Potential to promote regional cooperation
Products & Services	• Lending: Short to long-term loans, typically extended in USD or Euros • Trade finance: Firms importing from Member States and regional exporters • SMEs: Financing through credit lines to local financial intermediaries • Bank/Equity funds: Equity investments, looks to take stake of 5-25% • Guarantees • Co-financings
Pricing	• BSTDB is not a profit maximizing organization; operations are priced according to risk with reference to market pricing • No politically motivated or concessional lending
Priority sectors	• Energy • Manufacturing • Public utilities • Financial institutions • Telecommunications • Transport • Municipal services • Environmental protection • SMEs & Trade Finance

6

BSTDB: Products

Loans

- ❑ Project financing
- ❑ Corporate financing

Credit lines to financial institutions

- ❑ Trade finance
- ❑ SME financing
- ❑ Mortgage financing
- ❑ Subordinated loans
- ❑ Leasing

Equity investments

Guarantee programs

7

BSTDB Products: Loans

Amounts:

- ❑ Minimum EUR 5 million.
- ❑ Maximum EUR 80 million (private sector).
- ❑ Maximum EUR 160 million (public sector).

Maturities:

- ❑ Up to 8 years (corporate),15 years (project loans).
- ❑ 5 – 7 years on average.
- ❑ Grace period: up to 2-3 years.

Limits:

- ❑ Project finance: up to 50% of total project cost.
- ❑ Corporate finance: up to 100% of financing.

8

Project and corporate finance: What are financing criteria

Borrowers:
- Solid financial position (debts, revenues, liquidity, etc.).
- Ability to service current and foreseen debt.
- Strong commitment to the project (allocation of own financial and human resources for the project).
- Project management ability (solid track record, adequate organizational arrangements, etc.).

Projects:
- Project "maturity" (feasibility study, environmental assessment, market analysis, etc.).
- Technical feasibility, financial soundness.
- Positive environment & development impacts.

9

BSTDB: Project approval process

10

ENI Activities

11

AES Maritza East I (Bulgaria)

Project Cost	**Total: EUR 1.1 bn** **BSTDB: EUR 18 m**
Borrower	**AES-3C Maritza East I EOOD**
Term	**16 years**
Sector	**Utilities**
Summary	**Construction, operation and maintenance of a 2x300MW lignite-fired power plant in Bulgaria**

12

Bulgaria Energy Holdings (Bulgaria)

Project Cost	Total: USD 550m BSTDB: USD 50m
Borrower	BEH
Term	5 years
Sector	Energy Utility
Summary	Participation in BEH's Eurobond issue with BSTDB funds specifically targeted to specific CAPEX program.

13

Energean Oil & Gas (Greece)

Project Cost	Total: USD 180m BSTDB: USD 52.5m
Borrower	Energean Oil & Gas
Term	5.5 years
Sector	Natural Resources
Summary	Support the company's existing oil development programme to access additional oil reserves in the Prinos, Prinos North and Epsilon operating oil fields, located offshore Greece (Prinos-Kavala Basin).

14

EnergoPro (Bulgaria)

Project Cost	Total: EUR 370 m BSTDB: EUR 42 m
Borrower	EnergoPro
Term	5 years
Sector	Utilities
Summary	Participation in the primary bond issue as an anchor investor to finance the ongoing improvement and developments of the electricity grid and metering system and of the other markets of Energo-Pro operations.

15

Galnaftogaz (Ukraine)

Project Cost	Total: USD 220 m BSTDB: USD 20 m
Borrower	Concern Galnaftogaz
Term	7 years
Sector	Utilities
Summary	CAPEX program and expansion of the Borrower's gas filling stations network in Ukraine

16

Gurmat Geothermal Power Plant (Turkey)

Project Cost	BSTDB: USD 1b
Borrower	Gurmat Electric Uretim
Term	15 years
Sector	Energy
Summary	Financing of the construction and operation of 170MW geothermal power plant south western Turkey

17

Hellenic Petroleum (Greece)

Project Cost	EUR 450m BSTDB 31m
Borrower	Hellenic Petroleum SA
Term	5 years
Sector	Natural Resources
Summary	Participation in the tap issue of the EUR 450m bond issue. Funding provided to implement ELPE's capital expenditure program in Greece and Bulgaria, including retail network expansion, modernization and environmental improvements.

18

Ingulets Solar (Ukraine)

Amounts	Total Project: EUR 56 million, including: BSTDB: EUR 19 million EBRD: EUR 19 million
Borrower	Ingulets Energo-2, the company of the Clean Energy Group, one of the large solar energy producers in Ukraine
Summary	Financing of the construction and operation of a 57 MW solar park in the Mykolaiv region of Ukraine

19

OTE – Hellenic Communications SA (GRe)

OTE
ΟΜΙΛΟΣ ΕΤΑΙΡΕΙΩΝ

Project Cost	Total: EUR 389 m BSTDB: EUR 50 m
Beneficiary	OTE
Term	3 years
Sector	Telecom / Utility
Summary	Loan to support strategic investments in Greece and the development of its network. OTE is expected to invest around EUR1.3bn over the next four years in the development of the Next Generation Access (NGA), the IP network transformation, as well as the launch of new products and services.

20

PPC – Public Power Corporation SA (GR)

Black Sea Trade & Development Bank

Public Power Corporation S.A.-Hellas
Always by your side

Project Cost	Total: EUR 1.7 b BSTDB: EUR 160 m
Beneficiary	PPC
Term	5 years
Sector	Energy / Utility
Summary	Corporate Loan for financing PPC's capital expenditure program for the period 2019-2020 which is expected for its electricity distribution networks.

21

Rengy Solar (Ukraine)

Black Sea Trade & Development Bank

Amounts	Total Project: EUR 52 million, including: BSTDB: EUR 18 million EBRD: EUR 18 million
Borrower	Rengy Bioenergy, the SPV co-owned by Scatec Solar (Norway) and Rengy Development Group (Ukraine)
Summary	Financing of the construction and operation of a 47 MW solar park in the Mykolaiv region of Ukraine

22

Shah Deniz 2 (Azerbaijan)

Black Sea Trade & Development Bank

Project Cost	Total: USD 1 bn BSTDB: USD 60 m
Borrower	Lukoil Overseas Shah Deniz
Term	12 years
Sector	Utilities
Summary	The gas exploration and production project aiming to further develop the Shah Deniz offshore gas and condensate field in Azerbaijan

23

SOCAR Turkey Enerji AS (Turkey)

Black Sea Trade & Development Bank

SOCAR

Project Cost	Total: USD 1,300m BSTDB: USD 30m
Borrower	SOCAR Turkey Enerji AS
Term	6 years
Sector	Energy
Summary	BSTDB has become a lender as part of the syndicate under a credit linked loan, along with Goldman Sachs, JP Morgan and other lenders.

24

Suvorovo Wind Farm (Bulgaria)

Project Cost	Total: EUR 103 m BSTDB: EUR 11 m
Borrower	Eolica Bularia AD
Term	16 years
Sector	Utilities
Summary	Construction and operation of 60MW wind farm located in the municipality of Suvorovo (North East part of Bulgaria)

25

Syvash Wind Farm (Ukraine)

Project Cost	Total: EUR 390 m BSTDB: EUR 30 m
Borrower	Syvashenergoprom LLC
Term	10 years
Sector	Utilities
Summary	Construction and operation of 250MW wind farm located near Kherson, southern Ukraine; along with Total-EREN (sponsors) and numerous DFIs/ MDBs.

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THANK YOU

BSTDB
1, Komninon Street
546 24 Thessaloniki
Greece
tel: + 30 2310 290477
fax: + 30 2310 290469
e-mail: ei@bstdb.org
www.bstdb.org

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Climate change impact and climate actions at the Bank of Greece

Mrs. Theodora ANTONAKAKI

Scientific Secretary, Climate Change Impacts Study Committee Bank of Greece

Historically, climate change can be attributed primarily to the actions of the large, industrialised countries. However, its impacts are diffused to all countries, whether small or large, developed or developing. This global nature of climate change means that cooperation and action at international level is important. Therefore, the international community, through long negotiations, has succeeded in reaching global agreements, such as the Kyoto Protocol and the more recent Paris Climate Agreement, in order to address the problem on a global scale.

Greece, along with other small countries in the climate-sensitive Mediterranean region, is expected to incur adverse effects from climate change. Acknowledging this fact, the Bank of Greece has been one of the first central banks worldwide to actively engage in the issue of climate change and invest significantly in climate research. Over the past ten years, the interdisciplinary Climate Change Impacts Study Committee (CCISC) of the Bank has been working on all aspects of climate change, from climate science to environmental macroeconomics, highlighting climate change as a key factor that should be horizontally integrated into policymaking as it affects almost all sectors of the Greek economy.

The studies highlight the wealth of Greece's natural resources, but also the risks to the country's natural and human environment. Climate change appears to be a major threat, as the impact on almost all sectors of the national economy is expected to be adverse. Under an inaction ("business as usual") scenario, the Greek GDP could, ceteris paribus, fall by 2% annually by 2050 and even further by 2100, while the total cost to the Greek economy could reach a cumulative €701 billion by 2100.[2,3]

Furthermore, according to a vulnerability assessment[4] that quantifies and ranks the expected climate risks for Greece, agriculture is the sector expected to be most severely hit by climate change in Greece, while the impact on tourism and coastal systems will also considerably affect household income and the economy as a whole. Moreover, the adverse impact of climate change on the water reserves sector is also of particular significance, given its implications for agriculture and water supply.

Decarbonising the energy system and financing the transition to a low-carbon economy, consistent with the "well below 2 Celsius degrees" goal set out in the Paris Climate Agreement, are among the major challenges of our time. Climate change and global warming are linked to anthropogenic activity, in particular the use of fossil fuels and carbon emissions. Current and future impacts on society and sustainable development are such that render the use of fossil fuels prohibitive. We need to mitigate climate change by rapidly and drastically reducing emissions, adopting appropriate energy management and high efficiency practices, financing green energy, fostering energy-saving investment and promoting a low-carbon economy.

Along these lines, the adoption of policies and technologies leading to a low-carbon Greece, in the context of European policies for climate change, can accelerate a transformation of the Greek economy that offers opportunities for economic activity. Likewise, efficient adaptation programmes, necessary as a damage control measure that has been found to reduce the cost of climate change by

[2] GDP contraction relative to base year GDP at constant 2008 prices.
[3] CCISC (2011), *The environmental, economic and social impacts of climate change in Greece*, Bank of Greece, pp. 453-457, available at:
https://www.bankofgreece.gr/BogEkdoseis/ClimateChange_FullReport_bm.pdf
[4] The vulnerability analysis is included in CCISC (2015), *National Climate Change Adaptation Strategy (NCCAS)*, pp. 7-13, available at:
https://www.bankofgreece.gr/BogDocumentEn/National_Adaptation_Strategy_Excerpts.pdf

almost 30%,[5] could provide a promising opportunity for Greece to boost its growth performance and competitiveness, while implementing climate policies.

Towards a sustainable future, scientific research and current developments confirm the need for a dynamic strategy and an action plan to adapt to the changing climate. Climate change adaptation, as a process of adjusting to climate effects in order to moderate the negative and enhance the potential positive impacts of climate change, is a crucial issue spanning across multiple economic, social and environmental policy areas.

Therefore, under a memorandum of understanding signed with the Ministry of Environment and Energy and the Academy of Athens, the CCISC drafted in 2015 the National Climate Change Adaptation Strategy, setting out the general objectives, guiding principles and implementation tools for an effective and growth-oriented adaptation strategy, in line with European directives and international experience.

Furthermore, fostering the adaptation process, the CCISC is currently working, alongside the Ministry of Environment and Energy and other key national actors, on the Life IP programme "AdaptInGR − Boosting the implementation of adaptation policy across Greece".[6] The programme aims at advancing the implementation process of the National Climate Change Adaptation Strategy of Greece by addressing specific objectives such as the systematisation and improvement of decision making for climate change adaptation, the promotion of adaptation policies and actions in all sectors, the establishment of monitoring mechanisms for the evaluation and review of adaptation policies and the strengthening of the adaptive capacity of the Greek society through awareness and dissemination actions.

Short CV

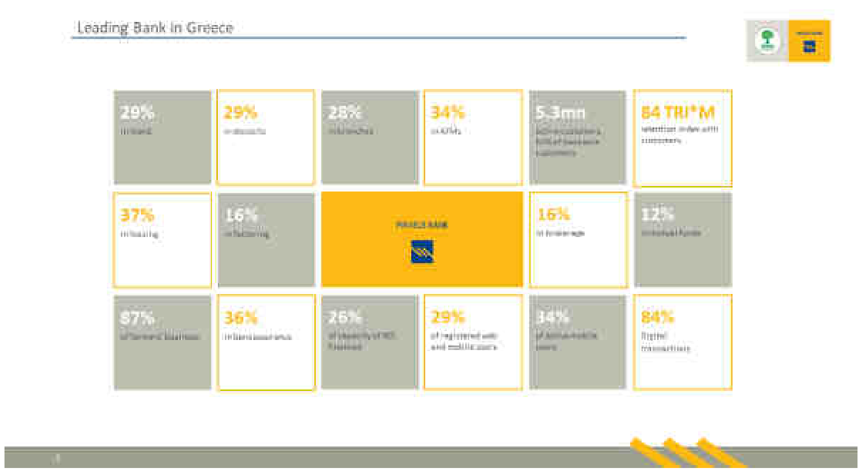
Theodora Antonakaki is coordinating the Bank of Greece's work on climate, sustainability and research at the Climate Change Impacts Study Committee (CCISC) since 2009 and representing the BoG at the Network of Central Banks and Supervisors for Greening the Financial System (NGFS). She obtained her Diploma at the Architectural Department of the Polytechnic School of the Aristotle University of Thessaloniki and the MSc in Built Environment at the Bartlett School of Built Environment of the University of London, where she was an Honorary Research Fellow. She has consulted companies in Greece and abroad in a wide range of projects, in planning, urban and architectural design, on issues of sustainability and socioeconomic impacts. She has participated in competitions and her work has gained awards from Europa Nostra and the Ministry of Foreign Affairs of Denmark. Theodora has been an Adjunct Professor at the Syracuse University, presented her work at conferences and has lectured at the Aristotle University of Thessaloniki, the University of Stirling, the School of Nordic Urban Design, University of London and the Hellenic Open University. She has written book chapters in edited books and her work has been published at peer reviewed journals.

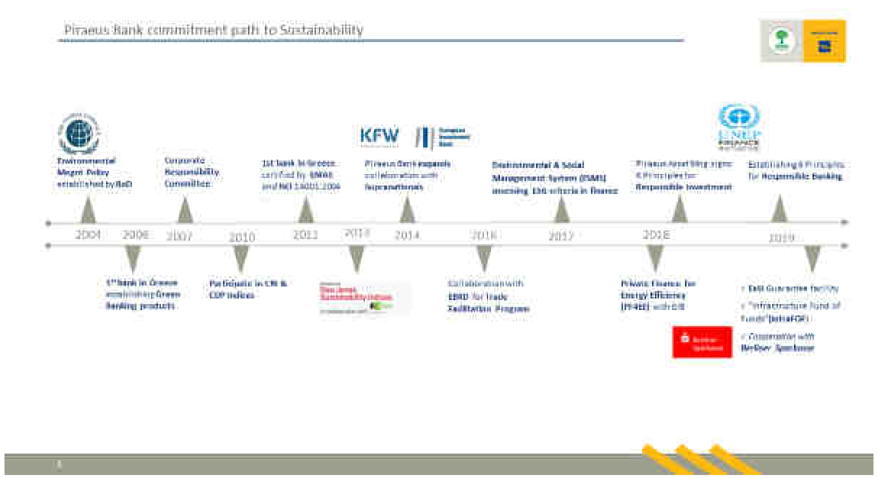
[5] CCISC (2011), *The environmental, economic and social impacts of climate change in Greece*, Bank of Greece, pp. 453-457, available at:
https://www.bankofgreece.gr/BogEkdoseis/ClimateChange_FullReport_bm.pdf

[6] www.adaptivegreece.gr

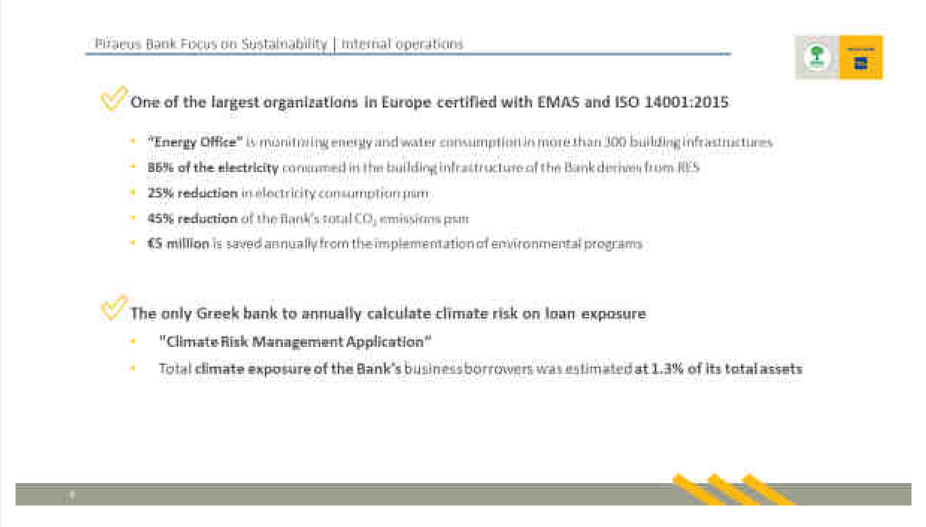
Financing a sustainable economy

Mrs. Marina KOTSORIDI, Manager, Piraeus Bank Group - Greece

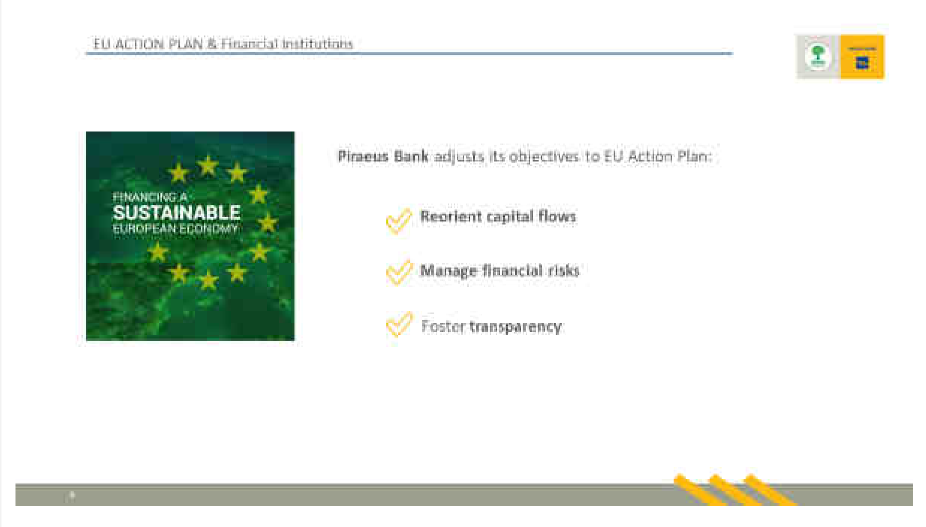




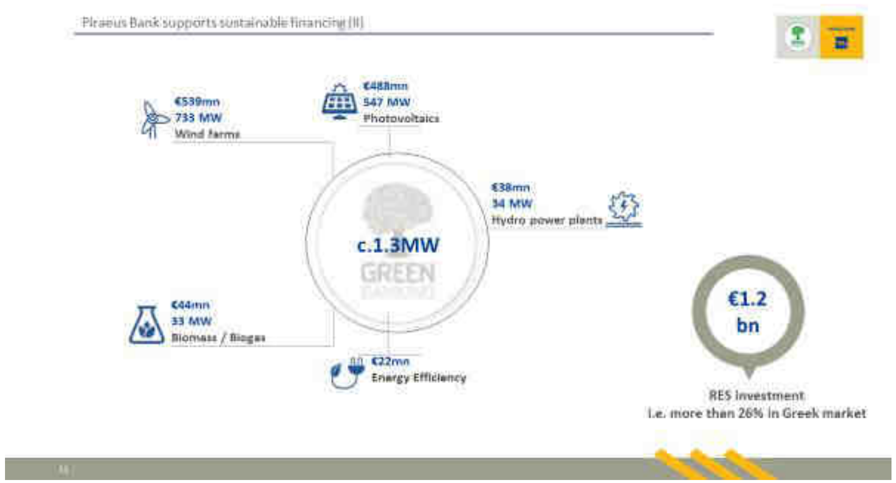

Piraeus Bank Focus on Sustainability | Indices
Piraeus Bank actively participates in global sustainability initiatives
Piraeus Bank ranks top in Greece and well above average globally in all assessments.
FTSE4Good Emerging Index
CDP (former Carbon Disclosure Project)
MSCI ESG Research
UNEP FI
UN Global Compact
Sustainable Development Goals
FTSE4Good
CDP
MSCI
ISS-oekom Environmental & Social Quality Score
ISS QualityScore
ISS QualityScore
RobecoSAM - Corporate Sustainability Assessment for the Dow Jones Sustainability Index
ROBECOSAM
Other assessments
vigeo eiris
Ethibel EXCELLENCE Investment Register
UN Caring for Climate
*Environmental, social and governance

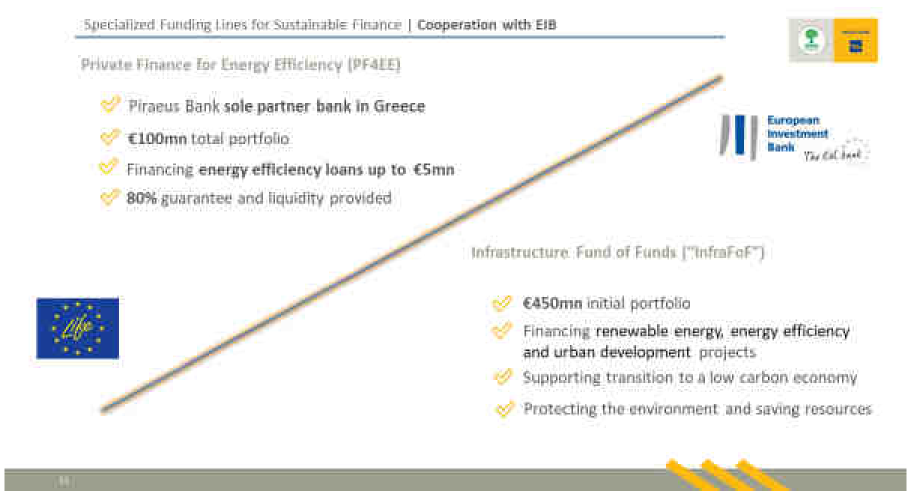

Piraeus Bank Focus on Sustainability | Internal operations
One of the largest organizations in Europe certified with EMAS and ISO 14001:2015
"Energy Office" is monitoring energy and water consumption in more than 300 building infrastructures
86% of the electricity consumed in the building infrastructure of the Bank derives from RES
25% reduction in electricity consumption psm
45% reduction of the Bank's total CO2 emissions psm
€5 million is saved annually from the implementation of environmental programs
The only Greek bank to annually calculate climate risk on loan exposure
"Climate Risk Management Application"
Total climate exposure of the Bank's business borrowers was estimated at 1.3% of its total assets

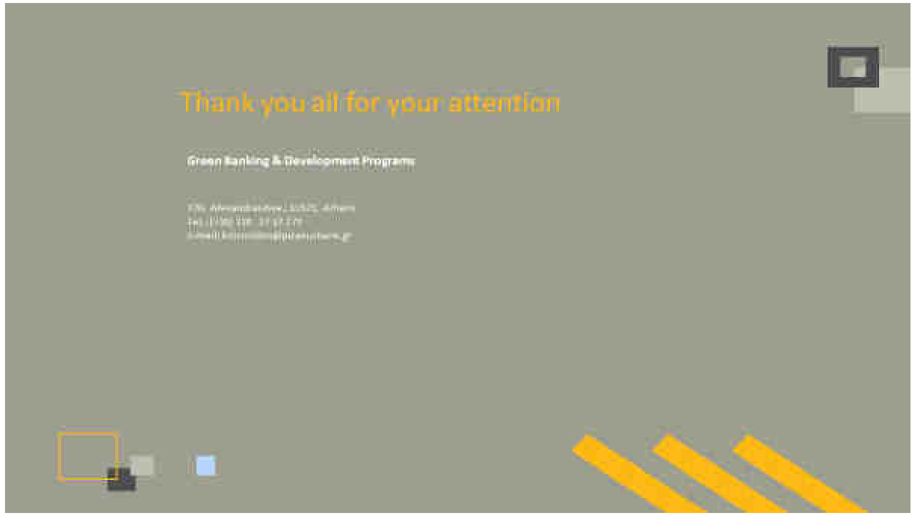

UNEP FI & Piraeus Bank
Piraeus Bank co-shapes the global sustainable banking scene.
The only Greek bank that worked in formulating the 6 Principles for Responsible Banking
One of the 130 other banks totaling $47 trillion in committing to a sustainable future.
Piraeus Asset Management MFMC joined the Principles for Responsible Investment (PRI)
6 PRINCIPLES
SHAPING OUR FUTURE
UNEP FINANCE INITIATIVE
PRINCIPLES FOR RESPONSIBLE BANKING
Alignment
Impact
Clients & customers
Stakeholders
Governance & target setting
Transparency & accountability
PRI Principles for Responsible Investment


EU ACTION PLAN & Financial Institutions
FINANCING A SUSTAINABLE EUROPEAN ECONOMY
Piraeus Bank adjusts its objectives to EU Action Plan:
Reorient capital flows
Manage financial risks
Foster transparency


Piraeus Bank supports sustainable financing (I)
Holistic Approach to Sustainable Financing
Product Development
Green Banking Products & Services
ESG in Risk & Credit Policy
Customer Support in Green Business
Business Units' support
Assessing all lending proposals for E&S risks
Branch Network support & employee training
Market Monitoring
Green portfolio analysis
Market analysis
Environmental & Social Management System (ESMS)
Operational in 2017
Environmental and social criteria part of loan evaluation process
Efficient management of the environmental and social risk of our business clients


Piraeus Bank supports sustainable financing (II)
€539mn
733 MW
Wind farms
€488mn
547 MW
Photovoltaics
€38mn
34 MW
Hydro power plants
c.1.3MW
GREEN
€44mn
33 MW
Biomass / Biogas
€22mn
Energy Efficiency
€1.2 bn
RES investment
i.e. more than 26% in Greek market


Specialized Funding Lines for Sustainable Finance | Cooperation with EIB
Private Finance for Energy Efficiency (PF4EE)
Piraeus Bank sole partner bank in Greece
€100mn total portfolio
Financing energy efficiency loans up to €5mn
80% guarantee and liquidity provided
European Investment Bank
The EU bank
Infrastructure Fund of Funds ("InfraFoF")
€450mn initial portfolio
Financing renewable energy, energy efficiency and urban development projects
Supporting transition to a low carbon economy
Protecting the environment and saving resources


Thank you all for your attention
Green Banking & Development Programs

Current Status and Opportunities for the Greek RES Market

Dr. Sotiris KAPELLOS
Energy Group of Hellenic – German Commercial and Industrial Chamber, Hellas

Short CV

Dr S. Kapellos is a graduate of the Chemical Department of NKUA. He received his PhD on the field of Physical Chemistry also from NKUA. Between 1993 and 2007, he worked in various managerial posts within the BP Hellas Organization: Quality, Health, Safety and Environment, Human Resources, Customer Services, Pricing and Credit, Retail Fuels District Manager Northern Greece. In 2007, he is appointed as the CEO of BP Solar Hellas, to setup the new business.

Since 2010, he works for ELPE Renewables (100% owned by ELPE Group). He currently holds the position of the Operation and Development Director of the company, being a BoD member, at the same time. The current RES portfolio of ELPE Renewables is 796 MW of PV, 77 MW Wind and 10 MW Biomass, of which 19 MW PV and 7 MW wind in operation. In February 2020, the acquisition of a 204 MW PV project in Kozani is signed to be constructed and connected to the Grid in 2021. This is the largest RES in Greece and within the 5th largest PV projects in Europe.

Dr. S.Kapellos has published several scientific articles in international magazines during his academic career and several articles on subjects related to RES, Solar Technology and Energy Policy for newspapers, relevant magazines and e-media. Since 2008, he is being an elected member of the board of the Hellenic Association of PV companies (HELAPCO) and since April 2013 Chairman of the board of the Association.

Current Status and Opportunities of the Greek RES Market

Dr. Sotiris Kapellos
Energy Group of Hellenic-German Commercial and Industrial Chamber

BSEC

6th Green Energy Investments Forum

9 October 2019, Athens – Greece
"Kostis Palamas", Akadimias 48 and Sina street

12th International Scientific Conference on Energy and Climate Change

Presentation content

- Long Term Energy Planning 2020-30
- RES Auctions
- The Target Model
- Beyond Tenders: PPAs and other Business Models
- Acceleration of Licensing Process for Increased RES Penetration
- Conclusions

Long-Term planning 2020-2030

Draft Targets 2030

Electricity Generation Source	Installed Power [GW] 2016	2020	2025	2030
Fossil Fuels - Lignite	4.3	3.4	3.5	2.7
Oil	2.5	1.8	1.5	1.4
Natural Gas	3.9	5.2	5.2	5.4
Hydro	3.4	3.4	3.7	3.9
Bioenergy (Biomas-Biogas)	0.1	0.1	0.1	0.3
Wind	2.4	3.4	4.2	6.4
PV	2.6	3.3	5.5	6.9
Solar Thermal	0.0	0.0	0.1	0.1
Geothermal	0.0	0.0	0.0	0.1
Total RES (Excluding Hydro)	5.1	6.7	9.9	13.8
Energy Storage Power	0.0	0.0	0.0	0.7

Long-Term planning 2020-2030

The Greek long-term energy planning is expected to *be concluded by year end*

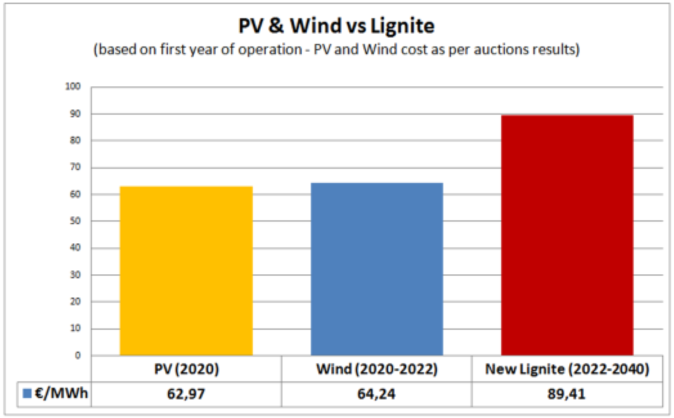
Preliminary target for cumulative until 2030:
Wind capacity : **6.4 GWp**
PV capacity : **6.9 GWp**

8.4 GW Additional RES until 2030

This target is **expected to increase**, as total RES share is decided to increase from 31% to 35% of gross energy consumption, resulting from old lignite energy plants withdrawal.

RES electricity share is expected to be over 60% by 2030

RES Auctions strike price lower than Lignite

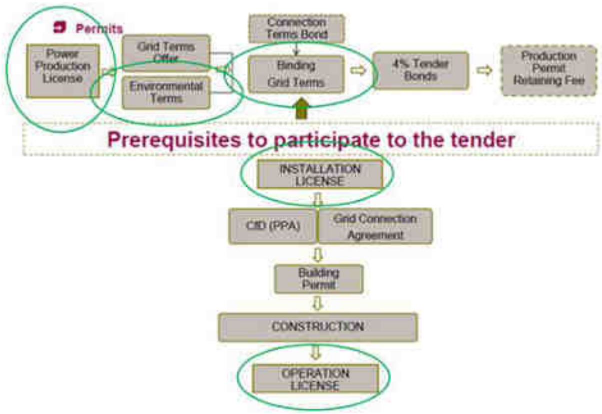


EU Target Model, subsidy-free RES projects, Corporate PPAs and Storage

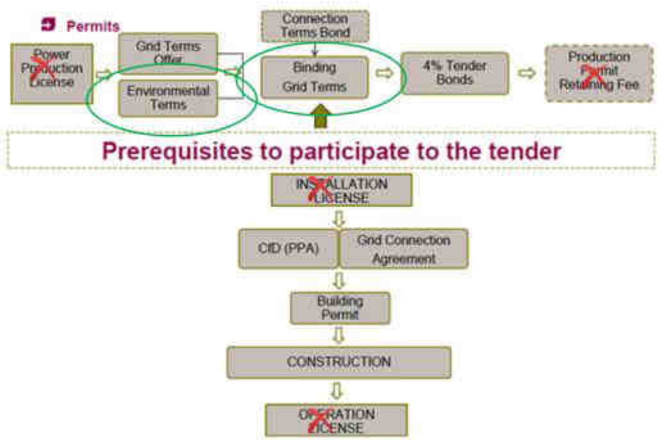
- The **EU Target Model** in Greece to be launched as of H2-2020 **New RES projects** will have to participate in the **energy markets (Day-Ahead, Intra-Day and Balancing)**
- **Corporate PPAs** to become possible
  (RES LCOE Competitive to Wholesale Prices)
  New Opportunities and Business Models for Energy Investors and Industrial Consumers
- **RES plus Storage market** (Behind the meter Storage) to be possible after 2020
- **In Front of the meter Storage**
- **Non-interconnected Islands Hybrid Projects** Regulatory framework to be finalized in 2020

The average wholesale market prices

Current RES Licensing scheme



Need for Simplification of the RES Licensing scheme



Conclusions

- More than 8.4 GW Additional RES until 2030
  RES Share to increase from 31% to 35%
- New Business opportunities Resulting Target Model Introduction (2H 2020)
- Licensing acceleration is needed in order for 2030 targets to be met

12th International Conference on "Energy and Climate Change"

6th Green Energy Investments Forum

The Sixth Green Energy Investments Forum, that took place in the frame of the 12th Annual International Conference on "Energy and Climate Change" in Athens, Greece (9 – 11 October 2019), offered an opportunity to learn about possibilities of investments for developing projects aiming at the green transformation of the economies of the BSEC Member States and the achievement of the UN Sustainable Development Goals in the BSEC Region.

The BSEC Member States have a significant potential to develop a sustainable energy future.

The Forum affirms its commitment to United Nations Sustainable Development Goal 7 that of ensuring access to affordable, reliable, sustainable and modern energy for all, and notes the designation of the Energy Policy and Development Center of the National and Kapodistrian University of Athens as the global hub of the United Nations Academic Impact in this regard.

The Forum recalls its own aspiration, through the *sine qua non* of a structured policy dialogue, to initiate procedures leading to concrete investment proposals that will transform ideas to green, bankable projects.

The Forum is encouraged by the expectation of the United Nations Secretary-General, Antonio Guterres, that the world will see a "number of meaningful plans on dramatically reducing emissions during the next decade, and on reaching carbon neutrality by 2050."

The Forum notes a number of possible initiatives proposed by Professor Dimitrios Mavrakis which it has discussed in this regard, including energy efficiency in building construction, up to Smart Zero Energy level, using sustainable green energy approaches to combat energy poverty, enhancing local access to natural gas and renewable energy sources, access to liquefied natural gas in remote or isolated areas, its use in land and maritime transportation and off-grid power generation, as a bridge to zero CO_2 emissions target in 2050 and the electrification of shorter maritime routes.

It notes the call to the Non-State National and Sub-national Actors (NSA) and especially the municipalities to develop International Cooperative Initiatives in close cooperation with the UNAI Hub SDG7. It notes that familiarity with the promise and pitfalls in energy use must inform students and young minds and welcomes the proposal to organise a youth contest on SDG 7.

In the United Nations Secretary-General's phrase, we must "unite behind science." The Forum welcomes the particular role of the United Nations Academic Impact in this regard and calls upon all involved in this critical endeavour, whether industrialists or environmental activists, government leaders or young citizens, investors or scholars, to constitute and share in this unity.

In its 75th anniversary year, the United Nations remains the single universal forum where the peoples of the world, the aspirations they share and the ideas they generate can come together in a global mission of "shaping our future together."

There is need to elaborate more concrete projects promoting energy efficiency, renewable energy in the BSEC Region and both the governments of the BSEC Member States and the International Secretariat of the Organization should intensify their efforts to find appropriate sources of financing them.

BSEC is encouraged to develop its cooperation with other specialized international financial institutions, in order to develop bankable project proposals in the frame of the UNAI Hub SDG7 in initiatives, at least for the BSEC Member States.

DAY 2: SCIENTIFIC SESSIONS

Session A: Environment – Climate Change

Tribute to Prof. Krzysztof WARMUZINSKI

From Prof. Dimitrios MAVRAKIS, Director of KEPA, UNAI Hub SDG7

Ladies and gentlemen,

Allow me to say a few words for a colleague, a friend, a dear person who for the last seven years was coming to meet us for the conference.

Prof. K. Warmuzinski graduated from the Silesian University of Technology, specializing in chemical engineering. His principal research areas included multicomponent diffusion, interfacial phenomena during gas-liquid mass transfer, reactor engineering and, more recently, pressure swing adsorption and membrane separation. In 1982-1983 he was a research fellow at Birmingham University, UK, working on Marangoni convection accompanying the absorption of carbon dioxide.

He also spent some time in the USA, Spain and Japan. For almost two decades he has been active in a number of European and international initiatives aimed at curbing greenhouse gas emissions and co-authored the IPCC Special Report on Carbon Dioxide Capture and Storage.

In 2003 he became director of the Institute of Chemical Engineering, Polish Academy of Sciences, and since then initiated several projects dealing with the mitigation of the environmental impact of energy production.

He first came at the 2012 Conference and since then he was supporting the event by coming every year and as a member of the Scientific Committee. During these years, he participated as a speaker, as a chairman, as a co-organizer of a session. He became one of our dear friends whom we were expecting to see during the event. His opinion was valuable since he would try to encourage us and propose actions for improving it. He was a fan of the Hellenic poet Kavafis, could read in Greek, enjoyed walks in Monastiraki and Plaka. His kindness and politeness were noticeable and perhaps and all these justify why we miss him this year.

I would like to devote a moment of silence to his memory.

Greening the blue-Governance challenges and solutions in the energy sustainability shift in maritime sectors

Thor Øivind JENSEN[1], Associate Professor*
and
Agnete HESSEVIK, PhD candidate*

*Department of Administration and Organization Theory, University of Bergen, Norway

[1]*Contact details of corresponding author*
e-mail: Thor.O.Jensen@uib.no
Address: Postboks 7802, 5020 Bergen, Norway

Abstract

The maritime sector is a main contributor to environmental pollution. Plastic, general waste and from the propulsion systems: CO_2, methane, sulfur, particles and NOx. For the climate challenge, the main contributor is CO_2. Shipping accounted for at least 2.6% of global CO_2 emissions in 2012. CO_2 emissions are projected to increase considerably. Projections are tightly coupled to general economic development and the achieved handling of global temperature rise, but they all include increases, ranging from 20 to 210% (CE Delft, 2017). These projections are all irreconcilable with the IMO resolution, adopted in May 2018, setting the goal to reduce the GHG emissions from international shipping by at least 50% by 2050. The background for this paper is: to evaluate possibilities for new low- or no-CO_2 emission technological regimes in different maritime subsectors.

The sector is traditionally seen as conservative and difficult to manage, due to internationalization and jurisdictional challenges. The technology for a major shift already exists in niches. The challenges are therefore to a large degree linked to factors of economy, motivational factors, market design, regulations, demand factors and public policies - in short the factors of governance.

In the paper we use a table, made in three steps. The rows are the different sectors of maritime services: a) long distance carriers; b) long distance passenger/cruise; c) regional boats for marine economic activity; d) regional passenger and tourism; and e) short distance passenger boats and ferries. The columns are: 1) the specific challenges, both (1a) technological and (1b) organizational/political; 2) the possible technological solutions for each; and 3) the major tools that can be used to push the shift over to sustainable energy propulsion systems for each group. From the classification of the very diverse energy needs and possible technological paths, we move to our target variable: Governing tools and factors that can make transition happen. Possibilities are linked to self-governance, public tenders, insurance, classification, harbor regulations, international agreements and indirect consumer push. Our purpose is to link known solutions to specific maritime segments together with possible governing mechanisms and contribute to a more complete framework to analyze the very different challenges, solutions and governance factors in the maritime sector. The overall impression after our exercise is that both in technology and governance the differences between subsectors of shipping are huge and obviously larger than one set of tools can grasp. But we also found governance setups with fast and large change abilities as well as some strategic elements of governance of smaller sectors and regions with a power to impact the larger shipping system. Finally the challenges of governance in international shipping also imply unique and interesting elements that easily slip away from a traditional governance state- and public policy -oriented perspective and thus make further studies of the shipping governance system, including informal, private and intermediate elements necessary both for understanding green change in shipping and to develop understanding of governance systems outside national state settings.

Keywords: Governance, Regulation, Shipping, Emissions.

1. The Challenge

1.1. Traditionally a conservative- hard to change- sector under pressure to change

The maritime sector at large is old, organizationally and technological mature, it is powerful, has developed its own institutional system; is to a degree self-governed and not easily regulated from the national state level. It is strongly path dependent and likely to not change fast or respond easy to external pressure, especially with traditional national governing tools (taxes, formal laws) (see Pettit S. et al. 2017).

Through the years the energy source has changed from wind to coal to oil and is now almost totally oil-driven, with large emphasis on heavy high-polluting variants. Both local pollution (harbors, coastal areas) and the dramatic global climate problems has brought the maritime sector under pressure to change. The problems are linked to sulfur emissions, particles (soot), NO_x, and CO_2 emissions, but the CO_2 problem and the climate change drama is coming quite strong on the agenda with accelerating and visible climate change and emission levels that are not dropping, in spite of series of political attempts.

The world has squandered so much time mustering the action necessary to combat climate change that rapid, unprecedented cuts in greenhouse gas emissions offer the only hope of averting an ever-intensifying cascade of consequences (UN Environment Programme, 2019).

Transport sectors are heavy contributors to CO_2 and other emissions that hurt the climate. Shipping has relatively small emissions pr. ton and km, but the volume of shipping is increasing and the total overall contribution is a significant 2,6% and might even increase significantly (a high estimate is in the 7% area) as trade and economy are developing according to prognoses (IMO, 2015). The situation, the drama of the climate problem and the anticipated problems of changes in the maritime sector makes it important to look into the possibilities for change. The first question is if it is possible in the meaning of technologically possible. Are there functioning alternatives to fossil fuels and/or can fossil fuels be used with dramatically much lower impact on the climate?

1.2. Change is technological possible and is decided, but how?

This general and not so optimistic picture has changed considerably the very last few years. International shipping was not a part of the original systems of climate agreements, but their own governing systems (the UN connected International Maritime Organization (IMO)) have just made a series of studies and decisions. The most important are the reduction of fuel sulfur in several steps down to 0,5% from 2020 and a more general plan from April 2018 to reduce total CO_2 emissions with 50%, even with calculated increase in shipping volume, in 2050 (Psaraftis H., 2019). Shipping may also be included in some of the general systems of emissions reductions (like EU quota system in 2023).

The reduction in sulfur will be done with a combination of cleaner fuel and scrubbers that cleans the emissions before released to air (but there are discussions and regulation regarding releasing it into the sea afterwards). The companies producing scrubbers are working hard to deliver before end of 2019. The plan for reduction in CO_2 before 2015 had no clear roadmap and was dependent on both governing systems and technological developments. We will describe the technological status briefly and attempt to analyze the governance challenges.

1.3. Theories of technological system change

Technology transition is not a simple development from innovation to a new regime. The standard theory of this process is now the multi-level theory of Geels and associates (Schot J. and Geels F. W., 2008; Geels F. W., 2010). The three levels are called Niche, Regime and Landscape. In the niches there is development and a multitude of possible solutions, none of them fully developed for large scale use, some of them in need for much and unpredictable development work and others functioning well and held back by lack of infrastructure or even by political forces linked to established regimes. Niches are often funded by state sources for research and development, underlining the role of the state in the change process (Mazzucato M., 2015). The sociotechnical regimes are the fully developed dominating systems including infrastructure and support systems of finance, knowledge, regulation and interest groups. These will have their path dependency and are often locked in by strong institutional mechanisms. The Landscape is the overall pattern, including values and institutional patterns. For our purpose we will look for the sustainable alternatives in the niches and try to understand the governance factors that might help a niche technology on its way to become a regime. For us it is also important to see the political forces of the landscape and its values and institutions because they might be pressing for change.

An additional reminder is that change processes are not only often slow and linked to institutional power and path dependence; change may also be dramatic and fast. When an established technology becomes illegal, or a new better and cheaper technology emerges, ordinary rules of depreciation of equipment do not apply. Schumpeter J. (1942) studied economic history and innovation and coined the phrase "creative destruction" meaning innovation and creative market forces actually leave the old as useless: as (ship) wrecks of wood with sail when steel and steam came, as millions of useless small cogs and parts when quarts wristwatches came in the 1970s, as cars made horses into sources of meat and when the Norwegian government shut down FM broadcast in 2017, leaving 6-20 million radios useless. Examples are many, some of us remember vinyl records, video cassettes, mainframe computers and typeset books and newspapers. In a historical perspective this underlines the realities when a niche of technology becomes a new regime; it might be slow or it might have revolutionary force.

1.4. The niche menu of sustainable solutions

Technological development is not among our main topics here, but we need to give some examples to indicate the validity of our assumption that governance is now a key variable. If the room for niches of sustainable maritime technology was almost empty or filled with projects that were far from practical use, our perspective would be less that fruitful. Our list of examples, (mostly Norwegian, sorry for that) follow our five selected categories:

1. Short coastal fixed-distance ferries and passenger transport
    - Small passenger ferry in Bergen, electrical from 1894, then diesel until 2015, again electrical;
    - Car ferries, fully electrical (2015-→)
        - High speed local sightseeing passenger Battery/Hybrid (2017);
        - High speed local sightseeing passenger fully electric (2018);
2. Regional passenger transport and ferries
    - LNG gas car/ passenger ferry Norway-Denmark (2014);
    - Battery/hybrid car/passenger ferry Norway-Denmark (2019);
    - Biogas (2019);
3. Supply ships and coastal fishing
    - Battery/hybrid supplyships (2018->);
    - Fully electrical small fishing boat (2015);
    - Fully electrical work boat in ocean farming (2017);
4. Long-distance passenger and cruise
    - Retrofitting scrubbers (2016->);
    - Retrofitting batteries/hybrid (2018);
    - New batteries/hybrid (2018);
5. Long distance heavy carriers
    - Scrubbers (linked to 2020 reform) only SO_2, not CO_2 ;
    - LNG (2012→);
    - Diesel-electrical drivetrains allow for flexibility and future developments;
    - Experimental: Hydrogen, Ammonium, Methanol.

In addition to these groups that we use for discussion, there are fully electrical recreational boats in sale, there are experiments with electrical self-driving barges and coastal freighters, fuel-cell hydrogen technology is tested and nuclear propulsion have new interests, at least in theory. The necessary infrastructure and port facilities are also developed and linked to regulation and market environments, especially for the solutions that are already in use and with more under construction, like shore power, fast charging and LNG supply chains. There are, however, only small overall changes in emissions so far. An IMO estimate is 0,5% (Psaraftis H., 2019) which indicates that there have been few changes at the regime level. Our examples show movement and realistic low-emission alternatives at the niche level. The important discussion for us is how the transition from niche to regime can happen, what kinds of governance system elements may help it happen. In our five groups the three first have more change than the two last, linked to both technological and governance reasons. The challenges and technological uncertainty is obviously more dramatic for heavy long-distance ships that require propulsion systems of high energy density. A new book written by a collection of top experts (Psaraftis H., 2019) shows a lot of problems and dilemmas for the new fuel alternatives when to come to the new variable of CO_2 emissions and argues for further development of the traditional slow-turning two-stroke engine running on traditional fuels. Some of the dilemmas are linked directly to the fuel (LNG), some are more indirect: Even if the fuel burning or utilization can easily be zero-emission, there are more indirect problems linked to fuel production and infrastructure. Some fuels are mainly energy carriers, so even if there are no emissions at sea, the total chain may have large emissions. Where electricity is used (Hydrogen, Ammonium) the CO_2 load can be high, but this also means that the fuel production can be driven by sustainable energy bringing that total emission result dramatically down. The different biofuels have the same challenges of the production chain and the sources for these fuels are valid, but they can be "circular", originating from waste and from sources with no alternative use.

The challenges may end up being preliminary bottlenecks in the development of alter alternatives, but are anyway pointing to this big subsector having significant challenges in reaching the 70% reduction before 2050, even if some new solutions, like LNG, already are implemented by some operators. The reduction must be 70% to achieve the overall goal of 50% due to predicted growth in traffic. We should, however, mention that the big ocean-travelling cruise ship sector already has a number of battery/hybrid ships in operation and under construction, indicating that governance and economy might be interesting factors as well. At the extreme opposite we find coastal activities (ferries, passenger, supply ships, fishing) where technology seems to be mature and well fitted to specific needs. Ferries travel short and predictable distances well fitted for full battery operation, sometimes (like in Norway) linked to 100% sustainable energy. This also applies to some coastal passenger/tourist operations and (December 2019) it is decided to make zero-emission standard on some high-speed passenger routes in Western Norway. Operation of supply- and fishing vessels have special advantages of electrical power, making hybrid vessels practical. For larger ships (cruise, regional ferries) the hybrid technology makes it possible to adapt to special requirements for running with zero emissions and low noise in special areas.

Even if there are obvious technological challenges, the niches of sustainable maritime power are many and well developed, which makes it logical to look into the system of governance.

2. The governance menu

As most popular analytical concepts, "governance" is not well defined. It points away from the narrow and more formal concept of "government" and in direction of a system-level mapping of not-predefined elements of influence. Here is one definition that attempts precision: *"Governance can be considered as the totality of interactions, in which public as well as private actors participate, aimed at solving societal problems or creating societal opportunities; attending to the institutions as contexts for these governing interactions; and establishing a normative foundation for all those activities" (Kooiman J., 2003).*

Even this long multi-element definition maybe a little restricted, because it is not very open for all those governing actors that are relevant for governing sustainability as a biproduct, maybe not even aware of their role (in shipping: insurance, classification companies, cruise passengers). The definition that opens the "Handbook of Governance (Bevir M., 2011, p1), is less precise: "*...governance refers to theories and issues of social coordination and the nature of all patterns of rule. More specifically, governance refers to various new theories and practices of governing and the dilemmas to which the give rise. These new theories, practices and dilemmas place less emphasis than did their predecessors on hierarchy and the state, and more (on) markets and networks [...] These delimmas require new theoretical reflection and practical activity if they are to be adequately addressed"*.

This broadness and lack of precision as actually a key advantage and part of the concept, carries much of the fruitfulness of the concept. It becomes necessary for us to be open and search wide for the components of governance, expecting to find unique and different governing systems for each case, not looking for a standard structure, not following the paths of national state legislation. For us, the importance is that we must search for and find the set of governing actors and factors, a "governance mapping" for each case and sub-case, and that it is not fruitful to restrict our search in a predefined top-down/state-oriented manner. This is not only generally relevant for our kind of market-state mixed societies, it is of special relevance and importance for sectors like shipping, with weak state governing systems, global activity, many private and half-private governing partners and strong historical tradition of self-governance (Furger F., 1997).

Let us start with a general list of governing elements to look for, starting with classic formal strong legislation and public ownership and move down to more loose, informal and socially defined elements:

1) Total political governance, (ownership)

This form of strong classical governance is not standard.

2) Public policy framing: a) jurisdiction; b) procurement; c) financial support

a) This form of classic political governing is more or less existing for all subgroups, that are, in principle under a national legal system. For coastal traffic it is even more relevant as it applies in different forms of ownership and traffic.

b) For parts of public transport there may be complicated buying of services or licensing that make political institutions able to use procurement systems.

c) Public bodies may also use direct economic support, to R & D and to climate-relevant projects (under some restrictions from EU). Together this gave the special conditions that shaped the rapid transformation to electrical ferries I Norway from 2017 (Bjerkan K. Y. et al., 2019, Skauge T. et al., 2018).

3) Classic regulation: a) national; b) international; c) ports/sectors

All subsectors of shipping are object to regulations, by a) national authorities, b) international arrangements (IMO) and c) special regulations for areas and functions, like in ports or in certain vulnerable waters. The last form seems to be of special importance for sustainability: Many ports (Amsterdam, Chinese ports, Oslo, Los Angeles, San Francisco, more general: Green Port initiative, World Port Climate initiative) and special areas: EU ECA areas, Norwegian world heritage fjords (2020), Baltic Sea (2021) UK local waters (2025). Such port and regional regulations and differentiated fees are making interesting impacts.

4) Market based institutional regulation (classification, insurance, finance)

By long tradition international shipping are linked to formally private globally acting companies with strong indirect governing capacity. Insurance (Lloyds) and their symbiotic relation with classification companies (DNV-GL) give the, significant standard-setting and regulative capacity. Their status as actors have also made them take roles in the sustainability shift in indirect ways (see 6 and 9 under).

5) Sector member/global organizations

From our interviews the role of the sectors "own" organizations was given emphasis (Hessevik A., 2019) and several mentioned the formally UN-affiliated organization IMO as a key actor for moving forward without ruining fair competition. The IMO decisions for Sulphur (2020) and 2050 and the connection to other UN climate negotiating processes are important.

6) Network groups: a) inside sector; b) spanning sectors

One of our studied networks are centered around DNV GL (se 4) and together with the other network underlines a network's ability to push one value (sustainability shift in shipping) and connect across several relevant subsectors (technology/science, politics, shipowners, shipbuilders. This ability to connect different other actors and subsectors seem to be important for pushing change (Hessevik A., 2019).

7) Consumer pressure a) direct b) indirect

The same effect seems to be pushing the cruise companies into changes. It is understandable that rich tourists that will see nature are easily put off by noise and pollution. The load of particles on the deck of a cruise ship is 160 timed the level of clean air and 16 times the level of a busy street (DNV GL). this is in addition the visible smoke and CO_2. Both classical cruise ships and coastal tourist vessels are being rebuilt as hybrids, to at least be able to be zero-emission close to shore, at port and in vulnerable areas (fjords, arctic areas). Also, the fisheries are now using information on sustainability in their marketing, and this can easily be applied to CO_2. The indirect consumer pressure is more complicated, but there are already goods on the market that are declared/certified to be low in total CO_2 emission, including transport, Some shipping companies are using their activities to lower emission as a competitive argument (e.g. Maersk).

8) Company culture, leadership, self-governance

The long history of shipping, its culture, its global character and flexibilities to shift national state registration is not necessarily "weak governance". It is also the fundament of significant levels of self-governance, both formal marked based (see 4) and more informal, as values, norms and sector culture (Furger F., 1997). These aspects have to be studied more closely than we have done so far, including the importance of values and social components in decision processes. So far (Hessevik A., 2019) one hypothesis would be the importance of networks (see 6) offering relevant personal contacts and social backing/trust for more sustainable decisions

9) Nudging cooperating sectors: a) banking, b) investor funds, c) insurance, d) classification

Several important actors around shipping are now clearly stating that they support and help transition to sustainability in several more or less formal ways. The classification company DNV GL is in the center of one of the networks. They publish, arrange seminars and connect actors in different ways. Also, insurance (Gard) and finance (Norwegian, Danish and Swedish banks) have examples of such soft governing attempts, especially are investor funds with an active green profile emerging. It is also possible for big organizations to use their "purchasing power" to require low or zero-emissions (Municipality of Oslo). In lack of a better word we will use the popular phrase "nudging" (Sunstein C. R. & Thaler R. H, 2008).

In the presentation above it is clear that different governance elements are of quite different kinds. Some are organizations or institutions, some are more diffuse groups, some are legal structures, and some are actors carrying values/cultural aspects (from the landscape). These elements come together in quite different configurations, making different governance systems for each subsector, as we shall see in the next part. We think this is a fairly realistic picture and consistent with the wide and process-oriented definition of "governance" as defined in part 1. To call all these elements "actors" is maybe not quite right, and probably we could develop our concepts further along that path of Latour (2007) and his Actor-Network-Theory (ANT), where the elements of connection and action are called "actants" and can be traditional human actors, organizations, laws, things or nature elements. That would be a more precise and fitting conceptual system for our analysis of the governance systems, but we will not go further in that direction in this setting.

In the next parts we will put together our discussion of subsectors and different governance elements and make some assumptions from this exercise on "governance mapping".

3. Analysis and discussion

With our discussion of the situation (part 1), choice of shipping subsectors (part 2) and our classification of relevant governance elements (part 3) we can put together two tables that help us see some patterns. Table 1 is the simple cross between subsectors and governance elements. Even in this simple form some important patterns are quite clear.

A first observation could be the general scattering of the X marks, which means that governance systems are very different between subsectors. The local ferry services that have changed so fast to battery technology are mainly with national public policy governing, linked to market elements through procurement rigged for this transition. International shipping has a very different governing system, dominated more by international organizations, companies, private and semi-private actors. In the table the ferries are in row 2,3,7 and international shipping in 4,5,7,8,9. The main picture is one of difference between subsectors The inner workings of the governance systems are also of importance.

The set up for local ferries (2017→)and passenger traffic (2019-→), as well as the Norwegian coastal passenger route (Hurtigruten) (biofuel and hybrid) have had benefits from a procurement strategy of tenders that reward lowering CO_2, and also possibilities

Table 1: The Governance matrix.

Category	Int Carrier	Int Cruise	Supply/fishing	Regional pass	Short distance
Public governmental ownership					
Public policy jurisdiction Economic support			X	X	Local ferries, Passenger transport
Classic regulation	ECA	ECA		EU, ECA	
Marker based (private or regional) regulation	X, Ports	X	X, Procurement	X	
Member organizations	IMO	IMO			
Network groups	X	X	X	X	X
Consumer pressure		X	Fishing	X	
Corporate culture, values	X	X	X	X	X
External nudging	X	X	X	X	

for direct economic support. The tourist elements in cruise traffic, both regional and international, also seem to create pressure for more sustainable solutions. Supply ships are competing for contracts from a few big oil companies. At least one (Equinor) is now rewarding long-term contract only to ships with installed batteries for hybrid propulsion.

Regulations are usually quite general for a whole sector (like the IMO-induced plan for 50% reduction of CO_2), but here we see (row 4) a number of quite simple strategic regulations that may start bigger changes. We have mentioned three examples: The first one is port power: Ports are usually semi-public organizations with some freedom to implement their own rules. They can reward low CO_2 or sulphur emissions with lower fees and they can require use of shore power. Benefits are not only lower local pollution but a pressure to make it sensible to change engines and technology, even installing hybrid systems. The second one is regional regulations to protect special waters, coastlines or fjords from pollution (EU ECA areas, Baltic Sea, UK coast, Norwegian fjords), again with a double benefit of both reducing emissions in some areas and making it more economically sound to build ships with better technologies.

Row number 7, on networks, is also interesting, indicating that a network can cross lines between subsectors, integrating even more than the ones on our list (shipbuilders, engineering forums).

As often is the case, change comes with a combination of factors. The trend to build and retrofit hybrid system for tourist boats are both pushed by consumer/competition and related to small-scale regulative arrangements in ports and in special areas (row 4 and 7).

One important factor that have not been given its appropriate place is the one of technological development. The niches may be on the edge of being mass-produced as a better alternative in some subsectors, but further away in time and development in other niches. If we (re-)introduce the technological challenges and focus on possibilities for future development we can make a more complex analytical and conclusive picture, like in Table 2.

Here we can put together a picture that in the last row has some assumptions for governance tools that might be most relevant for change, and again can we see how the suggestions are very different between subsectors. International shipping has different and more difficult technical solutions, a different governance structure and different suggestions for governance elements for a change process.

So far, all our discussion has been about closing the gap between possible sustainable niche technologies and the existing regime. There are two important other factors that must be mentioned.

Table 2: The matrix for change.

Category	Int Carrier	Int Cruise	Supply/fishing	Regional pass	Short distance
Tech Challenge	High, Energy density, global fuel access	High, Energy density, High energy needs, Onshore Power	Low, Variable needs	Medium, Energy density, safety, Infrastructure, onshore Power, energy source	Low, Infrastructure
Org/Pol Governance pattern	Polycentric, Self-governance, International, (IMO, EU), jurisdiction challenge	Polycentric, Self-governance, sector organization, International	National and semi-national, oil sector power	National, semi-national and port jurisdiction	National, regional
Maturing sociotech solution	LNG, biofuel, Hydrogen, ammonium, Methanol	Battery hybrid, LNG, biofuel	Battery hybrid, hydrogen	Battery, Hybrid, LNG, biofuel, hydrogen	Full battery, hydrogen
Governance tools for change	Int sector (IMO, EU) regional (ECA), port, indirect consumer, Normative	Consumer direct, regional (ECA), port reg, Normative, Networks, Financial	Governmental regulation/support Sector networks, Procurement, Cost sharing	Consumer, Port, national regulation, regional (ECA), Financial, environmental org	Public regulation = procurement. Cost sharing, Environmental org, Networks including

First is the role of the whole sociotechnical landscape that have markets, citizens, values and institutions pushing for CO_2 reduction and pressing on the different sectors of shipping. The second factor is the possibility of the existing fossil fuel regime surviving and adjusting. There are potentialities for improvement in existing technologies. Realistic possibilities for improvements are in the areas of hull shape, engine development, multi-fuel possibilities, slower speed, better navigation and logistics (Psaraftis H., 2019). CO_2 storage may also be a game-changer. We will not deny these possibilities, our project has been to understand some of the governance issues involved in what is the usual definition of the problem: a necessity to change away from fossil fuels to technologies that seem to be possible in the niches.

4. Conclusion

Our attempt to analyze the maritime sector with the governance perspective have given us several important lessons. The wide perspective of governance has made is possible to see the very different governing configurations of the maritime subsectors, including informal networks, market forces, and regulative arrangements of many kinds and very different kind of actors. The differences between the subsectors are of a magnitude that indicate that it might be problematic to grasp it within one governance framework. The fastest changes have been in the sectors of heavy national and regional political power. Some configurations of regulative action seem to be of special strategic importance. Regulations in ports and for special vulnerable sea areas are triggering bigger changes. Semi-formal networks have abilities to cross boundaries between the very different subsectors. For the biggest challenge; the international heavy transport over long distances our analysis may be at its weakest: We have too little precise knowledge on the practice of self-governance, the private global supportive and regulative sectors, the role of networks and the decisional systems that makes the governance configurations of international shipping. This call for further studies, not only because we need better "governance mapping" for this sector, but because the knowledge is needed to help reduce emissions in the years from the decision by IMO in 2018 to reduce emissions with 50% before 2050. International shipping has a polycentric, globalized and networked semi-private governing pattern (Furger F., 1997, Gritsenko D., 2014, Pettit S. et al., 2017). Networks, self-governance and sector normative factors are important, also for building bridges between subsectors. We need more studies of actors, values and networks and how they interact with bits of regulation into governance configurations.

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Applying Computable General Equilibrium Modelling to the Circular Economy

Hans KREMERS[1], Chief Economist*

Sameer REGE, General Manager*

* ModlEcon (company)

[1] *Contact details of corresponding author*
Tel.:+49 171 2273566
e-mail: hk01@modlecon.com
Address: ModlEcon, Rue de l'Alzette 94, L-4010 Esch-sur-Alzette, Luxembourg.

Abstract

A popular subject in the current public policy debate is the transformation of the current economy, considered as being wasteful and dirty, with an economy they refer to as the 'Circular Economy'. What is this 'Circular Economy'? How should we operationalise the transition to a 'Circular Economy', i.e. what kind of policies should be implemented to this end? What benefits and costs to the economy's welfare are associated with the implementation of these transition policies? This paper attempts to find out what the 'Circular Economy' is by implementing the concept of 'circularity' in a computable general equilibrium model.

The replacement of 'linearity' in the current waste economy with the circularity of the 'Circular Economy' would bring producers to introduce a form of recycling into their technology processes instead of wasting it into the environment and thus prevent damages to land and water. The inclusion of circularity in the computable general equilibrium model would allow policy makers to associate (social) costs and benefits to their transition policies hence facilitating decisions on which policies to apply.

Keywords: Circular Economy, Computable General Equilibrium, Waste Management, Recycling

1. Introduction

As regular attendants of the biannual European Resource Forum, organised by the German 'Umweltbundesamt (UBA)', we noticed the often aggressive promotion of the term "Circular Economy" by speakers and organisations. Aggressive to the point that the European Commission was being pushed to take up the "Circular Economy" as an important environmental policy goal. "Circular Economy" seemed to be better than any existing market economy since "it is not linear". The discussion among the forum attendees seemed to be based on some very vague and badly-defined concepts underlying the "Circular Economy". While looking at the literature on this area, it seems that this has not gone unnoticed. Su B. et al. (2013) noticed the rhetoric around the implementation of the "Circular Economy" in China, while Reike D. et al. (2018) provided a current overview of all the existing controversies on the "Circular Economy" and challenges scholars to take up a more active role in bringing a consensus on the conceptualisation underlying this term, among the parties involved. Let us therefore take up this challenge.

As economists, mainly applying Computable General Equilibrium (CGE) modelling, we are writing this paper to see how ideas and principles from the "Circular Economy" debate could be implemented into the general equilibrium model. If not, how should the general equilibrium model be adjusted in order to be able to include them. A major advantage of introducing concepts from the "Circular Economy" into a CGE model is that the model enables to provide a quantitative assessment of the (social) costs and benefits of local, national, and EU policies intending to change the current "linear economy" towards "circular economy".

The concept of a circular economy has been first raised by two British environmental economists, Pearce and Turner (1990). In their

Economics of Natural Resources and the Environment, they pointed out that, quoted from Su B. et al. (2013),

> ”*a traditional open-ended economy was developed with no built-in tendency to recycle, which was reflected by treating the environment as a waste reservoir. Yet, under the first law of thermodynamics where total energy and matter remains constant in a closed system, the open-ended system could be and should be converted to a circular system when considering the relationship between resource use and waste residuals. In another words, facing existing environmental problems and resource scarcity, they called for a need to contemplate earth as a closed economic system: one in which the economy and the environment are not regarded by linear interlinkages, but by a circular relationship, Boulding (1966)”.*

Many alternative definitions exist though for the “Circular Economy”. García-Barragán et al. (2019) even try to define the “Circular Economy” using a metric.

Pioneers on the implementation of (concepts of) the “Circular Economy” were Germany and Japan. While Japan’s effort focused on redeveloping stagnating industries, Germany’s industry had waste-management goals. After realising that much of its exponential growth during the last decades is causing a major toll on its natural resources, China seems to be seriously considering implementing ideas from the “Circular Economy”. For an assessment of the implementation of the “Circular Economy” in China, see Su B. et al. (2013). China’s socioeconomic environment however provides a different context, thereby making it an ideal laboratory for new, expanded “Circular Economy” policies. China’s agencies are considering linking the implementation of the “Circular Economy” to China’s low-carbon strategy. Its national plans to implement principles from the “Circular Economy” seem to have gained traction in the form of urban municipal solid waste treatment, energy saving, and emissions reduction plans, developing tax policies supporting resource recovery in industrial practices. Furthermore, billions of dollars are being invested in “Circular Economy” - oriented pilot projects, from applications of clean production techniques in specific sectors to municipal and regional eco-industrial development. Many Chinese application studies can be found. Wu H. et al. (2014) analyse the efficiency of a Chinese 11-year plan to introduce the “Circular Economy”.

The methodology underlying assessments of the impact of introducing ‘circularity’ in the local economy applies various performance indicators to manage environmental development and provide guidelines to improve “Circular Economy”-related policies. These indicators are based on well-known assessment methods: energy, Material Flow Analysis (MFA), Life-Cycle Analysis (LCA), CO_2 emissions, and economic returns. Geng Y. et al. (2013) pointed to the fact that these indicators may not optimally fit the needs for a “Circular Economic” assessment because they were not originally designed for the systemic, closed-loop, feed-back features that characterise the “Circular Economy”. Flow quality and characteristics, as well as the complexity of interactions between the natural environment and socioeconomic systems are often disregarded. Furthermore, indicators of eco-efficiency, such as carbon and ecological footprints, LCA, economic and energy valuation, mainly focus on individual parameters. Although useful at the local scale of specific processes or products, this specificity is unlikely to provide a complete picture for managing circular economic policies. A more economy-wide approach is needed, possibly even an integrated-assessment approach with ecological and climate models. In my opinion, an appropriately adjusted and calibrated CGE model (possibly integrated with an ecological, climate, or system dynamic model) might provide an answer.

Many assessment methods originate from an engineering point of view. Reh L. (2013) takes an explicit process engineering approach to analysing the “Circular Economy”. García-Barragán J. F. et al. (2019) take a more mathematical approach by defining a metric to define the “Circular Economy”. The economics view should certainly not be forgotten in order to prevent the mistakes made in the climate change debate. This paper hence takes an economic approach and applies (computable) general equilibrium modelling to obtain a better understanding of what the “Circular Economy” is all about from the economic point of view. Since CGE modelling once originated applying an engineering approach to economics, it might serve as the necessary bridge to bring both worlds more together. Furthermore, it tries to derive indicators from the model that could be used to assess the impact of circular economic policies in such a way that the concerns of past researchers might be answered. The work should be seen as an attempt to provide a more scientific and economics-related approach. This would combine the neoclassical general equilibrium model with the ecological environment within an integrated assessment. As such, it provides a neoclassical alternative to the model proposed by Geng Y. et al. (2010).

Recently, Kalmykova Y. et al. (2018) provided a review of the theories and practices as well as an overview of the development of implementation tools within existing research on the "Circular Economy". Korhonen J. et al. (2018) suggested a model for research on the circular economy that helps in the categorisation, classification and organisation of the research and investigation. How do these theories, tools, and practices compare to the methods of CGE modelling? Li S. (2012) develops an input-output table for his circular economy concepts, and this input-output table could start a Social Accounting Matrix (SAM) for our CGE model to be calibrated upon.

The ideas and concepts underlying the circular economy seem to originate from research on global value chains and life cycle assessments. If we would like to import circular economy ideas, concepts, indicators, and implementations into a CGE framework, we should first look for applications of CGE modelling to global value chain assessments and life cycle analysis. This means that we should construct the SAM underlying the CGE model in such a way that value chains and life cycles (over time) should be distinguished in the SAM data. Antimiani A. et al. (2018) described an adjustment, GTAP-VA, of the often applied GTAP model, GTAP (2019), to include such value chains. GTAP-VA could hence be taken as a starting point for the paper.

2. A CGE model and environmental damage

The CGE model (see Shoven J. and Whalley J. (1992), and Ginsburgh V. and Keyzer M. (1997)) is based on a theoretical model referred to as an exchange economy with nonlinear convex constant returns to scale production technologies (see Arrow K. J. and Hahn F. (1971), Debreu G. (1959)). This model consists of a number of goods which the applied model distinguishes into commodities and production factors. Commodities are produced for consumption or as intermediate inputs in their production processes at given market prices. Production factors are goods like capital, labour, and land, but also natural resources like gas and oil wells. These goods are supplied as production factor inputs to the production activities in the economy, at given market prices.

The production factors are owned by the consumers in the economy, who hence have an endowment of each production factor. Notice that the theoretical model also allows the consumer to have endowments of commodities. The consumer possesses a preference ordering over all goods in the economy depicted by a (homothetic) utility function, which it is assumed to maximise. The standard CGE model assumes that the consumer obtains no utility from its endowments of production factors, which makes it optimal for the consumer to supply in its total to the market at prices p^f, which it takes as given. This provides the consumer with an income that defines a budget which the consumer spends on the consumption of all commodities that maximise his/her utility, at given market prices p. The consumers are hence price takers, where utility maximisation results in an optimal demand or supply function for each good.

The producers or production activities produce the commodities using a (constant returns to scale) technology that takes the goods as inputs. The technology thus defines a production-possibilities set from which the activity chooses a production bundle which maximises the activity's profits, taking market prices p and p^f as given. The producer is hence also a price taker on the market. Notice that the constant returns to scale assumption on the producers' technology makes profit maximisation equivalent with the minimisation of the cost to produce one unit of the output good, at given market prices. Hence to cost to obtain a production or activity level of y units equals y times these unit costs. Cost minimisation defines the input-output matrix as a function of the good prices.

The (*competitive*) *equilibrium* in this economy is then defined as the activity levels y and utility levels u, price levels p and p^f, such that there exist a market equilibrium on the commodity and production factor markets, the commodity prices are determined by a nonpositive profits condition to guarantee the existence of an equilibrium, i.e. the output price equals the marginal cost as well as the average cost to produce one unit of this good, and total expenditure equals total income for each consumer. Laan G. Van der and Kremers J. (1993) prove the existence and uniqueness of an equilibrium. The equilibrium in this model satisfies the two Theorems of Welfare that the equilibrium is (Pareto) efficient and that each efficient equilibrium can be obtained with a suitable reallocation of the consumers' endowment, under the assumptions that guarantee the equilibrium.

A CGE model is usually calibrated on data collected and organised into a SAM of values. Table 1 provides the SAM underlying the calibration of the general equilibrium model above A matrix is SAM if, among other properties, the row totals of the matrix equal the column totals of the matrix. The SAM contains values which equal price times quantity, where the quantities flow from row to column, and the cost or expenditure flows in opposite direction. Notice that, in Table 1, this property of the underlying SAM coincides with the conditions defining an equilibrium in this economy. As such, the SAM provides a good (non-mathematical) representation of the economy.

The model, as well as the data organised in a SAM only refer to the economy. In order to quantify the impact of economic interactions on the environment, we should collect the necessary data on the environment and compare them with the economic data in the SAM, and theorise on possible interactions with the economy by adding the necessary relationships to the economic model. An example is the comparison of carbon emissions with the specific demand for fossil fuels in order to obtain fossil fuel specific carbon emission shares. This simple relationship is then added to the economic model for determining the total carbon emissions in the economy. A more elaborate example of linking the economy with the environment is the linking of economic models with e.g. climate models into a so-called integrated assessment framework.

Kremers H. and Steiner B. (2017) apply damage functions to construct a link between economic output, in particular the carbon emissions associated with economic activities, and environmental damage in the form of land productivity losses. They formulate the simplest possible (Leontief) production function relating the output of apples to the input of land through a land productivity parameter. The latter parameter is then subdivided into a damage parameter d and a remaining productivity parameter α. For the damage parameter d,0 ≤ d where a value of d less than one indicates a loss in land productivity, $d = 1$ indicates no influence on the land productivity, and a value of d larger than one an improvement of the land productivity, producing apples. The production function then looks like $y = (\alpha \cdot d)\ x$ where y denotes the output in tons of apples and x denotes the input in hectares of land. The value of the parameter d is then determined by estimating a damage function δ relating damage related losses in land productivity d to climate variables, mean local temperature and precipitation.

Houba H. and Kremers H. (2009) consider the theoretical implications of including damage coefficients and related damage functions into the standard microeconomic model of consumption and production and redefine the equilibrium.

In order to extend the ideas in Kremers H. and Steiner B. (2017) to the inclusion of waste related damages instead of climate damages, we have to define a damage function δ that relates the waste damage related losses in land productivity d to variables related to the amount of goods obtained from the economy as waste being put into the land units. The value of the damage coefficient then determines which economic uses remain profitable for the land, following Ricardo's land use theory, see Ricardo D. (1973).

Table 1: The Social Accounting Matrix of the data underlying the model.

	Activities	Commodities	Consumers	Total
Activities		Output		Revenue
Commodities	Inputs		Demand	Market Demand
Consumers		Endowments		Income
Total	Cost	Market supply	Expenditure	

Table 2: The Social Accounting Matrix including production and waste.

	Act_Comm	Act_WasteD	Comm	WasteD^2	Land Use	Factors	Consumers	RoW	Total
Act_Comm / **Act_WasteD**			Domestic output					Exports	Revenue
Comm	Comm Inputs	Comm stocks					Demand		Market Demand
WasteD^2							WasteD		
Land Use	Land Use	Landfill							Value added
Factors	Factor inputs							Exports	
Consumers			Comm stocks		Endowments		Max {0,CAB}		Income
RoW			Imports			Imports		Max {0,CAB}	
Total	Cost		Market supply		Total endowments		Expenditure		

Table 3: The Social Accounting Matrix where a part ψ of the formerly wasted stock of consumption goods are being recycled in their original production activities.

	Act_Comm	Act_WasteD	Comm	WasteD^2	Land Use	Factors	Consumers	RoW	Total
Act_Comm / **Act_WasteD**			Domestic output					Exports	Revenue
Comm	Comm Inputs +ψ · stocks	(1-ψ) · Comm stocks					Demand		Market Demand
WasteD^2							WasteD		
Land Use	Land Use	Landfill							Value added
Factors	Factor inputs							Exports	
Consumers			Comm stocks		Endowments		max {0,CAB}		Income
RoW			Imports			Imports		max {-CAB, 0 }	
Total	Cost		Market supply		Total endowments		Expenditure		

Applying soil remediation techniques, one could make the land profitable for other types of land use too. Heavily contaminated land may be unusable and hence unprofitable for agricultural objectives, but it may still serve to build a parking lot.

The values for the waste variables can be obtained from the equilibrium computed by the applied CGE model and can as such be found in the newly obtained SAM. Hence, the damage function forms in its most general form a function Δ relating the damage parameters *d* with the SAM, i.e. d = Δ(SAM). We assume that the damage adjusted land productivity parameter becomes valid for the next period a recursive dynamic version of the model, since it would result in parameters that are a function of the economic variables. The latter would be a violation of the constant returns to scale assumption on production. We should however assume that the changed land productivity parameter becomes valid for the next period in a recursive dynamic version of the model. For the same reason, we need a recursive dynamic version of the applied model here, instead of a fully dynamic model where temporal decisions are being taken.

3. Introducing waste management into a CGE model

Wasting a good implies that part of the final demand goods in the form of consumption or input of this good is not being used as such anymore. A consumption good is hence either directly consumed, or it is wasted. Before it is wasted it should be added to a stock or endowment of the consumer in this good. The theoretical general equilibrium model allows for the consumer to have endowments in not only production factors but also in the consumption goods. Each period, a part of this stock or endowment ends up as waste on land or water causing significant environmental damage.

Part of the output of a production sector may not reach the consumer as a consumption good or other production sectors as an input to its production process. In this case, it should be added to the production sector's stocks of output goods. In the SAM, the output good will also function as an input to its own production process. The SAM depicts the value flows in the economy during a year. Outside of the SAM, these flow values are applied to update the existing stocks of the production sectors in their output goods, and to update the consumer's endowments in consumption goods. Each year, part of these stocks and endowments end up as waste on a particular areal of land, e.g. a garbage belt, or on the water, e.g. the enormous amounts of plastics drifting over the oceans. In the case of capital goods, the waste could be seen as the old industrial areas left to rust, for example. In the case of labour, the army of unemployed could come to mind. In the case of natural resources such as oil, one thinks of the environmental damage caused by oil leaks of ships or burning oil wells. Gas leaks will cause local fires destroying everything on the local land. In this way, these waste flows add to stocks of waste on the land or on the water. These volumes are served up as an input to the damage functions introduced in Section 2 to compute the loss of land productivity.

In Table 2, we add a production activity to the economy which produces an output good 'waste' which uses (a part of) the current consumers' stocks or endowments of each commodity as an input to its (constant returns to scale) production technology. We abstain from production stocks, also because these stocks might be modelled as owned by the consumer households who are also the shareholders of the production sectors. Notice that the stock of waste commodities is called a landfill. The 'waste' production sector contains garbage collection, which collects the stocks of commodities built up over the years as waste. The consumer demand for the 'waste ' commodity refers to their expenditure on waste or garbage collection services. In this sense, 'waste 'is an abstract good being an aggregate of the collected commodities.

One of the most worry-some aspects of the production of waste is that huge parts of waste are exported by the western world to developing and underdeveloped regions for which they form a significant part of income but also enormous environmental risks. Who does not remember the huge floats of waste drifting in the seas? We therefore include international trade into the SAM of Table 2. Here we have the choice between a multi-region trade model or a single-region trade model. For simplicity, we initially choose a single-region trade model, concentrating on one region trading with the Rest of the World ("RoW"), although the multi-region trade model, which partitions the world into several trading regions, is more often applied in non-economic circles. A single-region trade model is relatively small and thus may allow us to focus on the modelling of waste and ’circularity’ into the economy.

We therefore add a microeconomic consumer household “RoW” (“Rest of the World”) to the SAM in Tabe 2. This consumer’s expenditure consists of the commodity and factor exports as well as a possible Current Account Balance (CAB) surplus, i.e. the value of total exports exceeds the value of total imports, for the domestic region. RoW’s income on the other hand, consists of its earnings from the imports of each good and factor into the domestic region plus a possible current account balance deficit, i.e. the value of total imports exceeds the value of total exports. There is trade in waste, while land remains an immobile hence non-tradable factor. From economic trade theory, we know that the current account balance equals the capital account balance, where the latter balance equals the difference between the domestic regions savings and its investments. Without a time index, savings and investments lose their meaning. Hence, we abstain here from modelling them. We will come back to this if modelling the circular economy would require us so. As the reader may already have noticed, the total exports might not equal total imports, leaving the domestic region with either a surplus or a deficit on the current account balance. The nonzero current account balance may either be an income (CAB > 0) to the consumer or an expense (CAB < 0). Notice that Table 2 also assumes domestic markets for all production factors. Land is also a factor input in the waste production sector. This land refers to the landfills required to store the waste. For the future supply of land, this land can be considered lost for most production sectors.

In Table 2, we have added a production activity called ‘Waste D(isposal)’, which takes the stocks of commodities offered by the consumers as their demand for the ‘WasteD’ output good to the garbage collection services as its (intermediate) inputs together with land in the form of landfills and other production factors such as labour. Notice that the amount of wasted commodity stocks is given to this sector, hence the ‘WasteD’ production activity determines the optimal, cost minimising amount of landfill necessary to store the waste. The wasted commodity stocks valuate at their market prices p. Notice that the stocks of wasted commodities are supplied to the market by the consumers but they are immediately taken off the market as demand by the ‘Act_Waste’ activity. This suggests that this waste has no influence on the market clearing prices of the consumption commodities. In case there should be an influence on the market prices, the input costs of these stocks as inputs into the ‘Act_Waste’ production activity should valuate at other prices than aforementioned market prices. According to the definition of goods in Debreu G. (1959), this would make the wasted goods separate goods with different underlying markets with appropriate clearing prices.

In order to extend the ideas in Kremers H. and Steiner B. (2017) to the inclusion of waste related damages instead of climate damages, we have to define a damage function that relates the waste damage related losses in land productivity d to variables related to the amount of goods obtained from the economy as waste being put into the land units. The value of the damage coefficient then determines which economic uses remain profitable for the land, following Ricardo’s land use theory, see Ricardo D. (1973). Applying soil remediation techniques, one could make the land profitable for other types of land use too. Heavily contaminated land may be unusable and hence unprofitable for agricultural objectives, but it may still serve to build a parking lot.

The values for the waste variables can be obtained from the equilibrium computed by the applied CGE model and can as such be found in the newly obtained SAM. Hence, the damage function forms in its most general form a function Δ relating the damage parameters d with the SAM, i.e. $d = \Delta(SAM)$. Notice that you cannot include the damage parameters as this function into the current equilibrium, since it would result in parameters that are a function of the economic variables. The latter would be a violation of the constant returns to scale assumption on production. We should however assume that the changed land productivity parameter becomes valid for the next period in a recursive dynamic version of the model. For the same reason, we need a recursive dynamic version of the applied model here, instead of a fully dynamic model where temporal decisions are being taken.

4. Introducing circularity through waste recycling in a CGE model

When talking about the "Circular Economy", the first idea that comes to mind is the idea of recycling. Instead of treating unused products as waste, the economy should try to reuse them, for example as inputs into new products, i.e. by "recycling" them. I would guess that the word 'circular' refers to the part "cycle" within this word. The idea behind the "Circular Economy" seems to be the generalisation of the idea of 'recycling' to all final demand goods. When considering value chains within the economy, this idea suggests a circle of values through the economy instead of the usual 'linear' chain of values. The latter would suggest two end points of the chain of values, a starting point where a product is initially introduced into the economy, e.g. by being produced at a certain market price. Hence there exists an initial value of this bundle of the good. The good may then be used as an input into another production sector, thereby generating value in the output good produced by this sector. The same can then be said about the latter output good, until it ends up as a waste product at the end of its life, and it is disposed of in the environment, i.e. the other end point of the 'linear' chain of values. In a "circular economy", the idea is to take away the latter "waste" end point by recycling it as an input into the former 'initial production' or "birth" end point, thereby reshaping this value chain as "circular" chain instead of a 'linear' chain.

Including the ideas and concepts behind the "Circular Economy" hence implies that we should distinguish existing value chains in the SAM of data underlying the applied CGE model. Antimiani A. et al. (2018) have adjusted the often applied GTAP model to refer to these value-added chains, called GTAP-VA. In this short paper, we abstain from addressing value chains, and refer only to the inclusion of recycling as a form of circularity into the SAM. Table 3 adds recycling to the SAM.

When recycling wasted commodity stock, a part ψ of these stocks is being recycled. This recycling is assumed here to be done within the original production sectors. This means the technologies as depicted in the model change. Notice that the model considers the production activities as a production sector which aggregate all firms that participate in producing the aggregate output good. This sector is now enriched with a recycling sector. The underlying (aggregate) technology as depicted by the cost structure to produce the aggregate good hence changes too. A recalibration of the model on the new SAM in Table 3 would lead to other values for certain share parameters. When considering recycling as the outcome of a policy impact on the SAM in Table 2, we should notice that there are price changes in all output goods of the production activities.

The introduction of new technologies with the possibility to recycle old stocks of the product has technological and economical effects. CGE models are not fit to study the technological impacts. They are economic models and should be handled as such. Within the CGE model, the introduction of a new alternative production technology to produce the same output good of an activity results in an alternative cost structure being introduced into the economy, taking the economy out of equilibrium. Computing the new equilibrium might result in the new technology breaking even in the new equilibrium while the old technology is making losses and hence is being put inactive.

The new technologies might however constitute an equilibrium where they do not break even and hence remain inactive. Here, the government might come in by introducing subsidies which make these technologies break even. The latter has been done by the German government when introducing the 'Energiewende', at huge cost of inefficiencies.

5. Computing the net costs of introducing the circular economy

Any policy maker would be most interested in computing the cost of introducing the circular economy into the existing wasteful economy. Hence, it won't suffice to compare a benchmark referring to the existing economy, call it a "Business-as-Usual" if you like, with a counterfactual that refers to a fully implemented circular economy. It may be clear that the circular economy, once in full operation, is way more efficient than the current economy. When computing the costs of the circular economy, we should put way more emphasis on the costs related to the transition from the old economy to the circular economy.

These costs depend on the policies of the government to bring this transition into reality. Germany for example already has experience with a transition of its economy from mainly fossil fuel based towards a fully renewable based economy. Instead of fading out nuclear technologies from the existing energy mix, the panic was so large that the transition was put into direct action as a reaction on the catastrophe with the Japanese reactors in Fukushima. Germany needed to remove all nuclear power from its energy supply, and preferably replace it with renewable resources. Berlin therefore immediately ordered all its energy companies to halt and remove their nuclear reactors from the grid. Consequentially, these companies got into serious financial trouble due to investments lost and the major costs of halting reactors. Furthermore, they started suing the German government for contract breach. The German government had just before the Fukushima disaster extended the nuclear contracts with these energy companies, under large protests of its civilians.

The “Energiewende” as it has become known in Germany, was introduced not with market-based policy measures but by central government planning. Instead of the production sectors involved, the preferred renewable energy techniques were chosen by the government. This meant that government subsidies were mainly directed to photovoltaic, wind power, and to a lesser extent biomass, based on technical conditions while ignoring the economic consequences. Germany did a wonderful job introducing photovoltaic techniques. But, since Germany is not a very sunny country, a necessary input to photovoltaic, it certainly does not have a comparative advantage in producing photovoltaic products in a cost-efficient way, compared to for example Spain. Hence, currently China is taking over production at much lower costs leading to German producers leaving the market.

Wind power is being subsidised guaranteeing producers a cost covering price using so-called “feed-in” tariffs. This meant that wind power producers receive a subsidy equal to the difference between their costs of producing electricity from wind, and the market price of electricity. This subsidising of wind power production is being covered by a tax on electricity demand by consumers and producers in Germany. The consequences of ignoring economics are costly.

First, the government instead of the market choosing wind power over possible alternatives meant that a lot of subsidies were put into technologies which were not market ready, i.e. without these subsidies these production sectors would quickly go out of business due to heavy losses. These costs were mainly due to technical problems. Here, it was the inability to store electricity for later use. In economic modelling, one could say that costs of storage would go towards infinity. In reality, this could be seen by the absurd measures with associated high costs, that had to be taken for the network not to collapse. Wind power is not a stable good, i.e in the case of no wind, there is no production at all. In the case of a heavy storm, the network is being flooded with an enormous supply of electricity. Since there are no sufficient storage options in Germany, the excess production had to be imposed on the sometimes rickety networks of Germany’s neighbouring countries. Poland angrily threatened to close its network for German electricity since it threatened to overload its rickety network. The Netherlands, contrary to Poland endowed with a solid electricity grid, were very happy with the excess electricity since it could offer the electricity against much lower prices. Germany pays Austria for taking up a lot of electricity which it “stored” by raising the water level in its lakes, and later selling this electricity again back to Germany thereby making money on the same good twice.

Notice that the excess supply of electricity by wind power on the German market during heavy winds, would lower the market price for electricity thereby providing the wind power-based electricity production sectors with too little income to remain viable on the market. Due to its ‘feedback tariff’ policies, German households and production sector are hence confronted with increased taxes on their energy demand, and hence with a higher electricity bill, while on the electricity market the price of electricity is decreasing due to an excess supply. Such perversities do not help the public to accept the “Energiewende” though it is being introduced with the best of intentions. And I left out the dislike of many people to have a wind mill in their back yard or the opposition of bird watchers who oppose the enormous slaughter these mills cause among birds.

The other case with wind power, when no wind forms a threat to the security of energy supply on the German market, urged the German government to keep several dirty coal industries online as a backup option. The latter may have also been for reasons of local labour protection policies. As a consequence, it recently became public that Germany will not reach its loudly self-imposed carbon emissions goals.

The subsidisation for farmers to support the production of biomass energy on their land caused these farmers to switch their land use, mainly of grains, wheat etc. towards biomass related production like rapeseed. Years ago, this caused a large deficit in the global production of food, in particular grains and wheat.

The market disturbing effects of subsidizing is well-known to any economist. Hence, if the German government would have listened to their economists' comments instead of arrogantly dispose of them as too theoretical or not practical, the associated huge costs on society could have been prevented, thereby increasing the acceptance of the "Energiewende" among its citizens and outside of the country. So, in these circles, a discussion on the circular economy is getting popular and we would like to learn from the experiences of the German "Energiewende" with introducing new technologies, here recycling technologies. We therefore need to discuss the costs of possible transition policies towards the Circular Economy. The idea of this paper is to prepare CGE model for participation in this policy discussion.

We noticed in Section 4 that the idea of circularity and linearity in an economy derives from concepts in value chain theory. Hence, any model trying to assess the impact of policies referring to the "Circular Economy" should explicitly contain these concepts. Antimiani A. et al. (2018) introduce a version of the well-know GTAP model that includes these value chains. They refer to it as GTAP-VA. So, a first idea is to use GTAP-VA as a starting point and develop the model further to include circularity into its value chains.

To change linearity into circularity with respect to each production technology in the economy means that we have to introduce technological substitution of recycling technologies into each production sector. Technological substitution plays an important role when considering the introduction of renewables into the energy economy, or when considering electricity production. Kremers H. et al. (2018) note that up until recently this has not been solved very well in computable general equilibrium models. They suggest a rather simple solution to this modelling problem. Our extension of the GTAP-VA model towards the inclusion of recycling technologies should refer to this solution.

Kremers H. et al. (2018) model technological substitution by considering the equilibrium problem as a so-called 'mixed complementarity problem' (see Cottle R. et al. (1992) for more mathematical details and literature on this subject). We thus consider the economic aspects of technological substitution. The complementarity underlying technological substitution in a computable general equilibrium model implies that a technology will only be substituted into the production of the output good when it starts to break even the production costs. The technology will remain inactive as long as the market conditions are such that the technology makes a loss. Notice the nonexistence of an equilibrium in the economic model if there exists a technology that makes positive profits, hence existence of an equilibrium requires us to impose so-called nonpositive profits conditions. An implication of Kremers H. et al. (2018) however is that there may exist an equilibrium with technologies making profits when these technologies' outputs have an upper bound, often referred to as the technologies' capacity. Notice that this requires us to assign the positive profits to the economy's consumers according to a certain share. The latter is completely ignored by the standard literature on technological substitution in CGE models, surveyed by Peters J. (2016).

Peters J. (2016) mainly surveys the modelling of technological substitution in the electricity market. Applying the ideas in Kremers H. et al. (2018) on the electricity market, new electricity production technologies will only be introduced into the production of electricity when production breaks even. The latter moment occurs when electricity production reaches its capacity level at which moment the excess demand increases the electricity market price to breakeven levels. Recycling is different. It looks acceptable that recycling technologies are already breaking even at the moment they are introduced on the market. This means that the current equilibrium is inefficient since it ignored the existence of the more efficient and environmentally friendly recycling technologies.

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Citizens' Perceptions in Participating in Recycling and Circular Processes

Mr. Constantinos KOUTELIDAKIS[1], Post graduate student*

Dr. Eleftheria ALEXANDRI, Lecturer*

* Hellenic Open University, School of Science and Technology, Patras

[1] *Contact details of corresponding author*
Tel: +30 210 2838884
e-mail: conk1978@yahoo.gr
Address: Prasinou Lofou 65, Herakleion, Attica, Greece

Abstract

Recycling and composting are perceived as means to reduce urban waste that end up in landfills, preserve natural and manmade resources, reduce methane emissions from landfills and promote circular economy. Although recycling has gained social acceptance during the last decades in most parts of the world, there are still people who do not participate in the recycling process, thus not contributing to the solution of problems, but persisting on their conservation. There have been several studies that try to identify the forces that drive or drive not people to recycling, but none has posed yet the research question which processes can encourage people in Greece to participate more in circular processes. The aim of this study has been to identify the reasons why people in the region of Attica recycle or not and to pinpoint the recycling policies that would encourage them to recycle and compost more. So as to address this question, statistical analysis has been made to the results of an online survey on the issue. Criteria have also been set that concern the relationship of recycling with sustainability, which have been assessed by citizens in the survey. Through the quantification of indicators that concern certain recycling policies and the weighting factors that have resulted by citizens, multicriteria analysis has been made (using Multi Attribute Utility Theory), so as to indicate the optimum recycling process for the region of Attica. Conclusions are drawn on circular policies that should be put forward, so as to result in more people participating in them.

Keywords: Recycling; Urban Solid Waste; Circular Economy; Separation at Source; Participation.

1. Introduction

Most ancient civilizations re-used their waste materials in various ways; thus, their discards were less voluminous than today (Wilson D.G., 1975). What is regarded as ultimate rubbish is really a cultural and economic perception. Up until the 19th century, urban dwellers were encouraged to dispose organic waste as fertilizers to the countryside, "*recovering those materials which the cities own to earth*" (Barles S., 2014). In Victorian households, in Britain, a servant would lose her job by throwing away useful waste, which could be reused or sold, as they had economic value (Hindeley E. et al., 2012).

The linearity of systems introduced in the 20th century economic production and management capsised this for millennia circular approach towards solid waste. The increasing volume and complexity of waste associated with modern economy and the consumerist way of life seriously endangers ecosystems and human health, causing air pollution, water and soil pollution, as well greenhouse gas emissions (United Nations, 2019; European Environment Agency, 2017). In addition, resources are lost, through secondary raw materials such as metals, wood, glass, paper, plastic waste streams ending up in landfills (European Commission, 2018a).

In Europe, 16 tons of material per person per year are used, 6 tons of which become waste (European Commission, 2018a). Of these, only 29.6% are recycled, 23.2% end up in landfills, 28.0% are incinerated and 16.8% composted (Eurostat, 2018). Especially in Greece most of municipal waste (81%) is destroyed, rather than recovered, while only 19% is recycled (European Commission, 2018b).

The solution, first and foremost, is to minimise waste. The second option is to reuse, then recycle, and to recover energy from what is finally left, the last option being their disposal, which includes landfill and incineration without energy recovery (European Commission, 2018a). The conversion of waste into resource is the key to circular economy. If citizens repair, reuse, recycle, and if one industry's waste becomes another's raw material, one can move into a circular economy, where waste and the problems caused by them are eliminated; resources are used efficiently and sustainably (Panagiotakopoulos D., 2002). In order to achieve this, the active participation of citizens is needed and the change of mentality towards what is ultimate waste and what has just lost its usefulness for its owner. The scope of this paper is to investigate whether or not citizens are willing to recycle and the reasons for their participation or not. The aim is to pinpoint which recycling policies, focusing mostly on economic policies could persuade more the inhabitants of Greece to participate in the recycling process and to change their perspective regarding waste.

2. Methodology

In order to achieve the objectives of this research, the following methodology has been applied: online survey, interviews with experts and multicriteria analysis. First the citizens of Attica (the county in which Athens, the capital of Greece, belongs) have been asked their perspective on recycling, composting, reuse of items and environmental protection, through an online survey, so as to draw conclusions on citizens’ point of view and motivational patterns. More specifically, the online survey has aimed to find out who is involved in circular processes (namely recycling and composting) and who is not, what the views and attitudes of citizens towards recycling, composting and re-use are, to highlight the reasons for not participating in these processes and to pinpoint policies that would increase participation rates.

The questionnaire had been posted from 14.02.2019 to 19.05.2019 in all Attica Municipalities groups as well as student community groups of social networking platforms (namely facebook) and has been sent through e-mails, in the form of snowball sampling. Elders, with no internet skills, have been interviewed individually, by the researchers. Thus, the sample has been selected randomly, covering a broad spectrum.

The questionnaire has consisted of three parts: the main questionnaire, which addresses the aforementioned goals, a demographic part and a last, small part, in which the participants are asked to assess the benefits from completing this questionnaire. In its 9 subsections the following are examined: a. The participants’ interest in the environment with 2 dichotomous questions; b. Knowledge of recycling and its benefits with 3 dichotomous questions; c. Knowledge of recycling policies and objectives with 2 dichotomous questions; d. Knowledge of recycling practices with 5 dichotomous questions; e. The source and adequacy of recycling knowledge with 1 dichotomous question and 2 multiple choice questions; f. The participation in recycling processes with three multiple choice questions, two 5-point Likert scale questions and one free text question; g. Knowledge and practices (e.g. reuse) about circular economy with 2 dichotomous questions and 3 multiple choice questions; h. Knowledge and attitude about composting with 6 dichotomous questions and i. The marking of sustainability assessment criteria with one Likert 5-point scale question. The results from this part of the questionnaire are used as weighing factors, for the multicriteria analysis.

Interviews with experts have had the form of semi-structured interviews, with the purpose to examine municipal officials’ and academics’ point of view on why recycling rate reach such percentages and what they believe should be made to increase citizens' participation. Apart from that, they are asked to evaluate the systems examined in the multicriteria analysis.

Finally, four economic systems for recycling have been investigated more thoroughly, namely Landfill Tax, ‘Pay As You Throw’ (PAYT) System, Rewarding Recycling and Product Fees, regarding whether they are capable to achieve sustainable goals through multicriteria analysis. This research has focused on these economic systems, as one of the main purposes of economic instruments is to create incentives to avoid waste (Federal Ministry for Economic Cooperation and Development, 2015; Ertz M. et al., 2016). As Fan et al (2019) have found out, there is a strong potential between recycling rates and incentives and therefore the role of subsidies should not be ignored. They even discovered that all kinds of recyclables can be collected through financial incentives.

This is achieved either through taxes and levies that discourage waste generation, or through subsidies and tax exemptions / rebates that encourage the reduction or recovery and recycling of waste (Federal Ministry for Economic Cooperation and Development, 2015). For this reason, the aforementioned economic systems have been selected for further investigation, as they are strongly suggested in existing literature (e.g. Parliamentary Commission for the Environment, 2005; Federal Ministry for Economic Cooperation and Development, 2015; European Commission, 2012; Tojo et al., 2008). In practice they are simple to implement, whilst they have been widely applied in both European and global level, capable of diverting waste from landfill (European Environment Agency, 2009). More specifically, landfill charges concern the charge per weight (e.g. tone) on the waste that ends up in the landfill, as an incentive to divert the waste from the landfill and to divert it to treatment and recycling (Federal Ministry for Economic Cooperation and Development, 2015; Parliamentary Commission for the Environment, 2005). Product charges are levied on products purchased by consumers, aiming to ensure that valuable or possibly hazardous materials are not disposed, but recovered, recycled or appropriately processed. Retailers have to pay a refund to consumers when they return the product or packaging waste (Federal Ministry for Economic Cooperation and Development, 2015; Parliamentary Commission for the Environment, 2005). Recycling subsidies, such as rewarding recycling, where citizens are directly rewarded for glass, plastic and metal packaging, paper etc., returned to Automatic Recycling Centers with coupons for free purchases at affiliated stores, or with coupons for competitions, promotions, free products, donations etc. (Rewarding Packaging Recycling, 2019). Finally, in the PAYT systems each household is charged according to the amount of waste it disposes. For this reason, it is often reported that waste collection costs using the PAYT system are more equitably distributed among the population (Bilitewski B., 2008). PAYT systems can be applied based on the volume of the bin, the weight of the waste, the frequency of the waste collection from the bin and the number of bags (Kyrkitsos F. et al., 2011).

The sustainability assessment of these four systems is made through identifying 11 sustainability indicators which can describe as well as possible sustainable growth (Bell S. and Morse S., 2012), taking into consideration not to repeat the same concepts on different criteria (Herva M. and Roca E., 2013). All criteria with which these four policies are examined (Figure 1) derive from the three pillars of sustainability: social equity, economic growth and environmental protection (United Nations, 1987). Twenty experts on waste management (academics, experts and officials engaged in municipalities and local governance) have been asked to mark each system for each criterion, apart from the criterion of 'social acceptance', which has derived from citizens' responses to the survey. Through the aforementioned questionnaire, citizens have also been asked to express how important they think each selected criterion is, thus attributing their weighting factors.

The combination of citizens' preferences, regarding criteria and the averaged values of the marks that experts have given to each recycling system are combined through multicriteria analysis, so as to prioritise the examined policies from a sustainability point of view. More particularly, the Multi-Attribute Utility Theory (MAUT) is incorporated, as a method that respects the axioms of reflexivity, comparability, transitivity of choices, continuity and dominance (Ishizaka A. and Nemery P., 2013).

3. Results and Discussion

3.1 Survey

The online survey has been answered by 647 people; For 95% confidence level, 4% error margin, and 50% population rate, the recommended sample size has been set to at least 601 individuals; the questionnaire response of 647 individuals has covered this requirement. Regarding the results of the survey, it seems that the inhabitants of Attica are aware of the environmental issues that solid waste may cause and are sensitive about environmental conservation;

Figure 1: Selected criteria to express the sustainability of the examined recycling policies.

99.4% are interested in protecting the environment, 99.5% know about recycling, while 98% are aware of the benefits of recycling in the environment and 89.3% of the environmental problems caused by landfill sites. Regarding composting, the percentages are much smaller; 88.6% know that composting is a natural process that converts organic materials into compost. 18.1% participate in environmental activities, 50.2% would like to but do not have the time and 31.7% do not participate. 93.5% declare to be aware of the benefits of a circular economy, while 31.27% believe that more efficient use of resources would have a positive impact on the environment, 28.46% on the quality of life, 22.55% on economic growth and 17.72% on employment opportunities.

Concerning policies and the economic aspects of waste management, citizens do not seem to be updated; 58% do not know that municipalities pay to Fylis'[7] landfill depending on the weight of the waste they dump, while 72.3% are unaware of the EU's objective of recycling municipal waste. A much larger percentage (93.7%) is unaware of the Municipality of Athens' target to reduce biowaste by 100% by 2030 (Skoula E., 2017).

On the issue of circular processes, recycling seems well established; 99.8% declare to know about blue bins (the bins dedicated to recycling) (Figure 2), while 99.7% know what to recycle in the blue bins and 74.3% know about

[7]A municipality in Attica, in whose landfill site solid, municipal waste from Attica municipalities end up.

rewarding recycling points. However, only 32.6% have returned recyclables to a rewarding recycling point; 45.0% have stated that there is no such infrastructure near their residence (Figure 3). Other circular processes, such as composting, have not attained such great awareness as recycling. Only 50.9% are aware of the 'brown' bins in which composting materials are disposed for decomposing (Figure 4). 54.6% have stated that they know how to use these compost bins, as this facility is not well established in all the municipalities of Attica; only 4.79% disposes organic waste in compost bins. 84.85% have responded that there is no such infrastructure in the area where they live.

On the subject of recycling facilities, 85.3% have confirmed that there is a recycling 'blue' bin near their home (Figure 5), but only 60% have declared that recycling is practiced in their workplace. Regarding composting, the results are quite discouraging; only 7.0% declare that such facilities exist near their house (Figure 6). On the issue of information on recycling, the majority has taken place through the internet, followed by television; 19.4% have been informed about recycling from the internet, 12.7% from the television, 11.4% from environmental organisations, 10.1% from school, 9.0% from the press, 8.4% from campaigns carried out by the Municipality (or the recycling company), 7.1% from brochures, 6.7% from the family or friends, 5.8% from the work, 5.3% from advertisements on bus stops or the subway and 4.2% from the radio.

More than half of the sample (53.9%) believe that the information they have received is sufficient to carry out recycling properly. Yet, this is not such a satisfactory percentage, regarding the confidence that citizens feel about their knowledge on recycling correctly; this is also expressed in free text answers; better information, awareness and education is needed on recycling (how items are recycled, what is recycled, which the benefits are - why citizens should recycle).

Most people seem to recycle on a daily basis (75.6%), 17.3% occasionally, 6.2% rarely and 0.9% never (Figure 7). Those who have answered 'rarely' or 'never' have been asked to be more specific about the reasons that they do not participate in recycling processes (Figure 8). The majority of those (29.6%) state a mistrust on the management of recyclable waste by local authorities (they believe that what is placed in the recycling bin ends up in the landfill site), 14.4% state that what obstructs them to recycle is the lack of recycling facilities near them, 12% due to lack of space inside the household, 11.2% due to lack of time, 8.8% due to lack of disposition, 8.0% state that they are too busy with their everyday activities to deal with recycling, 7.2% due to the lack of space to separate recyclables from non-recyclables within the household, 3.2% because they find it difficult to separate recyclables from non-recyclables, another 3.2% because they find recycling a complicated process, 1.6% because they do not know about recycling and only 0.8% because they are not interested in environmental protection.

The greatest motivation for starting / increasing recycling has been found out to be the facilitation of recycling, either with the presence of recycling commodities near the house (4.14 /5), or with the offer from the municipality of household recycling bins (4.01/5). Economic motivation follows these practical issues; rewarding benefits (recycling) is the most desired economic system (reaching 3.84/5), followed by product charges (3.76/5). The reduction of municipal fees depending on the weight of the waste that ends up in landfills is marked with 3.43/5, followed by the imposition of a fine for not separating recyclables from non-recyclables (3.35/5), while the charge of household waste by weight is the last preference (3.23/5) (Figure 9).

Regarding influences, the majority (34.53%) declare unaffected by the behaviour of others, 26.43% that they are affected by the participation of a family member, 16.50% by a friend's participation, 14.14% by colleagues' participation in the workplace and 8.40% by neighbours' participation.

On the subject of points of view (Figure 10), the statement that '*environmental protection is our responsibility*' has been rated quite highly (4.77/5), as has that '*recycling is beneficial for the environment, economy and health*' (4.75/5), followed by the '*separation of waste into recyclable and non-recyclable is a manifestation of culture*' (4.54/5). High marking has also been given to the statements that '*we have borrowed the environment from our children*' (4.39/5) and also that '*it is selfish not to spend some time for recycling*' (4.23/5).

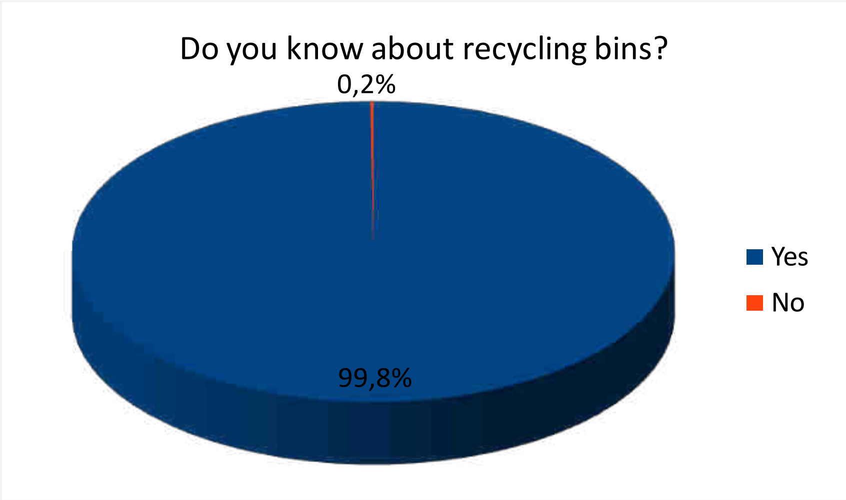

Figure 2: Familiarity with recycling infrastructure.

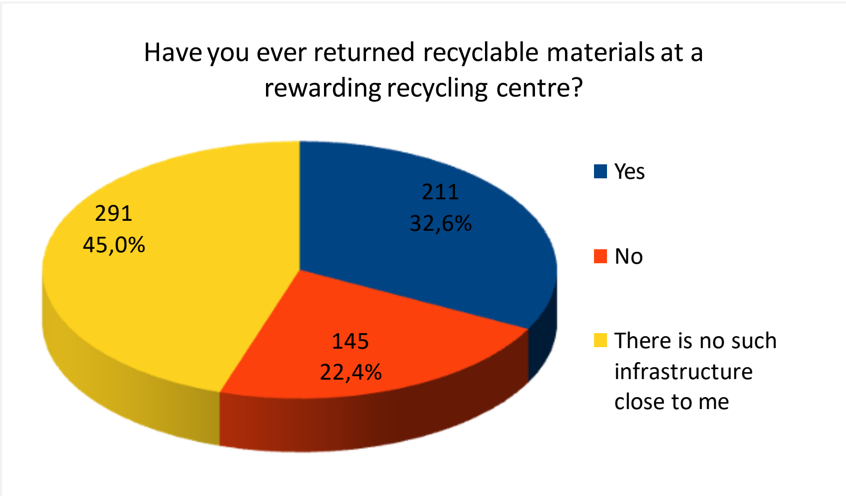

Figure 3: Use of rewarding recycling centres.

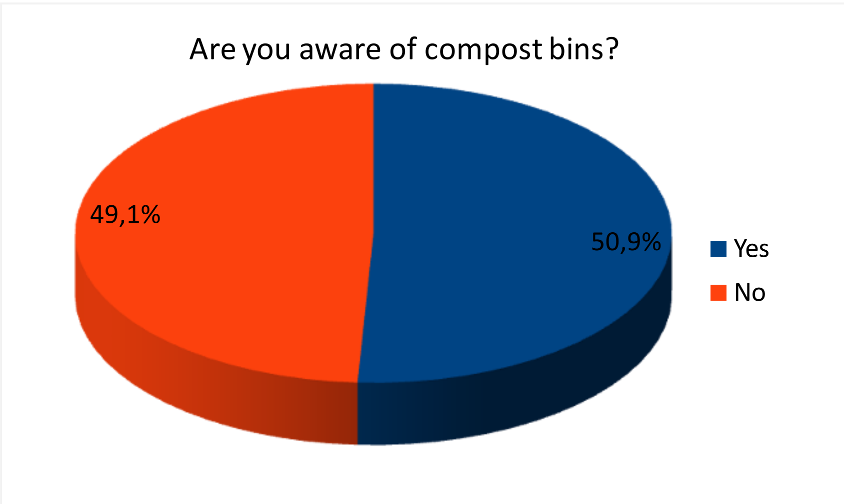

Figure 4: Familiarity with composting infrastructure.

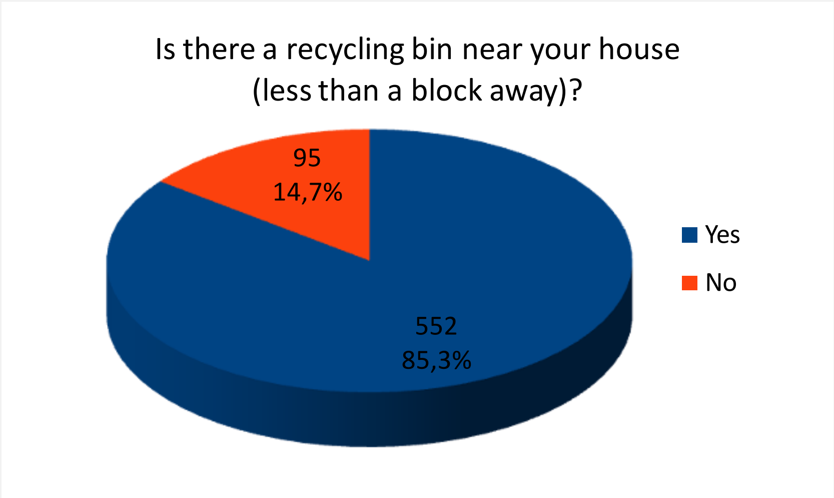

Figure 5: Accessibility to recycling infrastructure.

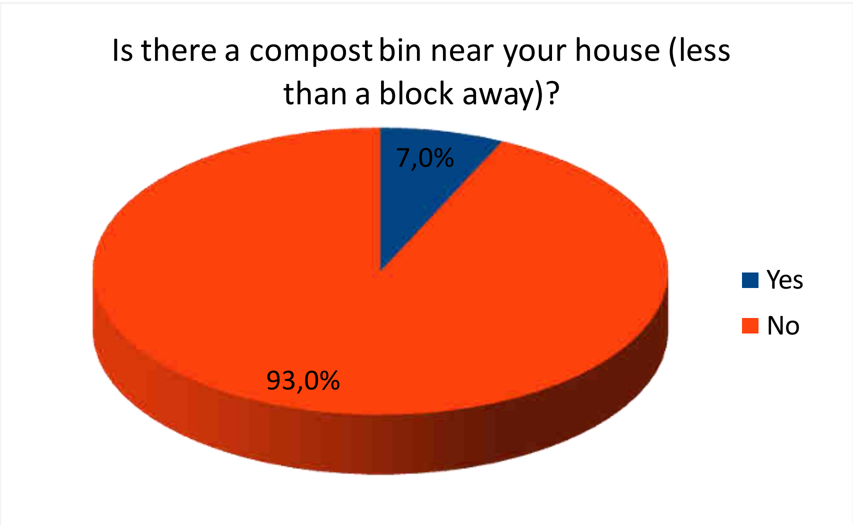

Figure 6: Accessibility to composting infrastructure.

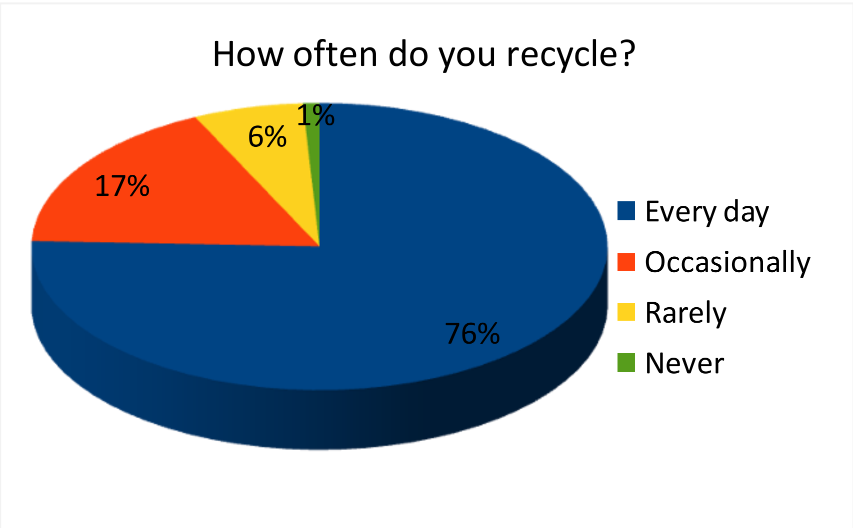

Figure 7: Frequency of recycling.

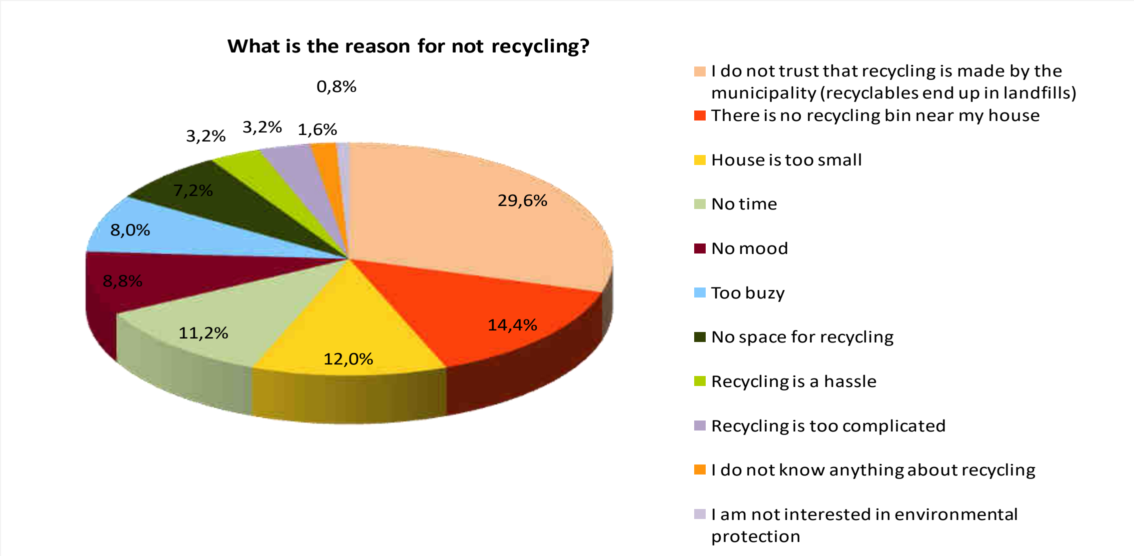

Figure 8: Reasons for recycling rarely or never.

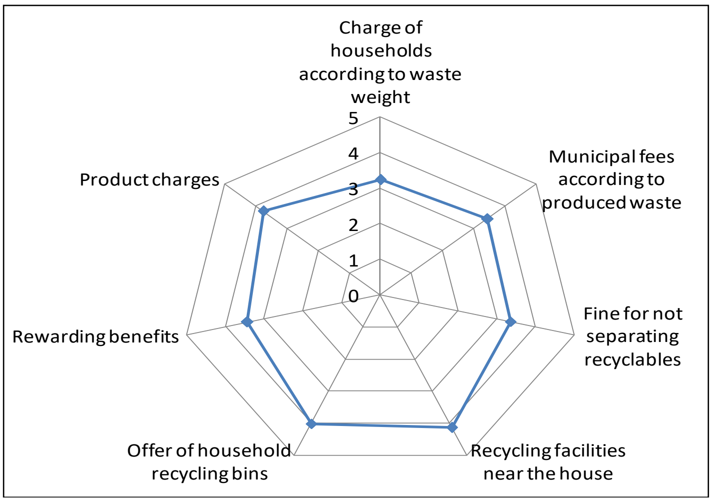

Figure 9: Motivational schemes for increasing citizens' participation in the recycling process.

Interestingly enough, the ranking of the statement that '*most people around us recycle*' (2.69/5) shows a mistrust in what other people' attitude, regarding recycling is. The negative statements on recycling, that '*recycling is a waste of time*' or that '*recycling is for loungers*' have both received low marking (1.24/5 both).

Similar results are reached by the answers to the free text question on the recycling process or citizens' participation in it: what people find more difficult in the recycling process is the lack of 'blue' (recycling) bins. A lot have stated that they wish there was greater awareness by their fellow citizens as well as information on what and how is recycled. Rewarding incentives have been suggested by many, while the mistrust on the management of recyclable waste by the local authorities is manifested also by the free text answers. Citizens also request facilities for composting and express the desire for more genuine interest from municipalities as well as information on the effects of recycling within municipalities.

Regarding habits towards circular processes, it seems that clothes have a stronger circular value than pieces of furniture or other household objects; 68.0% declare that they donate unwanted clothes to church or organisations or to family friends, 28.8% put them in special bins for recycling, while only 3.2% throw them away (Figure 11). Regarding unwanted old objects or pieces of furniture, 56.8% give them to relatives / friends / acquaintances, 25.4% give them to antique dealers and the much larger percentage of 17.8%, in comparison to clothes disposal, disposes them to the landfill (Figure 12).

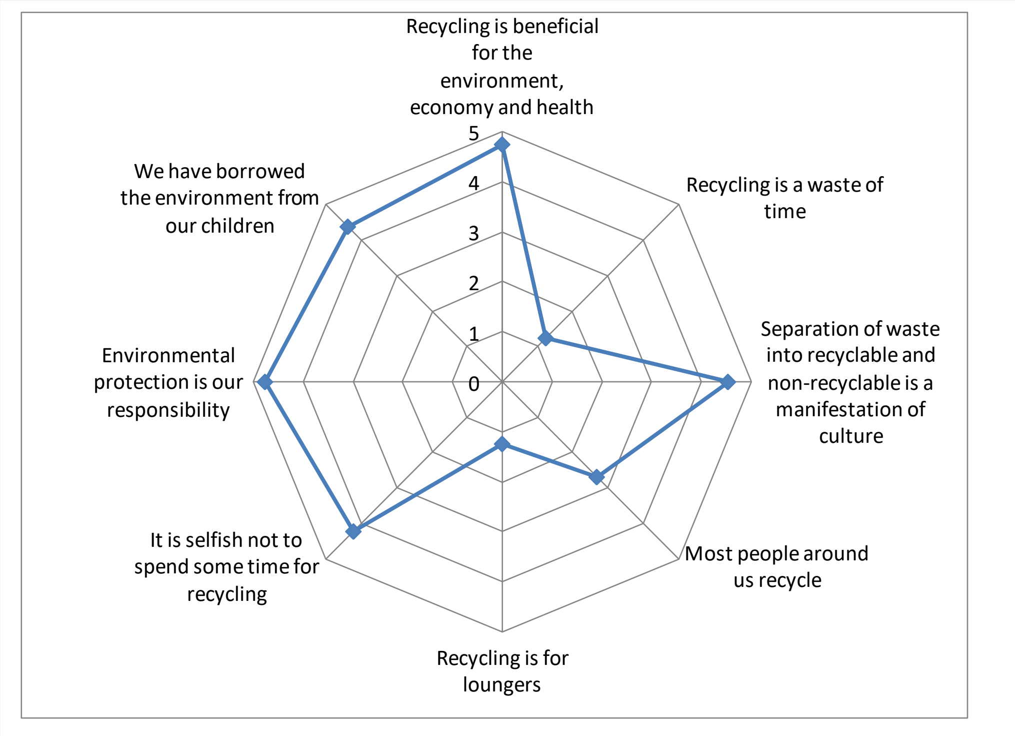

Figure 10: Points of view regarding recycling and environmental protection.

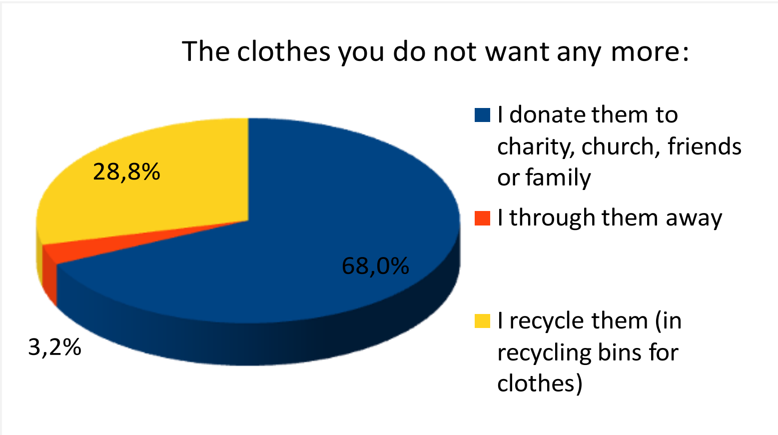

Figure 11: Attitude towards unwanted clothes.

Figure 12: Attitude towards unwanted furniture / items.

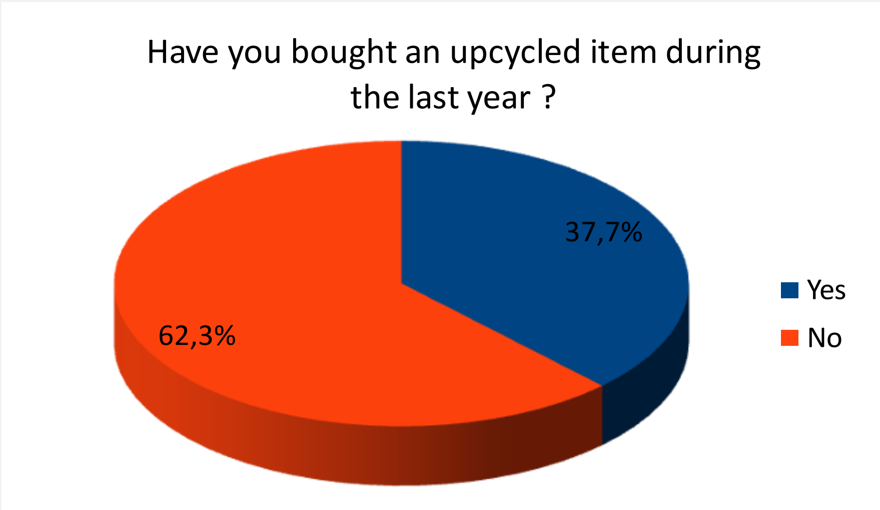

Figure 13: Relation with upcycled items.

On the issue of up-cycled commodities, the majority (62.3%) declares that they have not bought a remanufactured good during the past year (Figure 13); such businesses have not yet flourished in the area. Comparing the results of this survey with respective surveys from 2014 and 2017 made for the Greek Recycling Company in the years 2014 (ALCO, 2014) and 2017 (Green Agenda, 2018), the main reasons for abstaining from recycling have also been found to be the absence of a recycling bin near the house, the mistrust to local authorities (belief that actually no recycling takes place) and the lack of space at home. If recycling is better facilitated, simply by placing recycling bins more densely, recycling might increase.

The environmental awareness of the participants in this survey is stated as very high, which should be taken into consideration by the Greek state, as environmental concern is the most important incentive for recycling (Vining J. et al., 1992; Jekria N. and Daud S., 2016). However, the mistrust towards central and local authorities in Greece that has been observed here and has also been monitored by Karageorgou M. et al. (2017), Karamitrou Z. and Benakou E. (2018) and by the City of Athens (2016), not only on decision-making processes, but also on practical issues is a great obstacle. This is a real issue on the success of any policies, whose solution lies beyond the limitations of recycling policies. The conviction that recycling material ends up in landfills has been found out to be the most important reason for putting people off from recycling. As Scott (1999) aptly comments, recycling officials should provide information on the effectiveness of public actions for recovering materials and what happens to raw materials once they are sold. In this way, any misinformation that may adversely affect public participation could be addressed and citizens might start trusting local authorities at least on some practical issues.

The majority of citizens are aware of the advantages of recycling and of the disadvantages of existing waste management. Nevertheless, Greece is among the last countries in the EU regarding recycling rates. This is attributed to the fact that while global environmental concern has a positive impact on the recycling trend, in the case that environmentally friendly behaviour entails cost (difficulty), the individual will usually act according to his/her personal interest (Bratt C., 1999).

The majority seems unaware of EU, national and municipal targets to reduce waste. It therefore appears that there is a need for more and effective public awareness on the objectives of waste reduction and recycling policies; citizens who are better informed about recycling policies and targets are more likely to be involved in the recycling process than those who are not so well informed (Sidique S. F. et al., 2010).

Practical issues, such as the absence of recycling facilities within the house's vicinity is the second reason that puts people off from recycling, preceded by the mistrust to local authorities. In addition, the existence of such a facility near the household, has been reported as the greatest motivation for increasing participation in recycling.

As the largest proportion of the participants have stated as their primary source for information on recycling to be the internet, the utilization of social media and electronic press by organisations and governments in a two-way form of communication might prove extremely influential (State of Connecticut, 2019; Thackeray R. et al., 2008; Szaky T., 2016). In addition, if further information and campaigns on composting is channeled through these media, the participation in composting will increase, as the effect of a convenient and well understood scheme can have a significant influence on behaviour (Barr S. et al., 2003; Hines J. M. et al., 1987), provided necessary infrastructure and management is offered.

The majority of the sample declares to be aware of the importance of circular economy. In practice, the majority tries to offer to someone else old clothes and old furniture. This shows that there is a differentiation between items that have lost their usefulness for their owner and items that are discards (cannot be valuable for anybody any more), at least for some utilities. Especially clothes seem to be more valuable than furniture; with the rise of 'fast fashion' clothes lose their perceived obsolescence much faster than furniture. Nonetheless, it is an encouraging finding that in people's mentality they are not registered as discards, but as items that can be reused by somebody else. Overseas charity is not the optimum solution, as the overconsumption of clothes in the west might cause social and economic problems not only in societies where cheap cloth is produced, but also in those in which it is disposed in the form of 'offer' (Morgan A. et al., 2015). The notion of the reintegration of used items locally several times, until they become discards, may lead to sustainable, circular models, as has already started happening in many businesses (e.g. Svensson V., 2017).

The participants' preference to rewarding recycling is expressed in both the free-text question and the answers to the question *'what would drive you to increase recycling'* (Figure 9). As will be shown in the following paragraphs, this seems to be the most promising scheme for increasing recycling in the county of Attica.

3.2 Experts' point of view

Through the interviews with academics and municipalities officers in Attica, it is concluded that, according to the experts, the following incentives should be promoted for the increase of recycling and circular processes in the area:

- Separation of organic waste and free distribution of compost bins to households,
- Organic waste collection programs from the restaurant industry, open air markets,
- Production of humus from organic residues,
- The creation of networks serving the entire area of the Municipalities as well as continuous and constant collection of items from recycling and compost bins,
- Continuous actions of environmental education in schools and raising awareness campaigns for citizens,
- Application of reward programs in combination with PAYT programs,
- Workshops within the municipalities regarding the collection of electrical appliances and bulky waste directly from houses / tertiary sector buildings.
- Collaborating with public, municipal, social and private organisations to develop new streams/implement new methods.

3.3 Multicriteria analysis

The assumptions and the results of the multicriteria analysis on which economic recycling system is the most sustainable one, can be seen in Table 2. As is observed, rewarding recycling ranks 1st (scoring 77.24), followed very closely by product fees (73.44). The system PAYT comes 3rd with large difference (scoring only 33.72), while landfill tax is the last preference (scoring 29.71). These results are in alignment with the answer to the question of the survey "*What would make you start or increase your recycling rate?*", where the rewarding benefits (for recycling) emerges as the most favourite incentive. This has also been vividly expressed in the free text question *"Something you would like to add to the recycling process or your participation in it"*. Rewarding recycling has also been pinpointed as a promising system for the increase of the participation in recycling by the experts.

However, as product charges have a very close score to rewarding recycling, a combination of both systems seems the most promising solution. After all, countries with better recycling performance have a wider range of measures and instruments than countries with low recycling rates (European Environment Agency, 2018).

Table 1: Demographic characteristics regarding recycling habits.

Demographic characteristics	Recycling on a daily basis (%)	Recycling rarely or never (%)	Difference (%)
Sex			
Men	32.9%	34.10%	-1.20%
Women	67.10%	65.90%	1.20%
Age			
15-19 year old	1.00%	-	1.00%
20-29 year old	22.30%	23.90%	-1.60%
30-39 year old	28.20%	21.70%	6.50%
40-49 year old	31.50%	39.10%	-7.60%
50-59 year old	13.70%	10.90%	2.80%
60-69 year old	2.90%	-	2.90%
70-79 year old	0.20%	4.40%	-4.20%
Above 80-year-old	0.2%	-	0.20%
Number of household members			
1- person household	16.30%	13.63%	2.67%
2- person household	22.70%	20.45%	2.25%
3- person household	20.80%	27.27%	-6.47%
4- person household	30.00%	27.27%	2.73%
5- person household	7.90%	9.09%	-1.19%
6- person household	1.90%	2.27%	-0.37%
7- person household and above	0.20%	-	0.20%
Educational level			
Highest education graduates	31.90%	34.09%	-2.19%
Higher education graduates	9.00%	-	9.00%
Professional school graduates	0.90%	6.81%	-5.91%
Technical school graduates	2.40%	4.54%	-2.14%
General school graduates	12.90%	9.09%	3.81%
Primary education graduates	0.70%	2.72%	-2.02%
Secondary education graduates	5.70%	18.18%	-12.48%
PhD	35.80%	25.00%	10.80%
Graduates of middle secondary education	0.20%	-	0.20%
Students	0.70%	-	0.70%
Occupation			
Unqualified workers	0.60%	-	0.60%
Unemployed	8.10%	11.36%	-3.26%
Senior executives	10.70%	6.82%	3.88%
Service sector	6.00%	11.36%	-5.36%
Farmers / fisher(wo)men / Breeders / Foresters	0.40%	-	0.40%
Free lancers	12.80%	9.09%	3.71%
Researchers	3.20%	-	3.20%
Lecturers / teachers	10.50%	11.36%	-0.86%

Demographic characteristics	Recycling on a daily basis (%)	Recycling rarely or never (%)	Difference (%)
Artists	2.40%	2.72%	-0.32%
Students / pupils	10.10%	20.45%	-10.35%
Sellers	0.60%	-	0.60%
Pensioners	2.10%	9.09%	-6.99%
Crafts(wo)men	1.50%	-	1.50%
Technicians	3.40%	4.54%	-1.14%
Office employees	27.00%	13.63%	13.37%
Industrial installations operators	0.40%	-	0.40%
Monthly income			
0-500€	9.90%	10.26%	-0.36%
500-1,000€	27.20%	15.38%	11.82%
1,000-1,500€	27.20%	23.07%	4.13%
1,500-2,000€	16.90%	10.26	6.64%
2,000-2,500€	13.40%	17.96	-4.56%
Above 2,500€	7.70%	23.07%	-15.37%
Size of house			
Under 40m²	3.70%	2.56%	1.14%
41-60m²	13.90%	15.38%	-1.48%
61-80m²	20.30%	10.26%	10.04%
81-100m²	32.50%	48.72%	-16.22%
101-120m²	16.80%	10.25%	6.55%
121-150m²	6.90%	7.69%	-0.79%
Larger than 150m²	5.90%	5.13%	0.77%
Position in the household			
Member / roommate	8.30%	-	8.30%
Male partner	2.30%	-	2.30%
Female partner	7.40%	2.43%	4.97%
Single male	2.10%	-	2.10%
Single female	2.30%	4.87%	-2.57%
Grandmother	0.50%	2.43%	-1.93%
Mother	35.00%	31.70%	3.30%
Child	22.60%	41.46%	-18.86%
Father	21.90%	17.07%	4.83%

More specifically, there should be product charges for packaging, electrical and electronic appliances, furniture, clothes, plastic and glass bottles, metal, plastic and glass containers, soft drinks, etc., to ensure their return. These items, upon their return, depending on their type and their condition, will either be repaired, if necessary and reused, or will be recycled. After all, these two systems can work complementarily as the return of a deposit for an electronic device is a combination of product charge and reward recycling (Parliamentary Commission for the Environment, 2005). Regarding the mentality of the population, as has been observed by Botetzagias I. et al. (2015) "*for the Greek context, the intention to recycle is based on an internalised, personal, feeling of moral obligation to 'do-what-feels-right' and not on some need to conform with social standards and to avoid social injunctions*". Thus, charging systems for the waste produced might not have the desired results.

Table 2: Weighting factors, marking for each criterion, hierarchy and ranking according to MAUT for each examined economic system for recycling.

Type of criterion	Criterion	Weighting factors (scale: 1-10)	Examined economic systems to increase recycling (scale: 1-10)			
			Landfill tax	PAYT system	Product Fees	Rewarding Recycling
Social	Capacity to create new jobs	8.28	3.43	5.64	5.14	5.29
	Social acceptance	7.40	6.87	6.47	7.52	7.68
	Low negative impact on the landscape	7.98	4.64	6.00	7.21	6.57
	Functionality	7.98	7.04	4.96	6.54	6.75
	Adaptability to local conditions	8.02	6.75	4.18	6.32	6.25
Environmental	Reduction of the amount of solid waste ending up in landfill site	9.30	4.07	7.07	6.86	7.07
	Low emissions of gases / odours	8.92	4.43	5.86	6.61	6.82
	Small occupation of public spaces for bins and necessary equipment	7.72	4.86	6.00	7.07	7.14
	Reduction of garbage track traffic	6.64	6.14	6.93	8.07	7.86
Economic	Investment cost	6.88	7.25	5.68	7.11	6.82
	Operational cost	7.10	6.25	5.96	6.14	6.43
		$U(a_i)$	29.71	33.72	73.44	77.64
		Ranking	4th	3rd	2nd	1st

After all, for implementing a PAYT system "*local conditions and attitudes are of critical importance for the outcome, and an effect seen in one town will not necessarily be seen in another*" (Dahlén L. & Lagerkvist A., 2010). As a result it is difficult to foretell whether people with a weight-based charge will adjust their lifestyles to produce less waste or discard them outside the usual collection system (illegal dumping of waste, transportation of waste to neighbouring communities, illegal burning of waste, increased amounts of pollutants in recyclable materials) (Dahlén L. & Lagerkvist, A. 2010). Such a system should first be thoroughly examined in pilot projects, prior to decision-making.

Concluding, giving a financial value to waste, as has been occurring in the past, appears to be a more promising economic system, than giving a penalty to waste, which might lead to illegal actions. Citizens in Attica seem more willing to accept systems in which useful waste are prized, than penalised.

4. Conclusions

About 250 years ago Thomas Paine (1776) famously wrote "*time makes more converts than reason*". This 'conversion of reason' regarding waste that occurred during the linearly consumerist frenzy of the 20th century, still dominates in the 21st. Circular processes, such as recycling and composting seem very promising solutions to the environmental and social problems that huge amounts of disposed waste cause. Through this research, it has been investigated why some households in the county of Attica do not participate in these processes and the policies that should be followed in order to increase participation in circular processes.

The appeal to environmental awareness is not enough to increase participation; through this research it has been found out that circular policies should improve in three main sectors: by facilitating the process, restoring citizens' trust towards local authorities and by adding economic value to useful waste. The facilitation of recycling and composting by placing more recycling and composting bins and by equipping households with such facilities can help increase participation in these processes, in combination with educating campaigns.

If municipalities manage to gain trust at least on practical issues, such as their efficiency in managing recycling and composting material, the participation of citizens in the process might also increase. Regarding economic schemes, the systems where a value is placed on waste (rewarding recycling, product fees) seem the most promising ones, as the results from all three followed methodologies (survey, interviews with experts, multicriteria analysis) have shown. The combination of such systems could increase their efficacy. It is obvious that giving an economic value to waste that can still be used is a great motivation for not disposing them to landfills but offering them to circular processes. Mentality towards waste has already started changing, as can also be observed by the high score that the statement '*separation of waste into recyclable and non-recyclable is a sample of culture*' has received.

Nevertheless, recycling is not the optimal solution for protecting resources and the environment, but just a policy to deal with waste resulting from excessive consumption.

As the best way to face problems (waste) is at their source (production of waste, caused mostly by the design of products, as well as by lifestyle), planned obsolescence and perceived obsolescence should be tactics of the past; products should be designed and constructed to be resilient, in an assembly for disassembly manner, so that the reuse of their various parts can occur easily, at the end of their long life. Consumerist values should also be replaced, the mentality towards consumer goods should also change, as well as the mentality towards waste; there must be a distinct differentiation between materials that are ultimate discards and materials / items that have lost their usefulness for their former owner but can still be repaired, reused or recycled. The use of distinct words for these two types of waste could be helpful towards the change of this mentality. Placing in practice the policies suggested in this paper can be some steps towards this change, turning the 20th first century linearity into a small glimpse in the history of humanity.

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CSP business models and value chain mapping: Insights from the CSP industry

Dr. Alexandra PAPADOPOULOU[1], Senior Researcher*
Mr. George VASILEIOU, Junior Researcher*
Mr. Serafeim MICHAS, PhD Researcher*
Dr. Alexandros FLAMOS, Associate Professor*

*University of Piraeus, Research Centre
Contact details of corresponding author[1]
Tel: +2104142460
Fax: +2104142342
e-mail: alexpapa@unipi.gr
Address: 80, Karaoli & Dimitriou str., 18534 Piraeus, Greece

Abstract

Although Concentrated Solar Power (CSP) was rapidly developed over the past decade, it now faces a stagnated deployment in European countries. Crucial parameters for this among others were the change of the policy support mechanisms adopted, combined with the Levelized Cost of Energy (LCOE) values' rather stable trend.

The CSP industrial stakeholders operate under a multi varying environment, which is continuously changing. The different arrangements used for CSP deployment worldwide are not able to justify a single business model that has been deemed successful. As a result, the business models adopted by these companies can vary significantly and relate to a number of parameters, such as the respective governmental policies, the relevant risks, the financing models in place, the modification of the models' value proposition, as well as the impact of new actors in the CSP value chain, especially from host countries outside EU. The herein presented analysis focuses on the current structure of the CSP value chain and the business models adopted. Following an extensive literature review for the most important parameters affecting the CSP industry's adopted business models, and consultation with an industrial stakeholder, a survey among companies activated in the CSP sector has been realised.

The results of the analysis demonstrate the significance of the policy support mechanisms, as well as the CSP industry's adjustment to them. The risks affecting the most CSP deployment relate to policy, regulatory and revenue risks, while beyond all technical related barriers, the lack of policy support, as well as its instability where provided are more highly evaluated. All these results can support the policy making regarding the structure of the future support mechanisms, as well as the design of more successful business models.

Keywords: business models, CSP industry, value chain, policy support mechanisms.

1. Introduction

The purpose of this paper is to identify the existing business models for CSP structuring and financing opportunities across Europe, providing thus the base for the derivation of new appropriate models.

Given the great range of stakeholders across the entire business process, CSP projects can be particularly complicated. Moreover, the use of different arrangements for CSP deployment in various countries cannot support the emergence of a single business model that has been considered successful. CSP business models can vary noticeably, since they are determined by the respective governmental policies and thus need to be thoroughly examined.

Governmental support mechanisms have been the main tool, on which the development of Renewable Energy technologies in general, and CSP specifically, has been based for many years, in order for them to meet the financial viability threshold needed for their implementation. Tian et al. (2019) have pointed out market pressure and government policy as the direct external factors that promote business model innovation. Henceforth, existing support mechanisms can play a crucial role in the CSP industry; studying the reaction of the CSP industry's adjustment to the market tools and mechanisms in place can thus lead to fruitful insights (Papadopoulou A. et. al., 2019).

The first support mechanisms for solar thermal projects were adopted in the USA, during the period 1984-1990, where Luz company completed the construction of nine SEGS in the Californian desert, under Public Utility Regulatory Policies Act (PURPA), which was a Power Purchase Agreement (PPA) scheme based on avoided costs of additional fossil fuel generation. Investments in solar technologies were fostered also by the Investment Tax Credit (ITC), which led to the reduction of investors' tax liabilities to the value of a certain percentage (30% in the case of past ITC) of the installed cost of the project (SEIA, 2019). The 1705 renewable energy loan guarantee program was introduced in 2009 as a part of the American Recovery and Reinvestment Act and served as a further boost for the construction of new CSP plants, such as Mojave Solar One (250 MW – $1.2 billion loan guarantee), Crescent Dunes (110 MW - $737 million loan guarantee), Ivanpah (392 MW - $1.6 billion loan guarantee) and Solana (250MW - $1.45 billion loan guarantee)[8]. In addition, the 64MW Nevada Solar One project was successfully commissioned in June 2007 via the exploitation of established RPS, ensuring the development of suitable PPAs with utilities (Solangi K.H. et al., 2011). Today, via the utilization of the aforementioned support mechanisms, the total capacity of CSP plants operating in the United States exceeds 1,800 megawatts (MW) (SEIA, 2018). Furthermore, the subsidy imbalance between fossil fuels and CSP, as well as the availability of long-term, low interest debt are expected to have a determinant role in future CSP deployment (HeliosCSP, 2018).

The production of electricity from renewables in Spain was mainly promoted via Feed In Tariff (FIT) which was introduced in 1994. In addition, two alternative payment options for green electricity generators were developed in 1998, a fixed tariff scheme and a premium tariff, which was paid on top of the electricity market price (Haas R. et al., 2011). The policies implemented by the Spanish government enabled a remarkable growth of CSP in Spain (2007-2013), resulting to 2,300 MW installed capacity over 7 years. This expansion period came to an end in late 2012, when the government ceased the FIT scheme. However, the industry remained and kept a dominant, but weakening, position until the present day (Lilliestam J., 2018).

The main pillars of the CSP policies under the Moroccan Solar Plan include: two-stage competitive bidding, long-term PPA and guaranteed offtake, public- private partnership, guarantees for viability gap funding. The construction of Noor I was fostered by a successful public-private partnership between MASEN and a private sponsor, thus providing a testing ground for a PPP model applied to a renewable technology with a significant viability gap and upfront investment needs, which neither the domestic financial sector nor foreign private investors could manage on their own. The contribution of concessional loans and grants was also considerable (Frisari G. and Stadelmann M., 2015; Cox S. et al., 2015).

The first CSP in Chile was introduced in February 2013 by the Ministry of Energy, through Corporación de Fomento de la Producción de Chile (CORFO). Abengoa Solar undertook the construction of Cerro Dominador, Chile's first 110 MW tower CSP plant, after winning a bidding process under CORFO, which provided soft financing and an upfront grant. The specific project stands out due to the following features: it will be the highest storage in the world lasting up to 17.5 hours, and the largest CSP project in Latin America (Servert J. F. et al., 2015).

CSP was introduced as a strategic ingredient in the Israeli electricity market in 2005 with the Ashalim 100 MW parabolic trough plant (CSP Today, 2008). The contract was based on the Build-Operate-Transfer (BOT) model and the first 121MW configuration began operating in 2017[9]. Nevertheless, current CSP incentives in the country remain unclear.

[8] https://www.energy.gov/lpo/portfolio/portfolio-projects

[9] https://www.evwind.es/2018/07/25/current-status-of-concentrated-solar-power-csp-globally/64041

The REIPPPP[10] program in South Africa enabled the construction of new CSP plants of different sizes at different sites, which were introduced in the system as grid-connected renewable energy Independent Power Producers (IPPs) (Baldini M. and Pérez C.H.C., 2016; IRENA, 2013). The development of the REIPPPP included five phases from 2010 to 2014. In the first bidding round (Bid Window), the average bidding prices were R2.69/kWh (0.248 €/kWh), and the projects developed include KaXu Solar 1 (100 MW with Thermal Energy Storage (TES) of 3 hours) and Khi Solar 1 (50 MW, 2 hours TES). The second bid window led to the development of the Bokpoort project (50 MW, 9.5 hours TES) with a bid price of R2.51/kWh (0.251€/kWh). However, a new tariff system was adopted during the third bid window: a base price of R1.65/kWh (0.122€/kWh) payable for 12 hours every day and a 270% premium on the base price payable for electricity dispatched during the 5 peak demand hours. The respective projects include Xina Solar One (100MW, 5 hours TES) and Ilanga CSP 1 (100MW, 5 hours TES). Bid window 3.5 led to the construction of Kathu Solar Park (100MW, 4.5 hours TES) and the Redstone project (100MW, 12 hours of TES), whereas bid window 4 did not include any additional CSP plants[11],[12]. All the aforementioned CSP plants remain operational, with the exception of the Redstone project.

As far as the Gulf countries are concerned, Kuwait, Saudi Arabia and the United Arab Emirates have made noticeable progress in CSP deployment. In particular, Shagaya, developed by the KISR[13], constitutes the most important showcase of Kuwait, as it includes a 50 MW CSP component with a storage capacity of ten hours, which still remains operational and connected to the grid. An Engineering, Procurement and Construction (EPC) contract was signed for the specific component in 2015 (IRENA, 2019).

In Saudi Arabia, Duba 1, Integrated Solar Combined Cycle (ISCC0, will include a 43 MW parabolic trough array, under an EPC contract, while at the same time two additional ISCC projects are being developed: the 1,390 MW Waad Al Shamal plant with 50 MW CSP and the 3,600 MW Taiba facility with a capacity of 180 MW CSP. The Taiba project was procured and tendered via the Original Equipment Manufacturer (OEM) and EPC models. Nevertheless, the implementation of the project is facing some delays, as the switch to IPP model is also under discussion.

Moreoever, Shams 1, commissioned in 2013, was Abu Dhabi's first CSP plant with a capacity of 100 MW and was based on a 25-year build, own and operate contract. A special purpose vehicle was developed for this reason and led by Masdar, in collaboration with Total, Teyma and Abengoa Solar (IRENA, 2019).

Dubai's Mohammed bin Rashid Al Maktoum Solar Park is the largest single-site solar park in the world, including a 700 MW CSP component, commenced in 2017 under a 35 years PPA scheme. The bid landed at 7.3 US cents/kWh, which was the lowest price for CSP on a global scale at the time (IRENA, 2019).

The presented analysis in this paper will attempt to describe the structure of CSP projects starting with a detailed examination of their most essential components and phases. The stakeholders and issues related to each phase will have to be mapped and explained. An extensive literature review and collaboration with a CSP industrial stakeholder for the identification of the most important parameters in regard with adopted business models, as well as a survey among companies involved in the CSP sector have been realised and the outcomes are presented at length.

Providing a clear picture of CSP's value chain and the allocation of the costs & benefits across this chain and to the relevant stakeholders, the scope of the analysis is to set the groundwork for the emergence of new business models that can support further CSP deployment.

Based on the above, the current paper is structured along the following sections:

- Section 2 focuses on the analytical framework regarding the CSP industry and the respective business models.

[10] Renewable Energy Independent Power Producer Procurement Program

[11] https://www.solarpaces.org/csp-technologies/csp-potential-solar-thermal-energy-by-member-nation/south-africa/

[12] https://www.ee.co.za/article/power-from-the-sun-an-overview-of-csp-in-south-africa.html

[13] Kuwait Institute for Scientific Research

- Section 3 presents the methodological approach adopted in order to explore the parameters affecting CSP deployment.
- Section 4, in which the results of the survey are demonstrated and analysed.
- Finally, conclusions are provided in Section 5.

2. Analytical Framework

Although business models have been widely used over the past two decades, a definition widely accepted both by scholars and the business community has not yet emerged (Björkdahl J. and Holmén M., 2013, Shafer S. M. et al., 2005).

As Biloshapka V. and Osiyevskyy O. have already pointed out (2018), it is generally agreed both by management scholars and practitioners that value creation and capture constitute the fundamental functions of a business model. Nevertheless, controversy has been engendered regarding the meaning of these terms, their measurement, and the factors and mechanisms affecting them. Hence, business models are focalised on structuring a company's or organisation's core strategy to generate economic value, normally in the form of revenue. This value creation can be identified across the entire value chain, encompassing the way a product is designed, manufactured and eventually marketed and sold (Papadopoulou A. et. al., 2019).

Concerning the roles of the actors involved, the CSP industry is characterised by noticeable complexity and diversity, given the great number of active companies in several parts of the CSP value chain (Herrera J. R., 2013). In addition, some of them envisage to expand their engagement throughout the value chain, aiming to multiply their revenue streams. In this context, organizations facing changes in their external environment, attach importance to business model innovation, as a pivotal renewal mechanism (Sosna M. et al., 2010).

Taking into consideration the existence of overlapping business models for the different actors in the CSP industry, the presented analytical framework emphasises on the identification of all related parameters affecting the CSP industry's deployment, and thus the development and evolution of the respective business models.

To this end, in order to identify opportunities and challenges for the evolution of the CSP industry's business models, the following key questions were selected:

- How familiarised is the CSP industry with the different support mechanisms and the main financing models in place?
- How are financial data, such as the debt and equity ratio requirements affected by external parameters?
- Which are the most important and most probable risk factors, as well as barriers, affecting a project's implementation?
- Which are the key characteristics for the business models of the CSP industry in place?
- What is the value creation and companies' activation over the CSP value chain?
- How can local companies outside EU be strengthened so as to contribute to the CSP value chain in their countries?

The factors related to the deployment rate and structure of the CSP industry are discussed in the following sections.

2.1 Support mechanisms and financing models

The already existing support mechanisms can have a vital contribution to the deployment of renewable energy technologies, especially in the case of CSP. In this context, a review of the current support mechanisms for CSP projects was conducted with emphasis on regions, where EU companies have been involved in the implementation of CSP projects, namely the EU, the United States and the MENA region. Overall, the adopted support mechanisms are the following: FITs, Feed in Premium (FIPs), Two tier tariffs, Tax incentives, Renewable portfolio standards (Quota systems) and Auctions, in line with Abolhosseini S. and Heshmati A. (2014) and Ecofys (2013).

However, the abiding evolutionary processes within the business market can set the groundwork for the emergence of new support mechanisms in the years to come. Consequently, a new support mechanism, the Corporate PPAs was also included in the analysis. A Corporate PPA offers corporate consumers the opportunity to purchase power on a long term basis directly from renewable energy generators without being co-located (Bird & Bird). In 2017, the total volume of corporate renewable PPAs signed in Europe exceeded 1 GW[14]. This mechanism has not yet been utilised for CSP projects, but could constitute an alternative for the future.

Towards the further deployment of CSP, dedicated support mechanisms are needed and should be focalised on the main asset of this technology, namely dispatchability, as well as on ensuring a steady cost reduction rate, so as to foster the development of new more efficient plant designs (Lilliestam J. et al., 2018). Ubiquitous mechanisms that can be exploited to this end include: time-of-day bonus, long term path for decreasing support, and high or no capacity limit in the support schemes. As financing for CSP projects remains an equally significant challenge, the presented analysis investigated also to which extent the CSP industry is familiar with current financing models. More specifically, Public Private Partnerships (PPPs), IPPs, Green Bonds and the BOT structure were examined.

2.2 Impact of external parameters on financial data

Project profitability is heavily influenced by the attraction of capital, which can be achieved mainly via debt and equity, provided by banks and investors respectively. Cost of equity is also considered a means of evaluating investment risks: attracting equity at lower costs designates a low risk for investments (Diacore, 2016).

In the case of solar technologies, project economics are measured by using either the project Internal Rate of Return (IRR) or the equity IRR. The project IRR does not depend on the financing scheme or the sources of funding. If the interest rate is lower than the project IRR and part of the debt can be covered by lenders, then the debt cost is lower than project IRR. As result, dividends can be paid by the remaining portion of the project cash flow and the equity IRR becomes higher than the project IRR. Henceforth, equity investors would aim to maximize leverage (debt share) in order to minimize their equity investment and maximize equity IRR. Furthermore, in a process where competitiveness of the power price is key, a high leverage and low capital cost can enhance the competitiveness of the project, as they would lead to lower capital cost (IEA Technology Collaboration Programme, 2017).

According to the international literature (Zhang Y. and Smith S. J., 2008; Frisari G. and Feas J., 2014; Caldes – Gomez N. and Diaz – Vazquez A. R., 2018), the debt / equity ratio in CSP projects can range from 75/25, to 70/30 and 60/40. Considering the difficulty of acquiring feedback from the CSP industry on the preferred debt / equity ratios for the various supporting structures, the analysis centered on whether and how the debt ratio is affected by different support mechanisms, as well as whether and how is the equity ratio affected by a variety of parameters, of which some are related to the risks and barriers encountered. Out of the parameters selected by the authors, in collaboration with a CSP industry stakeholder who provided the CSP industry viewpoint, the predominant ones were: the policy and regulatory framework in the country, the project developer's track record, PPAs in place, state guarantees, energy yield predictions and operator's experience in similar types of projects.

2.3 Risks and barriers

Based on the international literature, the authors have selected a set of risks related to CSP investments, after reviewing both general (Diacore, 2016) and CSP specific studies (Komendantova N. et al., 2012; Zou Z. et al., 2012; Lilliestam J., Patt A., 2015; Schinko, T. 2015; Richardson C., 2016). These include:

- *Policy risk:* Low level of political stability in a country, including lack of support from local governments.
- *Regulatory risk:* Refers to the uncertainty regarding governmental energy strategy and power market deregulation and liberalisation.
- *Country risk:* Includes political stability, level of corruption, economic development, legal system and exchange rate fluctuations.
- *Revenue risk:* Uncertainties regarding governmental energy strategies, exchange rates, market distortions such as fossil fuels' subsidies, limitations to energy market liberalization etc.

14 http://www.solarpowereurope.org/priorities/corporate-sourcing-2/

- *Financial risk:* Limited availability of local or international capital, lack of familiarity and skills with project finance structure, uncertainty regarding the long-term solvency of project partners etc.
- *Administrative risk:* Refers to the difficulties, complexity and time required for project developers to acquire all related permissions and licenses.
- *Technical risk:* Risks regarding lack of infrastructures for grid connection, interconnections, as well as the efficiency of the technologies adopted.
- *Transit risk:* This relates to the transport of key components across long distances, often overseas, and potential damages in the equipment.
- *Construction risk:* Risks involved in the development of CSP plants, due to reasons such as lack of contractor experience, limited access to land and unclear land ownership etc.
- *Operational risk:* Risks concerning on-site fires and other incidents.
- *Resources risk:* Availability of natural resources, such as accurate measurements of DNI, land and water.

As far as the barriers are concerned, according to Schinko T. (2015), 42 factors have been identified across the aforementioned risk categories. However, the interrelations between these factors had to be considered as well. Therefore, the authors in collaboration with the CSP industry, have arrived at the following set of barriers:

- Sufficient incentives provided at the policy level through the PPAs.
- Instability of national regulations regarding the prices of the PPA.
- Exchange rates.
- Lack of interconnections.
- Land access and availability issues.
- Lack of CSP experience of the company itself.
- Lack of skilled contractors at local sites.

2.4 Characteristics of CSP industry business models

Depicting the business models of different CSP actors can be a rather complex process, whence the presented analysis emphasised on how the companies have adjusted their business models. Richter M. (2013) has pointed out the following pillars in regard to the conceptualisation of business models:

- Value Proposition pillar, describing the product or service that is offered to the customer, e.g. shifting from production of electricity at large amounts, to production under peak demand.
- Customer interface pillar, encompassing the overall interaction with the customer. Customer relationship, customer segments, and distribution channels are included. This pillar has not been taken into account for the CSP business model.
- Infrastructure pillar, presenting the company's organization towards value creation, focusing on the organizational structure, know-how and partnerships.
- Revenues pillar, reflecting how costs for the production of the value proposition are related to the revenues stemming from offering the value proposition to the customers.

Therefore, the validation of the CSP industry's business models is oriented towards identifying (i) modifications of the original structures; (ii) adaptations of the value proposition pillar, including other RE technologies or additional services; (iii) adjustments of the infrastructure pillar enabling the integration of more stages of the CSP value chain; (iv) possible cooperations with reliable manufacturers of CSP components in other countries, in relation to potential adjustment of the current business model; (v) and alterations of revenue models and profit margins caused by the lower prices of the PPAs offered.

2.5 Value created over the CSP value chain

Value creation throughout the CSP value chain is deemed a credible indicator of collaboration opportunities or interest conflicts between the actors. Consequently, emphasis was given on detecting the impact of the various pillars on the overall creation of value, as well as investigating to which extent collaborations with local actors at host countries outside EU can be implemented, given the current conditions.

The steps of the value chain adopted, were: (i) Project Development; (ii) Materials production and supply; (iii) Components (key, secondary, other) production and supply; (iv) Plant Engineering and Construction; (v) Operation and Maintenance.

2.6 Strengthening local elements of the CSP value chain

After examining the maturity level of local collaborators along the CSP value chain in non EU countries, the main drivers linked to the improvement of their operation were investigated as well.

A more thorough classification of CSP components was used, by means of encompassing all potential services offered by local stakeholders. These services include civil works, installations, EPC engineering, assembling, construction of receivers / mirrors, mounting structures, heat transfer fluid, connection piping, storage system and electronic equipment (World Bank, 2011).

The main drivers, identified by the World Bank (2011) report are the following:

- attractiveness of local markets,
- technology transfer for capacity building,
- technological expertise, including precision of processes and lifetime stability,
- training and education of workforce, including structure and skills of the workforce,
- large financial investments in production capacities;
- competitive location factors including attractive costs for local manufacturing, availability of required raw materials, and infrastructure and logistic networks;
- improvement of quality standards;
- improvement of regulatory framework with financial and legal issues.

The above mentioned analytical framework has been integrated in the methodological approach adopted in order to explore the CSP industry, which is analysed in the following section.

3. Methodology

The methodological approach adopted for the identification of the characteristics of the CSP industry's business models comprised of the following three steps:

- Step 1: Literature survey.
- Step 2: Development of analytical framework.
- Step 3: CSP industry survey.

The structure of the methodological approach is illustrated in Figure 1. The three aforementioned steps are detailed in the following paragraphs.

3.1 Literature survey

A thorough literature review was conducted, encompassing all the components of the business models' structure for the CSP industry. Besides detecting all relevant literature, focus was also placed on tangible examples. The study was focalised on the following areas:

- the support mechanisms used for CSP deployment on a global scale, with emphasis in the role of EU companies,
- the CSP value chain components and the respective know-how of the EU CSP industry,
- the existing financing models along with relative examples,
- the financing parameters related to the business model adopted,
- collaboration opportunities for businesses created via upstream or downstream activities,
- risks and barriers related to the development of CSP.

To this end, the desk research included scientific papers, reports from industry and research organizations, as well as other institutions involved in the CSP industry (the European Commission, IRENA, OECD, IEA, World Bank etc.). News items from newspapers, governmental and CSP company websites were exploited as well.

3.2 Analytical framework

A set of 15 questions was prepared initially, according to the outcomes of the literature review conducted, covering all the financing, business and industrial parameters affecting the deployment of CSP.

Through consultation with CSP industrial stakeholders, these questions were modified, reaching a final number of nine (9). The main reasons for the alterations were the wide variety of subjects covered by the initial questionnaire, as well as the need for a less time-consuming structure. The main pillars of the selected topics are the following:

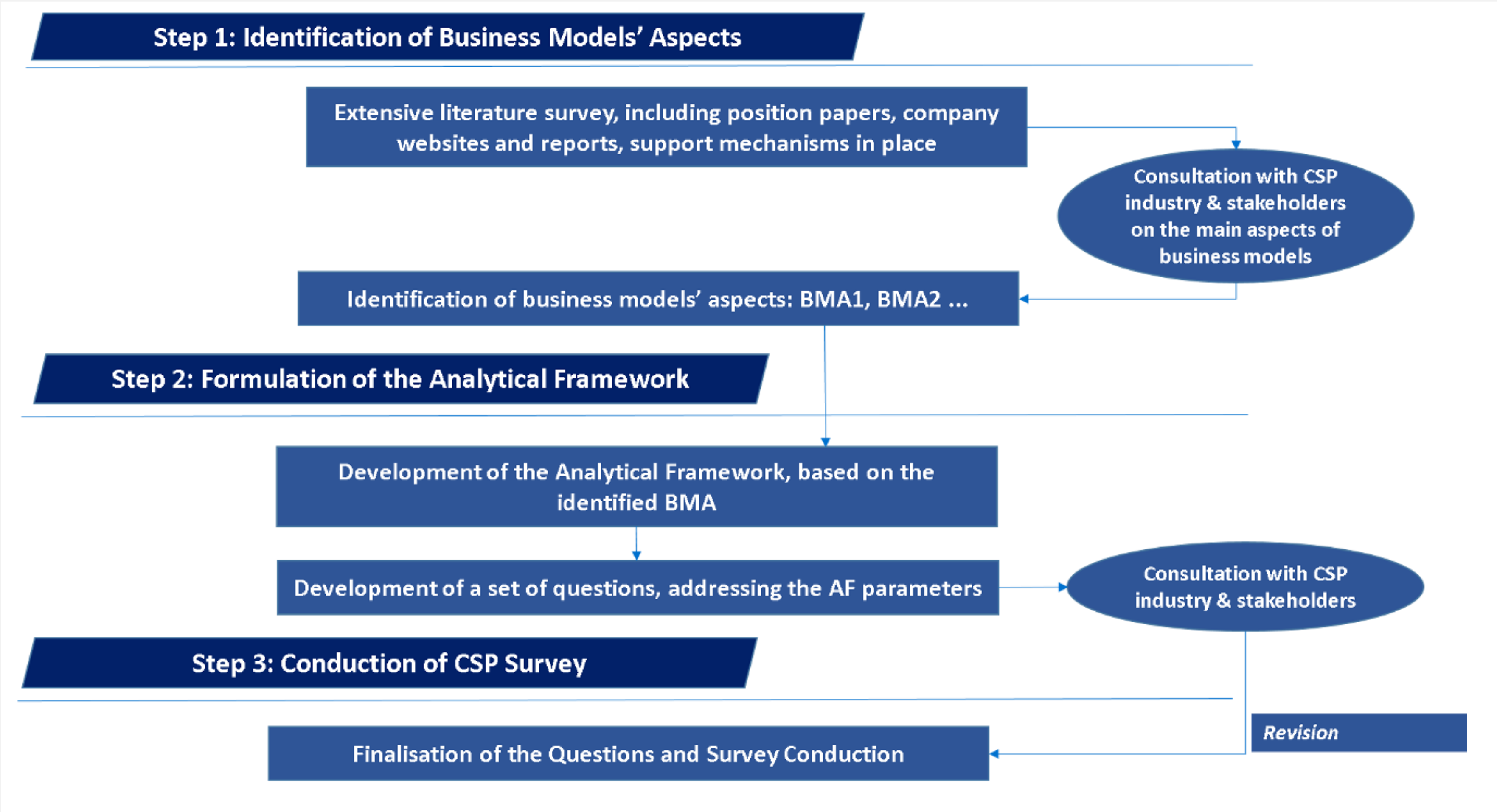

Figure 1: Methodological approach.

- Wide geographical distribution of CSP projects, emphasizing on countries where the EU CSP industry is largely involved.
- Long time range, during which many mechanisms and their variations have been used for CSP projects.
- Risks and parameters related to pivotal parts of the CSP value chain; industrial actors with a minor involvement in the CSP sector were not taken into consideration.

3.3 CSP Industry Survey

The main scope of the survey was the analysis of the decision-making process adopted by the EU CSP industry in relation to the evaluation of future projects. In this context, European Solar Thermal Electricity Association (ESTELA) distributed the questionnaire electronically to its members, while two follow up reminder rounds were realised. On top of these, a printed version of the questionnaire was also distributed among the participants of ESTELA's general assembly in February 2019.

Overall, out of 30 recipient companies in total, only 5 questionnaires were collected. Confidentiality reasons command that respondents remain anonymous. Although the response rate is around 17% and cannot be categorized as satisfactory, it is reasonable, given the small number of companies activated in the EU CSP industry sector, in particular plant owners and developers. Some of the companies contacted during the survey were not eager to proceed, as it did not relate to their experiences. Moreover, inhibitory impact can be also assigned to the complexity and the multidisciplinary nature of the questionnaire, as well as to confidentiality concerns.

Being familiar with the nature of the survey's topic per se, the authors' team had predicted the emergence of such impediments in advance. Thus, all possible efforts were placed in order to tackle them to the extent possible, as mentioned above. Nevertheless, the usefulness of the exercise should not be neglected, as fruitful conclusions can be abstracted.

4. Results

The aim of the first question was to examine the experience of the CSP industry in the various support mechanisms utilised so far, as well as its eagerness to implement CSP projects exploiting these mechanisms in the future.

The responses to "How would you characterize your company's CSP experience with these support schemes so far?" in a scale of -3 to 3 are presented in Figure 2. As expected, FITs presented a clear lead over the other mechanisms in terms of familiarization, while relevant support schemes such as FIPs and two tier tariffs turned out to be the second most important ones. On the contrary, green certificates (quota systems or renewable portfolio standards) were the least known mechanisms. More specifically, only one company claimed to be familiar with this mechanism to a satisfactory extent.

With reference to the "How probable would be for your company to implement a CSP project in a country under this support scheme?" question, the responses are available in Figure 3. The answers to this question are more or less similar to the previous ones, deviating only in regard with the significant increase for Corporate PPAs and Two tier tariffs.

The second question was investigating how the debt ratio is related to the type of support mechanism adopted, and was formulated as "How strongly you believe the debt ratio for a CSP project would be increased based on the type of support mechanism adopted?".

The specific question was answered by 4 out of 5 companies. As can be clearly seen, FITs stand out in terms of reliability, closely followed by FIPs and two tier tariffs. On the other hand, green certificates, corporate PPAs and tax incentives presented significantly less reliability concerning the increase of the debt ratio.

The third question referred to another financing source of CSP projects, namely equity funding, and how it can be influenced by selected uncertainty parameters. It was phrased as: "How do uncertainties in each parameter affect the equity ratio required by project financiers?". As the outcomes clearly demonstrate, financial and regulatory uncertainties are considered to have a much more significant impact on the equity ratio, compared to the technical ones, including the operators' track record.

More specifically, the latter ones received varying rates, with some respondents supporting that current forecasts are characterized by a high level of security and thus tend to abolish the influence of technical parameters on the decision-making process.

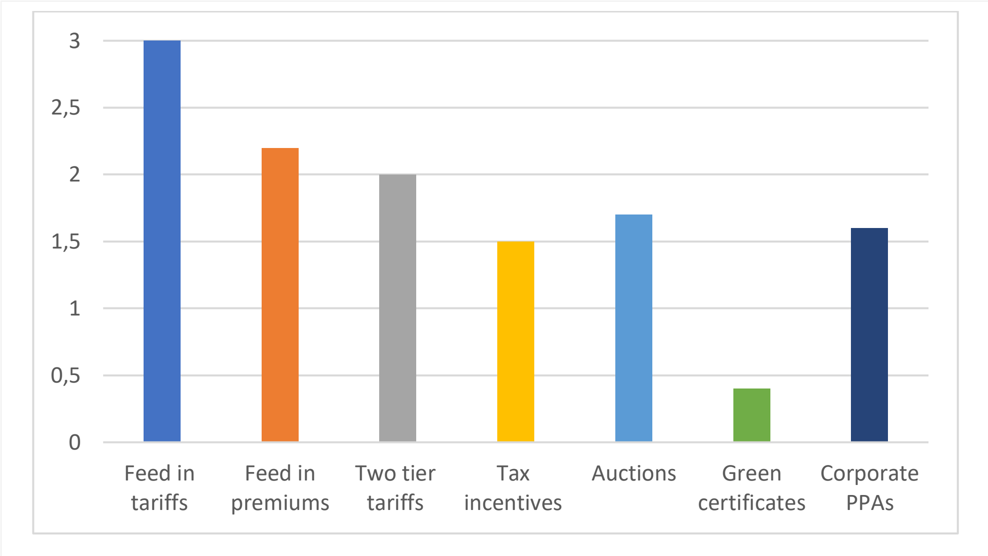

Figure 2: CSP companies' experience with support mechanisms.

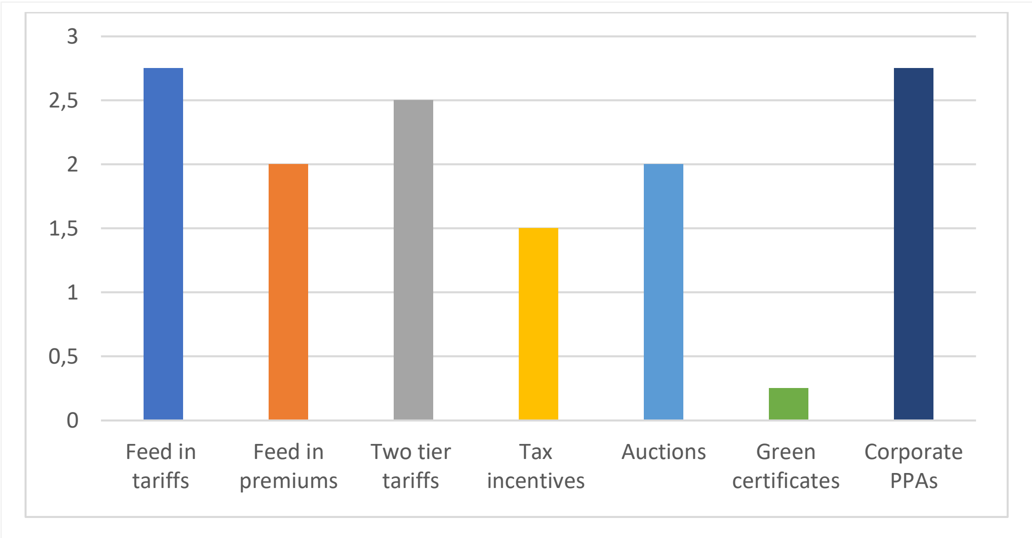

Figure 3: Likelihood of engagement in future CSP projects, depending on the support mechanism.

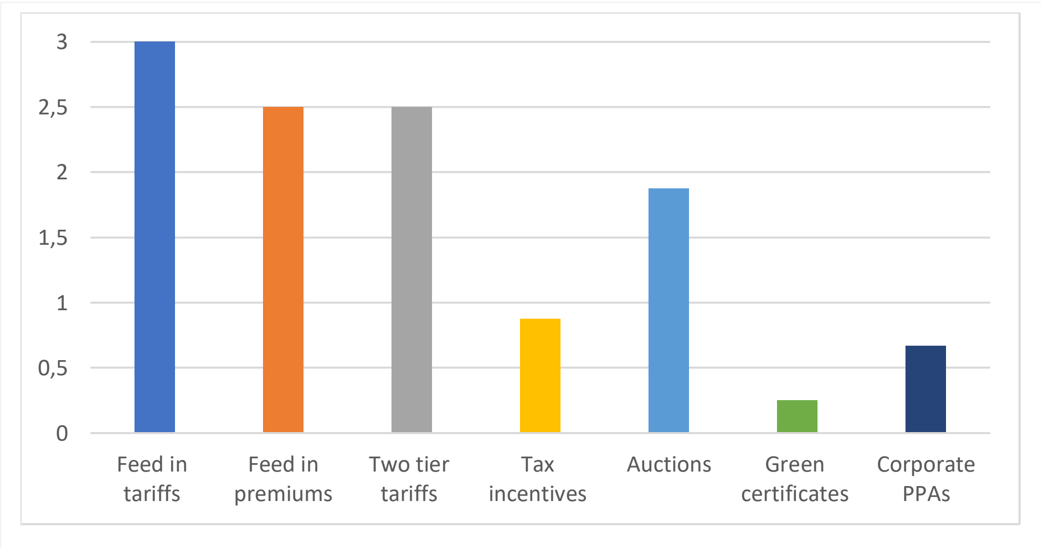

Figure 4: Debt ratio and support mechanisms.

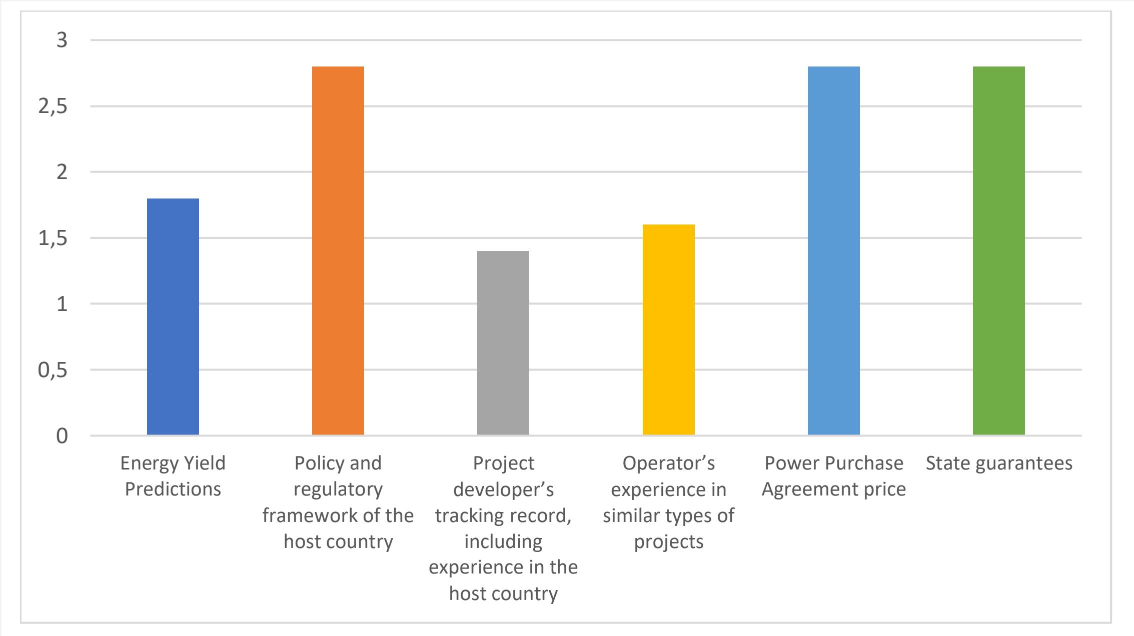

Figure 5: Equity ratio and uncertainties.

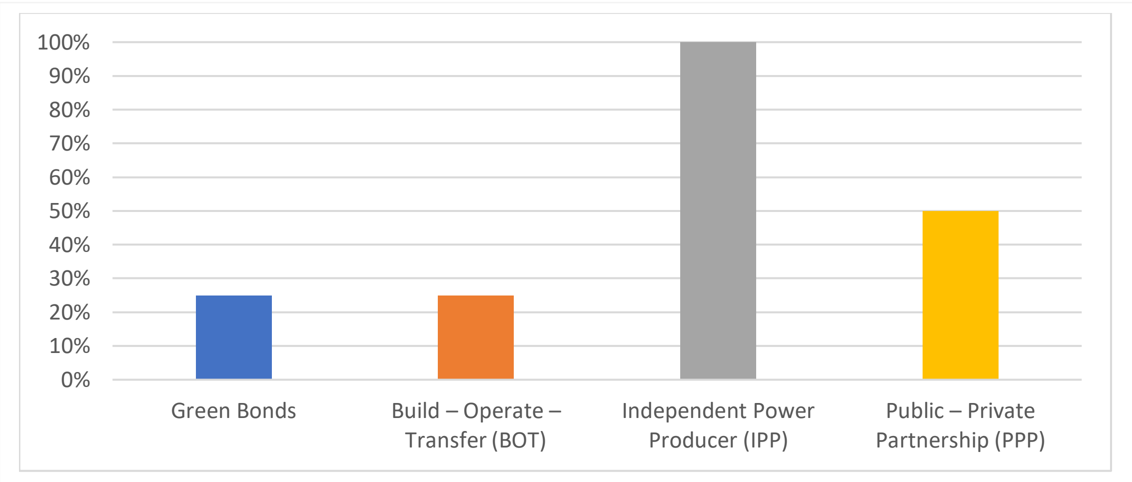

Figure 6: CSP industry experience with the financing models in place.

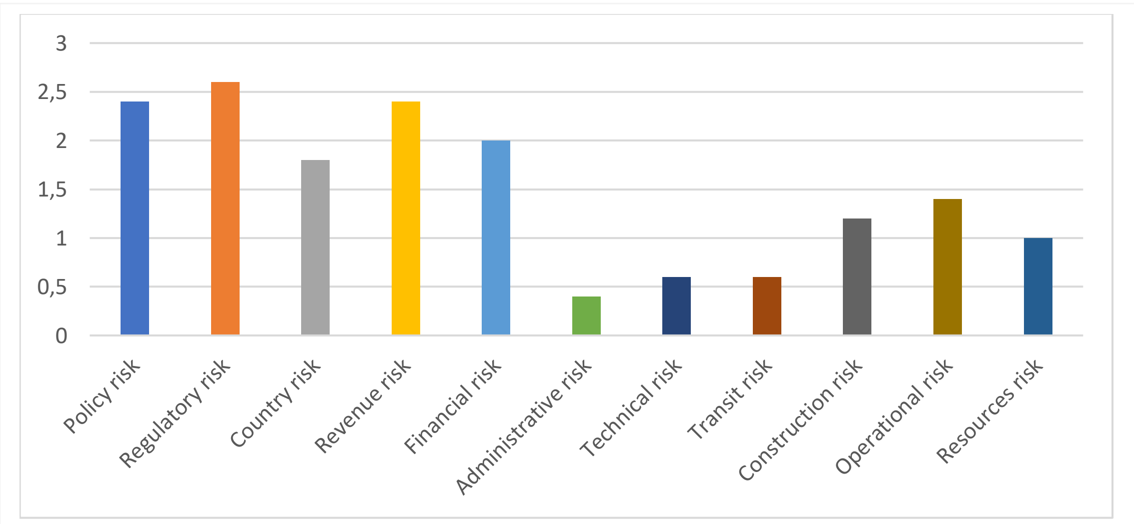

Figure 7: Impact of risk categories on the CSP industry's decision making process.

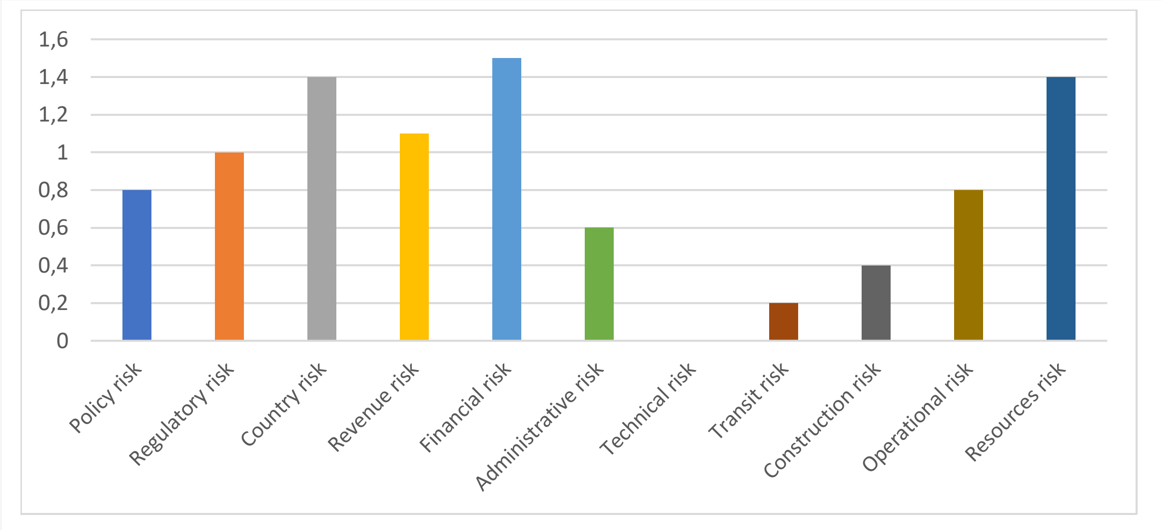

Figure 8: Probability of risk categories during project implementation.

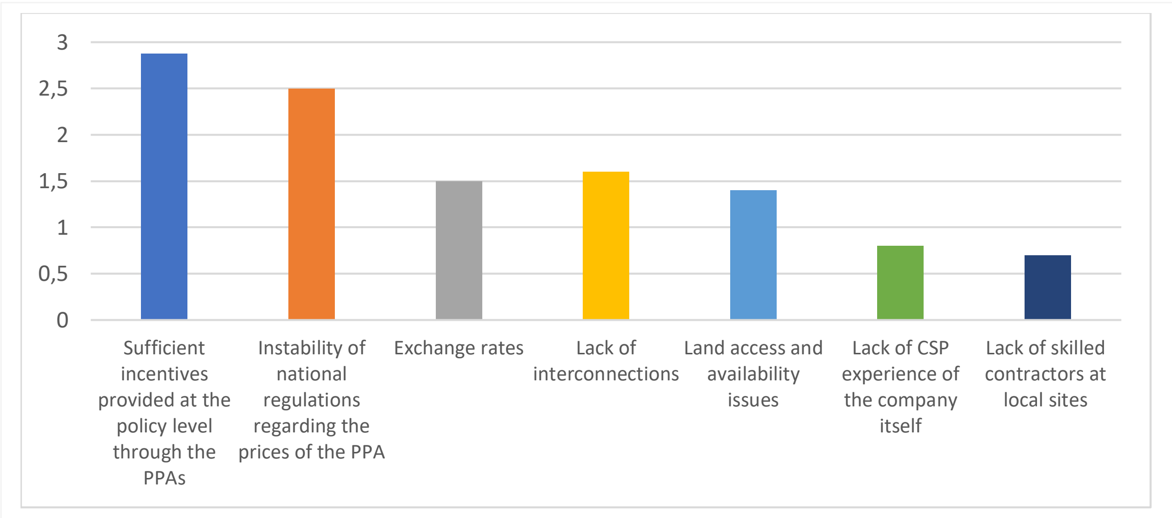

Figure 9: Barriers affecting CSP project implementation so far.

Other types of uncertainties were also mentioned, including the bankability of off-takers, O&M contractor's guarantees, EPC warranties and performance guarantees.

The next question was related to the experience of the CSP industry with the different financing models in place and was answered by 4 out of 5 companies. The respective results are presented in Figure 6.

The most noticeable feature is that all companies claimed to be experienced in the independent power producer model, while only half of them demonstrated experience in public – private partnerships. Only 1 out of 4 respondents was familiarized with Green bonds as well as BOTs.

The fifth question investigated how important and probable each risk was considered in relation to the realization of a CSP project. The responses to the question "How important is each risk on your decision for the realization of a project?" are depicted in Figure 7, whereas answers to "How probable is each risk during the implementation of a CSP project?" can be observed in Figure 8.

As the above Figure clearly demonstrates, the regulatory risk constitutes the most critical one, as far as the realization of CSP projects is concerned. The second most important risks are those related to policy and revenues, presenting equal scores. On the contrary, the administrative risk, followed by the technical and transit risks landed at the lowest scores. Concerning risk probability, the overall picture is characterized by ambiguity. The highest probability is allocated to financial risks, with the resources and country risks occupying the second place. Nevertheless, no reliable conclusions can be drawn about the low-probability risks (with technical risks being the least probable ones), given the fact that answers varied significantly.

The next question included the rating of a set of parameters linked to the above risk categories, considering their overall weight on realizing CSP projects so far, as well as in the future. Figure 9 illustrates "How has each barrier affected on the implementation of your CSP projects so far?"

In accordance with the previous answers, the highest scoring barriers refer to the regulatory (instability of national regulations regarding PPA prices) and policy risks (sufficient incentives provided), and the least scoring ones to the construction risk (lack of CSP experience and skilled contractors). The fact that lack of infrastructures (technical risk) exceeds the scores of the respective risk category, stems from the reasons explained above. On the other hand, although the resources risk was placed among the most significant ones, the respective barrier (land access and availability issues) is regarded to have a more or less medium impact on the implementation of CSP projects.

In regard with the future status quo of CSP projects, no major differentiations arose and the results can be seen in Figure 10. However, the lack of interconnections, experience and skilled local contractors presented a mild decline. Such a trend can be deemed reasonable, considering the technology's learning curve, as well as the interconnection targets set at the EU level.

Subsequently, the qualitative traits of the business models adopted by the CSP industry were explored, while at the same time taking into consideration any changes realized so far. In this context, the seventh question encompassed six features and was phrased as:

"Indicate with a Yes or No the characteristics that apply in your company's business model, and provide a short explanation in case of a positive answer". The results are displayed in Figure 11. It should be remarked that 4 out of 5 companies answered the last question. According to the answers demonstrated in the Figure 11, the CSP industry has adopted the measures needed in order to comply with the changing situation. In particular, more services have been added, as well as additional stages of the CSP value chain have been covered. The profile of the companies was defined as EPC and / or technology providers in the initial data. Additional services provided can include consultancy, engineering services, quality assurance, optimization and financing. Concerning the CSP value chain, additional stages refer to project development, Operational & management (O&M) services, technology construction and supply (main component).

Most companies have enriched their business models' value proposition by means of integrating other renewable technologies, namely PVs, whereas other companies prefer flexibility in the use of such technologies, based on the respective needs. The following question covers the percentage of the value chain created per phase. The results can be found in Figure 12.

The phase of components is predominant, with the EPC process being next in line. The rest of the phases (project development, materials, O&M) represent similar contributions. Most companies claimed that they covered all CSP phases except for materials. In addition, all of them supported that current conditions enable all CSP value chain phases to be undertaken at the host country, outside EU, either partially (40% of the answers) or fully (60%).

Finally, the companies had to evaluate the conditions needed for reinforcing local CSP manufacturers in non-EU countries. To this end, the CSP value chain was disaggregated into more specific components, according to the report by World Bank (2011). The respective results related to each one of the components are provided in Figure 13. Some conditions were not considered relevant to all components, whence fewer parameters were selected for specific components. This Figure clearly demonstrates, local demand is prevailing in comparison to the other parameters linked to the production of CSP components, namely receivers, mirrors, and connection piping, with electronic equipment and mounting structures being next in line.

Improvement of quality assurance standards can have a significant impact on all components, being predominant in the cases of installation, assembling and civil works, as well as the production of specific components, such as receivers and mirrors. However, its role is less significant in regard with EPC engineering and electronic equipment. As expected, training/ education is vital for installation works, as well as for the construction of CSP components, while competitive location factors have a more important role in civil works, mounting structures, heat transfer fluid and connection piping. Moreover, technological know-how is foremost required in storage systems, EPC and electronic equipment.

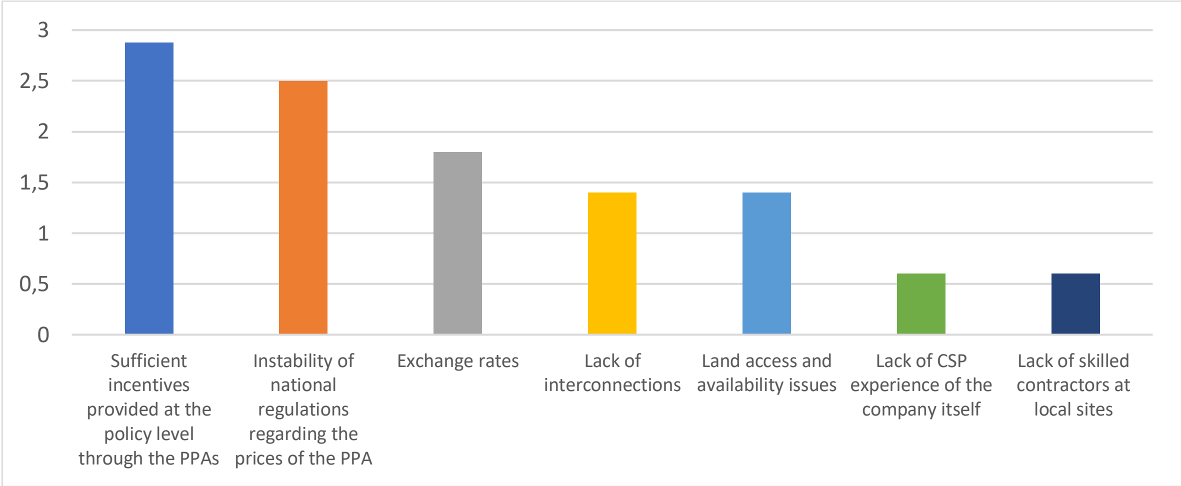

Figure 10: Barriers potentially affecting CSP project implementation in the future.

On the contrary, financial investments presented an average impact only in the case of components such as mirrors and heat transfer fluids. The same contribution was also attributed to the investment and regulatory framework, in particular on components such as receivers, mirrors and mounting structures.

5. Conclusions

The scope of this paper was to delve into the structure and value chain of CSP projects, in order to accent the applicable business models in the CSP industry.

Given the competitive business environment of the CSP industry, the stagnation of CSP projects in EU, as well as the feeble development rates observed in other markets, companies that still remain active are oriented towards higher levels of flexibility.

As no single business model can address all challenges occurring in the various cases, a thorough review was conducted in collaboration with a CSP industrial stakeholder. Its aim was to determine the key parameters affecting the evolution of CSP business models.

These parameters encompass the experience in current support mechanisms, as well as varying financing models, risks and barriers related to the implementation of an investment, the key characteristics of the business models of the CSP industry utilised so far, the value creation of the different steps of the CSP value chain, as well as the potential impact of local actors. The low response rate of the survey cannot lead to the extraction of fully valid conclusions. However, according to the results, the following insights were obtained:

- The FiT scheme was the most familiar support mechanism according to all stakeholders. A more or less average level of familiarization can be observed for the rest of the mechanisms, except for green certificates, the score of which was by far the lowest.
- All stakeholders declared their eagerness to invest in CSP in the future under the aforementioned support mechanisms. In particular, FiTs, two tier tariffs, corporate PPAs, FIPs and auctions accounted for really high scores. Tax incentives presented an average impact, while green certificates were the least preferred mechanism.
- The impact of the support mechanism selected on the debt ratio of a CSP project is very significant. More specifically, higher debt ratios are attributed foremost to FiTs, FiPs, two tier tariffs and auctions. On the contrary, tax incentives and corporate PPAs landed at remarkably lower scores, while at the same time green certificates remained at the last rank.
- The equity ratio depends mostly on the uncertainty of policy and financial parameters, namely the PPAs price, the state guarantees and the policy and regulatory framework of the host country. On the contrary, technical related parameters are considered to exert a remarkably weaker influence.
- All CSP companies have significant experience in the IPPs financing model, with the PPPs being the second most familiar model (50%). The scores of Green bonds and BOTs were considerably lower, landing at 25%.

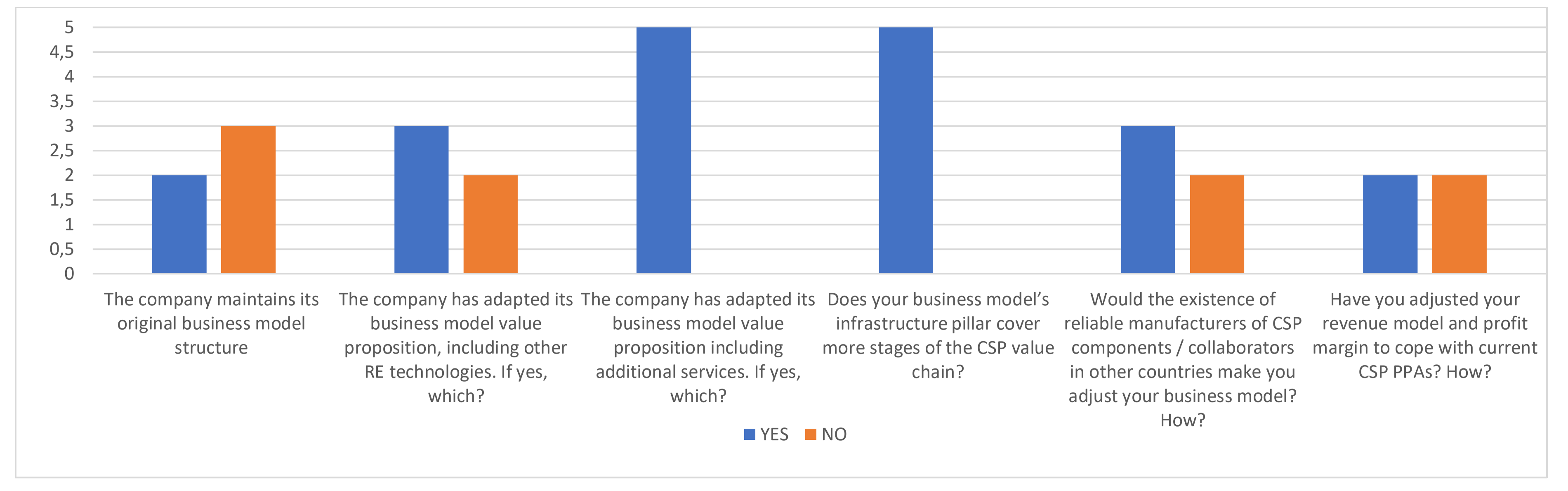

Figure 11: Business models characteristics and adjustments.

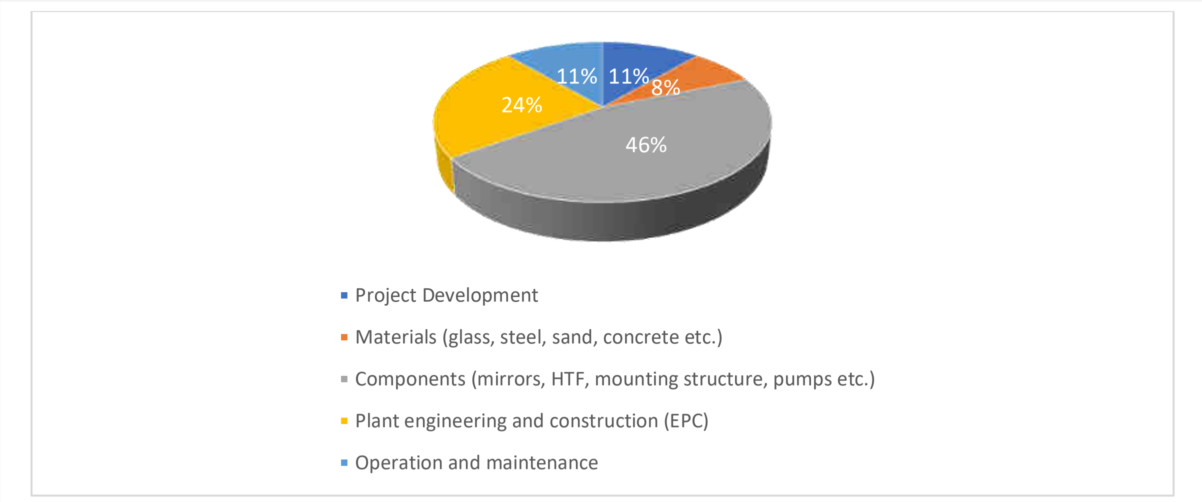

Figure 12: % per component in the CSP value chain.

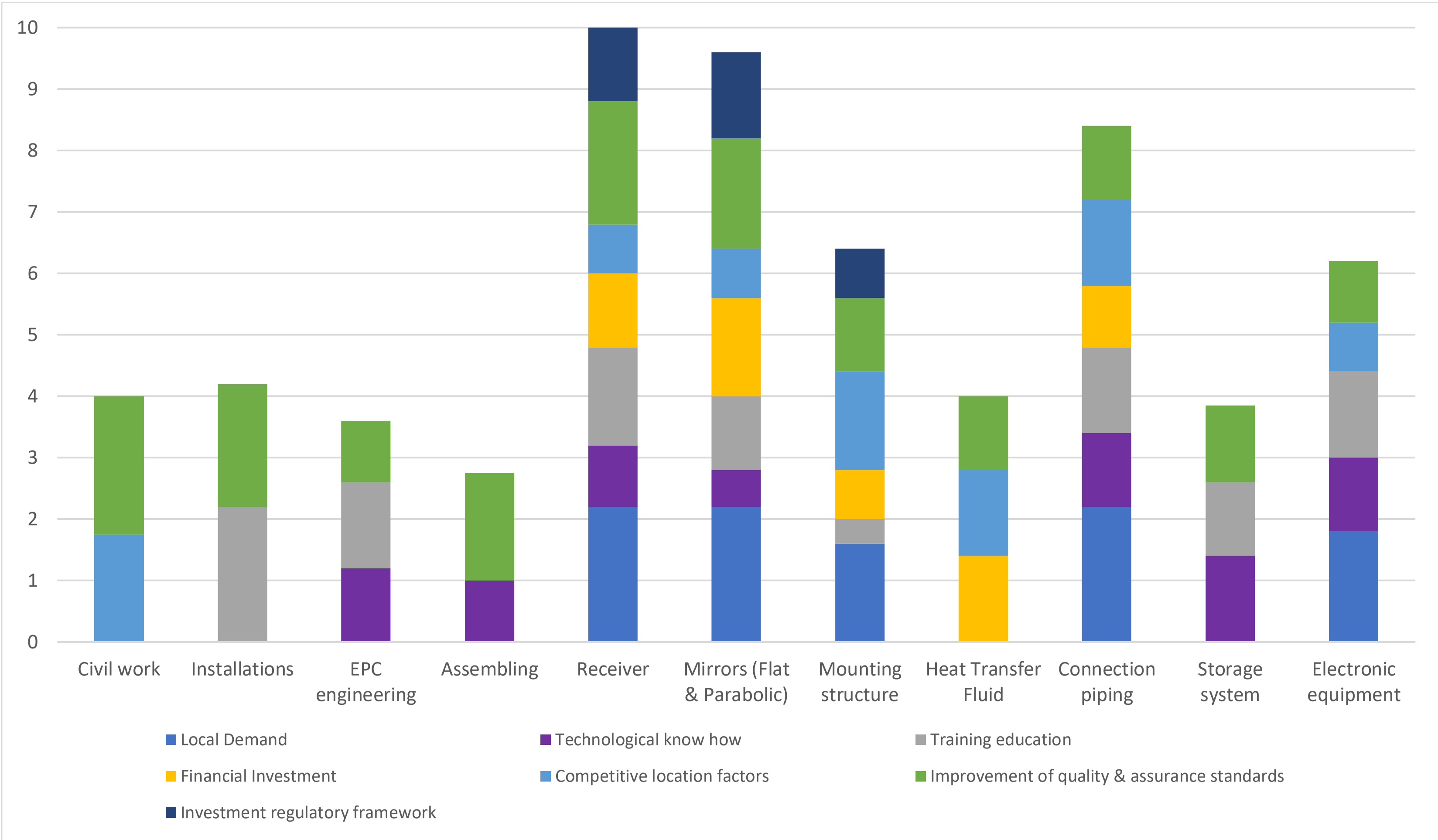

Figure 13: Evaluation of conditions to enhance CSP components' local production.

- The most important risk regarding the decision-making process for the realization of CSP projects is the regulatory risk. The policy and revenue risks are next in line with slightly lower scores. This result is reasonable, considering the question on the equity ratio. Financial and country risks accounted for medium to high scores, whereas the construction, operational and resources associated risks reached only medium to low ranks. Technical, administrative and transit risks were considered by far the least important ones. Concerning risk probability, the financial resources and country risks amounted to the highest scores, although none of them exceeded 1.5. Regulatory and revenue risks were assigned low probability ranks, whereas operational and policy risks were considered even less probable. The remaining risks presented a very low probability, while technical risks at the operational phase presented a score of zero.
- The barriers affecting the CSP projects the most are related to regulatory (instability of national regulations regarding PPA prices) and policy risks (sufficient incentives provided), while the least important ones refer to the construction risk (lack of CSP experience and skilled contractors). An intermediate impact was assigned to exchange rates, land availability issues and lack of interconnections. The estimations regarding future CSP project implementation present a similar picture, indicating that no major changes are expected to occur in the near future.
- The CSP industry has shifted to more adaptable business models, integrating additional services and stages of the CSP value chain. Most companies have changed their business models' value proposition by including other technologies, namely PVs, as well as other forms of renewables, depending on their needs.
- The phase with the highest contribution to the CSP value chain is related to the components (46%), while the EPC process is next in line with a percentage of 24%. The rest of the phases (project development, materials, O&M) scored equally with percentages of approximately 10%. Regarding their business models, most companies were covering all CSP phases, except for materials.
- The most significant conditions for reinforcing the role of local manufacturers include: (i) the increase of local demand in relation to the production of key components, (ii) the improvement of quality assurance standards in regard with components and (iii) training/education connected to installation works.

All things considered, the CSP industry was obliged to modify its original business models, integrating additional services and stages of the CSP value chain. Furthermore, the low CSP deployment rates observed both in EU and non-EU countries have also led to alterations in their value proposition, namely the introduction of other technologies. The current conditions are considered mature enough for all CSP value chain phases to be implemented at host countries outside EU, either partially or fully.

Given that the revenue, policy and regulatory associated risks and barriers are considered the most significant ones, higher revenues can be expected to stem from changes in the electricity market in combination with the carbon emission allowances. In this context, the provision of ancillary and balancing services is deemed to be of vital importance. In addition, the stability during the application of a selected support mechanism is regarded as more pivotal than the type of the mechanism itself. Furthermore, the impact of technical barriers is considered weak by the CSP industry. On the contrary, project financiers take them into account, although they do not constitute their main concern.

Acknowledgement

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LIST OF ABBREVIATIONS	
BOT	Build-Operate-Transfer
CORFO	Corporación de Fomento de la Producción de Chile
CSP	Concentrated Solar Power
DNI	Direct Normal Irradiance
EPC	Engineering, Procurement, and Construction
ESTELA	European Solar Thermal Electricity Association
EU	European Union
FIT	Feed In Tariff
FIP	Feed in Premium
IEA	International Energy Agency
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
IRR	Internal Rate of Return
ISCC	Integrated Solar Combined Cycle
ITC	Investment Tax Credit
KISR	Kuwait Institute for Scientific Research
MASEN	Moroccan Agency for Solar Energy
MENA	Middle East and North Africa
O&M	Operation & Management
OECD	Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
PPA	Power Purchase Agreement
PPP	Public- Private Partnership
PURPA	Public Utility Regulatory Policies Act
REIPPPP	Renewable Energy Independent Power Producer Procurement Program
RPS	Renewable Portfolio Standard
SEGS	Solar Energy Generating Stations
SEIA	Solar Energy Industries Association
STE	Solar Thermal Energy
TES	Thermal Energy Storage
USA	United States of America

Risk Governance in Public Sector-led transitions: The case of electrification of ferries in Norway

Prof. Tom SKAUGE [1], Head of Department*
Prof. Paul BENNEWORTH*
Prof. Ole Andreas BREKKE*
*Western Norway University of Applied Sciences

[1] *Contact details of corresponding author*
Tel: +47 916 06 803 /+47 55 58 77 30
e-mail: tom.skauge@hvl.no
Address: Møllendalsveien 6, Postboks 7030, 5020 Bergen

Abstract

Decarbonisation is one of the most existential challenges facing European society today.There is much less consensus regarding who should bear the costs of this transition in ways that do not unnecessarily cap the speed of change with public spending requirements. There is indeed particular interest in terms of understanding how to incentivise business to invest in innovation to reduce carbon output, developing the technologies, processes and organisational forms to deliver decarbonisation in practice, something which can potentially be highly lucrative for businesses. But developing these technologies is a highly uncertain process, because of their incorporation within wider infrastructure elements that are often dependent on the parallel success of many innovation trajectories for their realisation.

A traditional public sector approach for acquiring these technologies is in subsidising the R&D&I of the components to push them towards market readiness. But in our case – electrification of ferries in Norway - the public sector bears most of the risks and receives little of the reward for those technologies that eventually become successfully adopted. In this paper we develop a risk sharing model for public to use a decarbonisation public sector tendering process, ensuring the optimal correspondence between those bearing the costs of risks and those that achieve the returns. An alternative approach to allocating risk and reward is in the use of innovative procurement approaches, in which tenders are developed which specify ends in terms of service provision and decarbonisation, and leave it to the tenders to specify the price at which they can deliver that.

Keywords: Risk governance, green maritime, decarbonization, green innovation, public-private.

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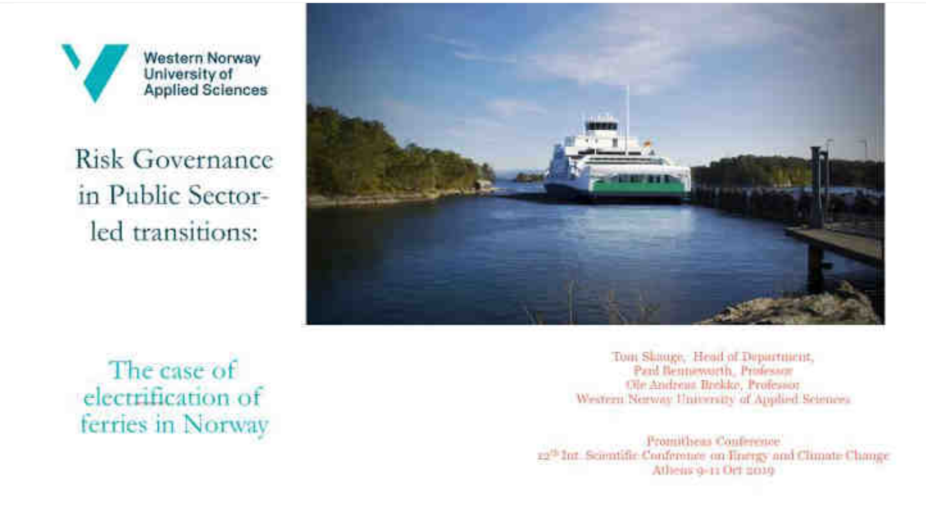
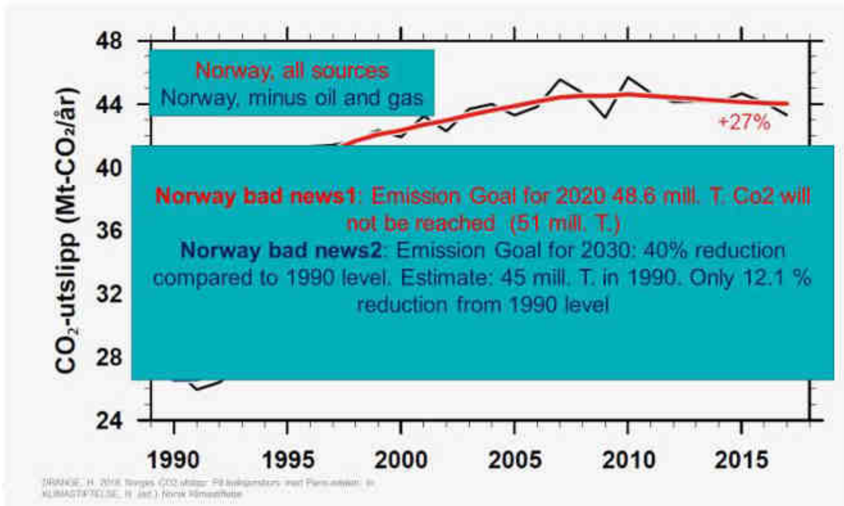
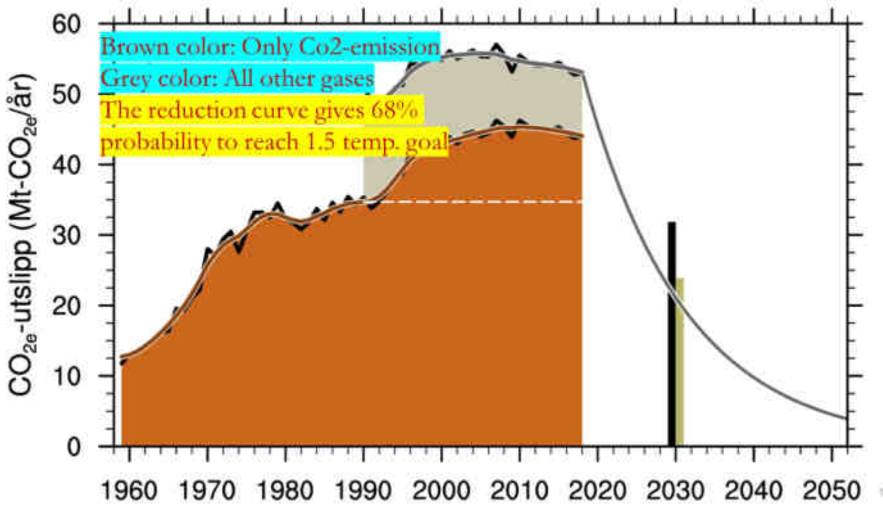

Western Norway University of Applied Sciences
Risk Governance in Public Sector-led transitions:
The case of electrification of ferries in Norway
Tom Skauge, Head of Department,
Paul Bennworth, Professor
Ole Andreas Brekke, Professor
Western Norway University of Applied Sciences
Prometheus Conference
12th Int. Scientific Conference on Energy and Climate Change
Athens 9-11 Oct 2019


Introduction - Climate challenges and necessary innovation for decarbonization


We have necessary knowledge of climate crisis
There is no need to argue for climate change actions. The UN IPCC report on Global Warming of 1.5 °C (IPCC, 2018), the report on ice melting and sea level rising (IPCC, 2019) and the UN Climate Action Summit September 2019 (UN, 2019) gives evidence.
ipcc
The Ocean and Cryosphere in a Changing Climate
Summary for Policymakers
ipcc
Global Warming of 1.5°C
UN Climate Action Summit 2019
A RACE WE CAN WIN


Norway, all sources
Norway, minus oil and gas
+27%
Norway bad news1: Emission Goal for 2020 48.6 mill. T. Co2 will not be reached (51 mill. T.)
Norway bad news2: Emission Goal for 2030: 40% reduction compared to 1990 level. Estimate: 45 mill. T. in 1990. Only 12.1 % reduction from 1990 level
CO2-utslipp (Mt-CO2/år)
48
44
40
36
32
28
24
1990
1995
2000
2005
2010
2015



We know the challenge

But we do not have sufficient knowledge on pathways for decarbonizing

Important research questions today are pathways to decarbonizing results.

One pathway is technological. This paper discuss lessons learned on risk-taking rising form one Norwegian green innovation case: The electrical revolution of the Norwegian ferry sector (Skauge et al., 2017, 2018).

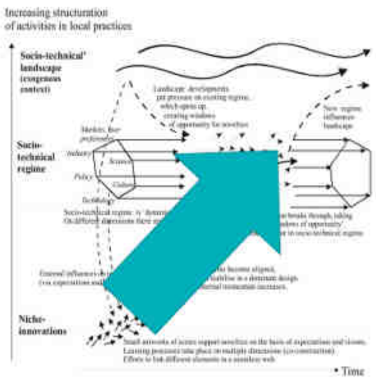
Our goal is to propose concepts and a model to grasp future lessons on rewards and risk distribution in radical innovation processes.

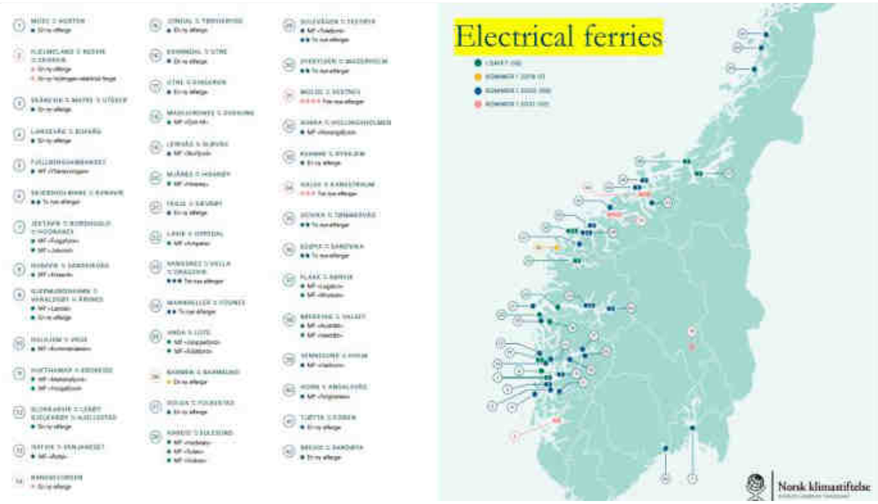
From Niche to Regime – Risk identification in green innovation

Landscape (Context)

Regime

Niche innovations





The two next innovation waves:
1) Fast- and local boat routes

Fast- and local boat routes are the worst transportation option for the climate.

No other means of public transport has higher emissions per passenger kilometer - not even domestic flights.

The high-speed passenger boats between Bergen and Sogn / Nordfjord alone use 6.6 million liters of diesel a year.

- New design for high speed boats with electric or hydrogen fuel for next tender periode 2021 -

The two next innovation waves:
2) Cruise Ships

Emissions from cruise ships are greatest when on board and not when docked. However, with 2,200 cruise calls in Norway in 2018 and expectations of traffic growth, the cuts achieved by switching to shore power will be significant.

One year ago, in May 2018, the Storting asked the government to introduce zero discharge requirements from tourist ships and ferries in the World Heritage fjords by 2026.

Bergen, which is Norway's largest cruise port with over 300 calls and 600,000 cruise tourists a year, is in the process of building Europe's largest onshore power plant, which will be able to supply three ships simultaneously.

Four Risk Challenges
According to EU Commission Expert Group

Define and assess risks and reward for all partners involved at the various stages of the procurement process, including:

1. Nature (kinds of risks) of risks, which may change during the various procurement stages,
2. Causes and sources of risk,
3. Likelihood of risks to occur
4. Potential consequences of risk occurrence (additional costs, reduced reward),

Risk typology – Nature of risk

Technological risks

"are all those risks that lead to **non-completion, under-performance or false performance** of the procured good and service. Due to its more innovative nature, the risk lies in the technical characteristics of the service or product or in its production, and thus originates in the suppliers' side. This risk appears of particular relevance in procurement of products in the fluid phase.

Organisational and societal risks

Organisational risks are all those risks of the procurement failing or under-delivering **for reasons situated within the organisation that procures.**

Societal risks

are those related to a **lack of acceptance and uptake by the users** of the new or changed servic delivered within society.

Risk typology – Nature of risks

Market risks

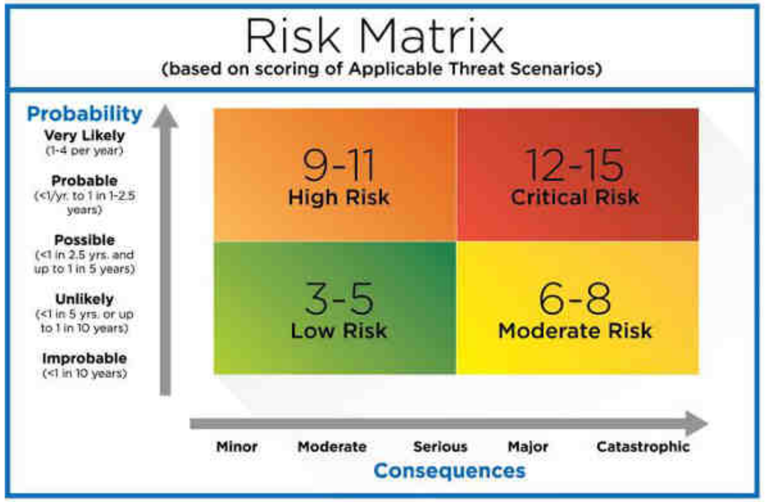
are to be found on the demand and supply side. The former occur when innovations in public procurement are also intended to spill over to private markets and those private markets are **not large or responsive enough or do not bui up quickly enough to justify capacity investment**. The latter are those that potentially disrupt or delay operations such as **political instability and volatile labour market; potential threats that a competitor will take over a supplier and potentially lock out supplies, risks related to delays and insufficient quality.**

The financial risks

in public procurement are related to **uncertainty in meeting target costs and the ability to secure the funds needed.**

Finally turbulence risks

– in fact turbulence **uncertainties as they are hard to predict and measure** – are associated with large scale-projects and emerge from a range of unforeseen events that lead various actors in the whole process to re-assess their priorities or change their expectations."



Stages in decision making and innovation – to search for risks

Stages i decision making:

- Initiative
- Assessment
- Decision on Tender process
- Tender process – Decision on contracts award
- Implementation phase
- Result - Learning

Stages in innovation circle:

- R&D stage
- Adoption by public sector
- Diffusion
- Maintanance and updating

Typology for mapping risks in green innovation

Source type	Institutional Societal	Financial	Market	Technological	Other	Source type
Stages in decision making						*Stages in Innovation cycle*
Initiative Assessment						R&D stage
Decision on Tender process						Adoption by public actor
Tender process Decision on contract award						Diffusion
Implementation				Risk / Rewards		Maintenance and updating
Result Learning						

Risk and Rewards

- **RISKS: failing to achieve transition if fail to develop a fair risk-sharing model**
- **PRIVATE risk:** if incentives do not allow reasonable return then will propose sub-optimal technologies (LNG, hybrid) or renegotiate.
- **GOVERNMENT:** if risk model not adequate then will subsidize innovations for private business with no rewards.
- **PUBLIC:** end up paying too much for reduced services with more pollution and undermining support for green transition policy instruments

- **REWARDS for all if successful transition made:**
- **PRIVATE COMPANIES**
- **Ferry companies**: concessions that reward the system integration work
- **Shipyards**: new product ranges developed and ready for wide launch
- **Subsystems developers**: creating demonstrator projects and electrification modules
- **GOVERNMENT**
- **Demonstrating competence** to voters
  Reducing cost of innovative service provision.
  Providing Jobs
- **PUBLIC Modernising** public services
  Guaranteeing longer term **decarbonisation**
  Reducing local diesel **pollution**

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The Two Most Serious Risks for Public Sector

Risk-sharing in funding:

Are the State and Private Sector willing to share the economic risk taken by the Regional Municipality?

Technology:

Can the battery and Grid system deliver expected service with necessary stability ?

22

Source type / Stages in	Institutional Societal	Financial	Market	Technological	Other	Source type / Stages in
Decision making						*Innovation cycle*
Initiative Assessment	Based on false premises for success?	Financial Risk Regional Municipality		Demonstration Project "Ampere" Good enough pilot result?		R&D stage
Decision on Tender process	Wrong decision on Tender premises: 70% price and 30% environment?	Financial Risk	Lack of high quality suppliers of electrical ferries?	Technology neutral Claim – A wise decision for best tech. alternatives?		Adoption by public actor
Tender process Decision on contract award	Shipbuilding and operating Company competent?	Financial Risk				
Implementation	Acceptance among ferry users fading in two districts/ Lack of public regulation - Grid	Financial Risk		Battery charging reduce service on long distance routes / Diesel as backup / Grid providers	From Moral high altitude	Diffusion
Result Learning		Serious Financial risk?		Long run stability	To Moral defeat?	Maintenance and updating

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Session B: Environment – Climate Change

On the relation between the seismic activity data and Hurst exponent in support of energy investments in Albania

Dr. Luis LAMANI [1], Lecturer*

M.Sc. Elva LEKA, Lecturer*

*Department of Applied Geology, Environment and Geo-Informatics

Contact details of corresponding author[1]

e-mail: luis.lamani@fgjm.edu.al

Address: Rr. Elbasanit, Faculty of Geology and Mining, Polytechnic University of Tirana, Albania

Abstract

Albania is located in a region with a dynamic seismic activity, therefore it is important to understand the nature of earthquakes, to support investments in power generation plants. In this paper we empirically examine the dependence between earthquake's magnitudes and their intrinsic value through Hurst's rescaled range analysis. The seismic activity time series for period 58BC to 2019 are considered for estimating the Hurst exponent. Estimating the Hurst exponent for a data set provides a measure of whether the data is a random process or has underlying trends. We measured the exponent and obtained a value of $H > 0.5$, indicating a long-term correlation in earthquakes magnitudes in Albania. Examination of seismic data series through Hurst's rescaled range analysis shows that seismicity is a memory process, not random.

Keywords: Hurst exponent; R/S analysis; seismicity analysis; renewable energy; earthquake magnitudes; energy strategy

1. Introduction

The "*Energy Strategy for Albania 2017-2030*" is the core strategic document for the country's energy sector. It is consistent with the national efforts to sustain economic development, and meet commitments to the Energy Community, EU integration and other international agreements, while increasing the security of energy supply and minimizing environmental impacts with affordable costs for Albanian citizens and the economy. One of the objectives that Albania intends with the implementation of this strategy is also increased use of Renewable Energy Systems (RES) technologies, based on least-cost planning, sustainability, climate action and environmental protection. Earthquakes constitute a threat to human activity and must be considered when designing engineering facilities.

The two most important variables affecting earthquake damage are: (1) the intensity of ground shaking caused by the quake coupled with (2) the quality of the engineering of structures in the region (Einstein A., 1956).

If we choose to accept very minor damages, then it should be designed for a relatively high level of oscillation and the necessary precautions to be taken for these oscillations can be costly. If higher levels of damage are tolerated, then lower levels of oscillation can be considered and the outcome of the project will result in lower costs.

Of course, a balance must be found between the short-term costs of anti-seismic design and the long-term potential costs (which for many structures may never be quantified) resulting from earthquake damage (Kramer Steven L., 1996).

All the seismicity parameters are analyzed based on traditional statistical method (Li Juan & Chen Yong, 2001). The greatest difficulty in determining oscillation parameters stems from the fact that it inevitably depends on subjective decisions being made based on incomplete or uncertain information (Kramer Steven L., 1996).

A focus[15] generates earthquakes of various sizes up to the maximum earthquake. Smaller earthquakes occur more often than larger earthquakes. Each focus (hypocenter) has a

[15] location

defined maximum magnitude which cannot be exceeded (Kramer Steven L., 1996).

The basic assumption of Probabilistic Seismic Hazard Analysis is the same as that of financial markets, and other disciplines that deal with self-similar processes.

As with many stochastic processes that exhibit a fractal behavior (e.g. landscape evolution, stock prices, Ethernet traffic (Chong K., 2003), and gene expression dynamics etc.) the spatial and temporal scaling of earthquakes obeys power law distributions.

We examine the dependence between earthquake's magnitudes and their intrinsic value through Hurst's rescaled range analysis (Li Juan & Chen Yong, 2001; Mandelbrot B. B., Hudson R.L., 2008; Mandelbrot B. B. et al., 2004; Mandelbrot B. B. et al., 1969).

Hurst's formula (Mandelbrot B. B., Hudson R. L., 2008) started by calculating the average annual rainfall or water discharge from a river and keeping a running tally, year by year, of the accumulated deviations from that average. Then he looked at the peak value and compared it to the lowest level reached. He called the difference, Range or just R. His formula gives the value of R, which indicates how big the reservoir should be to avoid floods or droughts downriver. It is determined by σ, the standard deviation of the discharges from one year to the other; N, the number of years under study; and α, the power-low exponent that drives the whole equation. Hurst, using logs, used the equation:

$$\log\left(\frac{R}{\sigma}\right) = K \log\left(\frac{N}{2}\right) \qquad (1)$$

Periods of high release of seismic deformation will most likely be followed by years of higher-than-average seismic strain release. Conversely, seismically quiet periods will tend to be followed by quiet years. This behavior mimics that of fluctuating long-term water storage in reservoirs (Barani S. et al., 2018; Hurst H. E., 1951).

According to the original proposition, Hurst exponent (H) = 0.5 would represent a random walk, a Brownian motion, in which the current value of the series would not be dependent of past values of the series. Hurst value between 0 and 0.5 indicates anti-persistent behavior of the series. Anti-persistent series display "mean-reverting" characteristics. Hurst value between 0.5 and 1 indicates a persistent behavior of the time series, which mean the series do not expand in a random walk.

2. The methodology

The seismic activity time series for period 58BC to 2019 (Booth E., 2018) are considered for estimating the Hurst exponent.

A statistical test called *rescaled range analysis* was developed by Mandelbrot and Wallis (1969). The H is calculated through rescaled range analysis (R/S analysis, - short for range divided by standard deviation) (Mandelbrot B. B. et al., 2004). The R/S is widely used for testing whether long-term dependence is present in a series of data.

The R/S formula simply measures, the amount by which the data vary from maximum to minimum, or which data is greater or smaller than what expected if each data point was independent of the last (Mandelbrot B. B., Hudson R. L., 2008). As Mandelbrot further explains, if different from expectations, then the precise sequence of the data must be important: a "run" of gains and losses must be pushing the extreme values further than they would otherwise go by pure chance.

For a given set of observations $X_i, i \geq 1$, with partial sum $Y_n = \sum_{i=1}^{n} X_i, n \geq 1$, and sample variance $S_n = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(X_i - \frac{1}{n}Y_n)^2}$, $n \geq 1$ the R/S statistic is defined as:

$$\frac{R}{S_n} = \frac{max_{0\leq t\leq n}\left(Y_t - \frac{t}{n}Y_n\right) - min_{0\leq t\leq n}\left(Y_t - \frac{t}{n}Y_n\right)}{S_n},$$

$$n \geq 1,\ where\ X_i - magnitude\ value \quad (2)$$

In practice, classical R/S analysis is based on a heuristic graphical approach, originally developed by Mandelbrot and Wallis (1969a, b, and c).

3. The calculations

Rescaled range analysis depends on multiple lengths of time to be analyzed. Hurst exponent is calculated as the slop of the line generated by taking log on *x* axis and log(R/S) on *y* axis. Series of rescaled range is calculated separately for different sample size.

We have a total of 4219 data (total number of earthquake's magnitudes). Table 1 displays the number of earthquakes with value N as the total number of events above the *minimum* magnitude and the number of earthquakes with magnitude above and equal to 4.5 (Booth E., 2018).

We performed the calculations using scripts written in Python. The same R/S analysis was carried on the interval of earthquake time series. By taking the average rescaled range (R/S) values for each of the region size, we calculate the Hurst exponent. We can obtain an estimation of the Hurst exponent from an R/S analysis. The Hurst exponent is the slope of the logarithmic values for the size of each region and for each region's rescaled range. It is also related to the "fractal dimension", which gives a measure of the roughness of a surface. The relationship between the fractal dimension, D, and the Hurst exponent, H, is $D = 2 - H$. It should be noted that the *time series* is not a real "time series", for the reason that the random variable does not vary with the time t, but the order of the events. The range R in earthquake frequency time series analysis is the difference of the maximum and minimum number of earthquakes. To put it simply, it is the maximum fluctuation of earthquake frequency during the time span τ. This fluctuation is not a constant over all time scale, but increasing with τ, which could be applied to seismic hazard analysis (Li Juan & Chen Yong, 2001).

4. Results

Rescaled range analysis, 50BC to Apr. 2019, N=4219

Hurst exponent (H) = **0.68**
Fractal Dimension (D) = 1.32
Average magnitude = 3.02
Maximum magnitude = 7.20
Minimum magnitude = 1.00

By plotting the logarithm of the size (x axis) of each series versus the logarithm of the rescaled range (y axis) we build the charts of the R/S analysis.

The Hurst exponent is estimated by a linear regression line through the points of Log Size (x) and Log R/S (y).

From our earthquake records with magnitude $M \geq 4.5$, a new random time series of the intervals between the subsequent two events can be created. Since the variable does not vary with the time t, but the order of the events, the random variable is sampled according the order of occurrence of events.

Rescaled range analysis, 50BC to Apr. 2019, $M \geq 4.5$, N=735

Hurst exponent (H) = **0.76**
Fractal Dimension (D) = 1.24
Average magnitude = 5.12
Maximum magnitude = 7.20
Minimum magnitude = 4.50

Table 1: Earthquakes records.

Region	N	$M \geq 4.5$	$M_{min(N)}$	$M_{avg(N)}$	$M_{max(N)}$
Albania	4219	735	1.00	3.02	7.20

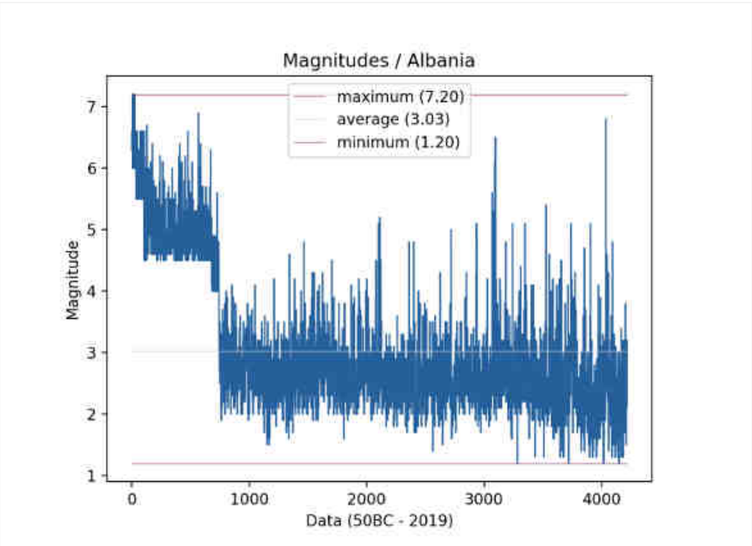

Figure 1: Magnitudes series in Albania, 4219 data, 50BC – 2019.

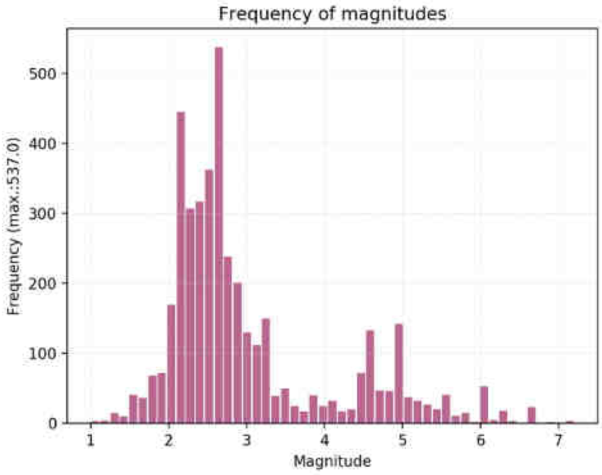

Figure 2: Frequency of magnitudes in Albania, 50BC – 2019.

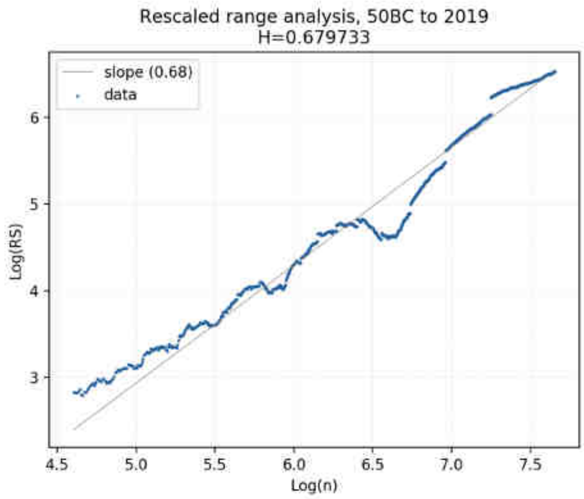

Figure 3: R/S - earthquake's magnitude data in Albania.

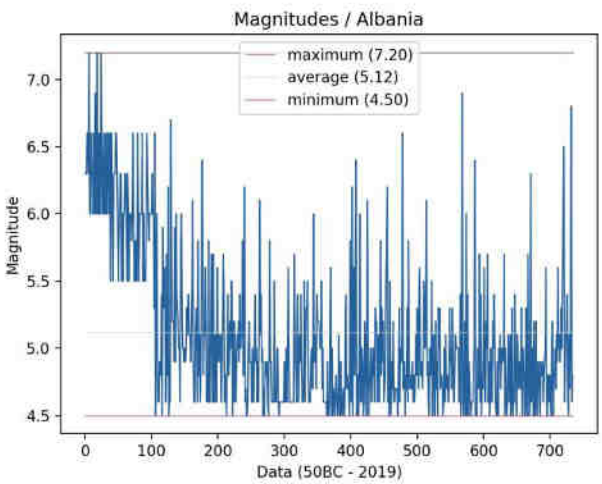

Figure 4: Magnitudes series in Albania, 735 data.

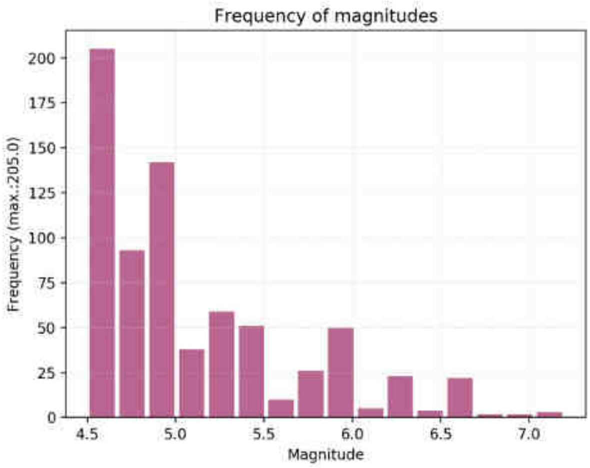

Figure 5: Frequency of magnitudes ≥ 4.5.

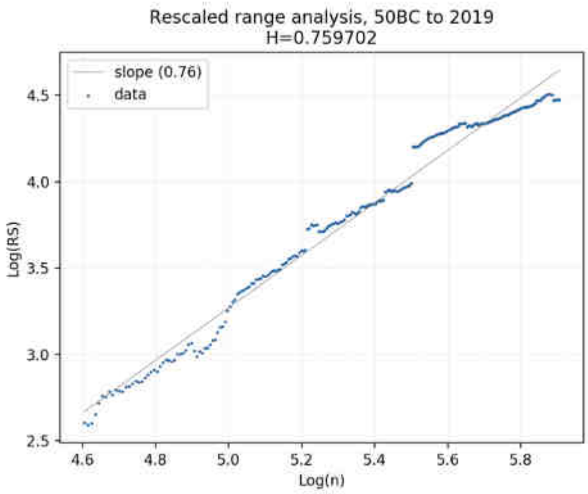

Figure 6: R/S - earthquake's magnitude data ≥ 4.5.

Based on his research, Hurst found (1951) that many naturally occurring empirical records appear to be well represented as a generalization of Einstein's equation in 1905 (On the movement of small particles suspended in a stationary liquid demanded by the molecular-kinetic theory of heat) in the following formula:

$$E\left[\frac{R}{S}(n)\right] \sim cn^{H}, c \rightarrow positive\ constant, n \rightarrow \infty \quad (3)$$

Let us go back on the original Brownian motion, and take an example of a particle moving in a fluid. How far will a molecule get from its starting position after x period of time? Einstein argued that the displacement of a Brownian particle is not proportional to the elapsed time, but rather to its square root (Einstein A. 1956). The Brownian square root rule, applies: if the molecule wanders 100 seconds will get around 10 times farther than one that travels just one second (Mandelbrot B. B., Hudson R. L., 2008).

When we study the potential seismic hazard in a certain region within the next *t* years, the most important thing is to make some estimation of the uncertainty of earthquake occurrence. As mentioned above, we could use rage R as such an uncertainty indicator and if we assume that the seismic time series is stationary, the deviation S(τ) does not change with the time (Li Juan & Chen Yong, 2001), we can gain a conserved and maximum estimation of the earthquake frequency fluctuation, which might occur in the future.

If presumed that S(N) is constant, the range R(N) is then increasing with the power of the time, and so the ratio of the fluctuation of the waiting time of the next 1000 events to the next 100 events is same as the ratio of the waiting time of the following 100 to the following 10 events. The existing of this long-term correlation makes it possible to get a view of the future earthquakes through the transforming of time scale (Li Juan & Chen Yong, 2001).

5. Conclusion

Based on the empirical results we conclude by indicating a long-term correlation in earthquakes magnitudes in Albania. Earthquakes do not have a purely Poissonian, memoryless distribution. Examination of seismic data series through Hurst's rescaled range analysis shows that seismicity is a memory process, not random. The data series with magnitude below 4 shows an anti-persistent correlation, while data series with magnitude above 4 indicate a persistent behavior, like the entire data set.

Let us take into consideration another parameter, which is the fractal dimension. Regarding the fractal dimension (D) we estimated that the seismicity in Albania has a dimension between the roughness of a snowflake (Van Koch Snowflake) and that of Sierpinski triangle. To better understand the nature of earthquakes and to find the balance between the short-term costs of anti-seismic design and the long-term potential costs resulting from earthquake damage we must take into consideration these estimations. In Albania there's a need to support the economy by building solar plants and green energy plants. Either building a pipeline, or a power generation plant we always look at the internal structure and behavior of the earth, particularly as they relate to earthquake phenomena (Kramer Steven L., 1996).

It is important to note that this study intends to bridge the gap between sustainable development and economic development in energy sector.

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Development and validation of Photosynthetically Active Radiation models over mainland Spain

Francisco FERRERA-COBOS[1,2,*] **-** PhD Student

Dr. Rita X. VALENZUELA [2] **-** Senior Researcher

Dr. Jose M. VINDEL [2] **-** Senior Researcher

Dr. Luis F. ZARZALEJO [2] **-** Senior Researcher

Ana A. NAVARRO[2] **-** Senior Researcher

Dr. José A. GONZALEZ[3] **-** Senior Researcher

[1] *E.T.S.I. Agronómica, Alimentaria y de Biosistemas, Universidad Politécnica de Madrid (School of Agricultural, Food and Biosystems Engineering. UPM).*
[2] *CIEMAT Energy Department. Renewable Energy Division.*
[3] *Department of Chemical Engineering. U. of Santiago de Compostela. School of Engineering*

* *Contact details of corresponding author*
Tel: +34 91 346 6043
e-mail: francisco.ferrera@ciemat.es
Address: Avda. Complutense 40, 28040 Madrid, Spain

Abstract

In this work hourly models of Photosynthetically Active Radiation (*PAR*) for the two main climatic zones (oceanic and mediterranean) present in mainland Spain are addressed. Seventy-two different models have been developed and validated. The models developed consist of thirty-six multilinear regression (MR) and thirty-six artificial neural network (ANN) models, which use as input variables such as Global Horizontal Irradiance (*GHI*), Global extraterrestrial Irradiance (G_0), clearness index (k_t), Solar Zenith Angle (*SZA*), solar azimuth angle (γ), and the cosines of *SZA* and γ. The field data used in this work were collected from four locations in continental Spain. The locations corresponding to the oceanic climate were Santiago EOAS (42.88° N, 8.56° W, altitude 255 m a.s.l.) and Vall d'Alinya (42.15° N, 1.45° E, altitude 1770 m a.s.l.). While the Mediterranean stations were CEDER-CIEMAT (41.60° N, 2.51° W, altitude 1095 m a.s.l.) and PSA-CIEMAT (37.10° N, 2.36° W, altitude 500 m a.s.l).

The results underline the importance of using *GHI* as input for *PAR* modelling since all the models which do not include it did not obtain acceptable values. The results also show a slight improvement when using ANN models respect of the MR models in Mediterranean climate. For the oceanic climate the best results were obtained using MR models.

Keywords: Photosynthetically Active Radiation; Global Horizontal Irradiance; Artificial Neuron Network; Multilinear Regression

1. Introduction

Photosynthetically Active Radiation (*PAR*) is the portion of solar irradiance corresponding to the visible spectrum (400-700 nm). This portion is which the plants convert into energy through photosynthesis. Thus, *PAR* addressing is of interest in many fields of study and industries such as biomass production, cultivation of algae, agrofood industry, energy balance in ecosystems, etc. Unfortunately, field measurements of *PAR* are scarce, there are only a few radiometric stations that provide *PAR* measurements. Moreover, there are significant differences between commercial *PAR* sensors (Mizoguchi Y. et al., 2010; Ross I. and Sulev M., 2000), making even harder to obtain reliable *PAR* measurements.

Thus, in order to get *PAR* data at a specific location is necessary to go to models that allow us to obtain *PAR* estimates. There are plenty of examples in the literature of the types of *PAR* models suggested or used to obtain *PAR* estimates at different locations with different climates. Most of the models are specific for a particular location, due to the dependence of the local atmospheric conditions. These models can be classified according to the mathematical technique used to develop them. For instance:

linear regressions, nonlinear regressions, multilinear regressions or Artificial Neural Networks (ANN). They can be classified as well according to the variables used as inputs to the model and also according to the frequency of the data used (hourly, daily, etc.). Examples of multilinear models are (Aguiar L.J.G. et al., 2012; Escobedo J. F. et al., 2009; Jacovides C. P. et al., 2010; Janjai S. et al., 2015; Peng S. et al., 2015). These multilinear models were developed in very different locations such as Brasil, Grece, China or Thailand. Nonlinear models developed with data collected in China were proposed in (Hu B. et al., 2016; Wang L. et al., 2015; Yu X. et al., 2015) for instance.

ANN are a learning machine technique proposed by McCulloch W. S. and Pitts W. in 1943. In this technique, the learning consists of an iterative process to obtain the optimal values of the function weights to achieve the most accurate ANN output for an input dataset. ANN are widely used to model and predict several phenomena and variables. Concerning *PAR* estimates, ANN model for *PAR* is found in several papers (Foyo-Moreno I. et al., 2017; Jacovides C. P. et al., 2015; López G. et al., 2001). These ANN models use as inputs: global solar irradiance, solar azimuth angle, clearness index, air relative humidity, clearness of the sky, brightness of the sky, air dew point temperature and precipitable water thickness; global solar irradiance, global extraterrestrial irradiance, sunshine fraction, air temperature and relative humidity; global solar irradiance, clearness index and solar azimuth cosine.

In the present work *PAR* modelling for hourly data is addressed. The study was carried out for oceanic and mediterranean zones in mainland Spain. Seventy-two different models have been developed and validated. The models developed are thirty-six Multilinear Regression (MR) and thirty-six ANN models. Both types of models use as inputs Global Horizontal Irradiance (*GHI*), Global extraterrestrial Irradiance (G_0), clearness index (k_t), Solar Zenith Angle (*SZA*), solar azimuth angle (γ), and the cosines of *SZA* and γ. The field data used in this work were collected from four locations in continental Spain.

The results underline the importance of using *GHI* as input for *PAR* modelling over the rest of variables since all the models which do not include it, did not obtain acceptable values. The results do not suggest a clear choice between MR and ANN models, as a slight improvement is shown when using ANN models in respect of the MR models in Mediterranean climate. But for the oceanic climate the best results were obtained using MR models.

2. Data and methodology

The field data used in this work were collected from four locations in continental Spain as Figure 1 illustrates. The locations were: Santiago-EOAS (42.88° N, 8.56° W, altitude 255 m a.s.l.) at the northwest of Spain with oceanic climate, Vall d'Alinya (42.15° N, 1.45° E, altitude 1770 m a.s.l.) at the northeast of Spain which also has an oceanic climate, CEDER-CIEMAT (41.60° N, 2.51° W, altitude 1095 m a.s.l.) at the center of Spain with continental Mediterranean climate and PSA-CIEMAT (37.10° N, 2.36° W, altitude 500 m a.s.l.) at the southeast of Spain with standard Mediterranean climate.

The analyzed periods were since 1st October 2016 to 31st December 2017 in Santiago-EOAS; since 2nd October 2004 to 26th November 2008 in Vall d'Alinya; since 26th January 2016 to 20th August 2017 in CEDER-CIEMAT; and since 24th February 2016 to 22nd June 2017 in PSA-CIEMAT. Hourly measurements of *PAR*, *GHI* were collected at all stations. *PAR* data at Santiago-EOAS were provided by University of Santiago de Compostela. All data of Vall d'Alinya station were obtained from FLUXNET dataset. The rest of the data were collected by CIEMAT from stations mounted and maintained following the provisions of (McArthur L.B.J., 2004; Sengupta M. et al., 2017; WMO, 2014).

Clearness index k_t was calculated as the ratio between *GHI* and G_0, while *SZA* and γ were calculated according to (Iqbal M., 1983).

This work presents 72 models to estimate PAR. The proposed models consist of 36 multilinear regression models (Models MR-1 to MR-36) and 36 ANN models (models ANN-1 to ANN-36). Each of the models uses as input combinations of the variables *GHI*, G_0, k_t, *SZA*, γ, cosine of *SZA* and cosine of γ, as is shown in Table 1. For the development of the models, the dataset was randomly split into two subsets, each of them containing 50% of the original dataset. The first data subset was used for training the models, while the second was used to validate the models.

During the training process, the ANNs carry out an iterative sequence in which the ANN is learning to assign the correct weight that each neuron must set to each input in order to obtain the desired output value, in our case PAR estimates. In this work, feed-forward ANNs with Levenberg-Marquardt algorithm (Marquardt D. W., 1963) with three layers (input, hidden layer and output) are used to produce PAR estimates. In preliminary tests this three layers configuration showed the best performance among all others. For all the 36 ANN models, input and output layers have one neuron each, while the best performance number of neurons in the hidden layer is applied according to empirical experience with each model.

3. Results

Oceanic climate

Santiago-EOAS

The expressions obtained during the training process of the multilinear models are shown in Equations (1) to (36). As the ANN works as a black box it does not give any expression or formula, it just gives the estimated results of the ANN when using the validation dataset as input. For the training and validation processes of the ANN models the same dataset as for the MR models was used.

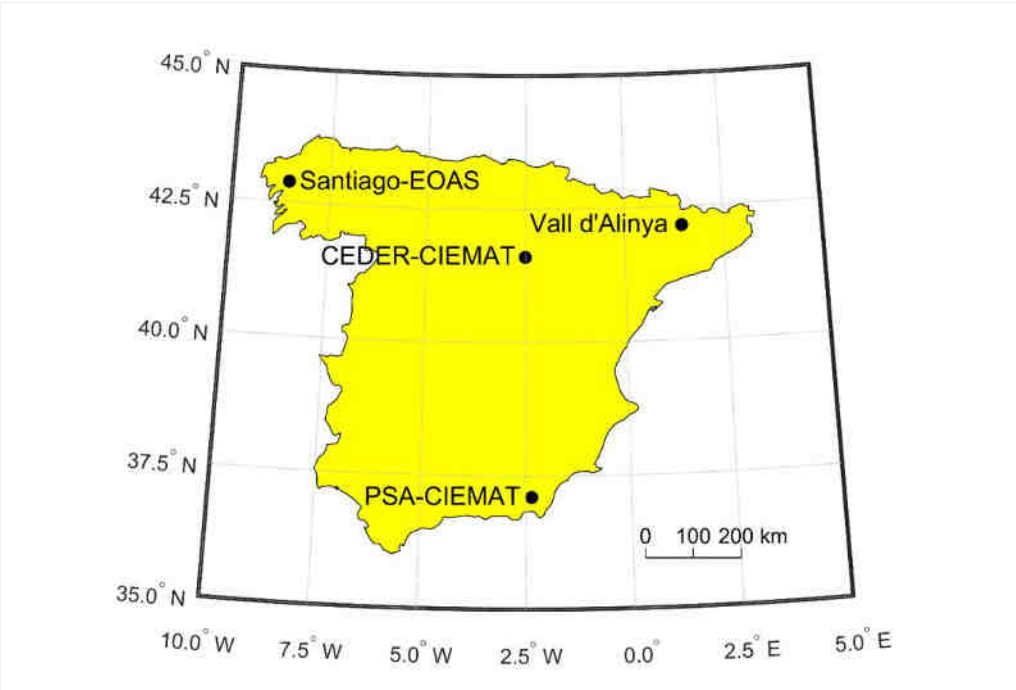


Figure 1: Location of the stations used in this work.

Table 1: Variables used as inputs in each of the models.

Model	Inputs
MR-1	*GHI* (W m^{-2})
MR-2	G_0 (W m^{-2})
MR-3	k_t
MR-4	*SZA* (deg)
MR-5	γ (deg)
MR-6	*cos(SZA)*
MR-7	$cos(\gamma)$
MR-8	*GHI·cos(SZA)* (W m^{-2})
MR-9	$G_0 \cdot cos(SZA)$ (W m^{-2})
MR-10	$k_t \cdot cos(SZA)$
MR-11	$GHI \cdot cos(\gamma)$ (W m^{-2})
MR-12	$G_0 \cdot cos(\gamma)$ (W m^{-2})
MR-13	$k_t \cdot cos(\gamma)$
MR-14	*GHI* (W m^{-2}), G_0 (W m^{-2})

MR-15	*GHI* (W m^{-2}), k_t
MR-16	*GHI* (W m^{-2}), *SZA* (deg)
MR-17	*GHI* (W m^{-2}), γ (deg)
MR-18	*GHI* (W m^{-2}), *cos(SZA)*
MR-19	*GHI* (W m^{-2}), $cos(\gamma)$
MR-20	*GHI* (W m^{-2}), G_0 (W m^{-2}), k_t
MR-21	*GHI* (W m^{-2}), G_0 (W m^{-2}), *SZA* (deg)
MR-22	*GHI* (W m^{-2}), G_0 (W m^{-2}), γ (deg)
MR-23	*GHI* (W m^{-2}), G_0 (W m^{-2}), *cos(SZA)*
MR-24	*GHI* (W m^{-2}), G_0 (W m^{-2}), $cos(\gamma)$
MR-25	*GHI* (W m^{-2}), k_t, *SZA* (deg)
MR-26	*GHI* (W m^{-2}), k_t, γ (deg)
MR-27	*GHI* (W m^{-2}), k_t, *cos(SZA)*
MR-28	*GHI* (W m^{-2}), k_t, $cos(\gamma)$
MR-29	*GHI* (W m^{-2}), *SZA* (deg), γ (deg)
MR-30	*GHI* (W m^{-2}), *cos(SZA)*, $cos(\gamma)$
MR-31	*GHI* (W m^{-2}), G_0 (W m^{-2}), k_t, *SZA* (deg)
MR-32	*GHI* (W m^{-2}), G_0 (W m^{-2}), k_t, γ (deg)
MR-33	*GHI* (W m^{-2}), G_0 (W m^{-2}), k_t, *cos(SZA)*
MR-34	*GHI* (W m^{-2}), G_0 (W m^{-2}), k_t, $cos(\gamma)$
MR-35	*GHI* (W m^{-2}), G_0 (W m^{-2}), k_t, *SZA* (deg), γ (deg)
MR-36	*GHI* (W m^{-2}), G_0 (W m^{-2}), k_t, *cos(SZA)*, $cos(\gamma)$
ANN-1	*GHI* (W m^{-2})
ANN-2	G_0 (W m^{-2})
ANN-3	k_t
ANN-4	*SZA* (deg)
ANN-5	γ (deg)
ANN-6	*cos(SZA)*
ANN-7	$cos(\gamma)$
ANN-8	$GHI{\cdot}cos(SZA)$ (W m^{-2})
ANN-9	$G_0{\cdot}cos(SZA)$ (W m^{-2})
ANN-10	$k_t{\cdot}cos(SZA)$
ANN-11	$GHI{\cdot}cos(\gamma)$ (W m^{-2})
ANN-12	$G_0{\cdot}cos(\gamma)$ (W m^{-2})
ANN-13	$k_t{\cdot}cos(\gamma)$
ANN-14	*GHI* (W m^{-2}), G_0 (W m^{-2})
ANN-15	*GHI* (W m^{-2}), k_t
ANN-16	*GHI* (W m^{-2}), *SZA* (deg)
ANN-17	*GHI* (W m^{-2}), γ (deg)
ANN-18	*GHI* (W m^{-2}), *cos(SZA)*
ANN-19	*GHI* (W m^{-2}), $cos(\gamma)$
ANN-20	*GHI* (W m^{-2}), G_0 (W m^{-2}), k_t
ANN-21	*GHI* (W m^{-2}), G_0 (W m^{-2}), *SZA* (deg)
ANN-22	*GHI* (W m^{-2}), G_0 (W m^{-2}), γ (deg)
ANN-23	*GHI* (W m^{-2}), G_0 (W m^{-2}), *cos(SZA)*
ANN-24	*GHI* (W m^{-2}), G_0 (W m^{-2}), $cos(\gamma)$
ANN-25	*GHI* (W m^{-2}), k_t, *SZA* (deg)
ANN-26	*GHI* (W m^{-2}), k_t, γ (deg)
ANN-27	*GHI* (W m^{-2}), k_t, *cos(SZA)*
ANN-28	*GHI* (W m^{-2}), k_t, $cos(\gamma)$
ANN-29	*GHI* (W m^{-2}), *SZA* (deg), γ (deg)
ANN-30	*GHI* (W m^{-2}), *cos(SZA)*, $cos(\gamma)$
ANN-31	*GHI* (W m^{-2}), G_0 (W m^{-2}), k_t, *SZA* (deg)
ANN-32	*GHI* (W m^{-2}), G_0 (W m^{-2}), k_t, γ (deg)
ANN-33	*GHI* (W m^{-2}), G_0 (W m^{-2}), k_t, *cos(SZA)*
ANN-34	*GHI* (W m^{-2}), G_0 (W m^{-2}), k_t, $cos(\gamma)$
ANN-35	*GHI* (W m^{-2}), G_0 (W m^{-2}), k_t, *SZA* (deg), γ (deg)
ANN-36	*GHI* (W m^{-2}), G_0 (W m^{-2}), k_t, *cos(SZA)*, $cos(\gamma)$

In Table 2, it is possible to see how the best result of the MR models is reached by models MR-1 an MR-14. While the best performance of the ANN models is the model ANN-19. However, there are various models that reach similar results for the best model. On the other hand, all the models that do not have *GHI* as input, did not show good results. The results do not show an improvement of the ANN models in respect of the MR models.

$$AR = 1.80GHI - 1.48 \quad (1)$$
$$PAR = 1.38G_0 - 377.99 \quad (2)$$
$$PAR = 1602.20k_t - 37.22 \quad (3)$$
$$PAR = -17.93SZA + 1656.97 \quad (4)$$
$$PAR = 7.78\gamma + 728.89 \quad (5)$$
$$PAR = 1437.55\cos(SZA) \ -131.31 \quad (6)$$
$$PAR = 373.50\cos(\gamma) \ +434.19 \quad (7)$$
$$PAR = 1.99GHI \cdot \cos(SZA) + 193.77 \quad (8)$$
$$PAR = 0.96G_0 \cdot \cos(SZA) + 228.80 \quad (9)$$
$$PAR = 2453.84k_t \cdot \cos(SZA) + 6.11 \quad (10)$$
$$PAR = 1.75GHI \cdot \cos(\gamma) + 150.38 \quad (11)$$
$$PAR = 0.82G_0 \cdot \cos(\gamma) + 189.21 \quad (12)$$
$$PAR = 1669.44k_t \cdot \cos(\gamma) + 96.30 \quad (13)$$
$$PAR = 1.73GHI + 0.13G_0 - 72.02 \quad (14)$$
$$PAR = 1.89GHI - 94.33k_t + 9.19 \quad (15)$$
$$PAR = 1.81GHI + 0.19SZA - 13.52 \quad (16)$$
$$PAR = 1.64GHI + 2.28\gamma + 65.97 \quad (17)$$
$$PAR = 1.81GHI + 17.31\cos(SZA) + 6.32 \quad (18)$$
$$PAR = 1.81GHI - 47.94\cos(\gamma) + 32.53 \quad (19)$$
$$PAR = 1.57GHI + 0.19G_0 + 134.64k_t - 123.97 \quad (20)$$
$$PAR = 1.57GHI + 1.19G_0 + 17.20SZA - 1755.12 \quad (21)$$
$$PAR = 1.55GHI + 0.14G_0 + 2.31\gamma - 13.23 \quad (22)$$
$$PAR = 1.56GHI + 1.35G_0 - 1564.43\cos(SZA) - 51.96 \quad (23)$$
$$PAR = 1.71GHI + 0.18G_0 - 108.89\cos(\gamma) - 26.90 \quad (24)$$
$$PAR = 2.17GHI - 324.54k_t + 2.76\mathrm{SZA} - 139.26 \quad (25)$$
$$PAR = 1.91GHI - 333.43k_t + 2.63\gamma + 114.21 \quad (26)$$
$$PAR = 2.18GHI - 325.89k_t - 221.40\cos(SZA) + 135.07 \quad (27)$$
$$PAR = 1.93GHI - 128.25k_t - 65.12\cos(\gamma) + 59.23 \quad (28)$$
$$PAR = 1.55GHI - 2.31SZA + 2.56\gamma + 220.49 \quad (29)$$
$$PAR = 1.81GHI + 12.42\cos(SZA) - 51.05\cos(\gamma) + 29.14 \quad (30)$$
$$PAR = 1.94GHI + 1.19G_0 - 330.58k_t + 19.85SZA - 1886.14 \quad (31)$$
$$PAR = 1.99GHI - 0.05G_0 - 392.25k_t + 2.69\gamma + 147.73 \quad (32)$$
$$PAR = 1.95GHI + 1.36G_0 - 346.40k_t - 1789.53\cos(SZA) - 84.58 \quad (33)$$
$$PAR = 1.51GHI + 0.27G_0 + 164.40k_t - 114.46\cos(\gamma) - 88.02 \quad (34)$$
$$PAR = 1.99GHI + 0.01G_0 - 394.62k_t + 0.86SZA + 2.60\gamma + 62.31 \quad (35)$$
$$PAR = 1.89GHI + 1.44G_0 - 317.23k_t - 1795.95\cos(SZA) - 118.81\cos(\gamma) + 122.64 \quad (36)$$

Table 2: Results of the models developed for Santiago-EOAS.

Model	Slope	Intercept	R^2	MBE (%)	RMSE (%)
MR-1	0.94	4.35	0.9956	-5.58	7.06
MR-2	0.42	377.82	0.3822	-19.44	44.71
MR-3	0.59	352.15	0.5954	-4.59	32.83
MR-4	0.33	457.26	0.3863	-20.66	45.31
MR-5	0.05	679.45	0.0072	-25.15	63.25
MR-6	0.33	458.79	0.3890	-20.48	45.17
MR-7	0.06	663.08	0.1254	-26.09	55.24
MR-8	0.95	-32.42	0.9061	-8.20	17.80
MR-9	0.37	416.71	0.3908	-20.16	44.70
MR-10	0.95	25.07	0.9586	-2.47	10.65
MR-11	0.88	17.77	0.8663	-9.87	21.14
MR-12	0.30	453.35	0.3301	-23.21	47.88
MR-13	0.66	238.53	0.6452	-9.51	31.91
MR-14	0.94	2.79	0.9952	-5.86	7.36
MR-15	0.95	-7.62	0.9962	-5.88	7.02
MR-16	0.94	5.06	0.9954	-5.58	7.11
MR-17	0.87	56.79	0.9599	-7.27	13.38
MR-18	0.94	5.06	0.9954	-5.58	7.11
MR-19	0.94	9.01	0.9954	-5.43	7.04
MR-20	0.92	19.07	0.9950	-5.58	7.49

MR-21	0.87	53.39	0.9574	-7.57	13.73
MR-22	0.87	55.71	0.9493	-7.60	14.41
MR-23	0.87	51.51	0.9514	-7.84	14.36
MR-24	0.93	12.65	0.9946	-5.64	7.46
MR-25	0.96	-26.63	0.9946	-6.50	7.62
MR-26	0.89	22.63	0.9294	-8.57	16.15
MR-27	0.96	-27.98	0.9947	-6.51	7.60
MR-28	0.95	-5.60	0.9963	-5.78	6.94
MR-29	0.87	54.66	0.9500	-7.56	14.31
MR-30	0.94	8.80	0.9956	-5.43	7.01
MR-31	0.89	21.19	0.9415	-8.51	15.18
MR-32	0.90	16.94	0.9278	-8.70	16.31
MR-33	0.89	16.65	0.9339	-8.85	15.94
MR-34	0.91	33.03	0.9943	-5.29	7.69
MR-35	0.90	17.11	0.9275	-8.72	16.35
MR-36	0.88	31.13	0.9294	-8.56	16.21
ANN-1	0.94	2.46	0.9894	-5.71	8.15
ANN-2	0.43	370.65	0.3443	-19.56	46.31
ANN-3	0.63	341.24	0.5685	-2.55	33.89
ANN-4	0.37	438.42	0.3453	-18.45	45.31
ANN-5	0.17	591.64	0.0587	-22.46	59.28
ANN-6	0.34	449.39	0.3356	-20.14	46.27
ANN-7	0.08	646.41	0.0504	-25.84	56.51
ANN-8	0.87	56.40	0.9172	-7.11	16.51
ANN-9	0.40	394.54	0.3677	-19.36	45.10
ANN-10	0.89	71.00	0.9293	-3.38	14.13
ANN-11	0.84	50.20	0.8447	-11.24	23.07
ANN-12	0.35	407.50	0.2541	-23.35	50.86
ANN-13	0.54	292.05	0.5294	-16.35	38.68
ANN-14	0.94	26.91	0.9628	-3.09	10.39
ANN-15	0.93	15.81	0.9371	-5.38	13.91
ANN-16	0.93	3.58	0.9693	-6.97	11.56
ANN-17	0.87	47.27	0.8636	-8.11	20.55
ANN-18	0.93	0.46	0.9476	-7.13	13.74
ANN-19	0.96	-12.21	0.9835	-5.50	8.66
ANN-20	0.98	-36.51	0.9535	-5.62	12.46
ANN-21	0.92	23.01	0.9354	-6.10	14.39
ANN-22	0.75	-99.56	0.3130	-34.79	68.00
ANN-23	0.88	15.67	0.8797	-10.30	20.50
ANN-24	0.93	-6.90	0.9323	-7.33	15.18
ANN-25	0.92	-9.09	0.9209	-8.73	16.82
ANN-26	0.84	17.46	0.8006	-14.09	26.92
ANN-27	0.94	-75.37	0.8323	-13.37	25.61
ANN-28	0.95	1.81	0.9539	-5.10	12.10
ANN-29	0.81	64.86	0.8415	-11.90	23.62
ANN-30	0.93	5.73	0.9363	-6.32	14.37
ANN-31	0.85	40.32	0.8764	-11.02	21.13
ANN-32	0.80	-13.34	0.6669	-21.20	37.28
ANN-33	0.78	-23.62	0.5968	-24.82	42.54
ANN-34	0.93	4.71	0.9071	-6.66	16.98
ANN-35	0.90	6.02	0.8845	-9.63	19.87
ANN-36	0.88	31.84	0.8616	-9.19	21.13

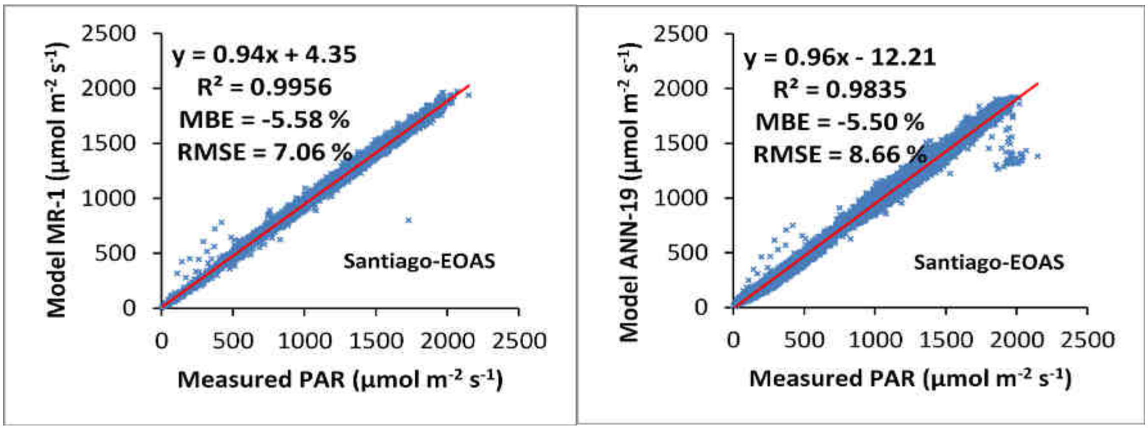


Figure 2: Correlograms corresponding to Santiago-EOAS station. (Left Model MR-1, right Model ANN-19).

Figure 2 illustrates two of the models which obtained the best results, in this case, MR-1 and ANN-19.

Vall d'Alinya

The training process of the multilinear models led to the expressions listed from Eq. (37) to (72). In this case the slope of Equation (37) is higher than in Equation (1). With the same subset of data, the ANNs were feed in order to make the training process. In Table are listed the results of each model applied to Vall d'Alinya dataset. The results of Vall d'Alinya are clearly worse than those of Santiago-EOAS. Comparing MR models to ANN models there are no significant differences between them. Furthermore, the differences between models are very scarce.

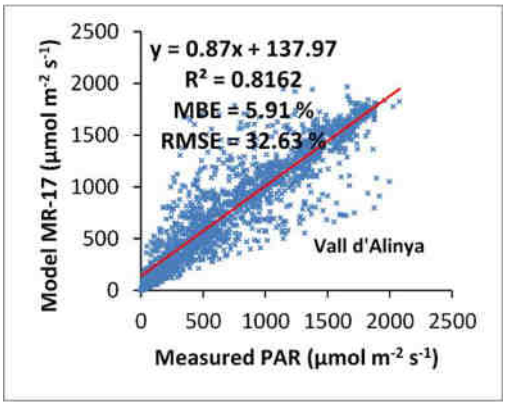
In Figure 3 it can be appreciated how both types of models did no produced good PAR estimates. Neither the best MR nor the best ANN model had acceptable results. The results of Mr-17 are slightly better than those of Model ANN-22.

$$PAR = 1.91GHI - 2.04 \tag{37}$$
$$PAR = 1.26G_0 - 86.32 \tag{38}$$
$$PAR = 1606.74k_t + 4.99 \tag{39}$$
$$PAR = -21.29SZA + 2024.21 \tag{40}$$
$$PAR = 1.05\gamma + 977.13 \tag{41}$$
$$PAR = 1717.46\cos(SZA) - 108.02 \tag{42}$$
$$PAR = 772.11\cos(\gamma) + 381.72 \tag{43}$$
$$PAR = 1.90GHI \cdot \cos(SZA) + 307.01 \tag{44}$$
$$PAR = 1.01G_0 \cdot \cos(SZA) + 397.68 \tag{45}$$
$$PAR = 2477.47k_t \cdot \cos(SZA) + 21.13 \tag{46}$$
$$PAR = 1.72GHI \cdot \cos(\gamma) + 260.75 \tag{47}$$
$$PAR = 0.90G_0 \cdot \cos(\gamma) + 367.82 \tag{48}$$
$$PAR = 1630.06k_t \cdot \cos(\gamma) + 207.96 \tag{49}$$
$$PAR = 1.88GHI + 0.06G_0 - 34.77 \tag{50}$$
$$PAR = 1.97GHI - 84.79k_t + 17.76 \tag{51}$$
$$PAR = 1.88GHI - 0.79SZA + 50.71 \tag{52}$$
$$PAR = 1.91GHI + 0.22\gamma - 0.95 \tag{53}$$
$$PAR = 1.88GHI + 64.82\cos(SZA) - 28.90 \tag{54}$$
$$PAR = 1.92GHI - 17.52\cos(\gamma) + 8.62 \tag{55}$$
$$PAR = 1.96GHI + 0.10G_0 - 73.95k_t + 10.18 \tag{56}$$
$$PAR = 1.88GHI + 0.10G_0 + 0.75SZA - 107.13 \tag{57}$$
$$PAR = 1.88GHI + 0.05G_0 + 0.14\gamma - 28.90 \tag{58}$$
$$PAR = 1.88GHI + 0.10G_0 - 67.50\cos(SZA) - 32.22 \tag{59}$$
$$PAR = 1.88GHI + 0.08G_0 - 48.20\cos(\gamma) - 17.49 \tag{60}$$
$$PAR = 1.99GHI - 102.84k_t + 0.28\mathrm{SZA} + 3.26 \tag{61}$$
$$PAR = 1.96GHI - 73.36k_t + 0.14\gamma + 15.77 \tag{62}$$
$$PAR = 1.99GHI - 102.30k_t - 21.78\cos(SZA) + 30.87 \tag{63}$$
$$PAR = 2.00GHI - 105.31k_t - 42.04\cos(\gamma) + 48.14 \tag{64}$$
$$PAR = 1.88GHI - 0.84SZA + 0.23\gamma + 54.77 \tag{65}$$
$$PAR = 1.89GHI + 90.12\cos(SZA) - 42.07\cos(\gamma) - 13.77 \tag{66}$$
$$PAR = 1.96GHI + 0.05G_0 - 73.47k_t + 0.74SZA - 61.57 \tag{67}$$
$$PAR = 1.96GHI + 0.00G_0 - 70.31k_t + 0.14\gamma + 13.61 \tag{68}$$
$$PAR = 1.96GHI + 0.05G_0 - 72.30k_t - 64.84\cos(SZA) + 11.62 \tag{69}$$
$$PAR = 1.95GHI + 0.04G_0 - 62.25k_t - 46.43\cos(\gamma) + 19.71 \tag{70}$$
$$PAR = 1.95GHI - 0.09G_0 - 66.55k_t - 1.60SZA + 0.31\gamma + 172.88 \tag{71}$$
$$PAR = 1.95GHI + 0.08G_0 - 61.08k_t - 55.09\cos(SZA) - 45.50\cos(\gamma) + 20.75 \tag{72}$$

Table 3: Statiscal results of the models using Vall d'Alinya dataset.

Model	Slope	Intercept	R^2	MBE (%)	RMSE (%)
MR-1	0.86	143.78	0.8126	5.90	32.88
MR-2	0.36	660.91	0.3934	26.90	63.84
MR-3	0.64	302.49	0.6428	6.11	44.74
MR-4	0.27	723.88	0.2264	26.54	70.73
MR-5	0.04	944.90	0.3267	34.47	78.98
MR-6	0.28	714.38	0.2331	26.20	70.37
MR-7	0.06	945.09	0.0271	35.71	82.43
MR-8	0.66	332.09	0.6970	12.14	42.69
MR-9	0.31	695.65	0.2948	26.75	67.81
MR-10	0.77	186.77	0.7657	3.02	36.03

MR-11	0.64	360.76	0.6526	13.69	45.82
MR-12	0.25	771.92	0.2273	30.95	72.23
MR-13	0.52	443.01	0.5360	13.33	52.26
MR-14	0.86	143.51	0.8139	6.04	32.81
MR-15	0.85	152.58	0.8130	6.48	32.90
MR-16	0.86	146.11	0.8122	6.01	32.92
MR-17	0.87	137.97	0.8162	5.91	32.63
MR-18	0.86	145.87	0.8121	6.00	32.93
MR-19	0.86	142.09	0.8128	5.79	32.85
MR-20	0.86	151.41	0.8132	6.43	32.88
MR-21	0.87	141.12	0.8152	6.04	32.72
MR-22	0.87	139.81	0.8161	6.03	32.64
MR-23	0.87	141.13	0.8154	6.05	32.70
MR-24	0.87	138.75	0.8150	5.79	32.70
MR-25	0.85	153.62	0.8132	6.56	32.89
MR-26	0.86	147.78	0.8154	6.41	32.71
MR-27	0.85	153.69	0.8132	6.57	32.89
MR-28	0.86	150.64	0.8136	6.36	32.83
MR-29	0.87	140.08	0.8161	6.03	32.64
MR-30	0.86	142.61	0.8125	5.77	32.87
MR-31	0.86	149.00	0.8145	6.42	32.79
MR-32	0.86	147.47	0.8154	6.39	32.71
MR-33	0.86	148.95	0.8146	6.43	32.77
MR-34	0.86	145.57	0.8144	6.13	32.76
MR-35	0.86	147.47	0.8155	6.37	32.69
MR-36	0.86	143.60	0.8156	6.13	32.67
ANN-1	0.86	146.33	0.8126	6.03	32.89
ANN-2	0.34	669.57	0.3741	26.59	64.52
ANN-3	0.59	317.84	0.6127	2.70	46.28
ANN-4	0.27	719.58	0.2303	25.89	70.27
ANN-5	0.15	859.08	0.1448	33.44	76.31
ANN-6	0.27	718.34	0.2280	25.90	70.42
ANN-7	0.11	871.27	0.0686	30.99	78.89
ANN-8	0.79	206.04	0.7387	7.86	39.02
ANN-9	0.32	682.44	0.3148	26.17	66.74
ANN-10	0.78	182.42	0.7661	2.83	35.99
ANN-11	0.69	309.03	0.6576	11.68	45.04
ANN-12	0.27	753.36	0.2625	30.37	70.56
ANN-13	0.58	386.60	0.5219	10.81	52.70
ANN-14	0.86	148.04	0.8106	6.22	33.10
ANN-15	0.86	147.35	0.8106	6.25	33.12
ANN-16	0.86	146.66	0.8112	6.02	33.01
ANN-17	0.87	142.15	0.8163	6.17	32.63
ANN-18	0.86	147.34	0.8122	6.16	32.95
ANN-19	0.86	143.42	0.8149	6.13	32.74
ANN-20	0.86	147.96	0.8106	6.22	33.10
ANN-21	0.86	144.33	0.8146	6.26	32.79
ANN-22	0.87	142.25	0.8148	6.16	32.77
ANN-23	0.86	143.97	0.8149	6.02	32.70
ANN-24	0.86	144.04	0.8152	6.05	32.68
ANN-25	0.86	143.08	0.8140	6.16	32.84
ANN-26	0.86	142.60	0.8153	6.12	32.71
ANN-27	0.86	146.97	0.8118	6.18	32.99
ANN-28	0.86	143.79	0.8136	6.19	32.87
ANN-29	0.87	142.80	0.8162	6.36	32.69
ANN-30	0.86	145.23	0.8102	5.78	33.05
ANN-31	0.86	145.24	0.8146	6.03	32.71
ANN-32	0.87	145.11	0.8160	6.72	32.79
ANN-33	0.86	145.15	0.8143	6.24	32.81
ANN-34	0.86	145.10	0.8161	5.94	32.55
ANN-35	0.86	145.10	0.8154	6.23	32.70
ANN-36	0.87	144.15	0.8174	6.59	32.63



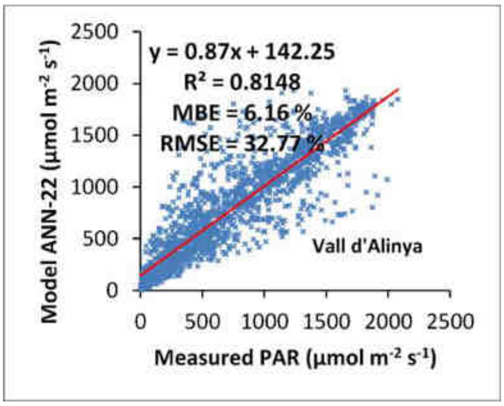


Figure 3: Correlograms corresponding to Vall d'Alinya station. (Left Model MR-17, right Model ANN-22).

Mediterranean climate

CEDER-CIEMAT

The expressions obtained in the training process of the MR models are shown from Equations (73) to (108). In CEDER-CIEMAT the slope of Equation (73) is lower than in Equations (37) and (1). During the training process of the ANNs, it was used the same dataset as in the training of the MR models. The results of the models trained with CEDER-CIEMAT dataset are illustrated in Table 4. Regarding the results of the MR models, the best performance is reached by model MR-36. While the best performance of the ANN models is reached by ANN-17. However, the differences between the best models are very slight. Comparing the results of the MR models to those of the ANN models, there is a slight improvement when using ANN models.

In Figure 4 the correlograms of two of the best of the MR and ANN models, are represented respectively. In this case the plotted results correspond to model MR-36 and model ANN-17. It is remarkable how the results of both types of models are clearly better than those of Santiago-EOAS and Vall d'Alinya. In this case the ANN improve the MR results.

PSA-CIEMAT

The training process for the MR models with PSA-CIEMAT dataset led to the expressions listed from Eq (109) to (144). Again, in this case the slope of Equation (109) is lower than in Equations (73), (37) and (1).

For the training of the ANN models, the ANNs were fed with the same dataset as the used for the MR models training.

$$PAR = 1.75GHI + 9.43 \tag{73}$$
$$PAR = 1.24G_0 - 135.06 \tag{74}$$
$$PAR = 1562.17k_t - 107.55 \tag{75}$$
$$PAR = -15.86SZA + 1567.85 \tag{76}$$
$$PAR = 2.35\gamma + 395.87 \tag{77}$$
$$PAR = 1230.61\cos(SZA) + 7.38 \tag{78}$$
$$PAR = -434.50\cos(\gamma) + 540.38 \tag{79}$$
$$PAR = 1.91GHI \cdot \cos(SZA) + 211.62 \tag{80}$$
$$PAR = 1.22G_0 \cdot \cos(SZA) + 185.94 \tag{81}$$
$$PAR = 2161.36k_t \cdot \cos(SZA) + 4.88 \tag{82}$$
$$PAR = -1.44GHI \cdot \cos(\gamma) + 373.39 \tag{83}$$
$$PAR = -0.76G_0 \cdot \cos(\gamma) + 423.96 \tag{84}$$
$$PAR = -1124.56k_t \cdot \cos(\gamma) + 421.08 \tag{85}$$
$$PAR = 1.72GHI + 0.04G_0 - 2.47 \tag{86}$$
$$PAR = 1.76GHI - 23.51k_t + 15.83 \tag{87}$$
$$PAR = 1.74GHI - 0.20SZA + 21.44 \tag{88}$$
$$PAR = 1.74GHI + 0.08\gamma - 2.01 \tag{89}$$
$$PAR = 1.74GHI + 14.89\cos(SZA) + 1.96 \tag{90}$$
$$PAR = 1.75GHI + 0.45\cos(\gamma) + 9.56 \tag{91}$$
$$PAR = 1.69GHI + 0.05G_0 + 19.25k_t - 11.47 \tag{92}$$
$$PAR = 1.72GHI + 0.03G_0 - 0.04SZA + 0.22 \tag{93}$$
$$PAR = 1.72GHI + 0.03G_0 + 0.06\gamma - 8.63 \tag{94}$$
$$PAR = 1.72GHI + 0.03G_0 + 2.39\cos(SZA) - 3.47 \tag{95}$$
$$PAR = 1.71GHI + 0.04G_0 + 9.07\cos(\gamma) - 2.48 \tag{96}$$

$$PAR = 1.76GHI - 20.23k_t - 0.11SZA + 22.52 \quad (97)$$
$$PAR = 1.76GHI - 20.08k_t + 0.08\gamma + 4.35 \quad (98)$$
$$PAR = 1.76GHI - 20.64k_t + 7.62\cos(SZA) + 11.23 \quad (99)$$
$$PAR = 1.77GHI - 25.95k_t + 3.33\cos(\gamma) + 17.44 \quad (100)$$
$$PAR = 1.73GHI - 0.34SZA + 0.11\gamma + 15.42 \quad (101)$$
$$PAR = 1.74GHI + 15.24\cos(SZA) - 0.72\cos(\gamma) + 1.58 \quad (102)$$
$$PAR = 1.69GHI + 0.05G_0 + 21.38k_t - 0.08SZA - 6.96 \quad (103)$$
$$PAR = 1.70GHI + 0.04G_0 + 16.20k_t + 0.05\gamma - 15.82 \quad (104)$$
$$PAR = 1.69GHI + 0.05G_0 + 21.13k_t + 5.71\cos(SZA) - 14.75 \quad (105)$$
$$PAR = 1.69GHI + 0.05G_0 + 19.97k_t + 9.20\cos(\gamma) - 11.82 \quad (106)$$
$$PAR = 1.69GHI + 0.04G_0 + 20.60k_t - 0.21SZA + 0.07\gamma - 5.79 \quad (107)$$
$$PAR = 1.69GHI + 0.06G_0 + 19.08k_t - 2.84\cos(SZA) + 9.62\cos(\gamma) - 10.21 \quad (108)$$

Table 4: Summary of the statistical results of the models using CEDER-CIEMAT dataset.

Model	Slope	Intercept	R^2	MBE (%)	RMSE (%)
MR-1	1.05	-71.04	0.9956	-1.94	3.81
MR-2	0.59	358.92	0.5715	-6.29	26.14
MR-3	0.50	368.95	0.5363	-14.64	30.22
MR-4	0.45	331.15	0.5880	-23.07	34.59
MR-5	-0.03	850.54	0.0074	-21.51	47.01
MR-6	0.43	353.52	0.5975	-23.56	35.10
MR-7	0.08	707.60	0.0426	-24.33	45.57
MR-8	1.17	-232.04	0.9041	-4.70	16.96
MR-9	0.77	140.39	0.5799	-9.56	28.54
MR-10	0.93	-65.30	0.9909	-13.19	13.90
MR-11	0.70	155.41	0.4887	-15.17	33.67
MR-12	0.34	475.57	0.2338	-20.08	40.38
MR-13	0.36	466.97	0.2330	-19.34	40.35
MR-14	1.05	-67.37	0.9949	-1.81	3.86
MR-15	1.05	-72.52	0.9952	-1.89	3.93
MR-16	1.05	-74.46	0.9955	-1.96	3.92
MR-17	1.04	-65.91	0.9949	-1.83	3.85
MR-18	1.05	-74.13	0.9955	-1.96	3.91
MR-19	1.05	-71.10	0.9956	-1.93	3.81
MR-20	1.04	-64.99	0.9951	-1.81	3.77
MR-21	1.05	-68.14	0.9949	-1.82	3.88
MR-22	1.04	-64.41	0.9945	-1.76	3.88
MR-23	1.05	-67.93	0.9949	-1.82	3.88
MR-24	1.05	-67.75	0.9949	-1.75	3.85
MR-25	1.05	-74.19	0.9951	-1.91	3.98
MR-26	1.05	-67.58	0.9945	-1.80	3.95
MR-27	1.05	-73.93	0.9951	-1.91	3.97
MR-28	1.05	-73.11	0.9952	-1.88	3.93
MR-29	1.05	-70.39	0.9943	-1.84	4.05
MR-30	1.05	-74.11	0.9955	-1.96	3.91
MR-31	1.05	-66.31	0.9951	-1.82	3.81
MR-32	1.04	-62.59	0.9947	-1.76	3.81
MR-33	1.04	-66.09	0.9951	-1.82	3.80
MR-34	1.04	-65.29	0.9951	-1.75	3.76
MR-35	1.04	-65.14	0.9944	-1.78	3.91
MR-36	1.04	-64.76	0.9951	-1.74	3.74
ANN-1	1.04	-58.74	0.9965	-1.86	3.36
ANN-2	0.60	336.78	0.5630	-7.37	26.72
ANN-3	0.52	353.44	0.5138	-13.96	30.40
ANN-4	0.45	342.11	0.5380	-21.80	34.45
ANN-5	0.07	752.19	0.0346	-20.96	44.10
ANN-6	0.46	341.95	0.5175	-21.40	34.51
ANN-7	0.09	714.02	0.0456	-23.22	44.96
ANN-8	1.04	-84.45	0.9551	-3.64	9.65
ANN-9	0.64	269.78	0.5806	-10.06	27.19
ANN-10	0.92	-50.12	0.9724	-12.62	14.31
ANN-11	0.67	198.12	0.4822	-14.04	32.91
ANN-12	0.34	475.11	0.2366	-20.34	40.36
ANN-13	0.37	457.06	0.2296	-19.27	40.69
ANN-14	1.04	-60.45	0.9959	-1.34	3.38

ANN-15	1.05	-64.55	0.9955	-1.21	3.56
ANN-16	1.02	-48.16	0.9921	-2.38	4.35
ANN-17	1.02	-47.00	0.9941	-2.00	3.78
ANN-18	1.04	-62.69	0.9963	-1.99	3.52
ANN-19	1.03	-54.72	0.9966	-1.93	3.30
ANN-20	1.05	-62.68	0.9957	-1.27	3.47
ANN-21	1.05	-64.08	0.9956	-1.62	3.58
ANN-22	1.03	-53.82	0.9944	-1.68	3.70
ANN-23	1.04	-60.24	0.9957	-1.66	3.51
ANN-24	1.05	-60.98	0.9956	-1.20	3.44
ANN-25	1.04	-59.91	0.9960	-1.77	3.46
ANN-26	1.04	-58.20	0.9947	-1.47	3.65
ANN-27	1.05	-66.38	0.9951	-1.84	3.80
ANN-28	1.05	-63.26	0.9955	-1.23	3.53
ANN-29	1.02	-45.27	0.9906	-2.26	4.53
ANN-30	1.04	-56.66	0.9958	-1.91	3.51
ANN-31	1.05	-63.94	0.9956	-1.57	3.59
ANN-32	1.03	-53.83	0.9954	-1.72	3.49
ANN-33	1.04	-61.60	0.9957	-1.67	3.53
ANN-34	1.04	-55.64	0.9958	-1.48	3.35
ANN-35	1.03	-50.24	0.9940	-1.87	3.78
ANN-36	1.05	-64.15	0.9948	-1.27	3.70

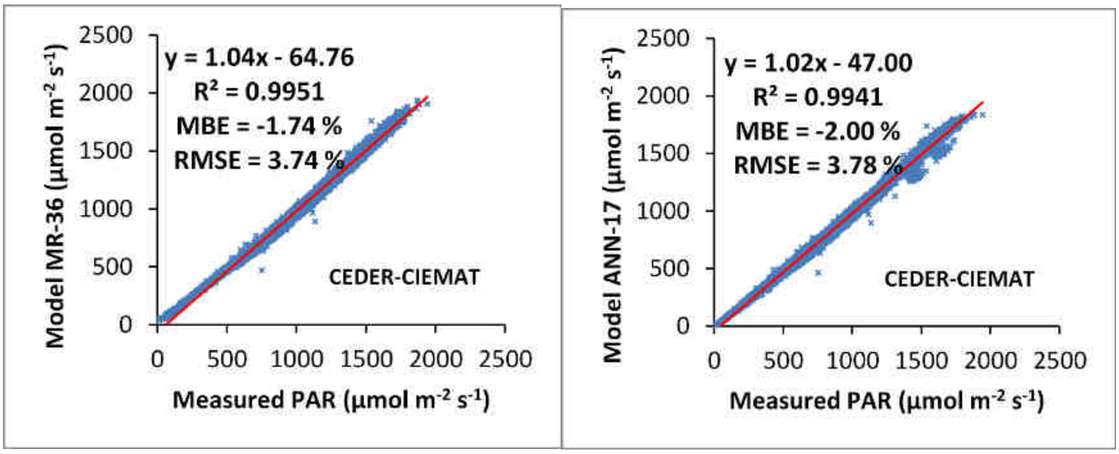


Figure 4: Correlograms corresponding to CEDER-CIEAMT station (Left, Model MR-36, Right, Model ANN-17).

$$PAR = 1.66GHI + 80.97 \quad (109)$$
$$PAR = 1.19G_0 - 27.05 \quad (110)$$
$$PAR = 1672.65k_t - 25.13 \quad (111)$$
$$PAR = -20.60SZA + 2037.01 \quad (112)$$
$$PAR = -0.61\gamma + 1156.84 \quad (113)$$
$$PAR = 1724.47\cos(SZA) - 64.05 \quad (114)$$
$$PAR = -230.71\cos(\gamma) + 912.63 \quad (115)$$
$$PAR = 1.48GHI \cdot \cos(SZA) + 441.76 \quad (116)$$
$$PAR = 0.92G_0 \cdot \cos(SZA) + 473.69 \quad (117)$$
$$PAR = 2301.57k_t \cdot \cos(SZA) + 84.25 \quad (118)$$
$$PAR = -1.01GHI \cdot \cos(\gamma) + 687.08 \quad (119)$$
$$PAR = -0.51G_0 \cdot \cos(\gamma) + 766.40 \quad (120)$$
$$PAR = -727.43k_t \cdot \cos(\gamma) + 772.61 \quad (121)$$
$$PAR = 1.70GHI - 0.05G_0 + 102.46 \quad (122)$$
$$PAR = 1.61GHI + 102.54k_t + 46.21 \quad (123)$$
$$PAR = 1.69GHI + 0.71SZA + 26.71 \quad (124)$$
$$PAR = 1.66GHI - 0.21\gamma + 120.08 \quad (125)$$
$$PAR = 1.69GHI - 53.30\cos(SZA) + 97.17 \quad (126)$$
$$PAR = 1.67GHI + 18.65\cos(\gamma) + 88.16 \quad (127)$$

$$PAR = 1.41GHI + 0.14G_0 + 268.87k_t - 69.07 \quad (128)$$
$$PAR = 1.70GHI - 0.12G_0 - 1.24SZA + 226.17 \quad (129)$$
$$PAR = 1.69GHI - 0.04G_0 - 0.18\gamma + 131.20 \quad (130)$$
$$PAR = 1.69GHI - 0.26G_0 + 312.53\cos(SZA) + 96.87 \quad (131)$$
$$PAR = 1.70GHI - 0.05G_0 + 15.80\cos(\gamma) + 106.58 \quad (132)$$
$$PAR = 1.45GHI + 230.43k_t - 1.93\mathrm{SZA} + 150.07 \quad (133)$$
$$PAR = 1.61GHI + 84.50k_t - 0.16\gamma + 82.84 \quad (134)$$
$$PAR = 1.41GHI + 259.43k_t + 197.88\cos(SZA) - 67.11 \quad (135)$$
$$PAR = 1.61GHI + 98.14k_t + 15.10\cos(\gamma) + 53.52 \quad (136)$$
$$PAR = 1.69GHI + 0.68SZA - 0.20\gamma + 67.96 \quad (137)$$
$$PAR = 1.69GHI - 45.87\cos(SZA) + 16.56\cos(\gamma) + 101.29 \quad (138)$$
$$PAR = 1.40GHI + 0.08G_0 + 267.04k_t - 1.11SZA + 43.14 \quad (139)$$
$$PAR = 1.42GHI + 0.14G_0 + 249.04k_t - 0.16\gamma - 31.49 \quad (140)$$
$$PAR = 1.42GHI - 0.03G_0 + 246.56k_t + 232.79\cos(SZA) - 59.00 \quad (141)$$
$$PAR = 1.40GHI + 0.15G_0 + 275.88k_t + 17.92\cos(\gamma) - 68.87 \quad (142)$$
$$PAR = 1.42GHI + 0.20G_0 + 246.41k_t + 1.14SZA - 0.20\gamma - 137.97 \quad (143)$$
$$PAR = 1.42GHI - 0.03G_0 + 252.86k_t + 243.24\cos(SZA) + 18.70\cos(\gamma) - 58.33 \quad (144)$$

Table 5: Results of the models with PSA-CIEMAT dataset.

Model	Slope	Intercept	R^2	MBE (%)	RMSE (%)
MR-1	0.94	76.58	0.9934	4.29	7.18
MR-2	0.62	366.32	0.6449	9.54	38.68
MR-3	0.63	430.57	0.5877	18.74	44.63
MR-4	0.26	800.36	0.2018	29.97	64.21
MR-5	-0.02	1074.47	0.0773	37.27	74.31
MR-6	0.27	797.85	0.1930	30.47	65.11
MR-7	0.08	977.40	0.1413	34.20	68.46
MR-8	0.67	353.45	0.8737	13.11	29.16
MR-9	0.43	583.45	0.5696	18.55	46.69
MR-10	0.77	310.08	0.7184	16.74	37.45
MR-11	0.45	617.44	0.6447	25.10	47.57
MR-12	0.24	820.42	0.3471	29.91	60.13
MR-13	0.29	778.52	0.4421	29.53	57.39
MR-14	0.94	81.37	0.9924	4.62	7.70
MR-15	0.95	69.89	0.9918	4.26	7.35
MR-16	0.95	65.00	0.9928	3.84	6.79
MR-17	0.94	87.82	0.9923	4.91	8.05
MR-18	0.95	66.05	0.9929	3.86	6.82
MR-19	0.94	78.51	0.9931	4.29	7.31
MR-20	0.97	45.90	0.9903	3.31	6.92
MR-21	0.92	108.05	0.9897	5.85	9.62
MR-22	0.93	90.02	0.9916	5.08	8.32
MR-23	0.87	163.03	0.9731	8.50	14.70
MR-24	0.94	82.57	0.9921	4.58	7.79
MR-25	0.93	92.95	0.9872	5.45	9.42
MR-26	0.94	79.84	0.9913	4.75	7.93
MR-27	0.93	98.74	0.9851	5.81	10.10
MR-28	0.95	71.74	0.9915	4.26	7.47
MR-29	0.95	76.66	0.9921	4.47	7.56
MR-30	0.95	69.23	0.9929	3.92	6.94
MR-31	0.95	70.09	0.9892	4.43	8.04
MR-32	0.97	56.03	0.9903	3.80	7.26
MR-33	0.92	109.67	0.9829	6.31	10.95
MR-34	0.97	46.34	0.9900	3.24	6.98
MR-35	0.98	33.54	0.9898	2.77	6.75
MR-36	0.92	112.99	0.9807	6.37	11.42
ANN-1	0.98	41.68	0.9936	3.02	5.97
ANN-2	0.55	449.35	0.6119	12.97	41.57
ANN-3	0.58	432.20	0.5661	13.82	43.67
ANN-4	0.27	797.09	0.1900	30.39	65.26
ANN-5	0.02	1047.30	0.0058	37.36	73.47
ANN-6	0.27	796.63	0.1868	30.09	65.26
ANN-7	0.12	915.70	0.1273	31.19	66.51
ANN-8	0.89	129.08	0.9229	6.04	18.57
ANN-9	0.47	551.17	0.5616	18.12	46.08
ANN-10	0.78	294.42	0.7189	16.14	37.30

ANN-11	0.44	630.39	0.6085	25.64	48.90
ANN-12	0.24	822.37	0.3043	30.13	60.98
ANN-13	0.30	764.64	0.4117	28.65	57.24
ANN-14	0.99	25.02	0.9845	2.21	8.13
ANN-15	0.97	43.89	0.9921	2.96	6.44
ANN-16	0.97	43.45	0.9935	3.11	6.05
ANN-17	0.97	44.35	0.9930	3.21	6.28
ANN-18	0.96	43.47	0.9879	2.12	7.38
ANN-19	0.98	34.04	0.9911	2.79	6.57
ANN-20	0.94	76.77	0.9884	4.27	8.49
ANN-21	0.90	145.70	0.9769	8.52	13.80
ANN-22	1.02	-6.91	0.9688	0.66	11.52
ANN-23	1.13	-52.08	0.9324	6.32	21.77
ANN-24	1.02	0.85	0.9767	1.65	10.05
ANN-25	0.94	89.62	0.9702	5.63	12.37
ANN-26	0.98	36.26	0.9922	2.58	6.18
ANN-27	0.95	110.19	0.9506	9.52	16.91
ANN-28	0.99	32.61	0.9888	2.94	7.28
ANN-29	0.97	46.15	0.9927	3.12	6.36
ANN-30	0.96	56.59	0.9905	3.11	7.19
ANN-31	0.98	42.20	0.9583	3.64	13.43
ANN-32	0.96	58.07	0.9890	3.42	7.66
ANN-33	0.99	37.92	0.9673	3.48	11.94
ANN-34	0.99	31.14	0.9824	2.92	8.85
ANN-35	1.04	-40.57	0.9732	-0.97	11.26
ANN-36	0.76	320.13	0.8435	17.70	31.03

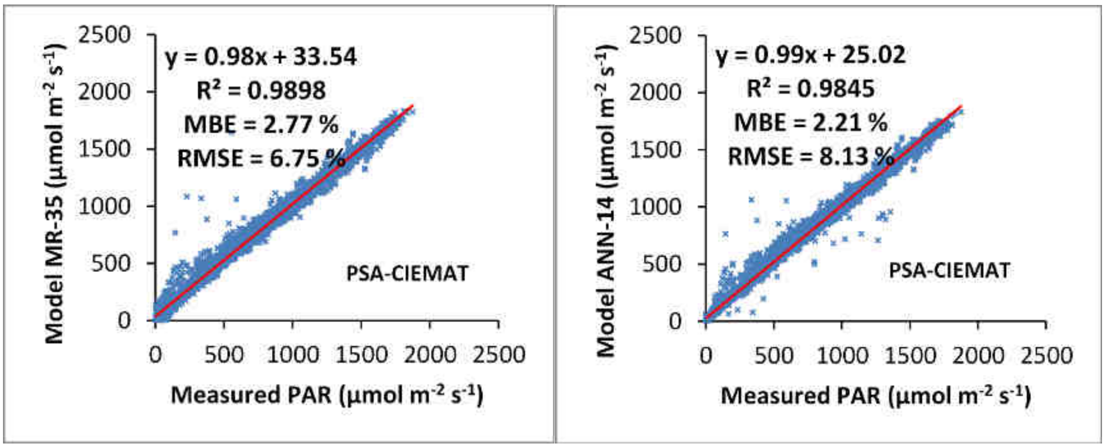


Figure 5: Correlograms corresponding to PSA-CIEMAT station. (Left Model MR-35, rigth Model ANN-14).

In Table 5 the statistics of the models performance with PSA-CIEMAT dataset are shown. In this case, the best results of the MR models correspond to model MR-35. While the best performance of the ANN models is obtained for ANN-14. Though there are various models that reach a similar performance to the best models. As in CEDER-CIEMAT case, a slight improvement is appreciated using ANN models.

The correlograms of two of the best models are represented in Figure 5. The results of the ANN models slightly improve those of the MR models. The results of both types of models with the PSA-CIEMAT dataset are similar to the results in CEDER-CIEMAT, and clearly better than in Santiago-EOAS and Vall d'Alinya. Thus, the results of the models in mediterranenan stations are clearly better than in oceanic stations.

4. Conclusions

In this work, we have addressed the modelling of *PAR*. For that purpose, 72 types of models have been developed and validated in four locations of mainland Spain, two of them corresponding to locations with Mediterranean climate and the other two stations corresponding to locations with oceanic climate.

The slightly different slopes obtained in Equations (1), (37), (73) and (109), where the relationship between *PAR* and *GHI* is shown, during the training process for the data of the four stations, evidenced the influence of the climate on these expressions.Indeed, the MR models expression for locations with an oceanic climate (Santiago-EOAS and Vall d'Alinya), have larger coefficients for GHI than the expressions for the locations with Mediterranean climate (CEDER-CIEMAT and PSA-CIEMAT). This is caused by the greater percentage of humidity that exists in an oceanic climate since the water in the atmosphere absorbs more radiation in the infrared spectrum increasing the ratio between *PAR* and global irradiance.

In both MR and ANN models the most important variable to model *PAR* is *GHI*, as when it is not included as input the results clearly worsen. Another similarity between MR and ANN models is that adding more variables does not clearly improve the results. Though there are various models that obtained similar results. The results also show a slight improvement when using ANN models respect of the MR models in Mediterranean climate. For the oceanic climate the best results were obtained using MR models. However in the four cases the differences between MR and ANN models were slight.

Comparing the results of the models in both locations, we can say that the models had a better performance in the Mediterranean ones. This behaviour was expected as the characteristics of the Mediterranean climate, steadier behaviour regarding the cloudiness, and hence regarding the radiation, entails greater regularity in the data and thus, more accurate models than in the oceanic climate which has a more irregular behaviour regarding the cloudiness.

In future works, our group intend to improve the *PAR* modelling by using satellite data for the training process. Besides, we recently started up a network of new meteorological stations with *PAR* radiometers over mainland Spain with the goal of having more available data that will allow in the future the development of more accurate *PAR* regional models.

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A Survey of Attitudes towards Environmental and Energy Problems, Impacts and Policies

Vasilios DOURMAS - Ph.D. Candidate[1]
Giorgos M. ANDREAKOS - Ph.D. Candidate[1]
Nicoletta KONTOULIS - Ph.D. Candidate[2]
John A. PARAVANTIS - Associate Professor[2*]
Giouli K. MIHALAKAKOU - Professor[1]

[1]*Department of Environmental Engineering, University of Patras*
[2]*Department of International and European Studies, University of Piraeus*

**Contact details of corresponding author*
Tel: +30 210 4142771
e-mail: jparav@unipi.gr
Address: 80 Karaoli & Dimitriou Street, Piraeus, 18534 Greece

Abstract

This research examines attitudes towards socioeconomic, environmental, institutional and political aspects and impacts of climate change and mitigation policies. An online questionnaire contained questions on: demographic data; attitudes towards the social impacts of climate change; attitudes towards the economic impacts of climate change; attitudes towards the role of organizations, global institutions and local governments; and attitudes towards the impact of European and national policies intended to address global environmental and energy problems like climate change. A total of 72 responses were collected, 30% of which was by males. Respondents were between 18 and 59 years of age, residing mostly in the wider Athens area; most with one or two children; most with university or graduate education; and working as private or state employees and freelance. Principal Component Analysis and Cluster Analysis were used to discover three clusters of like-minded individuals that are considered climate change tribes: upper income single expatriates, with the pro-environmental but cool-minded and business friendly attitude found in European countries; lower income single respondents blaming firms and industry for climate change, and thinking that everyday life will have to change to address climate change; and middle income respondents with families living in Greece, less concerned about contributing to climate change, and more concerned with its regional and local effects. It was recommended that energy and environmental policies be designed so that they distill elements of experience and wisdom from these three mindsets. A forthcoming larger survey will be based on an improved version of this questionnaire.

Keywords: climate change, attitude survey, Principal Component Analysis, Cluster Analysis.

1. Introduction

Climate change has direct and indirect impacts on socioeconomic systems. These impacts result from (and are mediated by) policies taken by governments and international organizations in their effort to mitigate climate change (Stern P. C., 1992). Such impacts affect the lifestyle, work, culture, health, personal rights, customs, beliefs and values of communities (Vanclay F., 2002), but vary among different societal groups and from one place to another.

This research used an online questionnaire designed to analyze attitudes towards the socioeconomic, environmental, institutional and political aspects and impacts of climate change and related mitigation policies, shedding light on the existence of such distinct groups among the Greek society.

2. Background

Global environmental problems created or greatly enhanced by anthropogenic activities (Nordhaus W. D., 1993, 2007 & 2008; Schneider S. H. & Kuntz-Duriseti K., 2002) include: global warming and climate change; reduction of the ozone layer; acid rain; industrial air pollution; water pollution; deforestation; desertification; coastal erosion; and decline of biodiversity (widely cited, e.g. Spash C. L., 2002; Owen A. D. & Hanley N., 2004; House of Lords, 2005; Michaels P.J. & Balling R.C., 2009; Duarte C.M. et al., 2013; Sivaramanan S., 2015). Of these, climate change is arguably the most pressing, with consequences that are complex and unpredictable (Berkhout F. et al., 2001). Social and political consequences in particular are characterized by great uncertainty (Mendelsohn R., 2009), interact with financial systems, and pose big challenges in global governance and international security (Cazorla M. & Toman M., 2000; Barnett J., 2001; Barnett J. & Adger W. N., 2007; Panagariya A., 2009). Some of these consequences, such as rise of poverty and environmental migration (Berkhout F. et al., 2001), exacerbated by problems such as water shortages (Lambin E. F. et al., 2001), are expected to aggravate social inequalities (Ewert F. et al., 2005; Stern P.C., 1992) and provoke internal and international conflict (Azis I. J., 2009).

The latest Eurobarometer data (European Commission, 2019) confirms that European citizens: consider climate change to be a serious problem; think that governments should get more energy from renewable sources; more public funding should be offered for transition to clean energy sources; and climate change mitigation measures adopted by businesses should make them more innovative and competitive. There is also agreement that adjusting to the severe consequences of climate change can bring about positive results. Yet, while it is easy to agree on issues like reducing the consumption of single use goods, and recycling, there is a diversity of attitudes towards the consequences arising from the policies intended to manage climate change and mitigate global warming. These have been underscored by a couple of research publications that wrote about "energy tribes", but have received little attention over time. Thomson M. (1984) wrote of the existence of three such groups in society: business as usual, middle of the road, and radical change now. Caputo R. (2009) wrote of the existence of four such ways of thinking in society: egalitarianism, individualism, fatalism and hierarchy. Membership in different energy tribes reflects overlapping sets of rationality, different sets of beliefs, and different cultural values. People in different energy tribes place different bounds on what is credible/incredible, possible/impossible, sensible/foolish and rational/irrational. As a result, they have different attitudes and beliefs, and accept different solutions. Since policies can move forward only if embraced by a large majority for a long time, the existence of energy tribes means that only "messy" or "clumsy" policy solutions, combining the logic of different energy tribes, have a chance of working.

This research investigated the existence of such "climate change tribes" in the Greek society via an online survey that is discussed in the next section. To the knowledge of the authors of this work, no such research has been published.

3. Methodology

This research answered the following questions: (1) Are there groups with similar attitudinal characteristics towards the socioeconomic, institutional and political aspects and impacts of climate change and related energy and environmental policies (i.e. climate change tribes) in the Greek society? If so, how many? (2) What are the demographic and attitudinal characteristics of these tribes?

An online questionnaire was designed, with multiple-choice items for demographic information, and Likert-scaled ratings for attitudes towards the socioeconomic, environmental, institutional and political aspects and impacts of climate change and related policies. The questionnaire was tested with a small number of respondents before being posted on the web (Bergmann A. et al., 2006). The test phase resulted in shortening, simplification, better structure, improved readability, and an overall more coherent questionnaire, as in similar studies (Hanley N., Nevin C., 1999; Borchers A. M. et al., 2007; Baker K. J., Rylatt R. M., 2008). The final questionnaire remained rather long, but great effort was put in keeping the list of questions interesting. More information on the structure and contents of the questionnaire is discussed in the next section.

3.1. Structure of questionnaire

The final questionnaire was made up of five sections. The first section contained multiple-choice demographic items on gender, age, education, family status, children, income, and residence. These provided a measurable link between the demographic profile of respondents, and the socioeconomic, environmental, institutional and political aspects and impacts of climate change (Heindl P., Löschel A., 2015; Bergmann A. et al., 2006).

The second section contained Likert-scaled ratings of various social aspects and impacts of climate change. Held M. (1983) and Ligus M. (2017) have argued that the analysis of social impacts helps find out whether people are willing to change their everyday life to face global warming. Social impacts included the physical and mental well-being of respondents; sociocultural consequences; detrimental land use changes; and social instability arising from population displacement and migration (Cernea M. M., 2004; Reddy A. K., 2000).

The third section contained Likert-scaled ratings of the economic and financial aspects and impacts of climate change. These have been reported to include: the way people live and work, e.g. citizens may be willing to change their way of life, but are unwilling to transform their employment and entertainment (Held M., 1983; Ligus M., 2017); urbanization; income and Gross Domestic Product (GDP); unemployment; inflation; economic concentration; quantity and quality of food; local production of goods and services; operation of markets; regional development; financial and monetary issues; and use of natural resources (Morrison D.E., Lodwick D.G., 1981; Vanclay F., 2002; Cernea M.M., 2004; Omer A.M., 2008; Del Río P., Burguillo M., 2008; Climate Change Impact Study Committee, 2011; Cambridge Econometrics, 2015; Ligus M., 2017).

The fourth section contained Likert-scaled ratings of environmental aspects and consequences of climate change, including: air and water quality; rising intensity of the Urban Heat Island; loss of forests and wood areas (e.g. because of fires); energy consumption and the energy mix; land use and agricultural production (with competition between food crops and biofuels); perceived importance especially when compared with other global environmental issues (like acid rain, ozone depletion and desertification); and perceptions about the responsibilities of municipalities, regions, businesses, industries, environmental organizations, national governments, and international organizations (Vanclay F., 2002; Cernea M. M., 2004; Del Río P., Burguillo M., 2008; Climate Change Impact Study Committee, 2011; Ji X., Long X., 2016).

The fifth and final section contained ratings on the institutional and political aspects and impacts of climate change, which affect: citizen participation and mobility; personal and property rights; democratization; political instability; environmental terrorism; political systems; and concentration of power in the international system (Morrison D. E., Lodwick D. G., 1981; Thompson M., 1984; Vanclay F., 2002; Greening L. A., Bernow S., 2004).

3.2. Data collection

The final version of the online questionnaire was sent to users of different age groups and occupations through e-mail and social media. Snowball sampling was used to collect a total of 72 responses, at a non-response rate just over one third (34.5%). Variable names and definitions are shown in Table 1. SPSS version 23 and Minitab version 18.1 were used for graphing and statistical analysis.

4. Results

The sample contained 72 responses, 22 of which were by male (30.56% of the total) and 50 by female (69.44%) respondents.

The age distribution of respondents was reported in classes and converted to class averages. Almost half of the respondents (45.83% of the total) had an average age of 34.5 years; about one in four (26.39%) had an average age of 44.5 years; about one in five (22.22%) had an average age of 23.5 years; and four respondents (5.56%) had an average age of 54.5 years. As regards the education of respondents, 4.17% of them were high school graduates; 12.5% had graduated from a junior college or other similar post-secondary institution; one fourth of the sample had graduated from a university; over half (55.56%) had completed graduate education; and two has a doctoral degree.

Of the 72 respondents, 42 were single (61.76%) and 26 married (38.24%). While married male were about equal to single male respondents (47.62% and 52.38% correspondingly), only about one third of the female respondents (34.04%) were married. Forty-six respondents had no children, 17 had one child, eight had two children, and one had three children. 63.89% of respondents did not have children. Turning to the profession of respondents, 40.28% of them worked in the

Table 1: Variable names and definitions (CC: climate change; RES: renewable energy sources).

Num	Variable name	Variable definition
1	14aChangLifeCC	Must change way of life to address CC
2	14bChangWorkCC	Must change work to address CC
3	14cChangEntertCC	Must change entertainment to address CC
4	14dRightChangEnviron	Have the right to change the environment
5	15aActionContrCC	Our actions contribute to CC
6	15bCCDemMigr	CC will cause demographic changes
7	15cCCHealthHappin	CC will affect health and happiness
8	18aCC-EconConc	CC will reduce economic concentration
9	18bCC+LocalProd	CC will increase local production
10	18cCCSmallBusDev	CC will provide opportunities for small business development
11	18dCCResLocalWealth	CC will use local resources and wealth
12	18eCC-Middle	CC will reduce middlemen
13	18fCC+Growth	CC will increase growth
14	19aCC+Empl	CC will increase employment
15	19cCC+TrainEdu	CC will increase training and education
16	19dCC+SpecWork	CC will increase specialized work
17	19eCC+WorkQual	CC will improve work quality
18	19fCC+Innov	CC will favor innovation and creativity
19	20aCCLiving	CC will affect living
20	20eCCSocDevel	CC will affect social development
21	20fCCLandRES	CC will affect land requirements of RES
22	20gCCInfl	CC will affect inflation
23	20hCCUnempl	CC will affect unemployment
24	23aCCImpEnvProbl	CC is an important environmental problem
25	23bCCFuturEnvImpact	CC will have future environmental impacts
26	23cCCImmedEnvAction	CC will require immediate environmental actions
27	23dCCChangDaily	CC brings changes to everyday life
28	25aCCInterOrg	International organizations are responsible for CC
29	25bCCGov	National governments are responsible for CC
30	25cCCPrefMunic	Prefectures and municipalities are responsible for CC
31	25dCCFirmIndust	Firms and industry are responsible for CC
32	25eCCEcolOrg	Ecological organizations are responsible for CC
33	26StateIncent	State must provide environmental incentives
34	27CCImport	How important is CC to you?
35	29aCCPolIndivPropRight	CC policies affect property rights
36	29bCCPolDecMak	CC policies affect individual decision making
37	29cCCPolDemoc	CC policies affect democratization
38	29dCCPolMobil	CC policies affect mobility
39	29eCCPolPublPrivServ	CC policies affect public and private services
40	29fCCPolGeog	CC policies affect geography and land uses

private sector;26.39% (about one fourth of the total) worked in the public sector; 15.28% worked as freelance; and 6.94% were unemployed. Smaller numbers of respondents declared another profession (5.56%), were students (4.17%) or homemakers (one person).

Table 2 presents a cross tabulation of the education and profession of respondents. All high school graduates worked in the private sector; most college graduates worked in the private and the public sector; most university graduates worked in the private sector (7), followed by the public sector (5), and freelance (3); most respondents with graduate education worked in the private sector (16), followed by the public sector (10) and freelance (6); finally the two respondents with a doctorate worked in the public sector and freelance. All in all, most respondents worked in the private or public sector and freelance, with smaller numbers being unemployed, in another profession, student or homemaker.

The distribution of the monthly income declared by respondents is shown in Figure 1. Most had an income around 500 to 1500 euros, with the richest respondents declaring incomes over 5000 euros. The average income per education of respondents is tabulated in Table 3. The three high school graduates (who worked in the private sector) followed by the two doctorate holders declared the highest income. In the other classes (graduate, university and college education), income was proportional to education.

The average income per profession of respondents is tabulated in Table 4. Freelancers had the highest income, followed by those who worked in other professions, the private and the public sector. As expected, students, homemakers and the unemployed declared the lowest income. Respondents who lived in big cities earned more money (1969) than the rest (1550). Also, respondents who lived in Greece (93.06% of the total) declared an average monthly income of 1228 euros, much lower than the 3664 euros declared by those who lived abroad.

Having completed a look at demographic data, attention now shift to the Likert scaled items that relate to the socioeconomic, institutional and political aspects and impacts of climate change and related policies.

Table 2: Education per profession of respondents.

	Education					
Profession	*High school*	*College*	*University*	*Graduate*	*Doctorate*	*All*
Private	3	3	7	16	0	29
Public	0	3	5	10	1	19
Freelance	0	1	3	6	1	11
Unemployed	0	1	1	3	0	5
Other	0	0	1	3	0	4
Student	0	1	0	2	0	3
Home	0	0	1	0	0	1
All	3	9	18	40	2	72

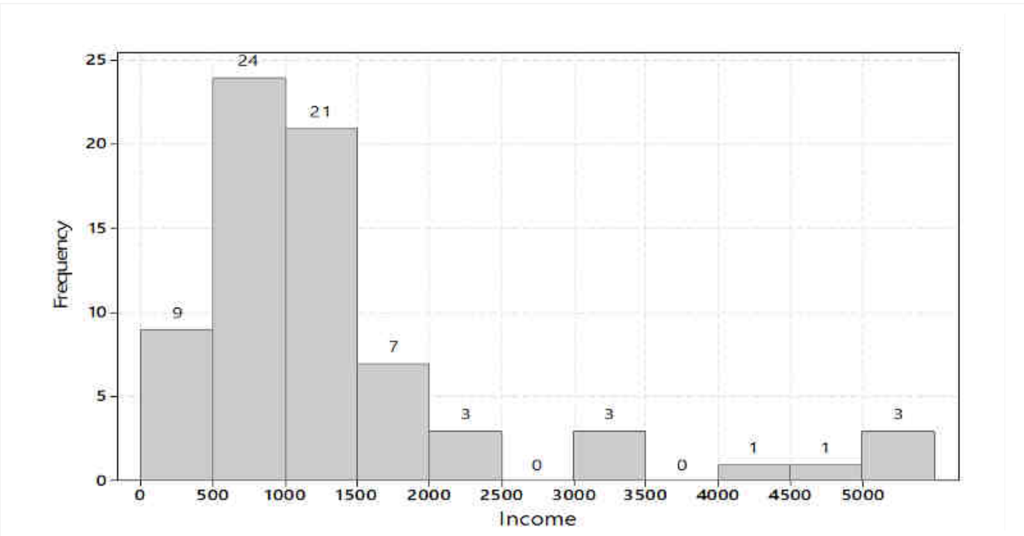

Figure 1: Histogram of income of respondents.

Table 3: Average income vs education of respondents.

Education	N	Average income
Doctorate	2	2250
Graduate	40	1433
University	18	1194
College	9	1139
High school	3	2333

Table 4: Average income per profession of respondents.

Profession	N	Average income
Freelance	11	1909
Other	4	1625
Private	29	1485
Public	19	1434
Student	3	417
Home	1	250.00
Unemployed	5	250.00

Table 5: Sorted average rating of questions.

Num	Variable	Mean	Num	Variable	Mean
1	26StateIncent	7.111	21	29bCCPolDecMak	3.993
2	27CCImport	6.986	22	20eCCSocDevel	3.958
3	23bCCFuturEnvImpact	5.556	23	18dCCResLocalWealth	3.903
4	23aCCImpEnvProbl	5.479	24	29eCCPolPublPrivServ	3.889
5	23cCCImmedEnvAction	5.472	25	20gCCInfl	3.875
6	14aChangLifeCC	5.125	26	29aCCPolIndivPropRight	3.875
7	25dCCFirmIndust	5.125	27	20hCCUnempl	3.861
8	15cCCHealthHappin	5.035	28	29cCCPolDemoc	3.833
9	23dCCChangDaily	5.028	29	19cCC+TrainEdu	3.722
10	20aCCLiving	4.722	30	25eCCEcolOrg	3.694
11	15bCCDemMigr	4.674	31	14cChangEntertCC	3.625
12	25bCCGov	4.556	32	19aCC+Empl	3.542
13	25aCCInterOrg	4.458	33	19eCC+WorkQual	3.528
14	20fCCLandRES	4.444	34	18bCC+LocalProd	3.403
15	25cCCPrefMunic	4.146	35	18cCCSmallBusDev	3.292
16	19dCC+SpecWork	4.083	36	18fCC+Growth	3.292
17	29dCCPolMobil	4.056	37	18aCC-EconConc	3.278
18	19fCC+Innov	4.014	38	18eCC-Middle	3.278
19	29fCCPolGeog	4.014	39	14bChangWorkCC	3.000
20	15aActionContrCC	4.000	40	14dRightChangEnviron	2.292

Table 5 shows the corresponding sorted average ratings of the respondents. Variables 14aChangLifeCC (average rating of 5.125), 15cCCHealthHappin (average rating of 5.035) and 20aCCLiving (average rating of 4.722) are conceptually almost identical, and their similar ratings provide evidence to the internal consistency of the questionnaire (Zikmund W.G., 1997; Bock G.W., Kim Y.G., 2002). Chronbach's alpha for the ratings items equaled 0.9677, indicating a very high level of internal consistency of the questionnaire.

Items 26StateIncent and 27CCImport received the highest ratings (around 7 out of a maximum of 8), showing that respondents believed very strongly that the state must provide environmental incentives, and climate change is very important.

Items 23bCCFuturEnvImpact, 23aCCImpEnvProbl, 23cCCImmedEnvAction, 14aChangLifeCC, 25dCCFirmIndust, 15cCCHealthHappin and 23dCCChangDaily also received high ratings (5 to 5.5 out of a maximum of 6). These ratings showed that respondents believed quite strongly that: climate change will have future environmental impacts; climate change is an important environmental problem; climate change will require immediate environmental actions; changes must be brought about in everyday life to address climate change; firms and the industry are responsible for climate change; climate change will affect health and happiness; and climate change will change everyday life. Of the rest of the items, the lowest rating of 14dRightChangEnviron (2.292 out of 6) showed that respondents did not think that people have the right to change the environment.

In an effort to reduce the number of variables, Principal Component Analysis (PCA) was run on the Likert-scaled items, indicating the attitude of the respondents towards climate change and its impacts. PCA was run on a total of 39 Likert-scaled variables (the right to change the environment item was excluded). The total variance explained is shown in Table 8 and the component matrix in Table 9.

As seen in Table 8, eight Principal Components (PCs) were extracted from the 39 variables, using an eigenvalue cutoff value of one. These eight PCs explained 72.58% of the total variance in the original data. The PC coefficients are shown in Table 9. The interpretation of the first four PCs is as follows:

1. PC1 included most variables, with coefficients that were positive and bigger than 0.3. Thus, high values of PC1 represented an overall agreement of respondents with the climate change questions as posed in the online questionnaire.
2. The following variables entered PC2 with negative signs: must change way of life to address climate change; climate change will affect health and happiness; climate change is an important environmental problem; climate change will have future environmental impacts; climate change brings changes to everyday life; firms and industry are responsible for climate change; and importance of climate change. So, high values of PC2 represented respondents that were skeptical regarding these aspects of climate change.
3. PC3 and PC4 are similar to PC1, but focus on different sets of variables, mostly having to do with interactions of climate change with the economy.

   The rest of the PCs (PC5 to PC8) had few coefficients bigger than 0.3.

Having obtained a set of PCs, attention now turns to Cluster Analysis, a method that may be used to profile the respondents. Formann A. K. (1984), as cited by Mooi E. and Sarstedt M. (2011), recommended a sample of at least 2^m cases, where m equals the number of clustering variables. This implies that the sample size of 72 observations could support up to 6 variables (2^6=64 while 2^7=128). Given that this is an empirical recommendation and Cluster Analysis is not an inferential technique, it was considered acceptable to use up to 7 clustering variables as long as a well-defined clustering scheme was obtained.

The following (quantitative and qualitative) seven variables were found to be the best set for Cluster Analysis:

1. Age
2. Education years (obtained by adding the average number of years up to the highest level of education)
3. Number of children (performed better than a children dummy)
4. Income (calculated as the average of the income class)
5. Country (a categorical variable)
6. Second (PC2) and third (PC3) principal components of the Likert-scaled responses (of the attitudes of respondents towards climate change and its impacts); the first (PC1) and the other PCs failed to offer any meaningful differentiation among clusters.

As to the number of clusters that were present in the dataset, observing the shape of the distribution of variables gave some hints (Everitt B.S. et al., 2011):

- The distribution of income hinted at two or three clusters (including a big one).
- Responses to the following Likert scaled items (including items related to climate

change) hinted at one, two (and in one case three) clusters (one of which bigger than the rest): people have the right to change the environment; environmental projects will have negative consequences on cultural heritage; climate change projects will have negative consequences (such as worker exploitation); climate change projects will bring about less economic concentration; climate change will create new jobs; climate change will create more specialized jobs; climate change will affect the (economic aspects) of living; governments bear the main responsibility for climate change; environmental organizations bear the main responsibility for climate change; climate change policies affect land changes and urban development;

Gender, a married dummy, profession and a big city dummy turned out to be "swamping" variables, i.e. they overpowered other weaker variables in determining the clusters.

Two-step Cluster Analysis (SPSS) was used, which is a method allowing both quantitative and qualitative variables to be used. The Akaike Information Criterion (AIC) was used for determining the number of clusters. A three cluster solution was arrived at, with a Silhouette measure of cohesion and separation just under 0.5, characterizing the solution as fair (bordering good).

Appropriate statistical tests (t-test in the case of two, and ANOVA in the case of more clusters) were used to test the significance discrimination of variables among the three clusters. It was concluded that the three clusters represented a meaningful solution that offered an interesting profiling of respondents regarding their attitudes towards the socioeconomic, environmental, institutional and political aspects and impacts of climate change and related mitigation policies.

The centroids of clustering variables are shown in Table 10. Table 11 shows the centroids of variables not used in clustering. Regarding variables used in clustering, age, number of children (NumChild), married, and income had cluster median values different at a 99.9% confidence level; and Principal Component 3 (PC3) had cluster median values different at an 85% confidence level. Regarding variables not used in clustering, 20fCCLandRES had cluster median values different at an 80% confidence level; and 20hCCUnempl, 23dCCChangDaily and 25eCCEcolOrg had median values different at a 75% confidence level.

The following are concluded as to the demographic nature of each cluster:

1. *Cluster 1* contained respondents that lived abroad; had an average age of 34.5 years; 80% of them were female; were educated for an average of 17.7 years (slightly more than the other two clusters); were all single; had no children; and earned the highest average monthly income of all clusters (3664 euros).
2. *Cluster 2* contained respondents with the following characteristics: they had an average age of 30.451 years, constituting the youngest cluster of the three; three fourths (75.61%) of them were female; were educated for an average of 17.366 years; one tenth (10.26%) of them of them were married; had no children (with few exceptions, average number of children in the cluster equal to 0.0488); and earned 859.8 euros per month, the lowest average income among the three clusters.
3. Finally, *Cluster 3* respondents had an average age of 44.5, constituting the most senior cluster of the group; 42.31% of them were male; were educated for an average of 16.942 years (slightly less than the other two clusters); nine out of ten (91.67%) of them were married; had an average 1.308 children; and earned an average monthly income of 1808 euros.

What about the attitudes of the respondents of these three clusters towards the socioeconomic, environmental, institutional and political aspects and impacts of climate change and related mitigation policies? As shown in Table 11, the highest ratings of respondents in Cluster 1 (upper income single expatriates) indicated that they believed (in decreasing rating, shown in parentheses) that:

- the state must provide environmental incentives to address climate change (7.8)
- climate change is an important environmental problem (6.8 out of 8, and 5.5 out of 6, in response to two distinct but similar questions)
- climate change will have future environmental impacts (5.8)
- climate change will require immediate environmental actions (5.8)

Table 8: Total variance explained by Principal Component Analysis (SPSS output),

Component	Eigenvalues		
	Total	% of Variance	Cumulative %
1	12.844	32.933	32.933
2	3.669	9.409	42.342
3	3.066	7.862	50.205
4	2.555	6.552	56.757
5	1.842	4.723	61.480
6	1.709	4.381	65.861
7	1.411	3.617	69.478
8	1.210	3.102	72.580

Table 9. Component matrix of the Principal Component Analysis of Likert-scaled questions (coefficients with an absolute value smaller than 0.3 are not displayed; SPSS output)

	Component							
	1	2	3	4	5	6	7	8
14aChangLifeCC	.570	-.320			.348			
14bChangWorkCC				.313	.577		.322	
14cChangEntertCC					.689		.393	
15aActionContrCC	.498						-.390	
15bCCDemMigr	.570						-.336	.496
15cCCHealthHappin	.589	-.382					-.306	
18aCC-EconConc	.459			.358		-.386		
18bCC+LocalProd	.436			.544				
18cCCSmallBusDev	.437	.345		.462	-.313			
18dCCResLocalWealth	.658			.325				
18eCC-Middle	.496		.372	.555				
18fCC+Growth	.377	.322	.437	.479				
19aCC+Empl	.486	.503		-.317		.393		
19cCC+TrainEdu	.601		.339	-.380				
19dCC+SpecWork	.492		.461	-.499				
19eCC+WorkQual	.465	.564	.339					
19fCC+Innov	.402	.465	.351	-.377				
20aCCLiving	.763							
20eCCSocDevel	.711					-.304		
20fCCLandRES	.627							-.362
20gCCInfl	.691							
20hCCUnempl	.685							
23aCCImpEnvProbl	.680	-.546						
23bCCFuturEnvImpact	.699	-.518						
23cCCImmedEnvAction	.629	-.579						
23dCCChangDaily	.532	-.673						
25aCCInterOrg	.524					.438		
25bCCGov	.630		-.400			.527		
25cCCPrefMunic	.604		-.404			.448		
25dCCFirmIndust	.542	-.494						
25eCCEcolOrg	.482			.315				-.438
26StateIncent	.583				-.407			
27CCImport	.572	-.364						
29aCCPolIndivPropRight	.693		-.485					
29bCCPolDecMak	.753		-.442					
29cCCPolDemoc	.586		-.347					
29dCCPolMobil	.608		-.504					
29eCCPolPublPrivServ	.656		-.498					
29fCCPolGeog	.632		-.423					

- climate change will cause demographic change (5.2)
- climate change will affect health and happiness (5.2)
- we must change our way of life to address climate change (5)
- climate change brings changes to everyday life (5)
- climate change will affect land requirements of RES (5).

The highest ratings of the respondents of Cluster 2 (lower income single respondents in Greece) indicated that they believed that:

- the state must provide environmental incentives to address climate change (7.171)
- climate change is an important environmental problem (7.049 out of 8, and 5.61 out of 6, in responses to two distinct but similar questions)
- climate change will have future environmental impacts (5.634)
- climate change requires immediate environmental action (5.585)
- we must change our way of life to address climate change (5.341)
- firms and industry are responsible for climate change (5.244)
- climate change brings changes to everyday life (5.22)
- climate change will affect health and happiness (5.085).

Finally, the highest ratings of the respondents of Cluster 3 (middle income respondents with families in Greece) indicated that they believed that:

- climate change is an important environmental problem (6.923 out of 8, and 5.269 out of 6, in responses to two distinct but similar questions
- the state must provide incentives to address climate change (6.885)
- climate change will have future environmental impacts (5.385)
- climate change will require immediate environmental actions (5.231)
- firms and the industry are responsible for climate change (5.038).

Table 10. Clustering variables cluster centroids with ANOVA p-value (after Levene's test to determine whether standard deviations should be pooled).

	Cluster 1	**Cluster 2**	**Cluster 3**	ANOVA p-value
Cluster name	*Upper income single expatriates*	*Lower income singles in Greece*	*Middle income families in Greece*	
Cluster size	5 (6.94%)	41 (56.94%)	26 (36.11%)	
Clustering variables				
Age	34.5	30.451	44.5	0.000
EduYears	17.7	17.366	16.942	0.411
NumChild	0	0.0488	1.308	0.000
Income	3664	859.8	1808	0.001
Country	Belgium=3 (60%) Netherlands=1 (20%) UAE=1 (20%)	Greece=41 (100%)	Greece=26 (100%)	
PC2	-0.145	-0.135	0.241	0.404
PC3	-0.051	0.195	-0.297	0.145
Other variables				
Male	0.2	0.2439	0.4231	0.269
Married	0	0.1026	0.9167	0.000
Profession	Private=3 (60%) Public=1 (20%) Other=1 (20%)	Private=20 (48.78%) Public=6 (14.63%) Freelance=4 (9.76%) Unemployed=4 (9.76%) Student=3 (7.32%) Other=3 (7.32%) Home=1 (2.44%)	Public=12 (46.15%) Freelance=7 (26.92%) Private=6 (23.08%) Unemployed=1 (3.85%)	

Table 11: Other variables cluster centroids with ANOVA p-value (after Levene's test to determine whether standard deviations should be pooled)

Num	Variable	Mean	**Cluster 1** (*Upper income single expatriates*)	**Cluster 2** (*Lower income singles in Greece*)	**Cluster 3** (*Middle income families in Greece*)	ANOVA p value
1	14aChangLifeCC	5.125	5	5.341	4.808	0.176
2	14bChangWorkCC	3.000	3	3.098	2.846	0.690
3	14cChangEntertCC	3.625	4.2	3.659	3.462	0.464
4	14dRightChangEnviron	2.292	2.2	2.268	2.346	0.969
5	15aActionContrCC	4.000	4.4	4.195	3.615	0.195
6	15bCCDemMigr	4.674	5.2	4.573	4.731	0.492
7	15cCCHealthHappin	5.035	5.2	5.085	4.923	0.788
8	18aCC-EconConc	3.278	2.8	3.22	3.462	0.506
9	18bCC+LocalProd	3.403	3.4	3.341	3.5	0.854
10	18cCCSmallBusDev	3.292	2.8	3.268	3.423	0.585
11	18dCCResLocalWealth	3.903	4.2	3.951	3.769	0.451
12	18eCC-Middle	3.278	2.4	3.341	3.346	0.293
13	18fCC+Growth	3.292	3.4	3.293	3.269	0.980
14	19aCC+Empl	3.542	3.6	3.683	3.308	0.620
15	19cCC+TrainEdu	3.722	3.6	3.927	3.423	0.313
16	19dCC+SpecWork	4.083	4	4.122	4.038	0.962n
17	19eCC+WorkQual	3.528	3.8	3.537	3.462	0.572
18	19fCC+Innov	4.014	3.8	4.073	3.962	0.656
19	20aCCLiving	4.722	4.8	4.829	4.538	0.674
20	20eSocDevel	3.958	4	4.024	3.846	0.856
21	20fCCLandRES	4.444	5	4.561	4.154	0.198
22	20gCCInfl	3.875	3.2	4	3.808	0.329
23	20hCCUnempl	3.861	3.4	4.098	3.577	0.208
24	23aCCImpEnvProbl	5.479	5.5	5.61	5.269	0.391
25	23bCCFuturEnvImpact	5.556	5.8	5.634	5.385	0.413
26	23cCCImmedEnvAction	5.472	5.8	5.585	5.231	0.253
27	23dCCChangDaily	5.028	5	5.22	4.731	0.233
28	25aCCInterOrg	4.458	4.2	4.366	4.654	0.629
29	25bCCGov	4.556	4.6	4.61	4.462	0.921
30	25cCCPrefMunic	4.146	3.9	4.293	3.962	0.617
31	25dCCFirmIndust	5.125	4.6	5.244	5.038	0.329
32	25eCCEcolOrg	3.694	2.6	3.805	3.731	0.245
33	26StateIncent	7.111	7.8	7.171	6.885	0.385
34	27CCImport	6.986	6.8	7.049	6.923	0.858
35	29aCCPolIndivPropRight	3.875	3.6	3.78	4.077	0.587
36	29bCCPolDecMak	3.993	4.3	3.829	4.192	0.543
37	29cCCPolDemoc	3.833	4	3.707	4	0.641
38	29dCCPolMobil	4.056	4.6	3.878	4.231	0.299
39	29eCCPolPublPrivServ	3.889	4.4	3.732	4.038	0.483
40	29fCCPolGeog	4.014	4	3.829	4.308	0.348

5. Discussion and conclusions

Comparing the attitudes of respondents towards the socioeconomic, environmental, institutional and political aspects and impacts of climate change and related policies, a number of interesting conclusions is derived.

The upper income single expatriates of Cluster 1 were more concerned that climate change will affect demography, migration and the land requirements of RES, but did not think that firms or the industry were to blame for climate change. These respondents placed the least blame for climate change on ecological organizations, and were the least concerned about inflation and unemployment being affected by climate change. These respondents were also the least concerned that climate change will affect small business development, but had the strongest conviction of the three clusters that the state must provide incentives. These characteristics show that the young Greek expatriates of Cluster 1 have become more cool-minded and even headed, adopting the business-friendly attitude of the European countries they lived in.

The lower income single respondents of Cluster 2 that lived in Greece were not as concerned with demography, migration or RES land requirements impacted by climate change. On the other hand, they had the strongest conviction of the three clusters that firms and the industry are responsible for climate change, and that everyday life will have to change to address the problem.

Finally, the middle-income respondents with families living in Greece of Cluster 3 were less concerned that we must change our way to life to address climate change, or that our actions contributed to climate change, or that the land requirements of RES would be impacted. Compared to the other two clusters, the respondents of Cluster 3 were more concerned with the impacts of climate change on small business development, economic middlemen, economic concentration, and local production. The middle-aged respondents of Cluster 3 were people with families, less concerned about contributing to climate change, and more concerned with its regional and local effects.

These three clusters reflect different political and personal world views, and may be considered as climate change tribes present in the Greek society. Their existence means that failures and successes in the fight against global warming make sense to only a subset of the Greek public. Different tribes argue from different premises and will tend to disagree. This research advises that climate change policies be designed so that they distill elements of experience and wisdom of each mindset, in particular those that are missed by the other mindsets.

Regarding the external validity of this research, it is reasonable to hypothesize that climate change tribes (possibly similar to those found here) are present in other societies in Europe and worldwide.

A larger survey is forthcoming, based on an improved version of this questionnaire and the findings of this research. A better form of pseudorandom sampling will be used there.

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Estimation of the Resilience of Urban Parks

Ms Emilia-Emmanouela KOTZAMANI [1], Post graduate student*

Dr. Eleftheria ALEXANDRI, Lecturer*

* Hellenic Open University, School of Science and Technology, Patras

[1] *Contact details of corresponding author*
Tel: +30 6976403921
e-mail: emily.kotzamani@gmail.com
Address: 12-14 Deinostratou St., 11743 Athens, Greece

Abstract

Urban resilience is a term that is gaining acceptance in the academic and policy making world, as a means of mitigating climate change and adapting to it. However, the methodology for assessing it, quantitatively and/or qualitatively has not been firmly established yet. Criteria and their respective indicators have started being developed at the scale of a city or a country. Little research has been made on the validation of smaller urban entities that are vital from an environmental, social and economic point of view, such as parks. The aim of this research is to fill in this gap and validate the resilience of urban green spaces. Its scope is to prioritise the processes that affect the resilience of urban green spaces and to propose an assessment, both with quantitative and qualitative indicators. Through an extended literature review, 63 environmental, social, economic and institutional indicators are chosen to express the resilience of urban green spaces. The indicators are both qualitative and quantitative. They are used to perform SWOT analysis (in regards to the circularity of each subsystem) for green spaces and estimate their resilience both quantitatively and qualitatively. The methodology is applied to two green spaces of Athens: the National Garden and Pedion Areos; these urban parks are comparative, in regards to their size, but differ significantly, concerning their environmental, social and economic effect as well as their institutionalisation. Through this investigation, conclusions are drawn on how each space can increase its resilience to climatic, social and economic pressures, thus participating efficiently in the city's overall resilience.

Keywords: park resilience, urban resilience, resilience indicators, resilience assessment.

1. Introduction

Resilience is a notion that is rapidly gaining ground within the global political agenda, mainly associated with climate change adaptation (Meerow S. et al., 2016). Within the environmental discourse the term has originated from natural sciences and ecology, traced back to Holling C.S. (1973), who defined resilience as the ability of ecosystems to absorb shocks and external pressures and adapt, while maintaining a functional state.

However, the term has been widely adopted by social sciences and public policy, which, by analogy to ecosystems, deal with the responses of spatial and social systems to global threats, like economic crises, climate change, natural disasters or international terrorism (Hill E.W. et al., 2008; Swanstrom T. et al., 2009). Relatively new terms in this field, if not well, scientifically established, are exposed to 'constructive ambiguity'; this might be useful for diplomacy or politics (Varoufakis Y., 2018), nevertheless it turns out catastrophic for science and for the term itself.

As a multidimensional concept, broader than sustainability (Meerow S. and Newell J. P., 2016), resilience incorporates environmental, social economic and institutional parameters; thus it is related not only to environmental protection, but also to the continuation and the evolutionary adaptation of anthropogenic systems. In the framework of urban design, resilience is often related to the perception of cities as complex adaptive systems (Batty M., 2016). In particular, urban resilience stretches beyond sustainable spatial design, and extends to areas of organisation, management, governance and interactions, in a dynamic rather than static way.

In order to define the terms (conditions) which ensure the resilience of urban systems, several parameters should be taken into account such as diversity, effectiveness, autonomy, durability, interdependence, adaptability and cooperation (Godschalk D.R., 2003; Henstra D. et al., 2004).

So far, the concept of urban resilience has been shaped through major international policy initiatives, which provide cities with the expertise to develop long-term strategies tailored to their specific needs (Leitner H. et al., 2018). Such initiatives are the "*Urban Resilience Hub*" by the United Nations (UNISDR - United Nations Office for Disaster Risk Reduction and the UN HABITAT-United Nations Human Settlements Project), the URBACT and RESILENS (www.resilens.eu) research projects launched by the European Union and "100 RESILIENT CITIES", developed by the Rockfeller Foundation.

In the context of "*100 Resilient Cities*", urban resilience has been defined as: "*The capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience*" (Rockfeller Foundation and ARUP, 2015).

In particular, the Framework for Urban Resilience (City Resilience Framework-CRF) of the project 100 Resilient Cities, sets four main dimensions of resilience, related respectively to: (i) health and well-being; (ii) economy and society; (iii) infrastructure and environment; (iv) leadership and strategy (Figure 1).

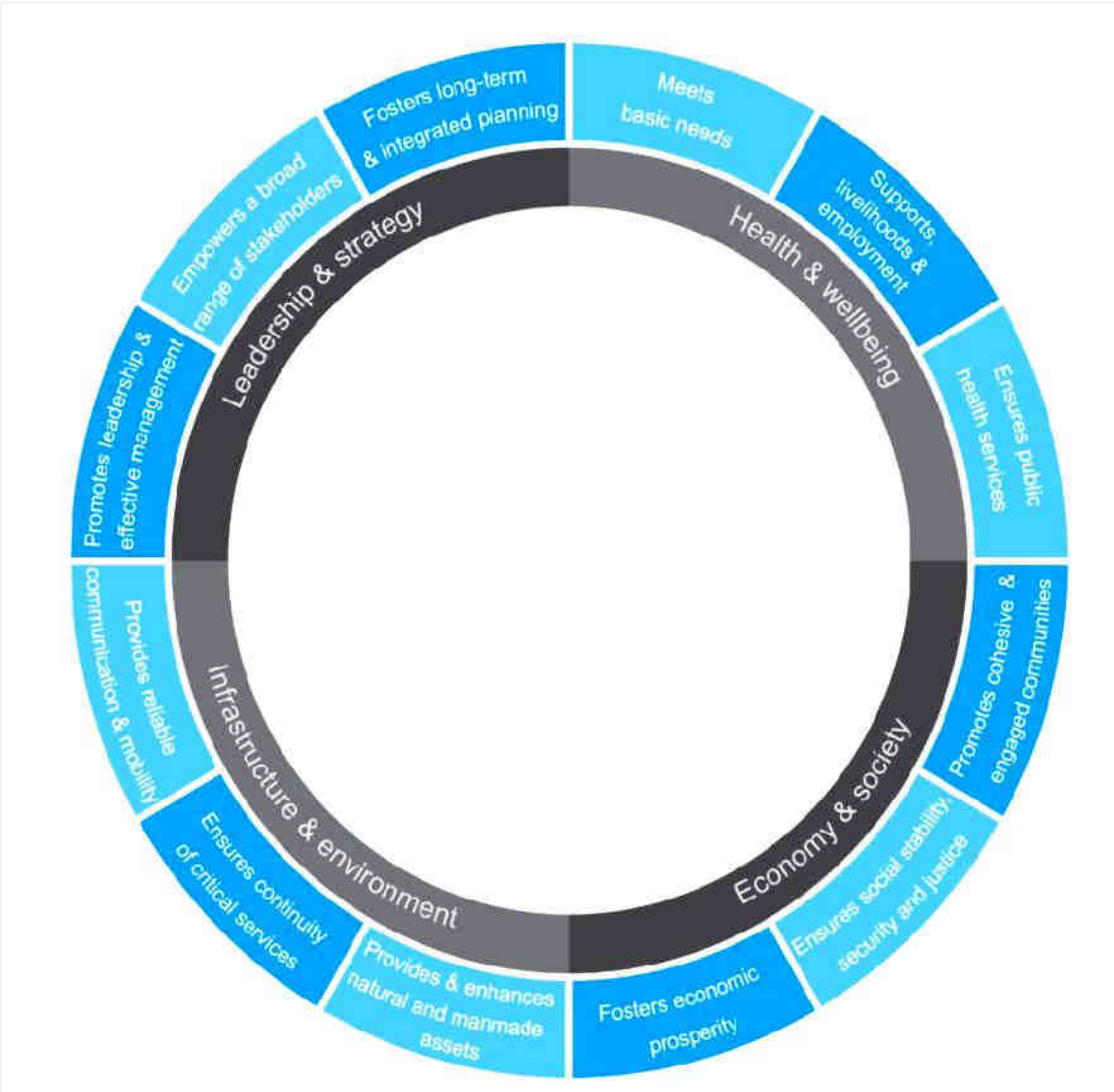

Figure 1: City Resilience Framework (Rockfeller Foundation and ARUP, 2015).

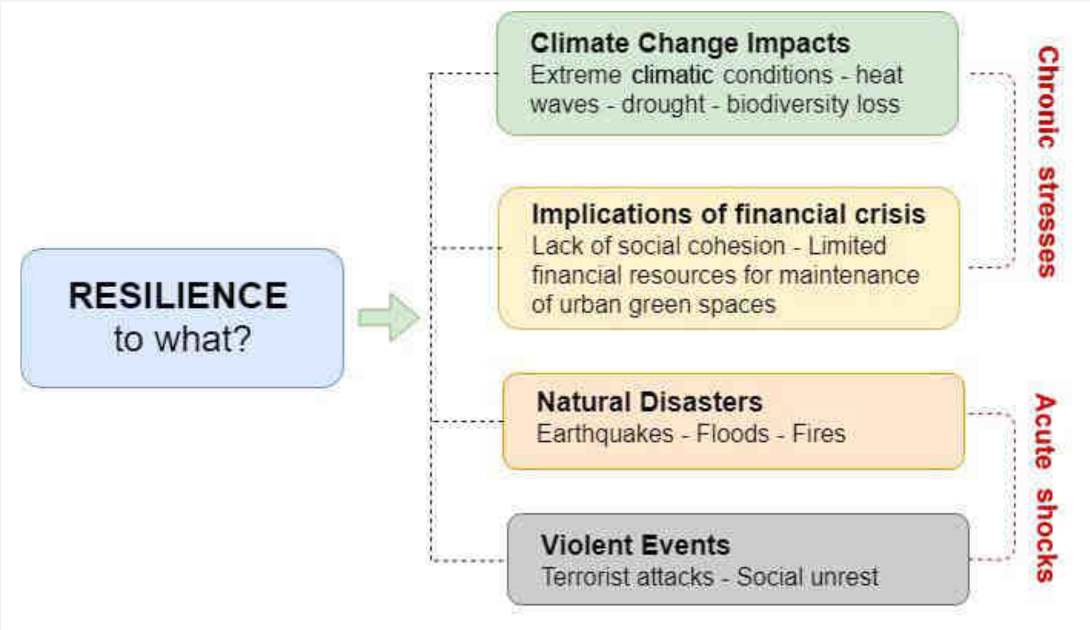

Figure 2: Parameters affecting the resilience of urban, green spaces.

Whereas there is a growing academic interest on urban resilience in the past 10 years (Meerow S. and Stults M., 2016), limited research efforts have been made for defining the resilience of urban parks and gardens, which are a crucial environmental, social and economic element of a city. The aim of this research is to identify a system for evaluating the resilience of urban green spaces, taking into consideration definitions, research and existing methodologies on urban resilience and sustainability indicators. The tool that has been developed is used to examine the resilience of two significant green spaces of Athens; the National Garden and Pedion Areos (Figure 4).

2. State of the art

Resilient public spaces can be defined as those open spaces that contribute in enhancing the overall resilience of the city, as an urban ecosystem on various aspects, such as mitigating the effects of climate change, reducing the risk and vulnerability of the urban environment and enhancing social cohesion.

To formalise a framework for assessing the resilience of urban green spaces, it is crucial to clearly define what constitutes a resilient space – which characteristics and qualities an urban green space must satisfy in order to be characterised as resilient (Figure 2).

The resilience of an urban green space depends upon a set of elements that enhance its adaptability to climate change, (high temperatures, extreme climatic conditions, flash floods, droughts, extremely high wind speeds). Such elements include the ability to preserve the health of the natural ecosystem, to ensure reduced maintenance requirements of the green infrastructure, including efficient irrigation, to keep energy consumption at a low level, to provide accessibility for all and a sense of security, social, extrovert and attractive public spaces, to respond immediately to acute socks and to face chronic stresses. Furthermore, it is important to strengthen community's structure and cohesion, to maintain the identity of the area and to promote active citizens' participation both regarding the use and the management of the site. It is equally important to have a long-term management plan, easily adaptive to critical situations, such as evacuation or coordination plans in case of natural or humanitarian disasters.

A common way to assess complicated issues, such as resilience and sustainability is the use of indicators (Bell S. and Morse S., 2012). Indicators and indexes are symbolic representations (e.g. numbers, symbols, graphs, etc.), designed to describe the properties and characteristics of complex systems (such as urban systems) in a way that is functional and easy to understand, aimed to facilitate decision making, based on solid data (ibid.). Their purpose is to describe complex, dynamic phenomena, which encompass change over time, in a simplified form. Therefore, indicators inevitably present a certain degree of simplification, as dynamic concepts such as sustainability or resilience are difficult to define as a whole in a reductionist way. Indicators can be selected using one or a combination of the following methods: literature review, expert survey and stakeholder consultation (Sharifi A., 2019a). Based on their similarity, selected indicators are often classified into themes and sub-themes (Sharifi A., 2019a). Most of the indicators developed for resilience assessment at city-scale, refer mainly to resilience towards climate or natural disasters (Rani W. N. M. et al., 2018; Cutter S. L. et al. 2010; Schipper E. L. F. and Langston L., 2015).

A crucial component for the development of any indicator is the spatial scale of reference (Bell S. and Morse S., 2012). Therefore, in order to introduce resilience assessment indicators fitting to the scale of urban green spaces, the systems of assessing sustainability have been examined and more specifically the environmental indicators which have been developed.

Since the 1980s and more intensively since the 1990s, after the Rio Summit, there has been a global effort, led by intergovernmental and research agencies and Non-Governmental Organizations (NGOs) to identify commonly accepted sustainability indicators for monitoring, assessing and improving conditions in large urban and suburban areas.

The World Bank has introduced the Global City Indicators Facility (GCIF), consisting of monitoring a range of services and parameters related to the quality of life, classified into 20 thematic units. The United Nations Human Settlements Program (UN-Habitat) has created a database (Global Urban Indicators Database), with indicators on infrastructure, social and economic development, environmental management and governance. Relevant data repositories have been established under Agenda 2030, by the UN and the EU (European Environment Agency). In all, there have been more than 14 transnational European projects and public assessment systems to assess sustainability at an urban scale, using 216 indicators in total (Balaras C.A. et al., 2017).

Sustainability indicators, although mainly oriented towards an environmental perspective, could act as a starting point for estimating resilience, as the environmental dimension is an important parameter of resilience as well. It should be noted, however, that not all indicators fit in every case study. The information content, the measurement capabilities, the scale of the urban set for which the indicators are designed, their communicability constitute important factors linked to their adequacy. Although international expertise in this field is growing rapidly, there is a lack of indicators specifically tailored to assess the resilience of urban green spaces.

3. Methodology

Based on the findings from the literature review, a system is created, so as to assess the resilience of urban green spaces. For the design and monitoring of resilient public spaces it is important, in addition to environmental parameters, to account for socio-economic and institutional parameters that are linked to urban metabolism. Such a process would allow the administrative bodies to identify weaknesses and opportunities for improvement, in order to respond more effectively by developing realistic strategies in the long run.

With a starting point the City Resilience Framework developed in 2014 by Arup for 100 Resilient Cities (Figure 1), a similar scheme has been developed, adjusted to the scale of urban green spaces, that identifies the parameters that affect their resilience, linked to the main components of resilience (environmental, economic, social and institutional)(Figure 3).

Building on literature review (Sharifi A. and Yamagata Y., 2014; 2016; 2018; Schipper E.L.F. and Langston L., 2015; Sharifi A., 2019a; Cumming G. S. et al.,2005; Béné C., 2013; Bahadur A. and Pichon F., 2017; Rani W. N. M. et al. 2018; Walker B. and Salt D., 2006; Gharai F. et al., 2018) a set of 63 indicators is proposed, which cover the parameters that determine the resilience of urban green spaces (Table 1).

Based on the aforementioned system, data have been collected and analysed for the examined two green spaces in Athens, in relation to in situ observations and the characteristics of the urban area in their vicinity. Data have been comparatively processed and SWOT analysis (Tables 2 and 3) has been conducted, to clearly identify the advantages and weaknesses of each space. The available quantitative data that exist and have been collected do not cover all resilience indicators depicted in Table 1.

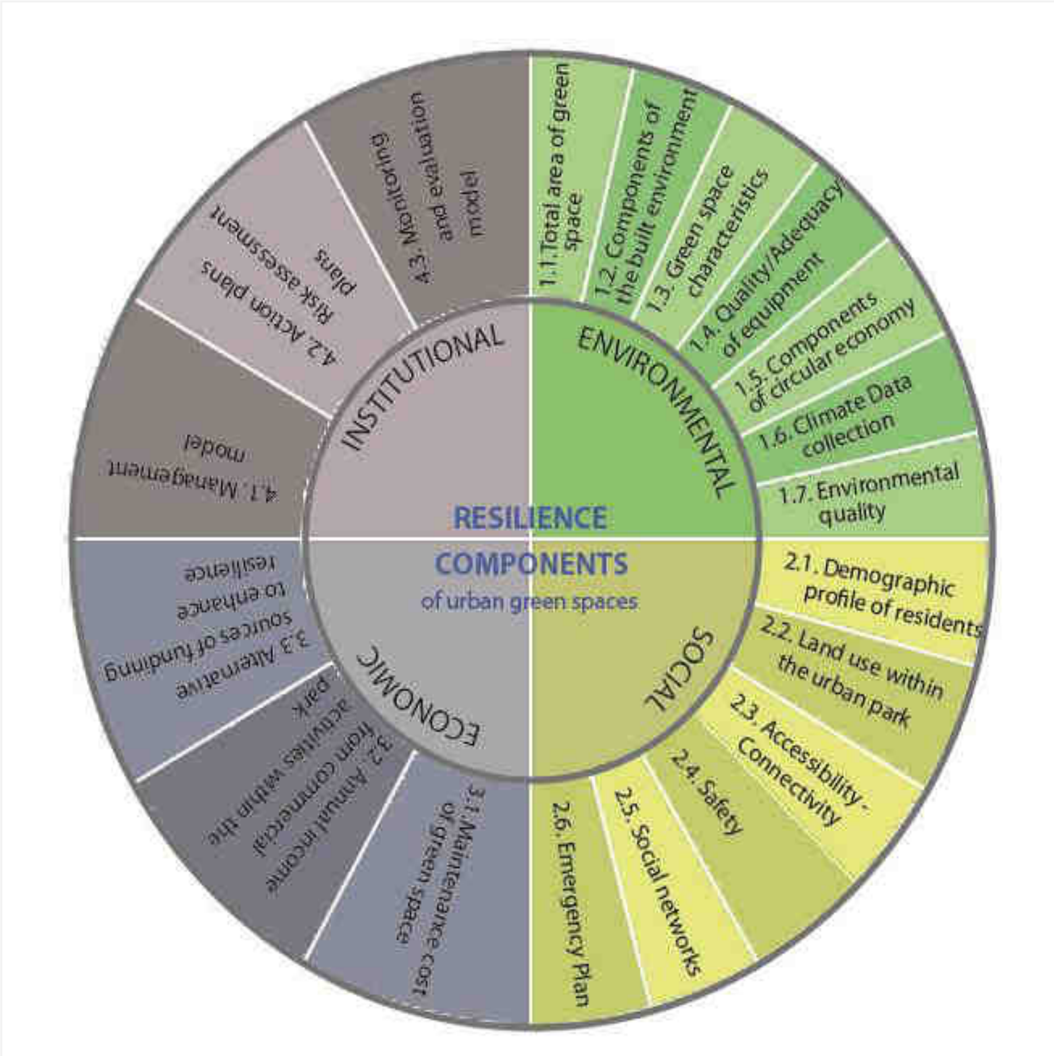

Figure 3: Components of resilience for urban green spaces.

Yet again, too complicated indicator systems might not be realistic to use, demanding impractical or sometimes trivial data to be collected, ending up in unnecessarily complicated systems, which finally are neither used in practice, nor do they describe the them satisfactorily. A prioritisation of criteria and indicators has to be made, for a tool to be useful in practice and usable (Balaras C. A. et al., 2018). Based on the available data for the two green spaces and also on indicators for which no data exist, but are crucial (e.g. energy consumption), Table 1 is simplified into Table 4, ending up in 16 crucial qualitative and quantitative criteria that can be easily depicted by values of simple characterisations (Yes/No, Good/Bad etc), for describing the resilience of urban parks. As a scale has not been assessed yet to characterise the values of each indicator (e.g. high green space index for an urban park, medium, low etc), the values depicted for each criterion are used in a comparative way between the two examined green spaces. The results from this comparison are analysed and conclusions are drawn on the capacity to describe resilience in deterministic terms. Finally, a comparative evaluation of the two green areas has been undertaken through SWOT analysis and in relation to the aforementioned selected indices. Conclusions are drawn about the strengths and the weaknesses of each site, what makes them resilient and what not and the aspects that each site needs to improve in order to enhance its resilience.

4. Case study areas – short description

The above-mentioned methodology is applied in two significant green spaces in the centre of Athens, in order to estimate their resilience. Both green spaces are significant, not only for bringing nature into the city and the environmental benefits of a park, but also for their historical significance in the city's recent urban development.

The creation of the National Garden (today 15.4 ha / ind. 1.1.1.[16]) started in 1839 as the Royal Garden of Queen Amalia, in a naturalistic form. It turned into National Garden, accessible to the broader public, in 1927. In the decade of 1930, there were plenty of activities from the state, for rescuing the National Garden from drought and from private buildings constructed in its space (Tamvakis N. and Bargianni E., 2016). During the same period, Pedion Areos (the Field of Ares[17] - today 22.0 ha / ind. 1.1.1.) was created, having been defined as a green space since 1887, following the forms of garden cities of the era, also rescued from the establishment of buildings and landfills inside it (Dimitrakopoulos A., 1935). Both spaces survived as green areas thanks to the Committee for National Gardens and Tree Lines, which was established in 1927 (Tamvakis N. and Bargianni E., 2016; Dimitrakopoulos A., 1935). With different inceptions, distinct evolution, regarding not only their physical characteristics, the features of their surrounding areas, but also their ownership and management status, both of them remain valuable spaces regarding the well-being of the inhabitants, acting as microclimatic regulators, conserving, up to a certain point, their historical characteristics.

5. Results and Discussion

In Tables 2 and 3 the strong and weak sides of each site are presented through SWOT Analysis. In Table 4 qualitative indicators (that represent resilience criteria) are presented comparatively for each site.

In environmental terms, the two sites share many common features. They both: occupy a key position within the urban fabric; exhibit high vegetation and large soil cover rate, significant biodiversity, and have a positive impact on the local climate, in a wider urban area.

The National Garden is a metropolitan park, located in the very heart of Athens, an urban area with mixed land uses (commercial, administrative, touristic and residential – 250 residents/Ha / ind. 1.2.5.). It is situated next to the Parliament House and close to Syntagma Square, the most frequented square in Athens, as well as many well-known historic and archaeological sites (Acropolis, Panathenaic Stadium, Temple of Zeus) / ind. 1.2.4., which attract thousands of tourists and locals, "feeding" the garden constantly with visitors. Thanks to its central location, it is easily accessible by many bus lines and the metro, as well as on foot (ind. 2.3.1.). The Garden offers many attractions, apart from its green and blue infrastructure, such as playground (ind. 2.2.2.), recreational spaces (ind. 2.2.3.), while many educational (ind. 2.2.5.), sports (2.2.1.) and cultural (2.2.4.) programs occur throughout the year. It is equipped with a significant collection of statues, as well as archaeological remains and exquisite 19th century metallic structures (ind. 2.2.4.). It can be easily accessed by disabled (ind. 2.2.3.), apart from a domain, where Roman, mosaic flooring is at a lower level than the surrounding garden. It closes at nights (ind. 2.4.1.) and is equipped with surveillance personnel (ind. 2.4.2.). It is maintained clean (ind. 1.4.3.), while there is need for maintenance for some of its urban furniture (ind. 1.4.1.) and its infrastructure – especially pathways (ind. 1.4.2.).

On the other hand, Pedion Areos although located in a central area in Athens, close to the National Archaeological museum and major academic institutions, in the heart of one of the most densely populated central areas – ind. 1.2.4. (500 residents/Ha / ind. 1.2.5.), has never acquired a metropolitan character and has always been a neighbourhood park, partly due to its problematic accessibility. The big avenues that surround it (ind. 1.2.3.), cause an unfriendly intermediate space between the park and the rest of the area. Apart from that, the bus lines close to it do not link many areas, while one metro station is within walking vicinity (ind. 2.3.1.), but not well connected with it. The station of regional, intercity coaches is attached to it on its western edge, producing an unfriendly environment. Hence, there is no organic relationship between the park and the abovementioned urban spaces, thus the park fails to attract visitors, coming from these destinations.

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[16] With the term 'ind. x.x.x.' the indicator corresponding to the number 'x.x.x.' in Table **Table** 1 is noted.

[17] God of War, according to Greek mythology.

The park presents a far more neglected image, having suffered the immediate effects of the social collapse of the surrounding area, which was directly linked to the economic and migrant crisis, failing to absorb this chronic stress. The residential area around Pedion Areos gradually begun to change character and demographic characteristics, as early as the 1980s, when long-term residents begun moving to the suburbs. The building stock was already old and gradually depleted. The area was largely inhabited by low income economic migrants, many of which had arrived in the area without their families (ind. 2.1.1.). Many buildings remain abandoned, ending up in a landscape of desertion.

In 2011, a major regeneration project was completed in Pedion Areos, designed by the acknowledged Greek architect Alexandros Tombazis, incorporating principles of bioclimatic design and strong alterations to the historic design. The statues were preserved (ind. 2.2.4.), as did its playground (ind. 2.2.2.). Its traditional café and theatre remained closed (ind. 2.2.3.), while buildings that were restored for reuse inside the park during its regeneration cause social reactions (vandalisms). However, judging by its present situation, the regeneration project has failed to succeed its goals. Within a few years after the completion of the project the park was neglected, most of its new infrastructure was poorly maintained, and back in 2015 in the midst of a huge migration crisis that hit Greece, the park turned to an informal refugee camp and soon after that, it was completely neglected and taken over by drug users. Residents begun to abandon the park as it became totally unsafe even during daytime (ind. 2.4.), while the lack of irrigation and the neglect of the rest of its infrastructure (closed playground, historical café and theatre, vandalised urban furniture, discards of drug use, insufficient light at night) turned it into a landscape of abandonment. In the past, the park had also hosted people during acute shocks (e.g. during the 1999 earthquake a lot of inhabitants had spent some nights sleeping in the park), but these had been only temporary stresses and not chronic ones, as had been the case from 2015 onwards.

Therefore, Pedion Areos appears less resilient compared to the National Garden, mainly due to a series of social pressures related to the surrounding urban area.

Equally crucial to the resilience of each site is the management model. The Municipality of Athens, which undertook the responsibility for the management of the National Garden for 90 years, in 2004, has an exclusive department (ind. 4.1.4.), staffed with trained, permanent personnel (0.18 employees/1,000m^2, including agronomists, gardeners and workers / ind. 3.1.2.), responsible for the maintenance and management of the National Garden.

In addition, having integrated the National Garden into the Athens Resilience Strategy for 2030 (ind. 4.1.3.) (City of Athens, 2016), the Municipality collects and processes digital data on plant, soil, and climatic characteristics (ind. 1.6.1.). It collaborates with various academic institutions and research networks for the transfer of knowledge and exchange of good practices regarding climate change adaptation. It has set up significant cross-sectoral partnerships and has a clear plan on how to enhance the resilience of the park by collecting and documenting data on the impact of climate change on the garden's ecosystems. Moreover, there are acute shock plans, which are followed, when specific values are reached (e.g. high wind speeds) or when the integrity of people inside the park might be jeopardised (e.g. during social disorders).

The Region of Attica is in charge of the management and maintenance of Pedion Areos. It runs a separate department for Pedion Areos which is staffed exclusively with administrative personnel (0.05 employees/1,000m^2 / ind. 3.1.2.), but lacks trained personnel for the safety and maintenance of the site. Safety and maintenance services are outsourced to sub-contractors, following public procurement procedures, which are in general time-consuming processes and might put at risk the well-being of plants ending up in the loss of some ground covering species (ind. 1.4.3.). Currently, Pedion Areos presents a rather neglected image because part of its essential infrastructure is damaged or dysfunctional, despite the recent efforts from the Region of Attica to save its greenery, restore part of its infrastructure and reactivate its historical theatre. The management model of the park is completely ineffective, failing to react quickly to improve maintenance issues (ind. 1.4.). As a result, the park has become quite unattractive for the residents of the neighbouring area. Moreover the park's administration has to deal with the negative reputation the park has gained during the last 3 years, while it was taken over by drug users. Few actions have been taken up to now to organise educational (2.2.5.), sports (2.2.1.) or cultural (2.2.4.) activities within the park, to invite people back to it. All these social components affect the park's attractiveness and undermine its resilience.

The managing bodies of both green spaces have taken measures to improve their resilience, though starting from completely different baseline conditions. The Municipality of Athens, that is in charge of the National Garden for 90 years, has set up a management team that introduced innovations, according to the international standards for the management of green spaces (GIS databases, smart agriculture apps / ind. 4.3.1.). It also collaborates and exchanges good practices with various players (universities, research networks, environmental NGOs, etc.); integrating the National Garden' s management in broader strategies for city resilience and climate change adaptation (ind. 4.3.3.).

On the other hand, Pedion Areos as evidenced by constant protests by locals (ind. 2.5.1.), has reached a neglected state, as it has suffered extensive damage and deterioration during recent years, due to the unforeseen accumulation of marginal groups (mainly drug users). The Region of Attica, who is responsible for the management of this site, failed to react immediately, and its late reactions only have had a temporary effect, as they were not part of a long-term strategic management plan. Unfortunately, the ambitious regeneration project, was soon made obsolete, failing to succeed its goals, as immediately after its completion there was an administrative gap and insufficient resources for its conservation and maintenance. Although high end bioclimatic spaces and infrastructures were designed to offer thermal comfort to the users, today a number of them is out of use, completely neglected or damaged, waterways and hydro-corridors are non-operational, while the maintenance of the greenery is just elementary (ind. 1.4.).

If these social, administrative and historic aspects are not taken into consideration, the quantitative data from Table 4 tell another, complementary story; generally, the National Garden has a slightly higher coverage of soil (ind. 1.3.2.), in comparison to hard surfaces (72.52%), in contrast to 68.18% in Pedion Areos. Yet impermeable surfaces (ind. 1.3.6.) in the former are much less (0.9%) than in the later (4.7%), while the percentage of built surfaces (ind. 1.3.8.) is greater (1.05% and 0.90%, respectively). The National Garden also has larger water surfaces (1.40%, in comparison to 0.60% in Pedion Areos / ind. 1.3.5.) and bigger density of trees – ind. 1.3.4. (0.044 trees/m^2), while Pedion Areos has 0.037 trees/m^2. From these quantitative indicators, it seems that the National Garden is more equipped with green and blue infrastructure that improves its microclimate and brings nature into the city.

Electrical consumption (ind. 1.5.5.) in the National Garden is quite low (0.19kWh/m^2), while there are no such data available for Pedion Areos. Neither of the sites has installed renewable energy sources (ind. 1.5.4.). Nevertheless, Pedion Areos consumes less water for irrigation – ind. 1.5.6. (3.40m^3/1000m^2 greenery), while the National Garden consumes 6.49m^3/1000m^2 greenery. Nonetheless irrigation in the latter is also combined with water fed to the artificial lakes and fountains, thus the amount of water consumed only for irrigation is hard to measure. Both spaces are watered through underground water, without consuming potable water for irrigation. Both sites compost their byproducts (ind. 1.5.2.), while there are no separate recycling bins in either park (ind. 1.5.1.).

Comparative evaluation of the two parks shows that sites with similar environmental characteristics (planting, soil cover, vegetation cover, (Figure 3 and Table 4) can evolve quite differently in terms of their resilience.

The wider urban context in which the site is located, the urban dynamics and the management model of the site are of great importance. So is the existence of a strategic management plan and the users' participation and interest for the site. Citizens' empowerment and activation may "feed" the managing body with innovative ideas and help to better monitor the site and thus contribute to its proper maintenance.

The dynamics of both systems are very promising, provided that there is a long-term plan to enhance their resilience. The plan should be based on a concise description of the current state based on quantifiable data, so as to register the systems potential.

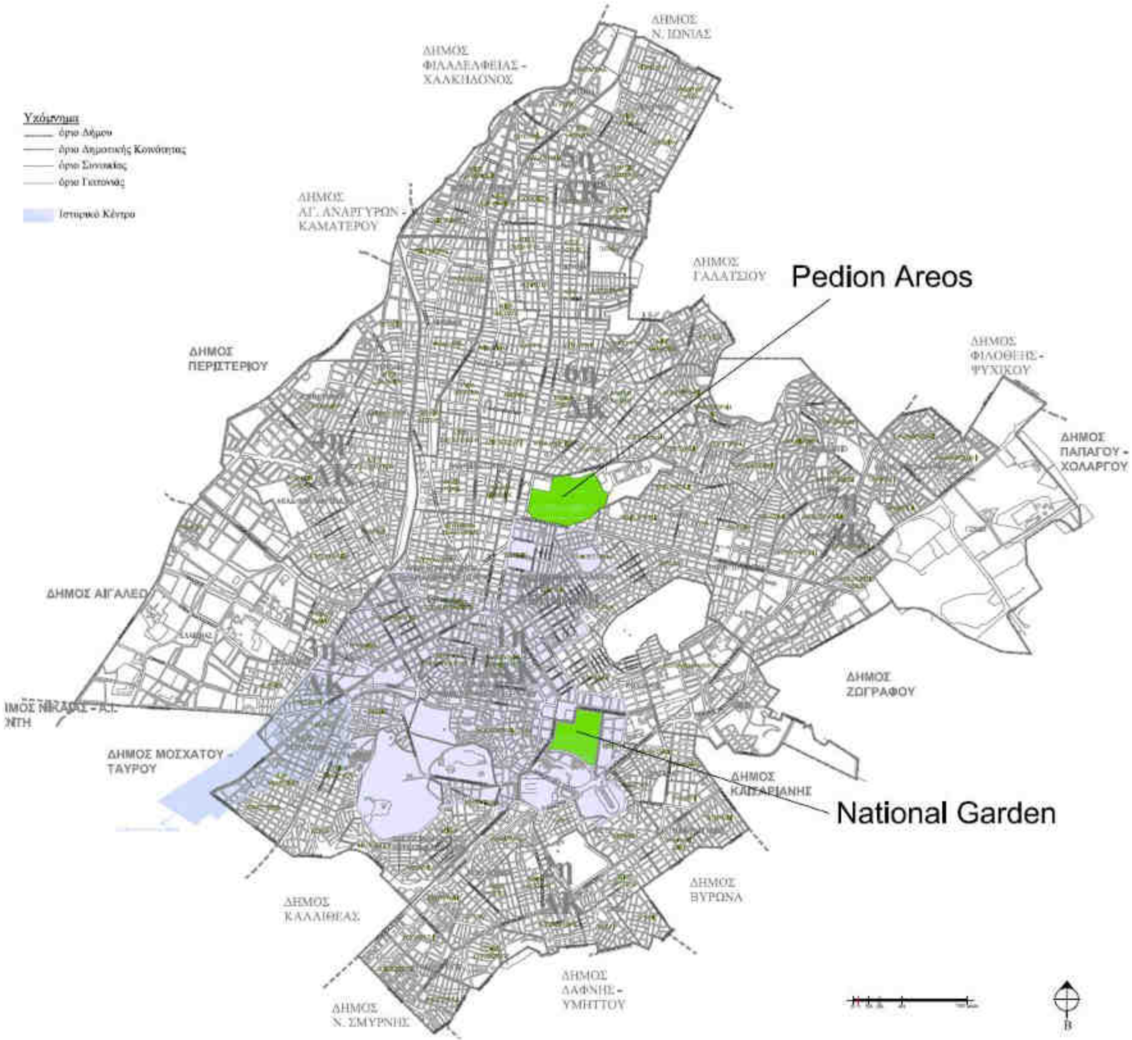

Figure 4: The National Garden, Pedion Areos and their relation with the urban fabric of the Municipality of Athens.

Table 1: Criteria for developing indicators for the evaluation of the resilience of urban, green spaces.

ENVIRONMENTAL DIMENSION	
1.1 Total area of green space	1.1.1. Total area (in hectares)
1.2 Components of the built environment (within 300m radius from the green space)	1.2.1. Building density / average floor area ratio 1.2.2. Average building height / average number of floors 1.2.3. Average road width 1.2.4. Land use 1.2.5. Residential density (number of residents/Ha)
1.3 Green space characteristics	1.3.1. Soil cover percentage 1.3.2. Percentage of vegetation cover 1.3.2. Percentage of impermeable surfaces 1.3.4. Number of trees/1000 m^2 of green space 1.3.5. Percentage of water surfaces 1.3.6. Endemic/alien species ratio 1.3.7. Biodiversity index 1.3.8. Percentage of built surfaces
1.4 Quality/Adequacy of equipment	1.4.1. Urban furniture quality 1.4.2. Infrastructure quality 1.4.3. Cleanliness - Maintenance
	1.5.1. Waste recycling

1.5 Components of Circular Economy	1.5.2. Composting of organic matter/waste 1.5.3. Secondary water treatment 1.5.4. Use of renewable energy sources / Annual electricity production (in kWh / m^2 of green space) from renewable energy sources 1.5.5. Annual electricity consumption (in kWh / m^2 of green space) from conventional energy sources 1.5.6. Annual water consumption (in m^3/m^2 of green space)
1.6 Climate Data	1.6.1. Annual recording of climate data
1.7 Environmental Quality	1.7.1. Atmospheric pollutants (CO_2, N_2O_x, S_2O_x, O_3, particulate matter) 1.7.2. Soil Quality (acidity or alkalinity, salinity, etc.) 1.7.3. Water quality (acidity, salinity, organic load) 1.7.4. Noise pollution
SOCIAL DIMENSION	
2.1 Demographic profile of residents – potential users -, in the wider area	2.1.1. Population composition – family status 2.1.2. Percentage of population by age group 2.1.3. Employment rate – Unemployment rate 2.1.4. Percentage of population at risk of poverty - vulnerable households 2.1.5 Educational status
2.2 Land use within the urban park	2.2.1. Sports facilities 2.2.2. Playgrounds 2.2.3. Recreation (café-restaurants) 2.2.4. Cultural facilities 2.2.5. Educational programs
2.3 Accessibility - Connectivity	2.3.1. Accessibility by public transport 2.3.2. Bicycle lanes - bicycle parking spaces 2.3.3. Accessibility for the disabled
2.4 Safety	2.4.1. Site enclosure – controlled entrances 2.4.2. Surveillance - security personnel 2.4.3. Adequate lighting
2.5 Social Networks	2.5.1. Active citizen groups - associations, NGOs, volunteers
2.6 Emergency plan	2.6.1. Plan for use of the site in case of emergency (earthquakes etc) -
ECONOMIC DIMENSION	
3.1 Maintenance cost of green space	3.1.1. Detailed annual maintenance cost of the site/m^2 3.1.2. Number of employees in the management and maintenance of the site / m^2
3.2 Annual revenue from commercial activities within the park	3.2.1. Revenue from renting recreation spaces 3.2.2. Revenue from the plant nursery 3.2.3. Revenue from organising cultural activities
3.3 Activate alternative funding sources to enhance resilience	3.3.1. Leverage funding from European programmes 3.3.2. Sponsorships – Crowd funding
INSTITUTIONAL DIMENSION	
4.1 Green space management model	4.1.1. Management by a public or private body 4.1.2. Co-management with active citizen groups - NGOs 4.1.3. Long term strategic management plan 4.1.4. Clear legislative - administrative framework
4.2 Action plans and risk assessment plans	4.2.1. Scenario-based Risk Assessment and Risk Management Plans 4.2.2. Hazard Maps
4.3 Monitoring - evaluation model	4.3.1. Periodic data collection and digitalisation and database enrichment 4.3.2. Annual report of actions 4.3.3. Evaluating the effectiveness of actions 4.3.4. Certification of all materials and evaluation process

Table 2: SWOT Analysis for the National Garden.

<table>
<tr><td colspan="2">NATIONAL GARDEN</td></tr>
<tr><td>STRENGTHS</td><td>WEAKNESSES</td></tr>
<tr><td>Centrally located in Athens – metropolitan character
Historic – monumental character
High percentage of green cover – favourable microclimate
Trees are in good condition
High percentage of water permeable surfaces
High biodiversity index
Large number of daily visitors
Easily accessible by public transport
Adequate Safety
Contains many attractions: playground, café, a zoological collection of farm animals, statues (some of them quite important), 19th century metallic structures (some of them connected with Queen Amalia), archeological spaces and artifacts
Cultural and educational activities
Plenty of activities so that children and adults familiarise themselves with the Garden and its services
GIS database of all plant species in the park
Transfer of knowledge from / to academic and research networks
Risk management plan
Adequately trained personnel
Nursery, where seeds and plants for the Garden are produced
Self-sufficient in water</td><td>Climatic conditions
Lack of interpretive signage on the historic identity and significance of the Garden
Vulnerability of old and tall trees to severe weather conditions
Old obsolete infrastructure
Inadequate maintenance – damaged equipment
Lack of financial resources for infrastructure maintenance</td></tr>
<tr><td>OPPORTUNITIES</td><td>THREATS</td></tr>
<tr><td>Design thematic walks and signage to highlight the historic significance and biodiversity of the National Garden
Enhance the relationship between the National Garden and adjacent green spaces and archaeological sites
Develop participatory activities with citizens groups
Develop applications to explore user's preferences and plan customised actions
Finance actions and plans through European funding programs
Expand collaborations with academic and research institutions to collect and process digital data
Adequate dissemination activities for the educational, sports and cultural activities taking place inside the Garden
Create an integrated management and monitoring plan
Produce all necessary seeds and plants in the Garden's nursery
In situ use of biomass and manure
Waste recycling
Water recycling
Creation of rainwater reservoirs for irrigation
Upgrade existing infrastructure (stabilise pathways, restore 19th century metallic structures)
Closer collaboration with the Ministry of Culture and Sports, so as to put the antiquities of the Garden in the epicentre</td><td>Climate change
Atmospheric pollution
Drought – Poor underwater conditions
Economic crisis
Mistrust - lack of confidence in public authorities</td></tr>
</table>

Periodic measurements for each individual resilience parameter and the maintenance of systematic databases are the necessary background for identifying and subsequently applying resilience indicators that are in line with international trends.

The contribution of users in the evaluation, monitoring and management of green sites is valuable. Furthermore, engaging community members in maintenance and inspection activities could help relieve pressures on limited resources and thus enhance resilience. It was the mobilisation of active citizens and their ongoing interest that prevented the complete collapse of Pedion Areos, by forcing the managing authority to take immediate action to improve the situation.

Nevertheless, the active involvement of the public in the management of open public spaces constitutes the modern European trend (e.g. Green Surge, Green Keys). Users can gather and exchange information on the quality of services, suggest solutions to existing problems, volunteer for cleanup, damage recovery, maintenance, etc. suggest - organise educational and recreational programs etc. The managing authority can deploy feedback from the users, in order to improve the management model of the site and the relationship between the managing body and citizens in a more interactive and creative one, enabling both actors to respond faster to both acute shocks or chronic stresses. By leading engagement programs that offer people meaningful opportunities to provide input, think more broadly about their park, and stay involved, the site could gradually become more attractive to the users by identifying their wishes and preferences.

Table 3: SWOT Analysis for Pedion Areos.

PEDION AREOS	
STRENGTHS	WEAKNESSES
Located in the centre of Athens High percentage of green cover The greenery is in good condition High percentage of water permeable surfaces Highly interested active citizen groups Historic character Contains playground, historical café and theatre infrastructures, as well as statues and important sculpture, such as the Grotto of Pan (1962, by Vassalos) Recent regeneration project	Atmospheric pollution Lack of interpretive signage on the history identity and significance of the park Vulnerability of old and tall trees to severe weather conditions Inadequate staff The dependence on subcontractors reduces the ability for immediate intervention / inability to react efficiently to acute shocks, thus turning them to chronic stresses Ineffective management model Obsolete and neglected infrastructure Extensive damage to the irrigation system Inadequate safety Limited accessibility
OPPORTUNITIES	THREATS
Refurbish and reactivate the features of the recent regeneration project, so as to do away with the sense of abandonment in some parts of the Park Collaborate with the Ministry of Education and Religion, so as to develop educational activities to attract targeted groups Organise thematic walks to highlight the biodiversity and significance of the park Expand collaborations to collect and process digital data Develop participatory actions with active citizens groups so as to create a new, more efficient management plan for the Park Reactivate historical infrastructures, in collaboration with local SMEs, thus create hubs for collectives, in order to bust up economic activities in the area Develop applications to explore user's preferences and plan customised actions Develop educational, sports and cultural activities to attract targeted public / adequate dissemination activities Leverage alternative funding (from European programmes, sponsors etc.) Create opportunities for green jobs Create an integrated management and monitoring plan In situ use of biomass Waste recycling Water recycling Reservoirs to use rainwater for irrigation Production of seeds and plants inside the Park	Climate change Atmospheric pollution The surrounding urban area has suffered social collapse Drought –poor underwater conditions Economic crisis Mistrust - lack of confidence in public authorities

Table 4: Quantitative and qualitative assessment of resilience indicators for the National Garden and Pedion Areos.

Indicator-based comparative evaluation			
	NATIONAL GARDEN	PEDION AREOS	Indicator of Table 1
Total area of green space	154,000 m^2	220,000 m^2	1.1.1
Percentage of soil coverage	72.52%	68.18%	1.3.2
Percentage of water surfaces	1.40%	0.60%	1.3.5
Percentage of built surfaces	1.05%	0.90%	1.3.8
Number of trees/ m^2 of green space	0.044	0.037	1.3.4
Percentage of impermeable surfaces	0.9%	4.7%	1.3.6
Number of employees/1,000m^2 of green space	0.18	0.05	3.1.2
Number of residents / Ha	250	500	1.2.5
Annual electricity consumption (kWh/m^2) of green space	0.19	No data available	1.5.5
Daily irrigation requirements (m^3 /1000 m^2 greenery)	6.49 [are combined with lakes and fountains]	3.40	1.5.6
Recycling	NO	NO	1.5.1
Composting	YES	YES	1.5.2
Use of renewable energy sources	NO	NO	1.5.4
Collection and process of climate data	YES* *in progress	NO	1.6.1
Safety	Good	Average	2.4
Administrative framework	Satisfactory	Insufficient	4.1.1

6. Conclusions

International experience in the field of urban resilience is constantly enriched, under the pressures of climate change and emerging socio-economic phenomena. As a result, the concept of resilience gradually prevails over sustainability.

There is a growing global scientific interest for the development of Resilience Indicators and their introduction in urban design. However, resilience is an extremely complex, multifactorial and dynamic concept, and indicators reflect this situation only partly. Thus, further research is needed in order to formulate a more effective framework, within which more informative and better adaptive resilience indicators can be developed, without the risk of misinterpretation or misuse of the term (Schipper E.L.F. and Langston L., 2015). Further improvements are needed to account for dynamics over time and across space.

Referring in particular to urban green spaces, resilience indicators, corresponding to the pillars of environment, society, economy and governance require adaptations to the micro-scale of local conditions.

The complex legislation scheme and the overlapping authorities' responsibilities in Greece constitute an important obstacle to the rational management of urban green spaces, such as the aforementioned ones. The Municipality of Athens has made substantial progress on the administrative level, by developing multiple collaborations and introducing innovations in the management of the park.

It is necessary to create mechanisms, able to prevent chronic stresses and acute shocks. Knowing which mechanisms to activate when necessary is the next crucial step; strategic plans, updated and tested regularly, including all interconnected officials and pertinent players can help green spaces overcome efficiently and fast any foreseen crisis. Yet again, the managerial and economic autonomy of a green space, as well as its equipment with adequate personnel (agronomists, gardeners, workers), regarding everyday necessary activities, seems the most suitable way to prevent redundant catastrophes, such as aridity.

The systematic collection of data for a range of urban green spaces, the maintenance, monitoring and use of updated databases are indispensable for the development of reliable indicators, tailored for the resilience of these sites.

The capacity of the managing bodies to intervene fast when the values of these indices surpass certain limits and to activate specific mechanisms or to take the necessary actions is crucial, so as to face several problems before they turn into crises. Apart from that, the use of these measurements / collected data in order to assess upper and lower limits for each index is fundamental for creating common resilience instruments for urban green spaces across the globe. A benchmarking approach could be beneficial for the creation of such scales.

The involvement of end-users in evaluating operating conditions as well as in proposing and formulating improvements is very important. Authorities should encourage players and citizen participation in developing assessment tools, with a view to combining a bottom-up with a top-down approach. Collecting and processing appropriately structured questionnaires is a key tool in identifying public trends and therefore in defining a specific resilience strategy.

The well-being of urban dwellers is directly related to the resilience of urban green spaces. On the other hand, threats to their resilience are intensifying. Therefore, as more and more cities develop resilience strategies, it is useful to benefit from this experience and expertise, to develop commonly accepted indicators for the evaluation of urban green spaces.

However, resilience is a complex concept which cannot be adequately described solely through a deterministic approach that quantifies it, such as the use of certain criteria and indicators, which attain certain values. Indicators can only be part of a tool that assesses some components of resilience and not the tool itself. Understanding interconnections, synergies and crucial factors that affect the resilience of green spaces are the key elements for estimating its resilience and also for making and activating resilience plans for an urban park.

The scope of the aforementioned tool is to help local authorities build the capacities needed to effectively and efficiently manage urban green spaces, with a view to enhancing their resilience over time.

About a century ago, the Committee for National Gardens and Tree Lines had been formed by the Greek State, in order to rescue and increase green spaces in Athens. Thanks to that institution, the National Garden was saved and Pedion Areos was created. With the potential that the concept of resilience offers today, there is no need to have to face disasters in order to take action, but to use adequate resources and tools; to create mechanisms and set in practice action plans so as to ensure the resilience of urban, green spaces under any circumstances, chronic stresses or acute shocks.

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Megacities, Energy and Climate Change

Panagiotis D. TASIOS
Department of Environmental Physics and Meteorology, National and Kapodistrian University of Athens

Despoina I. KOUMENOU
Attica Tollway S.A.

John A. PARAVANTIS [1], *Associate Professor*
Department of International and European Studies, University of Piraeus

[1] *Contact details of corresponding author*
Tel: +30 210 4142771
e-mail: jparav@unipi.gr & paravantis@gmail.com
Address: 80 Karaoli & Dimitriou Street, Piraeus, 18534 Greece

Abstract

Urbanization and climate change are two major issues that humanity faces in the 21st century. United Nations data show that the urban population of more and less developed regions will represent almost three quarters of the total population in 2050. Megacities are large urban agglomerations with more than 10 million inhabitants that emerged in the 20th century. The world's top 100 economies include: many North and South American megacities, such as New York, Los Angeles, Chicago, Mexico City, Toronto, Sao Paolo and Buenos Aires; European cities such as London and Paris; and Asian cities such as Tokyo, Osaka/Kobe, Seoul, Shanghai and Mumbai. Their rapid economic and population development amounts to a ballooning ecological footprint and threats to human health as well as geopolitics. Megacities are major greenhouse gas emitters, and today represent about 15% of global GDP, 12% of global waste disposal, and almost 10% of electricity use. In this paper, a review of megacity research with emphasis on their energy metabolism and the Urban Heat Island is presented. Urban planning and transportation systems constitute interconnected components that affect the development of infrastructure. In particular, the role of transportation governance is examined as a contributing mechanism of area expansion and megacity development. Socioeconomic, energy and environmental data concerning the biggest megacities are described and analyzed. Changes in use of the built environment are depicted in energy consumption and emissions. Research that carries out a similar analysis of a complete list of megacities is forthcoming.

Keywords: Megacities, urbanization, climate change, air pollution.

1. Preamble

This paper assesses the contribution of megacities to climate change by focusing on trends and findings related to their following aspects: growth and expansion over time; energy consumption and carbon dioxide emissions; ecological footprint; urban sprawl and transport governance; and the Urban Heat Island (UHI) and heat mortality.

2. Urbanization

"Cities have developed into the hotspots of human economic activity" (Folberth G. A. et al., 2015). This is the case for many cities throughout history since many traits and characteristics that apply on modern cities, applied also on many settlements of the past. After the emergence of towns and cities, made possible by the onset of agriculture 10,000 years ago (Bugliarello G., 2009), cities like the ancient city of Babylon (2300 BC), Athens (1500 BC) and Rome (750 BC), and later New York (1898 AD) and Beijing (1045 BC) have been at the epicenter of human activities and processes. Industrial revolution and technological advancements brought many changes, affecting significantly both urban and rural areas (Franco S. et al. 2017). Factories settled near the cities provided job opportunities and higher wages, and posed a major motive for rural residents to migrate into the cities, trying to achieve better living conditions for them and their families.

Furthermore, the progress that was made in technology and science, provided the farming sector with the necessary tools and equipment, improving the production process. That lead many workers in the farming sector to unemployment and subsequent migration since new machines were more efficient in production and cost. In addition, wars, rural degradation and lack of natural resources boosted migration to urban areas (Madlener R. & Sunak Y., 2011). There is little doubt that, in terms of demographic change, the transition of people from rural areas to cities has represented a revolution of historic magnitude (Evans M. 2016).

From 1950 until 1980 and at different times in each country, the world experienced the most intense industrialization and urbanization process. Many cities were rebuilt and new cities were established, enabling growing industrial production (IPEA, 2016). From that point and onward, urban population has constantly grown, beginning at 30% of the total population in 1950, surpassing 50% around 2007, and being around 55% at the time of writing (UN, 2019). This upward trend is estimated to continue, reaching 68.4% by 2050, i.e. 6.7 out of an estimated 9.8 billion.

In 1950, as shown in Figure 1, about 60% of the population lived in urban areas with fewer than 300,000 inhabitants, while just 17% resided in urban areas with 1 to 5 million inhabitants. By 2015, about 42% of the population lived in urban areas with fewer than 300,000 inhabitants, having dropped by 17.5% since 1950. At the same time, the urban population living in urban areas with 1-5 million and 10 million or more inhabitants, increased to 22% and 12% respectively, with the latter presenting the highest increase over time (8.5%). These opposite trends underscore the urbanization process that took place as the population moved from smaller settlements to larger urban agglomerations, resulting in increased urban energy consumption, higher urban air pollution etc.

Urbanization intensifies problems like crime, transport fatalities, pollution, and morbidity. These problems are directly and indirectly linked to increased administrative, infrastructure and public health costs. The statistics that are derived from related cost analyses affect risk assessment linked to insurance institutions. For example, the UHI and increased air pollution are both environmental impacts of urbanization. In the future, more climate change and more urbanization are expected to aggravate global warming and air pollution in metropolitan areas that are highly urbanized.

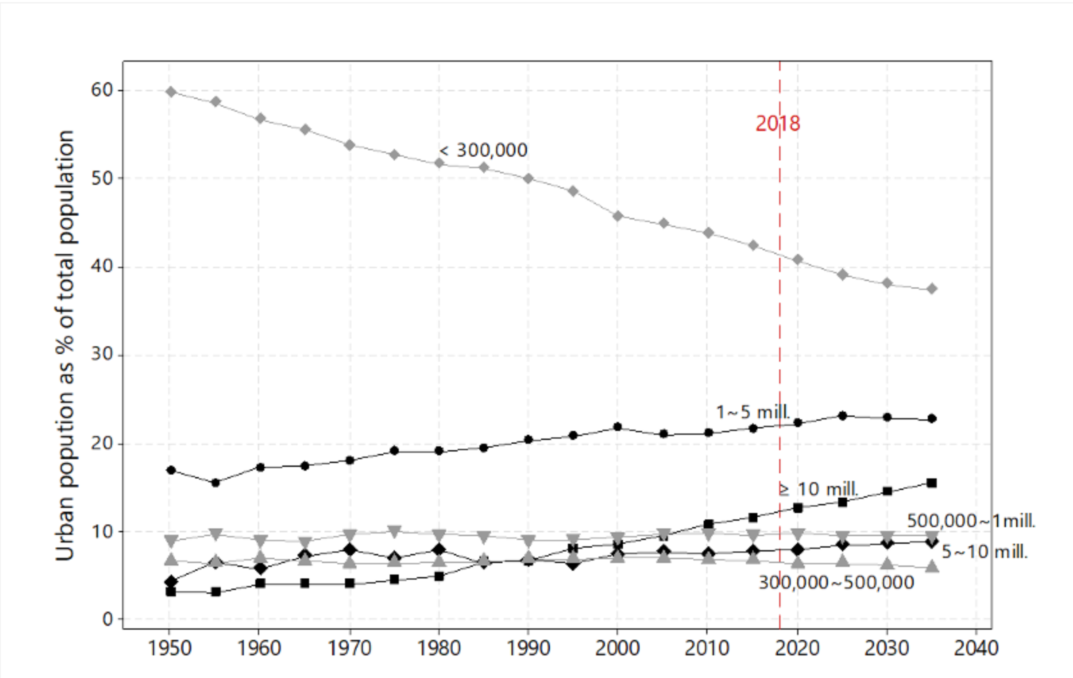

Figure 1: Urban population as percentage of total population for different city sizes (data after 2018 are projections; UN, 2019).

Such impacts will deteriorate health and comfort standards in megacities, with a bigger impact on vulnerable social groups, such as the elderly. The elderly, in particular, have a hard time both avoiding such problems (by moving to a less populated area) and confronting it (by covering rising health expenses). The predicament of elderly people is complicated by the fact that, contrary to the active workforce, they have to live on finite financial resources.

Urbanization has a direct effect on the energy consumption of urban as well as agricultural areas, since agricultural operations become more mechanized, use more commercial fertilizers, and put more effort on processing to allow foodstuff to travel further, all of which require energy further to that used in traditional agriculture (Jones D. W., 1991). According to the 2010 World Energy Outlook (IPEA, 2010), urban areas are responsible for 71% of global energy-related carbon emissions, and this percentage will increase as the urbanization trend continues. Thus, the environmental impacts of urban areas, in particular their contribution to climate change and the overall air quality, have always been apparent and a subject that had troubled scientists from various fields.

Global trends are heading towards a highly urbanized future, and the massive flow of population to urban centers added to the normal population growth, will apply more and more pressure on the already stressed urban environment.

3. Megacities

Urbanization is a striking issue of the 21st century and a determinant of the overall quality of living conditions. The massive migration from rural areas is one of the main drivers for the increasing number of megacities that, acting like spatial concentration points, contribute significantly to the increasing share of urban population and GDP to the country totals (Facchini A. et al., 2017). Megacities are the result of spontaneous processes and are complex organisms that are extremely important for the socioeconomic development of regions and countries. They are instruments of birth rate reduction, human diversity, social and cultural centers, and they have turned to economic hotspots providing new market opportunities (Bugliarello G., 2009).

Even though a specific definition does not exist (Folberth G. A. et al., 2015; Baklanov A. et al., 2016), it has been accepted (by general consensus and United Nations Population Reports) that cities that exceed a population of ten million inhabitants may be called megacities, and can be constituted either by a single metropolitan area or converged areas (Folberth G.A. et al., 2015). In 1950, there were only two megacities worldwide, New York (12.3 million) and Tokyo (11.2 million); only after 1980 the emergence of new megacities became more vigorous. Until 1980, only five megacities existed globally, with Sao Paulo, Osaka and Mexico City added to this urban group; five years later, the number of megacities almost doubled, reaching nine megacities that hosted almost 310 million residents, accounting for 6% of the global population. Until the end of the 20th century, another six megacities appeared. As shown in Figure 2, from that point on until today, the number of megacities has nearly doubled, reaching 33 megacities in 2018. According to the UN Population Division, it is estimated that they will be 48 megacities globally by 2035, in which almost one billion people will reside.

Today, over 520 million people, which accounts for 7% of global population, live in 33 megacities around the globe (Figure 3), with Tokyo being the most populated megacity, housing more than 37 million people, followed by Chongqing with almost 30 million. Of the 33 megacities, 20 are located in Asia, with a cumulative population of 334 million, accounting for almost two thirds (64%) of the total megacity population, and 5% of the global population.

Comparing the different megacities among themselves and smaller cities as shown in Figure 4, it is concluded that their population grows faster than the total population of the country they are located in. This highlights the migration pattern from smaller settlements to these huge agglomerations. To put this into perspective, Osaka's ten-year growth rate (scale of left vertical axis) was 120 times bigger than Japan's (scale of right vertical axis); similarly, Beijing's growth rate was 55 times bigger than China's; and Bangkok's growth rate was almost 50 times bigger than Thailand's. This is corroborated by Figure 1, where it was seen that the population of smaller cities (especially those with fewer than 300,000 residents) has been decreasing over time, while the percentage of the population of megacities rose from 3% in 1950 to 12% in 2015. As shown in Figure 5, the megacities that presented the highest growth rates were those with a lower GDP per capita (e.g. Delhi, Lagos); as the megacity GDP per capita increased, the population growth decreases. This observation was also made by Kennedy C. et al. (2015), who noted that cities that were characterized with a fast increase of their population were cities like Dhaka and Beijing, whereas megacities like New York, Osaka and Tokyo increased at a slower pace. So, poor megacities grew faster; as they became richer, they slowed down.

Extreme environmental phenomena are key dynamic components that affect population mobility towards already developed areas. Several such environmental impacts have been noted in the recent years, correlated with intensifying competition for scarce resources and climate change effects such as sea level increase and the occurrence of tsunamis. Rapid economic growth and urbanization have consequences.

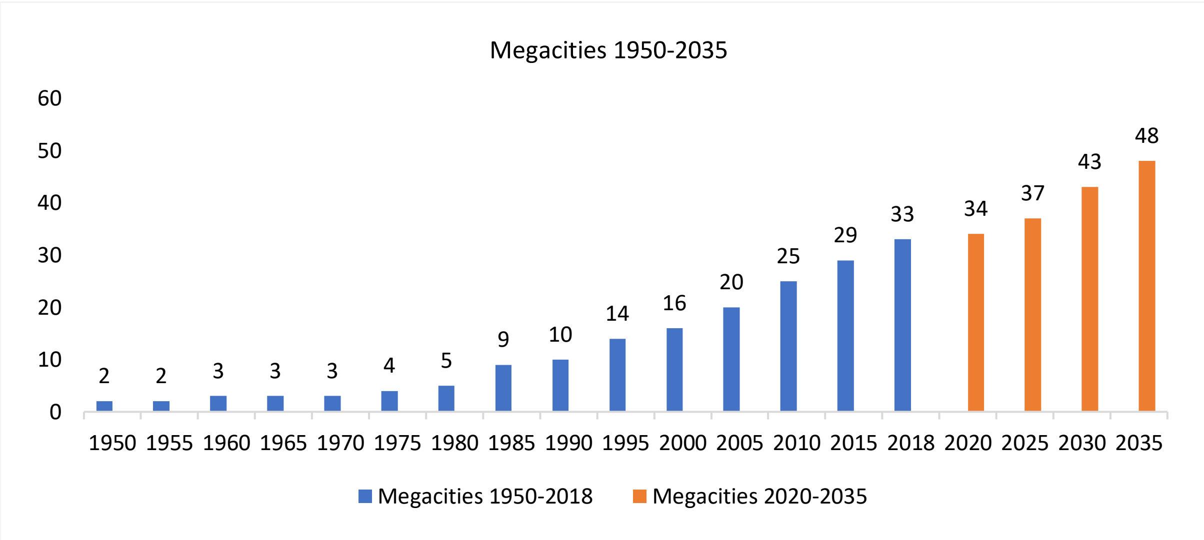

Figure 2: Number of megacities 1950-2035 (UN, 2019).

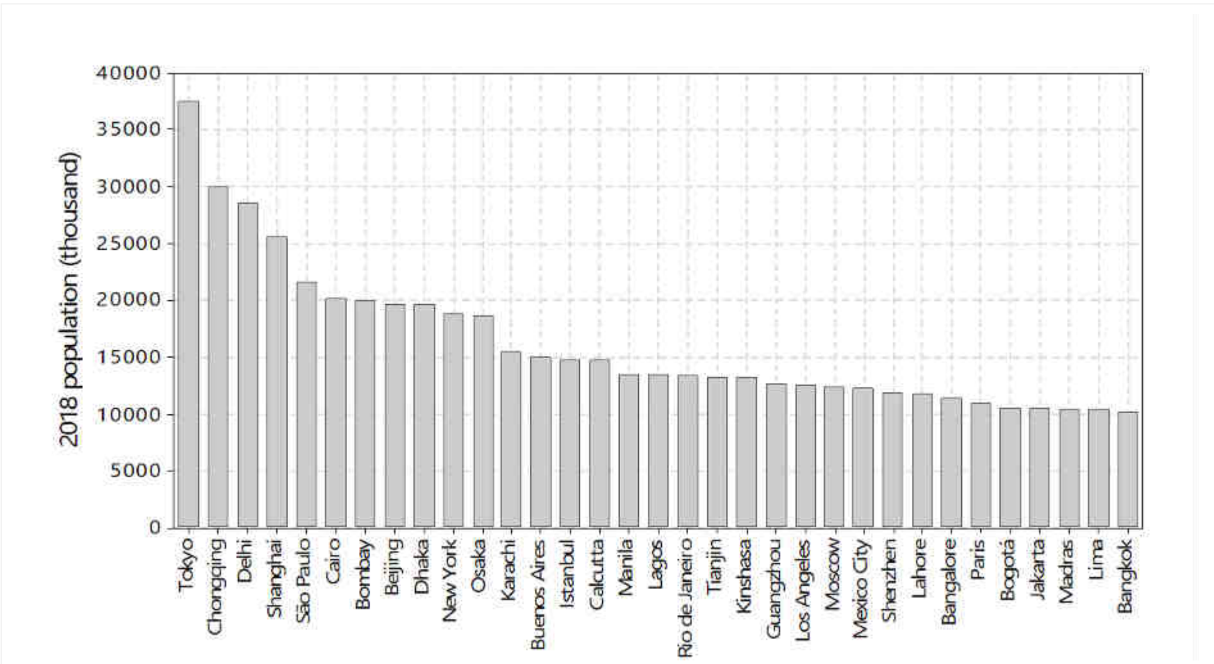

Figure 3: 2018 megacities population.

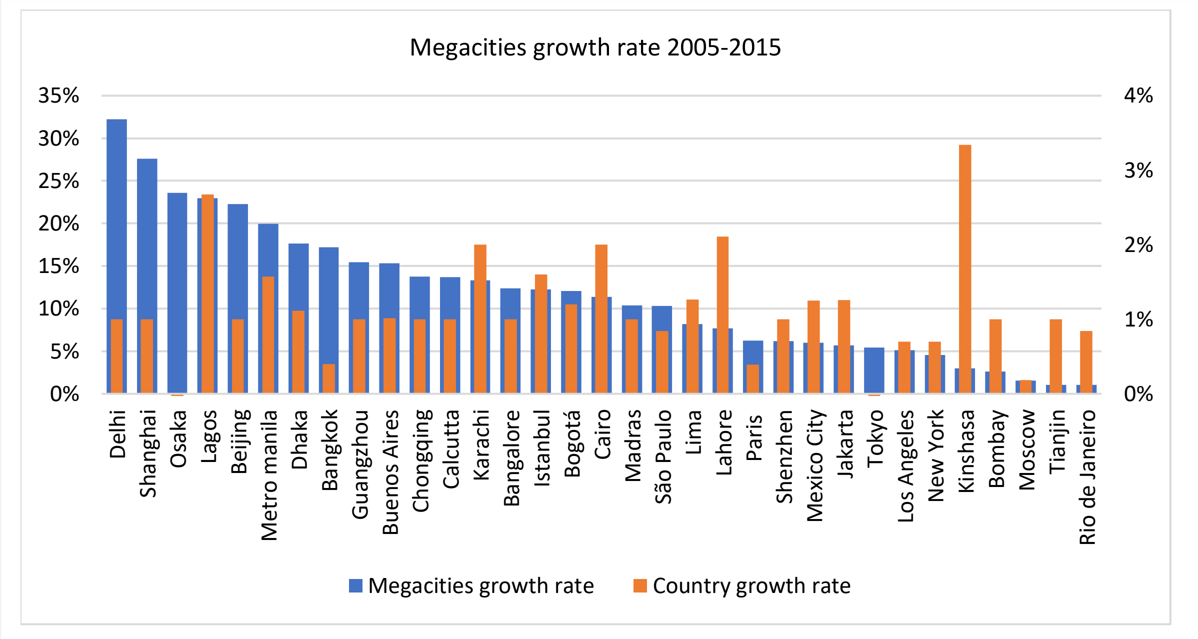

Figure 4: 2005-2015 growth rate of megacities (left vertical axis) scale and countries (right vertical axis scale).

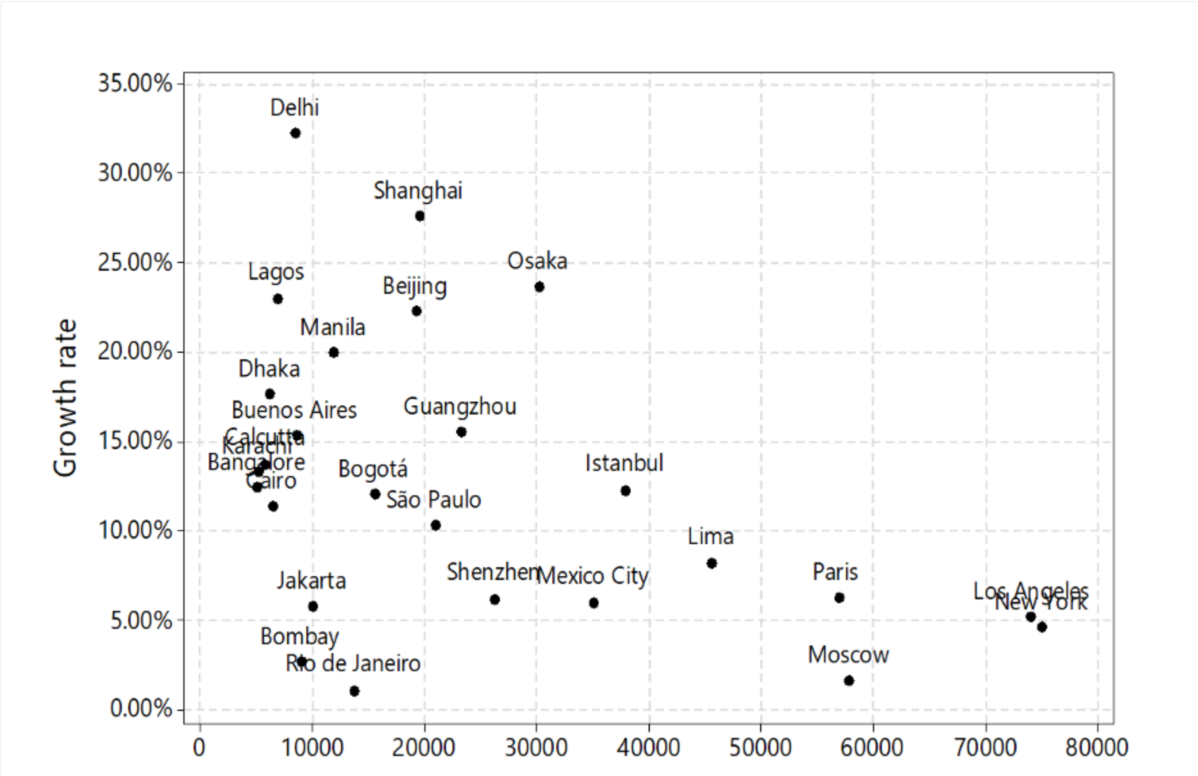

Figure 5: Growth rate/GDP per capita.

According to O' Dempsey T. (2009) and Munslow B. and O' Dempsey T. (2010), the non-strategically planned growth of megacities transforms them to unmanageable metropolitan areas. Crowded living conditions and lack of access to key amenities (such as clean water) are a direct consequence, and set the megacity populations at risk of fatalities and epidemics. Moreover, the rapid urban growth, high population density and high consumption rate of residents in megacities have led to a wide range of local and global socioeconomic and environmental impacts. These require attention from the world community since they affect global sustainability and future prosperity; thus, they have attracted the interest of scientists and researchers from various fields.

4. Energy consumption and carbon dioxide emissions

Megacities are complex economic and metabolic centers in constant need of energy and other resources. According to Kennedy C. et al. (2015) megacities account for 15.2% of global GDP, 11.7% of global waste disposal, and 9.3% of electricity use with megacities like New York, Los Angeles and Tokyo being economies of a 1 trillion GDP. While cities occupy only 2% of earth's area, and megacities even less, they account for over 70% of energy consumption and related carbon emissions having significant impact in global warming and climate change (Madlener R. & Sunak Y., 2011). To accommodate the influx of more people to urban areas, leading megacities will grow rapidly in both number and population, mainly in Africa (122%) and Asia (67%).

To meet their needs and sustain their development, cities are in constant demand of more food, water, fuel and energy, which in turn causes increasing emissions, refuse and wastewater disposal (Kennedy C. et al., 2008). Climate change is regarded as a crucial and urgent problem, with global impacts such as increasing global temperature, sea-level rise, and desertification. The 2015 Paris Agreement is considered a milestone in the struggle against climate change, setting important targets to limit the global temperature increase bellow 2℃, and even 1.5℃ in the long run. For the first time, cities took a front runner role in this struggle, since the energy landscape is largely shaped by cities (IEA, 2014). Most energy consumption occurs in cities because of the high concentration and intensity of human activities. As shown in the scatterplot of Figure 6, total energy consumption is positively associated to GDP per capita, with their natural logarithm-transformed values exhibiting a moderately strong linear relationship; this linearity in natural logarithms means that as GDP per capita changes by one percent, energy consumption changes by one percent as well. With cities like Bangalore (India), Lagos (Nigeria) and Dhaka (Bangladesh) being at the bottom left end, and cities like Los Angeles, New York, Paris and Moscow at the upper right end of the relationship, it is obvious that megacities in rich countries were locations of high energy consumption. The relationship between these two quantities will be investigated further in a forthcoming publication by the authors of this research.

Kennedy C. et al. (2015) were among the first to report on megacities and their energy metabolism. They examined 27 megacities, with New York having the highest 2011 energy consumption (2,600 PJ) followed by Tokyo, and the lowest energy consumption being recorded in Kolkata (78 PJ). The total energy consumption of megacities was reported to account for 6.7% of global energy consumption and 10% of global electricity consumption. New York scored a higher overall energy consumption than Tokyo (which was the most populated city) because it consumed about twice as more energy per capita on transportation and heating. In terms of electricity consumption, Tokyo recorded the highest electricity consumption (241,000 GWhr), followed by Los Angeles (153,000 GWhr) and New York (149,000 GWhr).

Megacities produce enormous amounts of pollutants, waste, and greenhouse gas emissions. Because of their high population density, the production of raw materials or energy cannot occur locally and must be transferred from other areas. This material and waste transportation put even more pressure on the environment. Moran D. D. et al. (2018) estimated the emissions of 13,000 cities around the world, including most megacities with a model incorporating various socioeconomic factors. Urban versus rural energy patterns and purchasing power have been shown to influence carbon footprint and were two important predictors taken into account. Wiedenhofer D. et al. (2018) showed that income was also an important predictor of carbon footprint. In another study conducted by Minx J. et al. (2013) for cities in the United Kingdom, carbon emissions were found to be strongly related to socioeconomic factors.

All in all, Chinese megacities are important contributors to climate change. Guangzhou had the highest annual carbon dioxide emissions, emitting 272 million tons of CO_2 (3% of total emissions of China) (Moran D. D. et al., 2018).

Chongqing recorded the second highest carbon dioxide emissions (about 225 million tons of CO_2), while Shanghai was responsible for 200 million tons of emitted CO_2.

In total, Chinese megacities accumulated 851 million tons of carbon dioxide emissions,

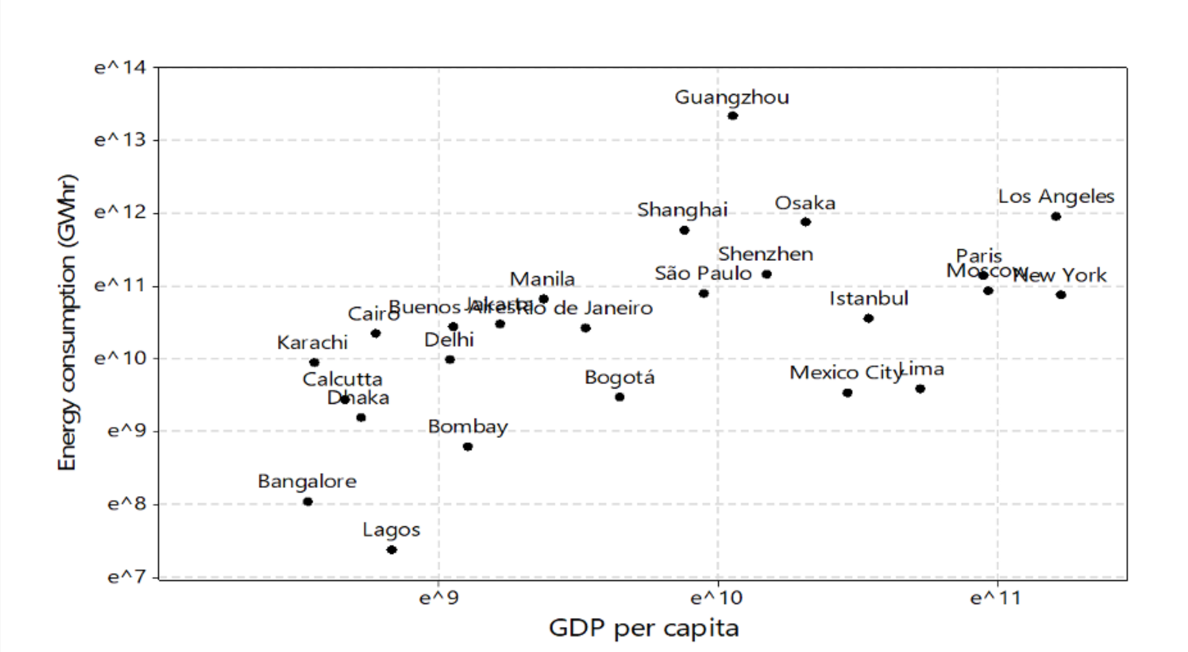

Figure 6: Total energy consumption over GDP per capita.

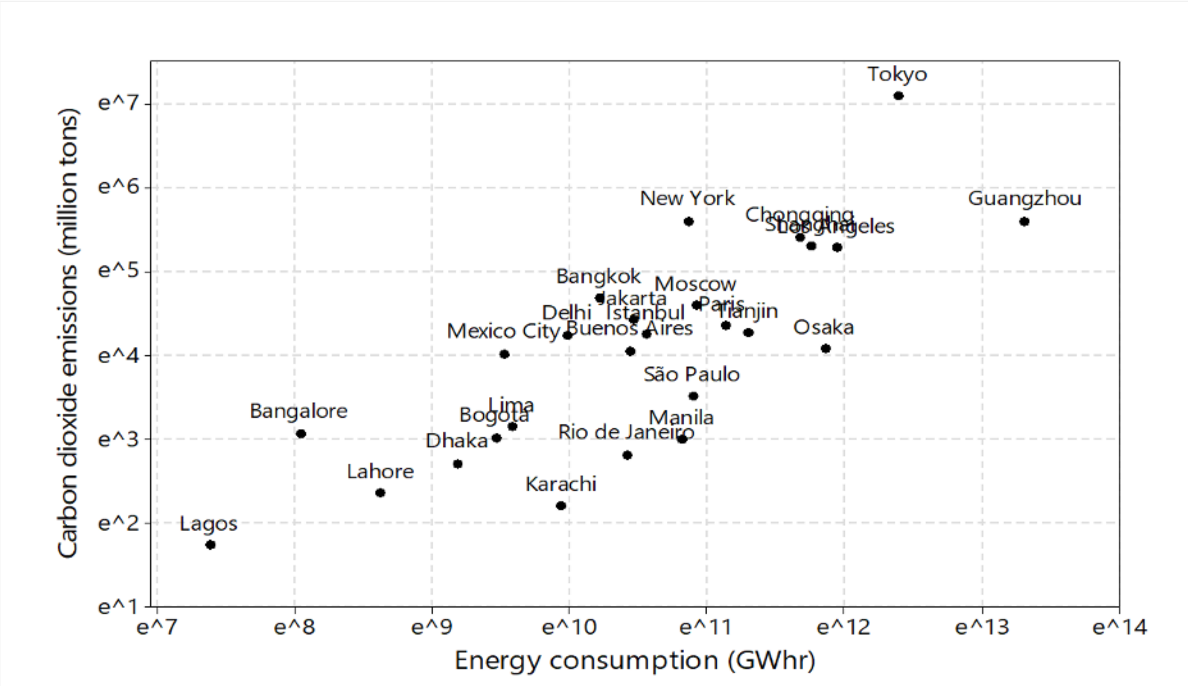

Figure 7: Carbon dioxide emissions as a function of energy consumption of megacities.

an amount that accounted for 10% of the total CO_2 emissions of China. In comparison, the megacities of North America emitted 360 million tons annually, accounting for 5% of total emissions of the region. Carbon dioxide emissions from cities are projected to undergo rapid change over the next two decades with growth in developing countries and stabilization in developed countries.

The scatterplot of Figure 7 shows that there is strong linear relationship between the natural logarithm of CO_2 emissions and the natural logarithm of the energy consumption of megacities. So, as energy consumption increases by one percent, CO_2 emissions also increase by one percent. Energy consumption is a strong predictor of CO_2 emissions, a fact that will be exploited further in a forthcoming publication by the authors of this research.

Further to climate change, since energy consumption is a necessary input for heating buildings and moving cars, it is also associated to a variety of urban air pollutants, which are sufficiently high to cause increased mortality, morbidity, deficits in pulmonary function and cause cardiovascular symptoms in certain areas (Mage D. et al., 1996).

5. Ecological footprint

The environmental impact of megacities (at a local, regional or global scale) may be expressed in various footprints, e.g. ecological, atmospheric or climate. The ecological footprint is defined as the area required to sustain the population of an area, provide the needed materials and resources for its operations and the management, process and disposal of its waste.

Adopting the usual approximation of the biocapacity (i.e. the capacity of ecosystems to regenerate what people remove from their surfaces) being equal to 1.6 hectare per person, a city like New York (with a population of almost 20 million) would need an area of 300,000 km² for subsistence; such an area is twice the surface area of Greece (131,957 km²), and equivalent to the surface area of Italy (301,338 km²). At the time of writing, the megacity with the highest ecological footprint is Tokyo (37.5 million inhabitants), reaching up to a stunning 600,000 km². To put this into perspective, Tokyo needs a surface area almost twice the size of Japan. Similarly, the megacity of Dhaka (19.6 million inhabitants) has an ecological footprint of 313,000 km², which is 2.4 times the surface area of Bangladesh. Other megacities with a significant ecological footprint to country area ratio are Osaka (0.82) and Metropolitan Manila (0.72). Bangkok on the other hand appears to have a small ecological footprint (199,000 km²).

More precise calculations of the ecological footprint would take into account that the biocapacity factor varies from year to year and from country to country according to ecosystem management, agricultural practices, ecosystem degradation, weather, and population size.

6. Urban sprawl and transport governance

The operational objectives of a country's transport strategy are to formulate proposals for national development in the transport sector; to promote innovative applicable programs towards sustainable transport; to propose development measures in the supply chain; and the formulation of national policy on matters concerning relations between the country and international organizations. The geography of a country determines its role in the global affairs by playing a determining role in the formation of networks, connectivity and partnerships (Hussain F. & Hussain M., 2017).

The growth of transport systems and development of infrastructure helped generate urban sprawl, and both of these trends contributed to the expansion of megacities when oil was cheap. In this era of peak oil and climate change, there is a need for retargeted urban planning and optimal management of transportation systems. Both of these targets may mitigate the environmental impacts of megacities, but involve high cost endeavors. Managing urban spaces and coordinating transport systems are interconnected tasks. Building and transport energy consumption depends on colonization density and operating allocation. Changes translate to emission alterations. Urban sprawl affects neighboring environmental areas, complicating and widening the environmental footprint of megacities (Tortajada C., 2008).

7. Urban heat island and heat mortality

Besides the global warming associated with climate change, cities face local problems like the UHI effect. The UHI is defined as the phenomenon where the temperature in urban areas is higher that its rural surroundings; it is measured by the Urban Heat Island Intensity (UHII), which equals the maximum temperature difference between the urban area and its rural environment (Arifwidodo C. and Chandrasiri O., 2015).

The urban heat island causes downtown areas, which are commonly more densely populated and concentrate large building infrastructures for various activities (residential, tertiary services, company offices, etc.) as well as transportation infrastructures, to have the highest temperature difference from the less populated areas of the city. Green parks act like temperature soothing spots and must be preserved in highly populated areas.

The UHI is one of the most documented urban aspects of climate change (Santamouris M., 2015) and can be used as an indicator of urbanization (Memon R. A. et al., 2009). The UHI is the result of various controllable and uncontrollable parameters (Oke T. R. et al., 1991), including the following: anthropogenic heat released by heating systems, air conditioning, cars, etc.; thermal properties of materials of buildings, pavements and other open spaces; urban greenhouse effect (caused by the high concentration of air pollutants); radiative properties of urban canyons; reduced heat transfer within streets; and reduction of evaporating spaces in the urban environment.

The UHII is maximum during the night since the heat absorbed by buildings, roads and other infrastructures during the daytime is emitted back to the environment. As urbanization increases, the UHI effect intensifies, since the massive flow of population into urban areas leaves less space for green areas and vegetation, whereas spaces are covered by roads, buildings and other cement infrastructure, decreasing the city's ability to control its temperature. Furthermore, the emitted heat from cars, transportation vehicles and other anthropogenic activities enhance the UHI effect even more.

Figure 8 illustrates how the average UHII of many megacities affects their microclimate. Most documented cases have reported UHII varying from one to 15°C. The highest UHI intensity reported by Tzavali A. et al. (2015) was for the megacity of Tokyo, where the UHII reached 12°C; a more recent report by Honjo T. (2019) found the UHII to be mostly around 10°C for 2014, reaching a maximum of 15°C. In Calcutta, the maximum UHII in 2012 was 8.8°C, with the temperature in the urban area of Calcutta, reaching up to 33.9°C (Sultana S. and Satyanarayana A. N. V., 2018).

There have been documented cases of even higher UHIIs in megacities like Delhi, where the UHII reached up to almost 11°C. In his review on one hundred cities in Asia and Australia, Santamouris M. (2015) observed UHI cases that reached up to 11°C (with non-standard measuring equipment).

The UHI can threaten the well-being of a city by: increasing the energy consumption for cooling, and consequently the emitted pollutants; deteriorating the thermal conditions indoors and outdoors; raising the concentration of harmful pollutants, such as ozone (Santamouris M., 2015); and exacerbating heat mortality especially during heat waves (Paravantis J. et al., 2017).

During a 1998 heat wave in Shanghai, the impact on fatalities was four times larger in urban than rural areas (Tan J. et al., 2010). Over 120 heat wave deaths were recorded in Delhi in the same year (Murari K.K. et al., 2015). During the 2003 heat wave in Europe, around 1800 casualties were recorded only in the city of Paris (Vandentorren S. et al., 2004). Finally, 800 people lost their lives in seven days during the 2015 heat waves in the megacity of Karachi (Pakistan) (Rizvi S. H. et al., 2019).

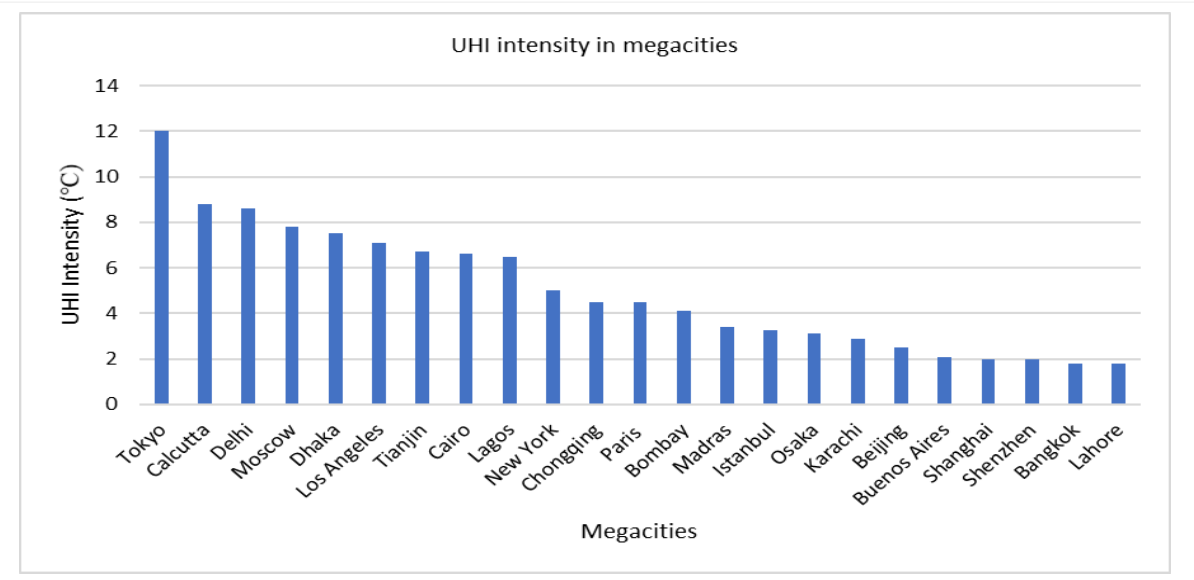

Figure 8: Urban Heat Island intensity in various megacities.

8. Conclusions

This paper reviewed literature that helped put the contribution of megacities to climate change in perspective. Their increase in number, population growth, and area expansion was discussed. Energy consumption and carbon dioxide emissions were examined and related to GDP. Their impressive ecological footprint was mentioned, as urban sprawl and transport growth created positive feedback loops for further urbanization. Important negative effects of megacities included the Urban Heat Island and heat mortality.

Urbanization and climate change are two correlated issues that humanity will have to face in the near future. The pace of temperature increase threatens to pose many documented (ice melting, extreme weather, sea-level increase, etc.) and undocumented threats for humanity. The population residing in urban areas will grow over the next decades; by 2050, seven out of ten people will live in urban areas. By 2035, megacities over 10 million people and cities with a population between one and five million will account for 16% and 23% of the urban population respectively. This trend raises the awareness of scientists and policy makers of all fields as they try to find solutions to mitigate the urbanization impacts at a global and local scale. Megacities, as major global energy consumers, play an important role in achieving this goal. Thus, the need for mitigation and adaptation policies targeting such large urban conurbations.

Research that carries out a statistical analysis of a complete list of megacities is forthcoming.

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Development Prospects of the Hellenic natural gas market

Prof. Dimitrios MAVRAKIS,
Director of KEPA – NKUA

Ioannis NTROUKAS. M.Sc., MBA[1]
PhD candidate, NKUA

Dr. Popi KONIDARI,
Research Fellow

[1] corresponding author
Telephone: 0030 210 72 75 732
e-mail: epgsec@kepa.uoa.gr/i.ntroukas@edaattikis.gr

Abstract

For the period 2015-2017, Natural Gas (NG) represented about 8% of the total energy consumption for each one of the Hellenic residential and commercial sectors (IEA, 2017; Eurostat, 2019). In mainland, the NG network is actually restricted to three regions: Attiki, Thessaloniki and Thessalia with a limited number of households (penetration rate of Attiki – 36% with 120.000 consumers/connections; Thessaloniki with 54% and 220.000 consumers/ connections; Thessalia with 90.000consumers) (HAEE, 2019). This paper describes the perspectives of the Hellenic NG market, through the scheduled projects for pipelines, Compressed NG (CNG) and Small Scale Liquefied NG (SSLNG) in mainland and island Greece (DEFSA, 2019; NECP, 2018). The aforementioned low coverage of the existing NG network in mainland Greece creates development prospects due to its expansion. Areas or individual end-users in mainland, which are not close to NG infrastructure, could be NG supplied by a combination of CNG and pipeline network, or SSLNG and pipeline network. On the other hand, in Island Greece, where currently there is no NG infrastructure, the local power generation and the prospects of fuelling maritime transportation under the framework of de-carbonization targets, set by IMO2050, create development prospects for the NG market through a combination of Small Scale LNG and pipeline network (RAE, 2018). Finally, perspectives for the Hellenic NG Market through NG Network, Small Scale LNG and CNG are discussed.

Keywords: Natural gas market, prospects, infrastructure.

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Eurostat 2017, available at: https://ec.europa.eu/eurostat/databrowser/view/ten00125/default/table?lang=en

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Development Prospects of the Hellenic NG Market

Ioannis NTROUKAS. M.Sc., MBA
PhD Candidate, NKUA

Structure

- EU framework
- International framework
- Size of Hellenic NG Market
- Share of DSO's
- Projection of NG Demand
- Existing and Development of NG Infrastructure
- Prospects Development of NG market in Mainland and Island Greece

Framework of EU Targets

Natural Gas (NG) is characterized as bridge fuel towards a low carbon economy but accounts only 8% of the total energy consumption in the residential and commercial sectors in Greece

Natural gas, as sustainable energy can help Greece to achieve reduction of GHG emissions and the EU targets (4% reduction of GHG emissions compared to 2005 levels up to 2020)

For Greece the final energy consumption discussed to be 19Mtoe of national final energy consumption, for year 2030.

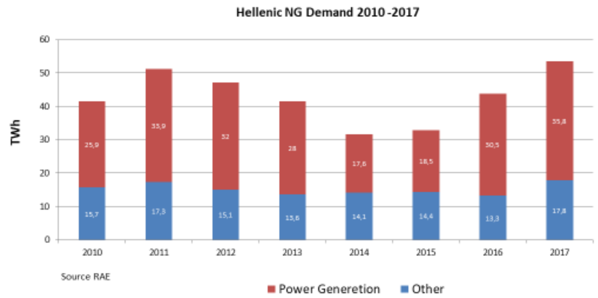
Framework of International Maritime Organization

All vessels that operate outside Emission Control Areas (ECAs) will be required to use fuel oil with a maximum sulfur content of 0.5%. Beginning January 1, 2020

Up to 2050 shipping industry must to comply to net zero CO_2 emission targets

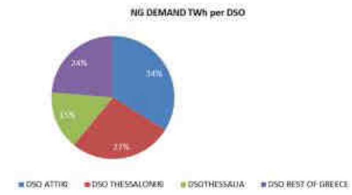
Ship-owners and operators have various options to meet the IMO sulfur cap requirements. These options include the use of compliant low sulfur fuels or alternative fuels such as liquified natural gas (LNG), liquefied petroleum gas (LPG), compressed natural gas (CNG), biofuel, solar power or fuel cells. SOx also can be controlled by using an alternative technology such as an exhaust gas cleaning system

Size of Hellenic NG market



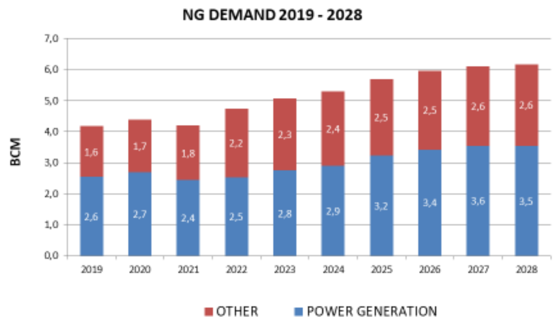
Share of Hellenic DSOs

- In 2017 NG consumption in Households was increased (59%) (3.64 TWh to 5.34 TWh), and In Commercial sector was reduced by (57%) (from 2.12 TWh to 0.91 TWh).
- in Industrial sector was increased by 20% (3.48 TWh to 4.16 TWh)



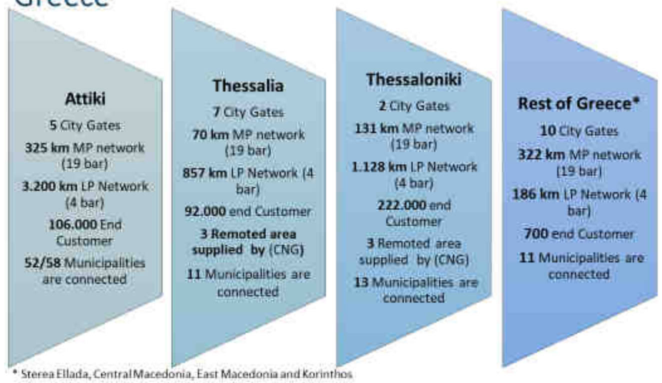
Source RAE

Projection of Total Hellenic NG Demand



Source DESFA

Existing NG Distribution Infrastructure Mainland Greece



* Sterea Ellada, Central Macedonia, East Macedonia and Korinthos

Source RAE

Development NG Distribution Infrastructure Mainland Greece 2019-2023

Attiki
586.242 km new network
74.669 new end Customer
114,9 mil € Investments

Thessalia
138,9 km new Network
119.000 end Customer
10 new remote area will be **supplied** by **CNG**
36.3 mil € Investments

Thessaloniki
162,7 km new Network
276.000 end Customer
10 new remote area will be **supplied** by **CNG**
51,2 mil € Investments

Rest of Greece*
Assignment of basic engineering study for NG supply in **13 New Municipality (CNG and SSLNG)**
Run Pilot program for new End Customer Connection
227,3 mil € Investments

* Sterea Ellada, Central Macedonia, East Macedonia and Korinthos

Source RAE

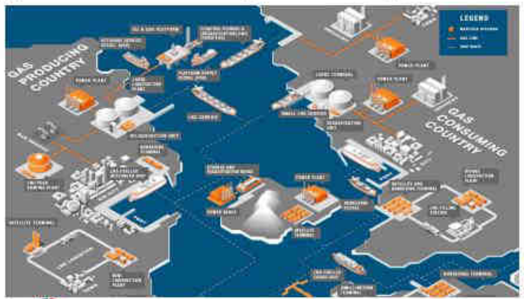
Development Prospects NG market in Mainland Greece

Supply Remote Areas from the existing NG network through CNG (Mother - Daughter station)

In this case, the NG operator receives the service of compression of natural gas in an installation gas compressor and carries compressed natural gas by a third party in order to the intended Remote Network to be a virtual extension of the existing Network

Development Prospects NG market in Mainland and Island Greece

Supply Remote Areas from the existing NG network through Small Scale LNG



Development Prospects NG market in Mainland and Island Greece

Up to Sept 2021 DESFA is going to Build Pilot Station Loading LNG, on Revithoussa Terminal LNG Station

- Truck loading capacity up to 50 m3 with supply loading capacity 100 m3/h
- LNG metering system with bridge gauge

Source DESFA

Development Prospects NG market in Island Greece

Supply Remote Areas from the existing NG network through Small Scale LNG

Source RAE

Most of the islands in Greece today are powered by stand-alone electric power generation systems mainly by local thermal power stations, which operate on fuel oil, heavy fuel oil and light diesel, and the power plants RES .

- Nineteen (19) 'small' stand-alone systems have a peak demand of up to 10 MW.
- Eleven (11) medium-sized stand-alone systems have a peak demand of 10 MW to 100 MW.
- Two (2) "large" autonomous systems have a peak demand of over 100 MW, namely Crete and Rhodes

Development Prospects NG market in Mainland and Island Greece

- Supply Remote Areas from the existing NG network through CNG in mainland Greece
- Supply Remote Areas from the existing NG network through SSLNG in mainland Greece and island Greece
- Installation of refueling LNG plant for vessel in island Greece under the request of IMO

Source RAE

Thank you

Ioannis NTROUKAS

Tel.: 0030 210 72 75 732

e-mail: epgsec@kepa.uoa.gr/i.ntroukas@edaattikis.gr

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SESSION C: ENERGY EFFICIENCY

Assessing Strategies for Cultivating an Energy Efficiency Culture

Prof. George PAPAGEORGIOU[1], Professor, EUC Research Center
Nicholas PROCOPIOU, European University of Cyprus
Loukia SHIAMPLETTOU, EUC Research Center
Natasa IOANNOU, European University Cyprus
Prof. Andreas EFSTATHIADES, Professor, European University of Cyprus

[1] *Contact details of corresponding author*
Tel: +00357-22-713-226
Fax: +00357-590-539
e-mail: g.papageorgiou@euc.ac.cy
Address: 6, Diogenous Str, Egkomi, P.O. Box: 22006, 1516, Nicosia, Cyprus

Abstract

Energy affects every aspect of human life and it is very important for economic growth and prosperity. Yet, our ever-increasing energy demands cost our planet heavily in terms of depletion of natural resources and environmental damage. This has led to the development of environmentally friendly technology such as solar panels and photovoltaic systems, wind farms, biomass and geothermal systems. Such technology has great potential to substitute conventional energy resources as they are clean, non-polluting, free of charge and abundant. However, there seems to be a reluctance towards adopting such technology as an alternative to conventional fossil fuel energy resources. Further, a lot can be done to increase energy efficiency which is very much dependent on the daily behaviour of people. This paper examines the obstacles of implementing energy efficiency measures in buildings and transport. As a result, a system dynamics model is proposed which includes the main elements contributing to an energy efficiency culture. The model is used to explore strategies in a computer-simulated environment that can shape people's attitudes towards higher energy efficiency. The proposed model incorporates factors at the socio-political, educational, economic and institutional levels. By experimenting with the model, strategies are emerging that promote an energy-efficiency mindset that can be configured and tested prior to implementation. In particular, we examine ways to properly invest in a campaign to raise awareness of energy efficiency aspects. As shown in the simulation results, we can significantly improve the diffusion of an energy-efficiency mentality.

Keywords: Energy Management Strategy, Energy Efficiency Culture, Sustainable Development.

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ASSESSING STRATEGIES FOR CULTIVATING AN ENERGY EFFICIENCY CULTURE

Prof. George Papageorgiou
EUC Research Centre

European University Cyprus

Agenda

- Introduction
- Literature Review
- Methodology
- Survey Results
- Energy Culture System Dynamics Model
- Conclusions

Introduction

- **Energy problem:**
- The ever-increasing energy needs
- The reckless use and waste of energy
- The depletion of energy reserves
- The impact on the environment and our lives

- **Need for:**
- Energy savings
- Recycling
- Utilization of Renewable Energy Sources

Prerequisite: **Creating a culture of energy efficiency**

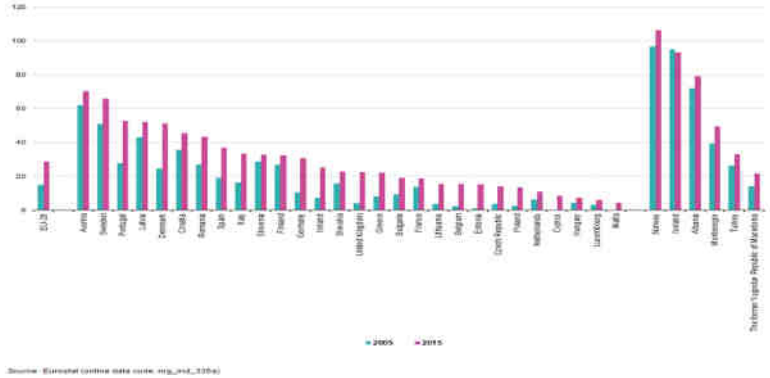
Introduction

- Energy affects every aspect of human life and it is very important for economic growth and prosperity. Yet, our ever-increasing energy demands cost our planet heavily in terms of depletion of natural resources and environmental damage. This has led to the development of environmentally friendly technology such as solar panels and photovoltaic systems, wind farms, biomass and geothermal systems. Such technology has great potential to substitute conventional energy resources as they are clean, non-polluting, free of charge and abundant. However, there seems to be a reluctance towards adopting such technology as an alternative to conventional fossil fuel energy resources. Further, a lot can be done to increase energy efficiency which is very much dependent on the daily behaviour of people.
- This paper examines the obstacles of implementing energy efficiency measures in buildings and transport. As a result, a system dynamics model is proposed which includes the main elements contributing to an energy efficiency culture. The model is used to explore strategies in a computer-simulated environment that can shape people's attitudes towards higher energy efficiency. The proposed model incorporates factors at the socio-political, educational, economic and institutional levels. By experimenting with the model, strategies are emerging that promote an energy-efficiency mindset that can be configured and tested prior to implementation. In particular, we examine ways to properly invest in a campaign to raise awareness of energy efficiency aspects. As shown in the simulation results, we can significantly improve the diffusion of an energy-efficiency mentality.

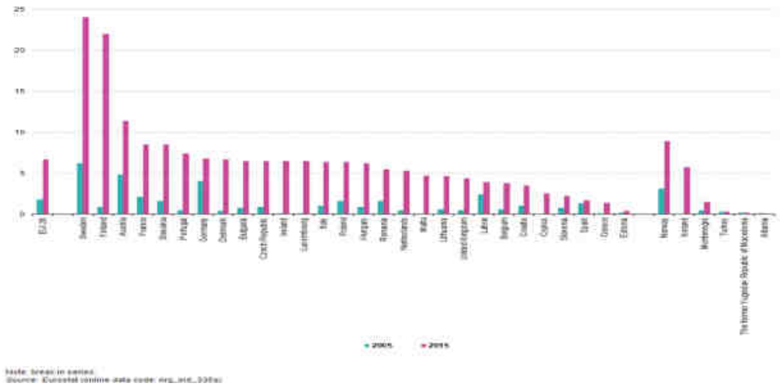
Literature Review

- Sanquist *et al* (2012) identified five lifestyle factors reflecting social and behavioral patterns. These were associated with air conditioning, laundry usage, personal computer usage, climate zone of residence, and TV use. It was shown that lifestyle factors based on social habits influence more consumption behavior than income.
  - Any strategic interventions should therefore be designed baring in mind cultural characteristics and the existing social norms.
- Jones et al 2015) identify the factors that have significant influence on energy consumption. These include socio-economic factors, dwelling factors and appliance factors.
- Konidari (2018) Quantification of energy end-user's behavioral patterns.

Use of Renewable Energy in Electricity Consumption



Use of Renewable Energy in Transport



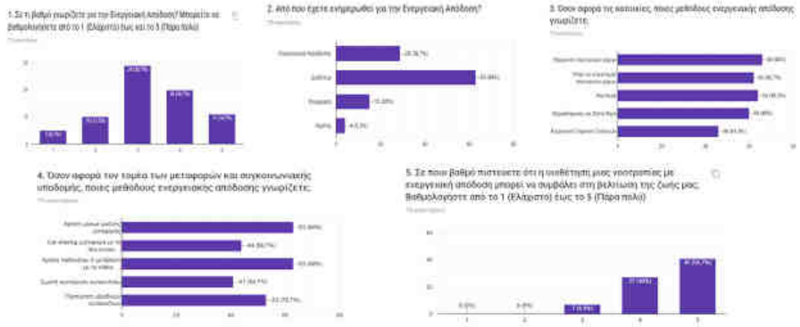
Methodology

- Pilot Study
- Survey Research in Cyprus
- Sample Size 136/200
- 68% Response Rate

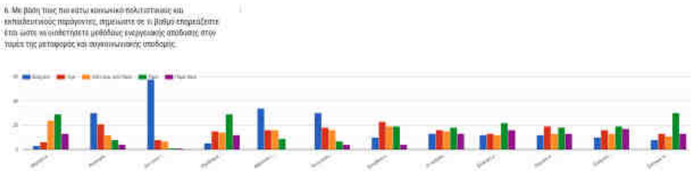
Results

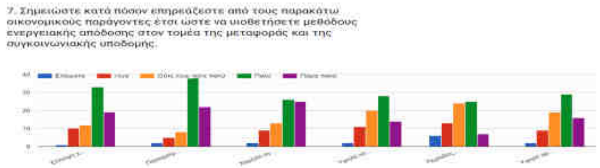
- Survey Research results
- Energy Efficiency as a diffusion process
- Integrated System Dynamics Model

Survey Research Results

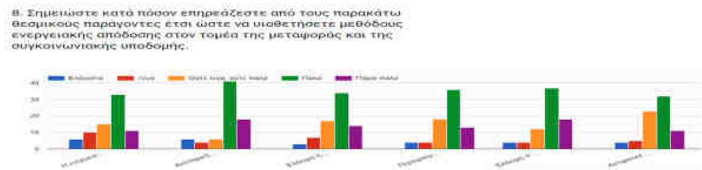


Survey Research Results

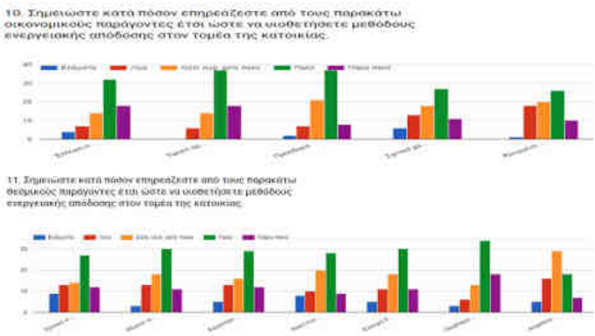




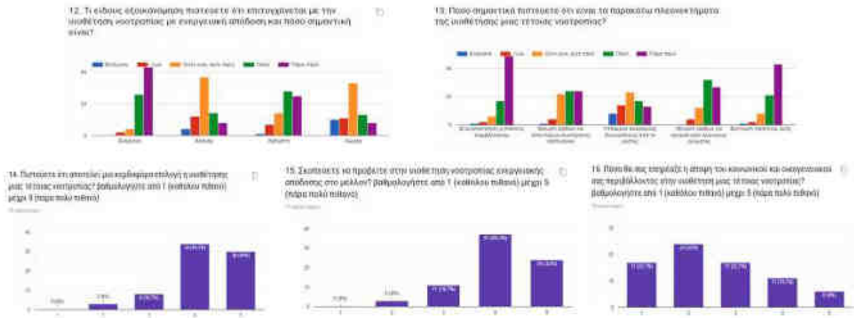
Survey Research Results



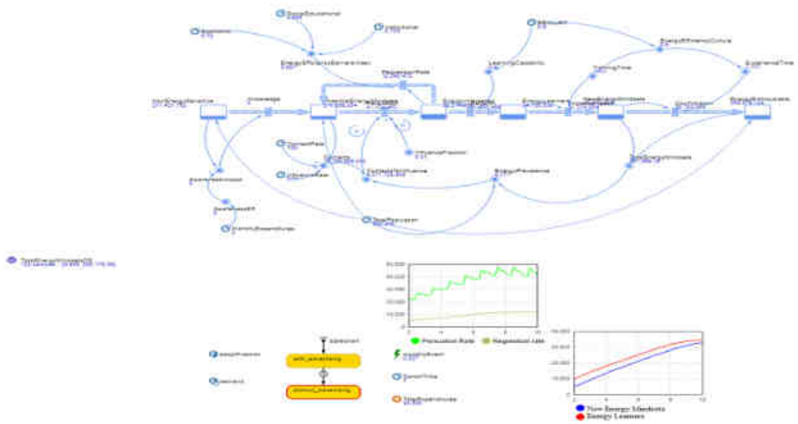
Survey Research Results



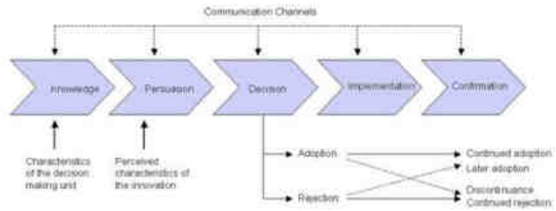
Survey Research Results



Energy Efficiency Culture System Dynamics

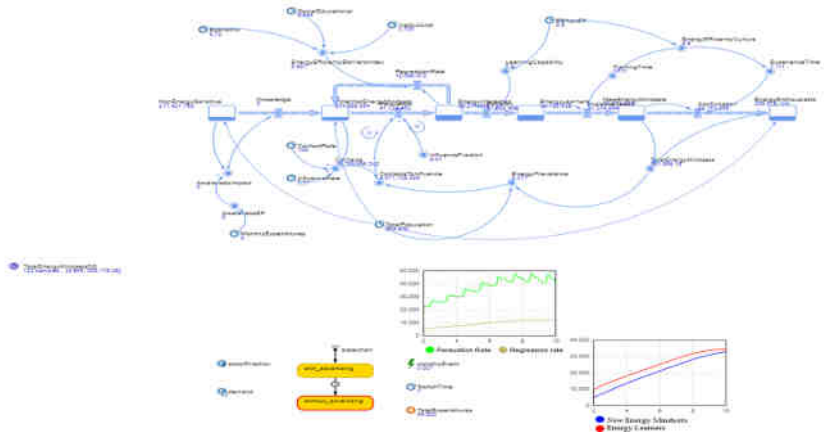


4.2 Accelerating diffusion



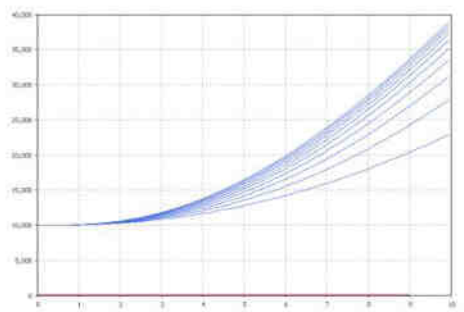
Innovation-decision process from Rogers(1995)

Energy Efficiency Culture System Dynamics

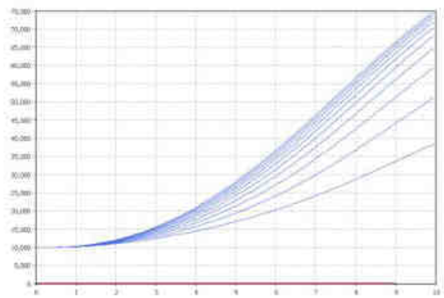


Energy Efficiency Culture System Dynamics

Energy Efficiency Promotion Campaign



Combination of Promotion Campaign and an Introduction of a Smartphone App Energy Tool



Conclusions

Energy is the basis of the economy and modern living on which industry, scientific research, telecommunications, services, transport, heating and air conditioning of the home are based, etc. Sustainability in energy production and consumption It is therefore one of the most critical issues today so energy policy, which includes securing, saving and disposing of energy, is a top concern. However, today's energy management is far from sustainable as fossil fuels are consumable and have their own impacts, and energy consumption is increasing exponentially year after year.

Addressing the energy problem is a matter for everyone and it is every citizen's duty to protect the environment in which they live. Everyone must be taught from a very young age how to consume energy and develop an energy-efficient mindset. Employing modern technologies and new material and mechanical systems creates a more energy-efficient culture. A key benefit of such a mindset is that it provides a better life in a healthier environment.

Conclusions

To reverse the current situation it is necessary to understand the need for a new energy mindset so that the application of energy techniques is the rule, not the exception. At the same time, it is necessary to leverage the funding provided through European programs to all industries, businesses and individuals, which aim at reducing energy consumption, the use of eco-friendly materials and the production of energy from renewable sources. It is clear that the creation of a comprehensive and integrated program that will provide information to the public, promote applied research, and support the energy-related economy by providing the necessary incentives is essential.

ASSESSING STRATEGIES FOR CULTIVATING AN ENERGY EFFICIENCY CULTURE

Prof. George Papageorgiou
EUC Research Centre

European University Cyprus

Design tool for thermal energy storage in buildings

Dr. Nikolaos STATHOPOULOS [1], Research Associate
Solar and Other Energy Systems Laboratory, NCSR 'Demokritos', Greece

Mr. Dorian BOVAGNE, 4th year engineering student
École Nationale des Travaux Publics de l'État (ENTPE), France

Mrs. Léa GRATAS, 4th year engineering student
École des ingénieurs de la Ville de Paris (EIVP), France

Asst. Prof. Pär JOHANSSON*

Prof. Angela SASIC KALAGASIDIS*, Research Group Leader, Vice Head of Department Education

*Department of Architecture and Civil Engineering, Division of Building Technology, Chalmers University of Technology, Gothenburg, Sweden

[1] *Contact details of corresponding author*
Tel.: +30 210 6503810
E-mail: nikstat@ipta.demokritos.gr,
Address: Solar and Other Energy Systems Laboratory, National Center for Scientific Research 'Demokritos', Neapoleos 10, Ag. Paraskevi 153 10, Agia Paraskevi, Greece

Abstract

The requirements on reducing the energy use and peak heating and cooling power in building applications is now in focus in many countries. Thermal Energy Storage (TES) technology has been meticulously studied during the past decades due to its benefits in terms of higher energy storage density per unit volume, as well as given and a narrow temperature operation range [Nazir et al., 2019]. However, the lack of full scale application of TES in building industry shows a need for development of easily accessible guidelines and validated design tools, for such technology to be promoted by designers, decision makers and researchers (Castell A., Solé C., 2015).

This limitation is addressed here by proposing a novel numerical design tool for TES in Building Applications. The tool, developed under MATLAB/GUI environment, is based on a physically sound TES model (Stathopoulos et al., 2017, 2016), providing a database with commercially available Phase Change Materials (PCM). The tool uses input from the potential user (type of application, energy demand, operating condition etc) to select suitable PCMs and calculate the dimensions of the proposed system and its operation profile (temperature, power and energy variation). Results are then presented in a separate file, summarizing the information provided by the user, the selected PCMs including their properties and the performance of the system.

The tool is targeted to designers, decision makers and researchers for increased possibilities for TES design in building district energy systems.

Keywords: Thermal storage, PCM, building, design tool.

1. Introduction

In an age where the installed renewable power generation capacity is increasing to significant numbers, the development and integration of energy storage technology is becoming more and more important. Among energy storage techniques, Thermal Energy Storage (TES) using Phase Change Materials (PCMs) presents the advantages of high storage densities and latent heat properties, as well as specific temperature operation range.

The building sector accounts for over 40% of total primary energy consumption in the U.S. and the E.U. (Cao et al., 2016). Furthermore, energy demand from buildings and buildings construction continues to rise at nearly 3% per year (IEA, 2019). PCMs can be used in a wide variety of building applications, including passive (wall, ceiling, floor, etc integration) and active ones (heat exchangers, storage tanks, etc). Active applications offer the benefits of on demand use and coupling with other energy systems, thus contributing to more efficient buildings and to a reduction of CO_2 emissions.

Over the last decades substantial research has been conducted on identifying materials suitable for PCM applications, suggesting desired properties and determining advantages and disadvantages for each case (Baetens R. et al., 2010, Cabeza L. et al., 2008, Zhou D. et al., 2012). Several systems have been proposed and studied thoroughly demonstrating the benefits and the potential of this technology. However, PCM technology has not yet reached a wide commercialization stage. One of the main reasons is the lack of guidelines on how to implement different types and systems of PCM into the building. Specifically, there is an absence of scientifically sound and experimentally validated design tools that can use input information from a desired project in order to propose a specific PCM application and present its energy performance (Castell A., Solé C., 2015).

The Thermal Energy Storage with Phase Change Material (TES-PCM) design tool - proposed here - addresses this lack by providing solutions for demand side management of thermal energy for heating and cooling of buildings (Figure 1). Based on initial information from the potential user, the tool simulates the performance of TES applications using PCMs and presents the results for different possible configurations.

The Thermal Energy Storage with Phase Change Material (TES-PCM) design tool was developed within the Building Physics Modelling group of the Division of Building Technology, Department of Architecture and Civil Engineering at Chalmers University of Technology, Gothenburg, Sweden.

2. Limitations of existing databases and tools

Nazir H. et al., 2019 present a comprehensive list of available PCM selection databases and software/modeling tools (Table 1). Out of the ten identified solutions, seven concern material databases and three software/modeling tools.

The first category (databases) provides useful information about PCM candidates, without however offering the possibility to evaluate their performance in a specific project. The second category (modeling tools) concerns software that can predict the composition and calculate phase diagrams and thermodynamic properties of materials (Thermo-Calc, Excel Workbook).

Figure 1: Homepage of the TES-PCM design tool.

Table 1: Currently available material selection databases and software/modeling tools (Nazir H. et al, 2019).

No.	Name	Database/software tool	Access
1	MatWeb	Online database	Free
2	MATERIA	Online database	Free
3	MPDB	Material property database	Paid/Demo
4	ThermoLit	NIST online database	Free
5	IDEMAT	Material selection online database and software	Free
6	CES Selector	Material selection software	Paid/Demo
7	GRANTA MI	Material database management software	Paid/Demo
8	Thermo-Calc	Thermodynamic properties calculation software	Paid/Demo
9	PCMexpress	Simulation tool	Free
10	Worksheet database	Computational Tool	Free

Only PCM Express can demonstrate the effect of PCMs in thermal management of the building, however limiting the integration of proposed materials to the envelope of the building, i.e. passive application.

In conclusion, existing databases and tools mostly focus on available materials (composition, properties, etc) and cannot provide information at the system level including active applications such as PCM heat exchangers. Both categories do not offer the possibility of an extensive investigation of the performance of PCMs at a system level nor the option to compare and classify materials according to desired characteristics of the system.

3. Survey on TES-PCM applications

A survey among potential users of the tool, such as energy consultants, real estate owners, PCM producers, technical managers, researchers, etc was conducted. The aim of the survey was to understand the knowledge of professionals regarding TES-PCM applications, the information that professionals usually have at an early stage of the design process of such technology and the needs of potential users of the TES-PCM tool. In total, 48 participants from different countries (mainly Europe) provided information on the aforementioned aspects that were used for the development of the TES-PCM tool: structure, required input from user, proposed solutions and presentation of results. Here are some examples:

- The use of thermal storage applications is more or less divided between residential, commercial, academic and office buildings (Figure 2).
- The majority of these applications are of small capacity (<50KWh) (Figure 2).
- An important part of the professionals in the sector is not sufficiently informed about certain aspects of the integration of MCP in the building, such as safety, health risks etc. (Figure 3).

4. Programming environment

The tool was developed under MATLAB environment. This choice allowed to use and modify a previously developed numerical PCM model (El Mankibi M. et al., 2015, Stathopoulos N. et al., 2016, Stathopoulos N. et al., 2017). MATLAB also provides transparent results, meaning that the tool is open to future modifications, adjustments and expansions. Furthermore, MATLAB offers tools such as Graphical User Interfaces (GUI) and Runtime, allowing the creation of standalone interfaces that can run compiled MATLAB applications or components without installing MATLAB.

The tool is composed of several different components/scripts, created and interconnected in a way to acquire information from the user of the tool, perform calculations and simulations and, lastly, provide the optimal solution(s).

5. Structure of the tool

The structure of the tool is presented in Figure 4. Through a specifically created Graphical User Interface, the user is at first introduced to the operation of the tool and can open a PDF document containing information on TES-PCM technology. The user is then asked to provide relevant and necessary information on the desired PCM application: purpose of system, energy requirements, type of PCM, Heat Transferring Fluid (HTF) and container. The acquired information is then introduced to a dedicated script in order to select appropriate PCMs from the PCM database and calculate the necessary mass and volume of the system. The performance of the selected materials is then simulated through the PCM model calculating important performance features, such as outlet temperature, power, stored and released energy.

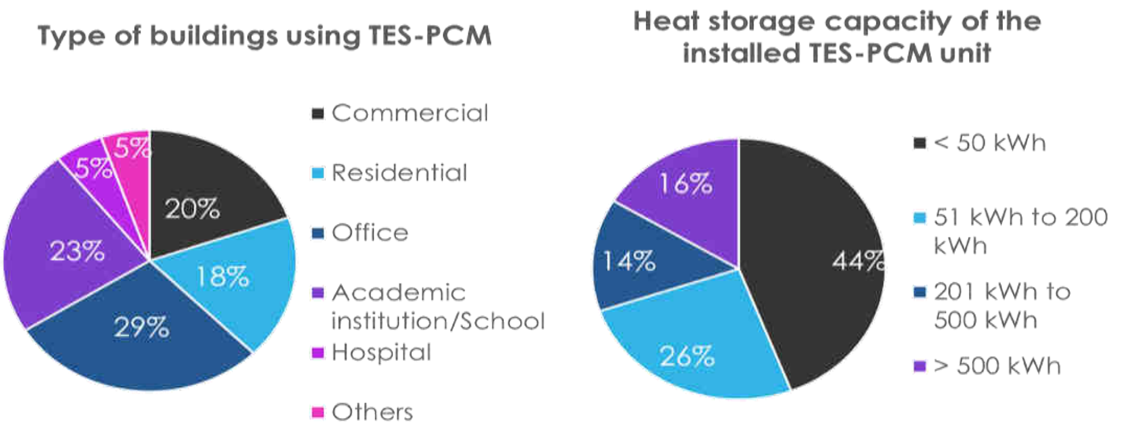


Figure 2: Building type using PCM and installed application capabilities according to the survey.

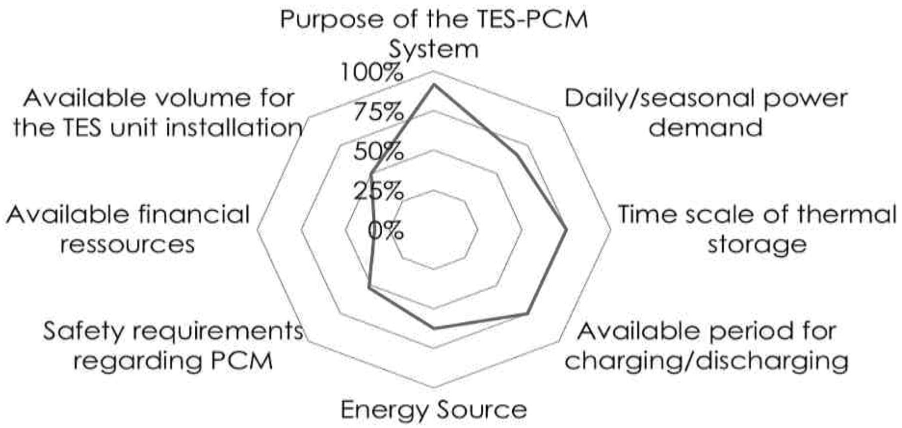


Figure 3: Available information during the design of a PCM project according to the survey.

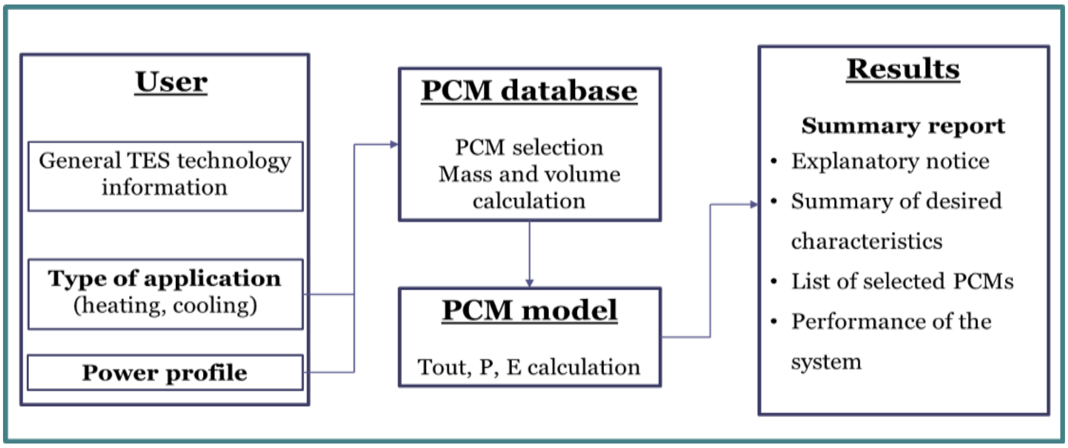


Figure 4: Structure of the Thermal Storage Application Design Tool.

Lastly, a PDF file is created, presenting the obtained results, along with an explanatory note of the document, a summary of the desired characteristics of the system and a list of the selected MCPs and their properties.

5.1 User component

As also verified by the survey, potential users of the tool might not have sufficient knowledge on various aspects of TES-PCM, mostly linked to phenomena such as supercooling or toxicity and leakage risks. To that aspect, at a first stage the user can receive general and specific information on PCM technology (Figure 5). This is available in two stages: some first basic material is directly readable through a specific section of the tool and a dedicated document is provided in PDF form upon request from the user.

This document first presents the main methods and principles of TES technology, continuing with a focus on PCM: fundamentals, advantages, materials (classification, properties and selection criteria), associated phenomena, containment methods and design considerations.

At a second stage, the user of the tool is asked to provide information on the system under development: heating or cooling purpose, system capacity, HTF, system inlet temperature, etc (Figure 6). This provided information is used as input for the selection process of the PCMs adapted to the specific case (sorted among several materials of the database).

5.2 PCM database

A thorough study of PCMs was performed, aiming to provide a list of suitable storage materials. Focus here was given to commercially available materials for heating and cooling of buildings. This means that PCMs with a phase change temperature between 0°C and 20°C were retained for cooling purposes and between 20°C and 60°C for heating ones. The study identified major worldwide PCM producers, as well as the type of information that they provide for every PCM.

Materials that satisfied these criteria (commercially available and phase transition within desired temperature span) were then used to create the PCM database of the tool. Desired properties, such as heat capacity curves (solid, liquid, phase change), density (solid, liquid), thermal conductivity (solid, liquid) and volume expansion were assigned to each PCM. In this way, the uploaded to the database PCMs can be used for further treatment, calculations and simulations.

5.3 Selection of suitable PCM(s)

A script was developed in order to create a list of suitable PCM(s) according to the desired characteristics of the application, as provided by the user. The script is designed to select PCM(s) based on the input from the user under the following criteria (listed by order of importance):

1. Temperature range of the phase transition,
2. Purpose of the application (heating or cooling),
3. Type of PCM and
4. Charging and discharging temperature of the HTF.

At the end of this process, a new and narrower list of PCMs (suitable to the desired application) is created in order to provide information to the other components.

5.4 Calculation of PCM mass and volume of the application

After the selection of suitable materials, a different script was developed in order to calculate the needed PCM mass and the volume of the PCM application. This calculation is based on the information that the user provides (energy requirement) and the PCM properties (heat storage capacity and density). Needed material mass and application volume is then calculated for every suitable PCM, as selected in the previous section.

5.5 PCM numerical model

The numerical PCM model was developed in the LGCB laboratory in ENTPE, France (El Mankibi M. et al., 2015, Stathopoulos N. et al., 2016, Stathopoulos N. et al., 2017) using a MATLAB S-function and Simulink environment. It uses the energy balance equation and the apparent heat capacity method. Three layers are considered: PCM, container and HTF and discretized lengthwise in several nodes (Table 2). Based on the properties and initial conditions of the PCM and the HTF, the model calculates the temperature evolution along the PCM application for the considered layers.

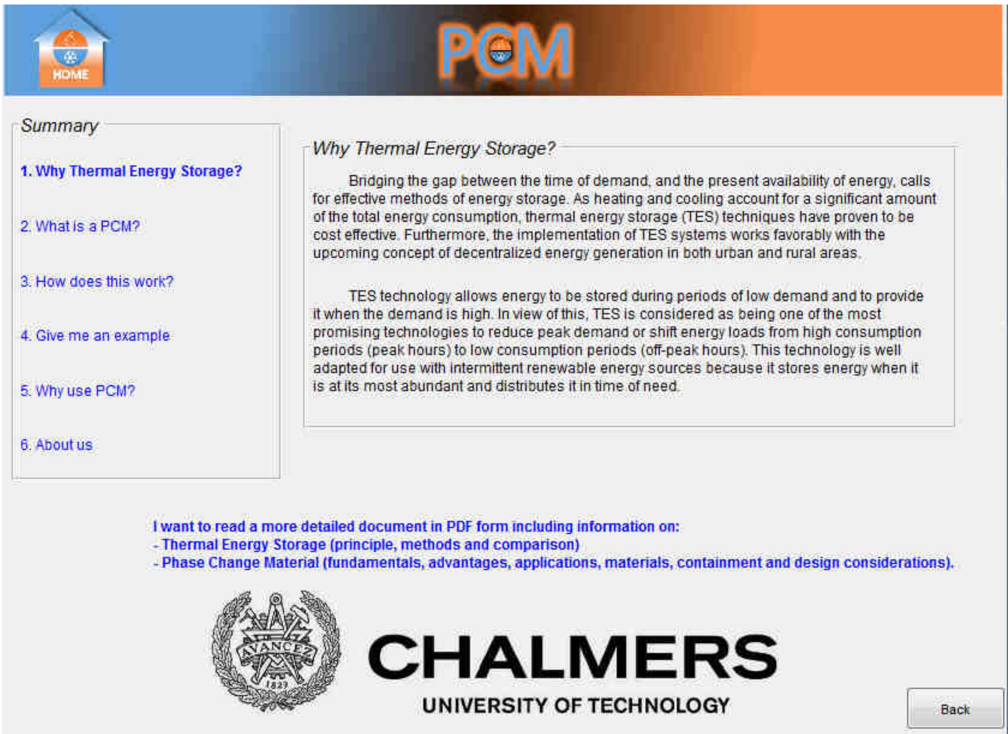


Figure 5: General and specific information on PCM technology.

Figure 6: Introduction of information by the user.

The model was adjusted for the needs of this project. Specifically, the properties of the considered layers and the geometry features were modified as inputs of the model so that different PCMs, HTFs and configurations can be introduced and simulated.

The model can provide the temperature evolution at different parts of the system, however for the needs of this tool only the outlet HTF temperature is considered. The model then performs consecutive simulations for each of the suitable PCM(s) and the respective mass and volume configurations;

Table 2: Considered properties for the PCM, container and HTF layer.

PCM properties	Container properties	HTF properties
Heat capacity: solid, liquid, phase change	Heat capacity	Heat capacity
Density: solid, liquid	Density	Density
Thermal conductivity: solid, liquid	Thermal conductivity	
Volume expansion		

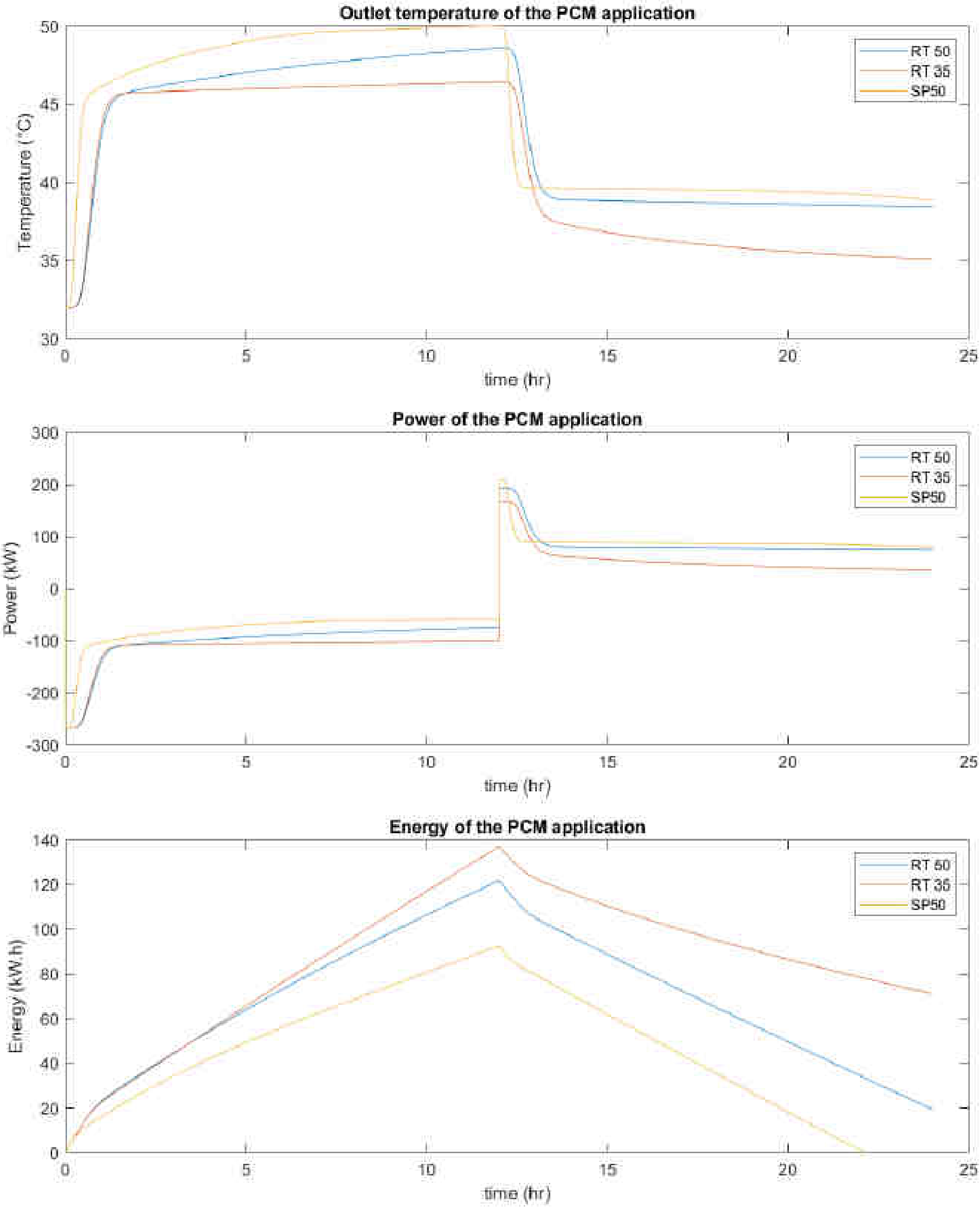


Figure 7: Presentation of key performance aspects of the desired application for all of the selected PCMs: Outlet temperature, Power and Energy provision of the system.

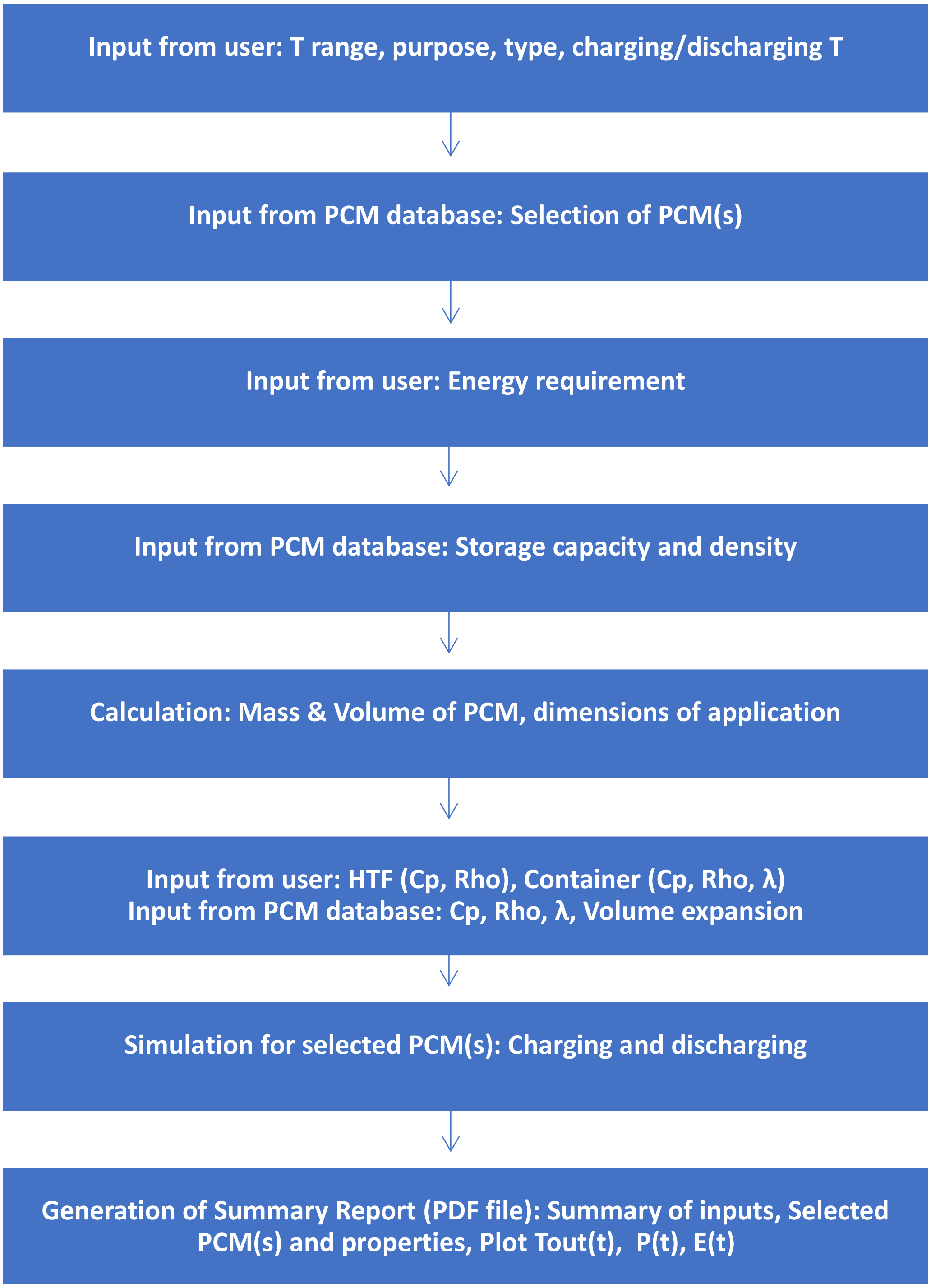


Figure 8: Process flow diagram of the TES-PCM design tool.

container and HTF properties are also used as inputs at this stage.

Lastly, the outlet HTF temperature is used to calculate the power and energy provision of the unit over time.

5.6 Presentation of results

The last component of the tool concerns the presentation and visualization of the outcomes of the tool. A script was developed to create PDF file divided in 6 sections and containing the following information:

- Section 1 presents useful information related to the operation of the tool and the PDF file.
- Section 2 summarizes the inputs of the user, i.e. the desired characteristics of the application.
- Section 3 presents the list of suitable PCMs, i.e. the selected material according to the

user's requirements, their properties and the respective estimated PCM mass and volume of application.

- Section 4 introduces important properties of the selected PCMs.
- Section 5 illustrates key performance aspects of the desired application for all of the selected PCMs: Outlet temperature, Power and Energy provision of the system (Fig. 7).
- Section 6 provides a list of detailed properties of the suitable materials.

6. Process flow diagram of the TES-PCM design tool

The complete process of the operation of the tool is summarized in Figure 8.

7. Conclusions

The TES-PCM design tool is a free, user-friendly and standalone software for suggesting the optimal PCM solution(s) based on commercially available materials. Based on a survey among potential users of the tool, specific characteristics of a TES-PCM system were identified and assigned as input information from the user. The tool uses this information to pinpoint a narrow list of adapted PCMs from a wider PCM database. It then calculates the necessary PCM mass and volume of the system and simulates the performance of the wanted system for the selected PCM options. It is possible to modify the current version of the tool by updating or enriching the PCM database or even proposing user defined PCMs. This would allow PCM producers or researchers to test the performance of materials under development.

The TES-PCM design tool is addressed to energy consultants, PCM producers, researchers, real estate owners, technical managers and other building and energy related professionals, offering them the possibility to choose the appropriate to their configuration PCM solution(s) and evaluate the performance of the desired system.

Acknowledgements

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Multicriteria Analysis of the Energy Upgrade of a Heritage, Office Building

Ms Amalia ZIKOU [1], Post graduate student*

Dr. Eleftheria ALEXANDRI, Lecturer*

* Hellenic Open University, School of Science and Technology, Patras

[1] *Contact details of corresponding author*

Tel: +30 26410 25586

e-mail: melina23zk@gmail.com

Address: Diamanti 45, 30133 Agrinio, Greece

Abstract

The energy upgrade of buildings has been investigated mostly with energy and economic criteria. There is very little research on the environmental effects of the energy upgrade of buildings and even less on the environmental effect of the energy upgrade of heritage buildings. The aim of this paper is to explore holistically, from a sustainability point of view, thus taking into consideration energy, environmental and economic criteria, the techniques of the energy upgrade of the building envelope, as well as RES applications on buildings, in order to turn a heritage office building into a nearly Zero Energy one. For this reason, a monumental building is examined (the City Hall of the Municipality of Athens), regarding its energy performance. Life Cycle Analysis is also carried out for the building as is and for chosen energy upgrade scenarios, examining both ecological and conventional building materials. After the quantification of the outputs from these analyses, 13 indicators are chosen to express sustainability criteria. Taking into consideration the performance of each scenario in each criterion, the Multi Attribute Utility Theory is applied, so as to prioritise the examined scenarios. Conclusions are drawn about which energy upgrade techniques should be preferred from a holistic point of view and which ones should be avoided; in some cases it has been found out that, with the examined criteria, it is better to let the building as is, than to assess energy upgrade techniques that have small positive effects on energy criteria but negative effects on environmental and economic indicators.

Keywords: Energy upgrade, Office building, Masonry structures, Life Cycle Analysis, nZEB, MAUT.

1. Introduction

Buildings in Greece are responsible for 39% of the total energy consumption of the country (*Approval of the Second Edition of the Long-Term Strategy on the Mobilization of Investments for the Renovation of the National Building Stock, according to par. 2 of Article 6 of L. 4342/2015 (article 4 of Directive 2012/27/EU)*, 2018). Old, uninsulated buildings (65% of the building stock, according to the latest census (Hellenic Statistical Authority, 2015)) are responsible for larger amounts of energy consumption for heating and cooling spaces than newer buildings, built according to specific thermal standards. As some of these older buildings are part of the country's architectural heritage and some of them have historical significance, it is important to investigate techniques which can achieve their energy upgrade, without putting at risk their architectural or cultural characteristics. Especially masonry buildings, whose main component is a natural, long-lasting material, with long-lasting structural characteristics, their core materials should be respected, and the building's upgrade should be made in ways that do not compromise their durability. A great number of heritage buildings are used as office buildings, which have certain peculiarities, regarding energy consumption.

More specifically, according to the latest census (2011), office buildings occupy 4,1% of Greece's building stock. Approximately 70% of office buildings are built before 1980, which means that they are not thermally insulated (Hellenic Statistical Authority, 2015). In the broader area of Athens (Attica county), 5.83% of buildings are office buildings, 59% of which are uninsulated (ibid.). Due to the increased energy demand of this sector, tertiary sector buildings (including office, commercial and municipal buildings) account for 38% of the Municipality of Athens greenhouse gas emissions, being more responsible for the city's contribution to climate change, than the more voluminous residential sector (31%) (Skoula E., 2017).

In order to face climate change, many cities have taken initiatives to adapt to climate change and also, to take actions for mitigating greenhouse gas emissions. More specifically, the Municipality of Athens has voted (Decision 568/2017 of the Council of Athens) for specific actions for the mitigation of greenhouse gas emissions (Skoula E., 2017), some of which concern the energy upgrade of municipal buildings, so that it reaches its goals for reducing carbon dioxide emissions by 40% in 2030 (ibid). However, these actions, if not looked into more thoroughly, and not only with energy savings criteria, could lead to more environmental problems, that future generations should face with the management or demolition of these buildings. Apart from that, the embodied energy of their energy upgrade retrofitting works might never be paid back during their life time (Alexandri E. and Androutsopoulos A., 2017), thus not contributing to the global effort of reducing GHG emissions, but, finally, energy saving measures ending up to contributing to their increase.

For this reason, it is important to compare various energy upgrading techniques in regards to their effect on various domains of sustainability. As most of conventional thermal insulation materials have a negative effect on the environment, during their life cycle (Berge B., 2009), it is interesting to examine and compare their environmental effect with that of thermal insulation materials that have been classified as 'ecologic' ones, regarding the energy upgrade of existing buildings.

The aim of this research is to look into and demonstrate holistically, which techniques should be used and the ones that should be avoided in the energy upgrade of the building envelope, so as to achieve sustainable solutions.

2. Methodology

Multicriteria analysis is used in order to assess energy saving measures in regards to sustainability of the energy upgrade of a monumental building and not merely energy savings. For this reason, a set of criteria and their indicators are chosen and applied on the examination of the various building envelope upgrade techniques. Energy, environmental and economic criteria are considered. Energy criteria concern embodied energy and operational energy consumption, the reduction of energy consumption achieved through the examined energy saving techniques, as well as the added energy value that these techniques enhance to the building and more specifically, how they affect its energy classification. Economic criteria affect the initial capital that has to be invested for the energy upgrade of the building, assessing whether it is cost beneficial through its payback period, taking also into consideration the reduction of life cycle costs and more specifically, operational costs for energy bills.

Regarding environmental criteria, whether the city can achieve its climate change mitigation targets is taken into consideration, with indicator the reduction of operational CO_2 emissions. The rest of the environmental criteria derive from life cycle analysis; global warming potential, acidification potential, human health particulate, eutrophication potential, ozone depletion potential and smog potential. For these criteria, their respective indicators carbon dioxide equivalent, sulfur dioxide equivalent, fine particulate matter, nitrogen equivalent, trichlorofluoromethane equivalent and ozone equivalent have been estimated for a period of 60 years. These last six environmental criteria are chosen as the essential criteria in life cycle analysis of a product (EUR24571:2011). All criteria and their indicators are shown in Figure 1.

The ranking of the examined scenarios with the aforementioned criteria is made with multicriteria decision analysis. More specifically, Multi-Attribute Utility Theory (MAUT) has been put forward, as a method that respects the axioms of reflexivity, comparability and dominance (Ishizaka A. and Nemery P., 2013). The weighting factors for primary, operational energy savings, CO_2 emissions reduction, energy classification, initial cost, operational cost, payback period derive from the survey of Alexandri E. and Androutsopoulos A. (2020). The weighting factors for the rest of the criteria derive from the survey of Alexandri E.

and Lampropoulos A. (2019). All used weighting factors can be seen in Table 3.

The energy consumption for each energy upgrade scenario, as well as its energy classification are calculated with the use of the software TEE KENAK, with the national assumptions that have been established by Androutsopoulos A. et al. (2017a) and Androutsopoulos A. et al. (2017b). This software has been validated with the method BESTEST (TEE KENAK, 2018) and has been used in several research studies (e.g. Dascalaki E.G. et al., 2013; Droutsa K.G. et al., 2016; Mitsopoulos G. et al., 2018). The cost of each energy upgrade work is estimated according to the Regulation on the *Descriptive Works Invoices for Public Works Contracts* (2017) and from information from market research and is input to the software TEE KENAK.

The environmental performance of the examined scenarios is estimated with ATHENA Impact Estimator for Buildings, Life Cycle Analysis software, which has been used successfully in research and practice to assess the environmental effect of buildings and building components (O'Connor J. and Bowick M., 2014; Stek E. et al., 2011). Finally, for the multicriteria analysis, the open access tool by Alexandri E. (2019) is used.

3. Building Description

The aforementioned criteria are applied on a heritage building of the tertiary sector and specifically to Athens City Hall (Figure 2). The building was designed by the architect Panagiotis Kalkos, during the mayorship of P. Kyriakou. It was constructed during the period October 1872 – May 1874 (Ministry of Culture and Sports, 2012).

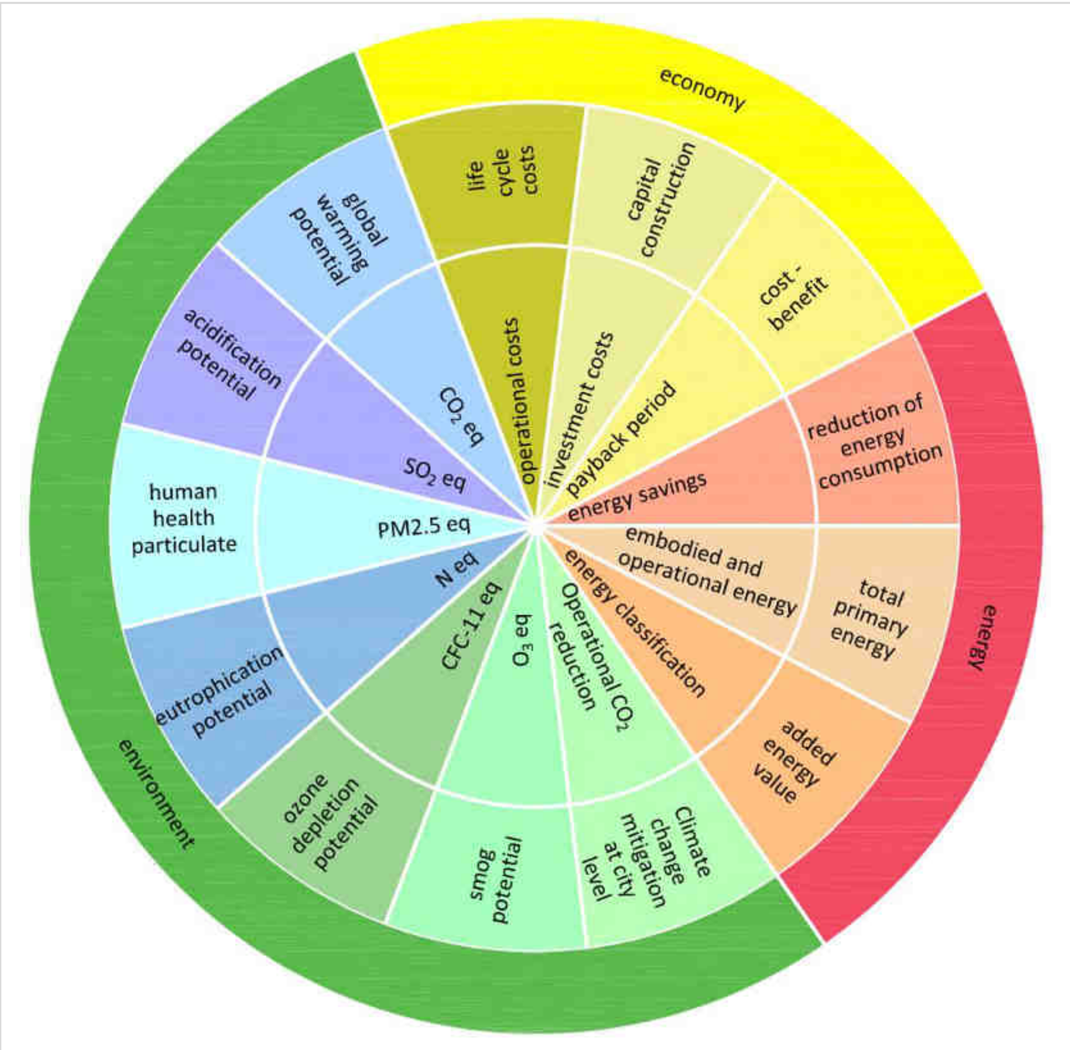

Figure 1: Examined criteria and their indicators.

Table 1: Short description of examined scenarios.

Scenarios	Short description
Scenario 0	Building as is
Scenario 1A	Vertical, opaque elements: conventional insulation
Scenario 1B	Vertical, opaque elements: ecological insulation
Scenario 2A	Horizontal, opaque elements: conventional insulation
Scenario 2B	Horizontal, opaque elements: ecological insulation
Scenario 3A	All opaque elements: conventional insulation (combination of Scenarios 1a and 2a)
Scenario 3B	All opaque elements: ecological insulation (combination of Scenarios 1b and 2b)
Scenario 4	Photovoltaic panels on the roof and above atriums
Scenario 5A	Combination of Scenarios 3a and 4
Scenario 5B	Combination of Scenarios 3b and 4

Figure 2: The historical building of Athens City Hall (Ministry of Culture and Sports, 2012).

Today it hosts offices of municipal services, the Mayor's office, the City Council Hall and seminar rooms. The internal surface of some of its envelope walls is embellished with frescos from important Greek painters.

Regarding the building envelope, it is made of masonry walls (natural stone) lined with marble slabs on the ground floor, while the external walls of the first and the second floor are made of masonry, plastered on both sides. The roof of the building is covered by a wooden deck, forming a ventilated roof. Three types of openings can be observed: openable windows with timber frame and double glazing; non-openable windows with metal frame and single glazing, embellished with paintings of famous artists; non-openable windows with timber frame and double glazing. The double-glazing windows replaced single glazing windows quite recently (15 years ago).

The building is air conditioned (both heating and cooling) mainly through three central air conditioners, which are located in the basement. The heating capacity of the two of them is 232.6kW and the cooling 210.0kW, with COP 3.110 and EER 2.599. The third one has 176.4kW heating capacity and 159.6kW cooling capacity, with COP 3.106 and EER 2.625. Additionally, there are some units installed on the roof, auxiliary for specific spaces that may be in use for longer. The most important of these is the one in the Mayor's office, with 31.5kW heating capacity, 28.0kW cooling capacity, COP 3.383 and EER 3.111.

The installed power for lighting is 49.22kW, while most light bulbs have been replaced with LED recently and, according to the information derived from the technical managers of the building, during its energy audit, the rest of the bulbs that are not LED, (in the Mayor's reception and in the basement) are going to be replaced with energy efficient ones soon. There are no automation systems, neither for natural lightning control, nor for motion detection.

The primary energy consumed by the building in question for heating, cooling, ventilation and lighting is estimated to be 306.7kWh/m^2 annually, according to the assumptions of the software TEE KENAK. According to national assumptions, the building is classified in energy class 'D'. However, in practice, it consumes much less energy for heating, cooling, lighting and appliances, reaching an average of only 146.7kWh/m^2 electrical (total) energy consumption annually (Figure 3).

4. Examined Scenarios

The energy saving scenarios which are investigated are summarised in Table 21. Existing openings[18] are quite energy efficient ones, thus their replacement is not examined. Although the heating and cooling systems are not ecolabel ones, as they are relatively efficient, their replacement would be a waste of resources. Lighting is also efficient; thus, no energy upgrade is necessary for this type of consumption. The placement of automatisms for controlling lighting and "Heating, Ventilation and Air Conditioning (HVAC) systems is beyond the scope of this research. More specifically, the following scenarios are examined:

- Scenario 0: Building as is,
- Scenario 1A: 'Conventional' thermal insulation (expanded polystyrene) is added externally on the external walls,
- Scenario 1B: 'Ecological' thermal insulation (blown cellulose) is added externally on the external walls,
- Scenario 2A: 'Conventional' thermal insulation (expanded polystyrene) is added on the horizontal elements (on the roof and on the floor that separates the non-air-conditioned basement with the ground floor),
- Scenario 2B: 'Ecological' thermal insulation (blown cellulose) is added on the horizontal elements (on the roof and on the floor that separates the non-air-conditioned basement with the ground floor),
- Scenario 3A: 'Conventional' thermal insulation (expanded polystyrene) is added on both horizontal and vertical opaque elements of the building envelope (combination of Scenarios 1a and 2a),
- Scenario 3B: 'Ecological' thermal insulation (blown cellulose) is added on both horizontal and vertical opaque elements of the building envelope (combination of Scenarios 1b and 2b),
- Scenario 4: Photovoltaic panels are installed on the surface of the roof, forming a ventilated roof. Apart from the roof, they are also installed on top of the two atriums, also offering shade on the openings of the atriums. The type of the selected photovoltaics is polycrystalline and they were placed horizontally, so as to respect the building's form, covering a total area of 1182.75m^2, with 224.7kW power,
- Scenario 5A: Combination of Scenarios 3a and 4,
- Scenario 5B: Combination of Scenarios 3b and 4.

5. Results and Discussion

The results for all scenarios and all criteria are in Table 3. Additionally, their hierarchy, regarding each criterion can be seen in Figures 4, 6 and 8. As can be observed, regarding energy criteria (Figure 4) the combination scenarios (5A and 5B) excel, followed by Scenario 4 (placement of PV panels).

The scenarios of the upgrade of the whole building envelope (3A and 3B), follow, as expected, preceding the scenarios of the upgrade of only the vertical, opaque elements(2A and 2B), while insulating only the horizontal elements (1A and 1B) have the lowest impact, regarding energy criteria, remaining at the same energy class and only 14.1% energy savings. Similar results have also been observed by Chidiac S. E. et al. (2011); the insulation only of the roof of a high-storey building reaches only15% energy savings.

[18] The only exception of openings which are not energy efficient, are the openings with artistic decoration, located at the staircases. These openings cannot be replaced, as they consist of vitraux by the eminent artist, Takis Parlavantzas. Apart from that, as they are located in a non-conditioned space (the staircases) they do not have a significant effect on the building's overall energy efficiency.

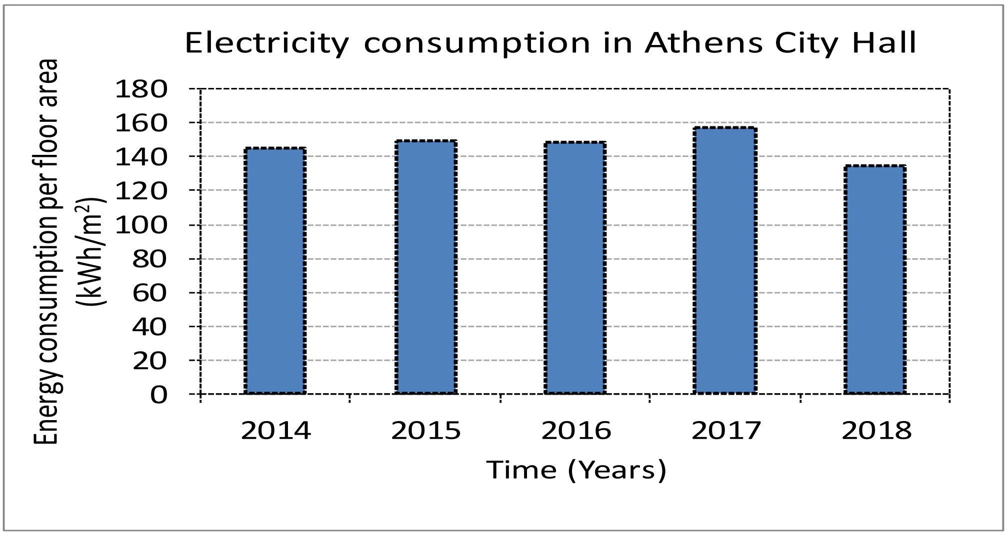

Figure 3: Total annual electricity consumption per floor area of Athens City Hall for the years 2014-2018 (Alexandri E., Badas T., 2019).

Regarding the incapacity to change energy class, it has also been observed by Katafygiotou M. C. and Serghides D. K. (2014); the placement of 0.05m of expanded polystyrene on the roof of the building they examined failed to improve its energy classification.

The largest energy savings are observed for the synergy of upgrading the building envelope and placing PhotoVoltaic Panels (PVs) (Scenarios 5A and 5B, which offer 0.1% energy surplus). These scenarios offer the smallest sum of embodied and operational energy, while the largest is observed for Scenario 0 (building as is). Moreover, both these scenarios upgrade the examined building from energy class 'D' to energy class 'A+', classifying the building as nearly Zero Energy Building (nZEB)[19]. Apart from these two scenarios, Scenario 4 also turns the examined building to a zero-energy building (energy class 'B+'), while the energy upgrade scenario of merely the building envelope (Scenarios 3A and 3B) reaches only energy class 'B'. Therefore, the use of renewable energy sources is necessary to convert the examined building to a nearly zero-energy consumption one. It is interesting to point out that according to the existing national definition, an nZEB can be quite energy consuming, as can be observed in Figure 5; Scenario 4 (classified as 'B+', thus 'nZEB') is estimated to consume 98.7kWh/m^2 annually for heating, cooling and lighting, which is far greater than the initial definition of 'nZEB' by Greek legislation (10kWh/m^2/year, according to the Law for the *New Construction Regulation* (2012)). As energy classification occurs with the comparison of the building with a reference building, which is the building itself with specific technical characteristics (Androutsopoulos A. et al, 2017a) and not with absolute values, it is not surprising that quite energy consuming buildings can be classified as energy efficient ones and thus, paradoxically, as 'nZEBs'.

Economic criteria change the ranking of scenarios dramatically (Figure 6). Generally, operational costs follow the same ranking patterns as energy criteria, while the ranking of scenarios for initial costs and payback period vary according to the examined technology. Scenario 0 excels in both initial cost and payback period, but comes last in operational costs. Scenarios with ecological thermal insulation have higher initial cost than scenarios with conventional insulation by an average of 26% for building envelope scenarios and by 13% for combination Scenarios 5; thus, they always rank after their respective conventional scenario, while operational costs are the same for both scenarios with conventional and ecologic insulation.

[19] According to the *Approval of the National Plan for Increasing the Number of nearly Zero Energy Buildings* (2018), an existing building has to reach energy class B+, so that it is characterised as nZEB.

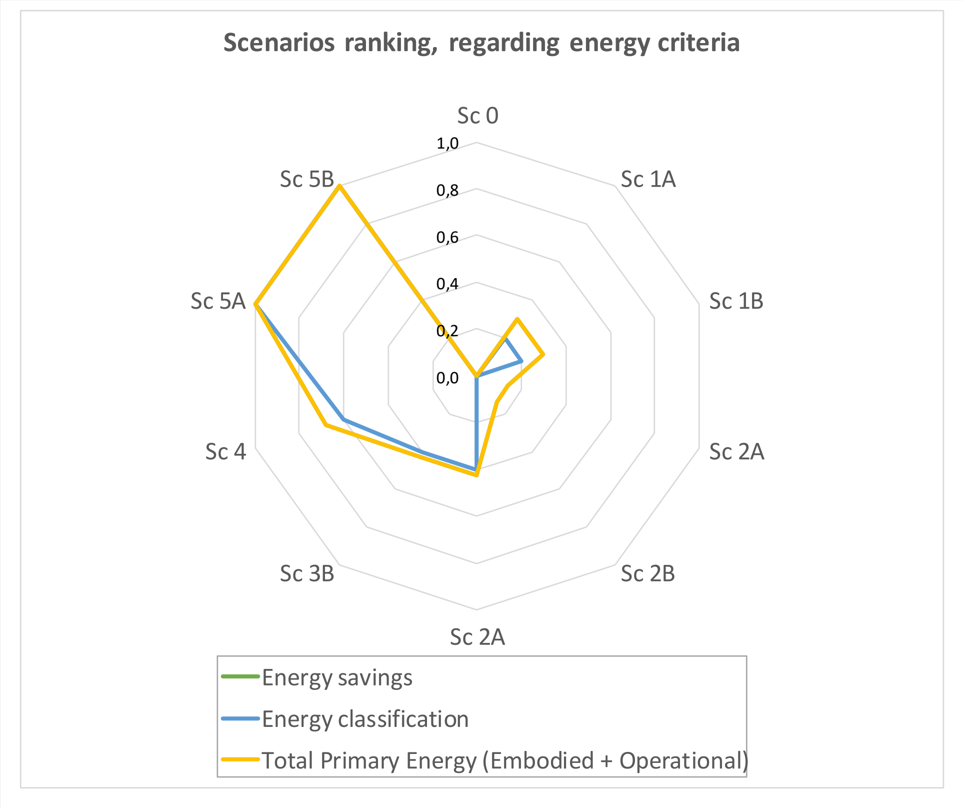

Figure 4: Scenarios ranking for the three energy criteria.

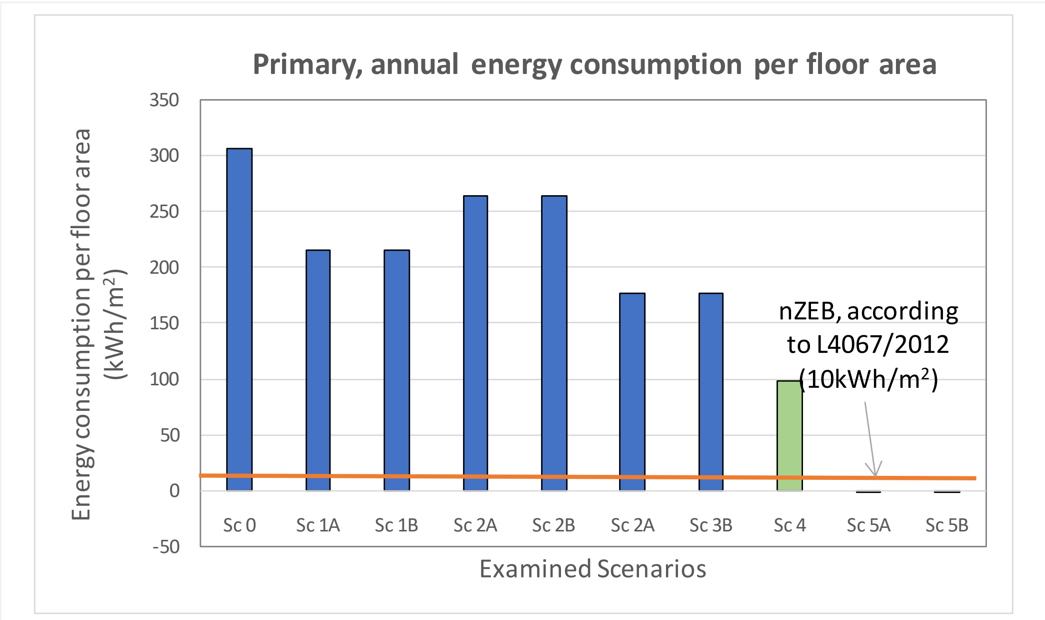

Figure 5: Annual primary energy consumption per floor area for the 10 examined scenarios. The scenarios which are classified as nZEB, according to Decision 85251/242/2018 are illustrated with green.

This makes their payback period greater, making them lag behind in this criterion as well (Figure 7). The largest payback period is observed for Scenarios 2 of insulating both roof and walls (from 15.5 years for conventional insulation to 19.7 years for ecologic one). Also, it is noteworthy that Scenarios 5A and 5B have quite short payback periods (9.3 years and 10.5 years, respectively) compared to their initial high investment cost (404,689.1€ and 457,330.9€, respectively). This is due to the fact that they reduce energy consumption by 100.1%, thus payback period is lowered. The shortest payback period (7 years) is observed for

Scenario 4 (placement of photovoltaic panels), which also reduces operating costs by 66,17%. Similarly, Gustafsson M. et al. (2017) examined office buildings in several European countries, concluding that in countries with a Mediterranean climate, the placement of photovoltaic systems on the roof of the building envelope is capable of reducing the overall building operating cost for its entire life cycle. Apart from that, the cost of Scenario 4 (201,067.50€) is quite close to the cost of Scenario 3A (203,621.60€), which means that the initial costs are about the same for both adding expanded polystyrene on the building envelope, or installing photovoltaic systems on its roof.

However, Scenario 4 is much more efficient than Scenario 3A, both at the rest of the economic criteria as well as at reducing energy consumption and CO_2 emissions. Ferrari S. and Beccali M. (2017) also reached the same conclusion, as in their examined building, they found out that the installation of photovoltaic systems is more economic and energy efficient compared to the thermal insulation of the building envelope.

Nonetheless, Pikas E. et al. (2014) came to the opposite conclusions; they found out in their case study that the scenario without photovoltaic panels is optimal in terms of cost-effectiveness in Estonia. As Estonia is a country with continental climate and with less solar radiation than Greece, photovoltaic panels perform less efficiently in this area than in Athens.

Regarding environmental criteria, most of them follow the pattern of energy criteria (Scenarios 5 ranking the highest and Scenario 0 the lowest), with the exemption of ozone depletion potential, where only Scenario 4 (photovoltaic panels) brings out positive results, reducing ozone depletion potential by 67.8%. Regarding this criterion, all the scenarios of adding thermal insulation on the building envelope have no effect at all.

It is interesting to observe that the differences between the respective scenarios As and Bs are not so large regarding environmental criteria, apart from the ozone depletion potential; the positive effects from reducing emissions from operational energy consumption supersedes the emissions caused during the production and the land filling of the thermal insulation material. Yet again, in all cases, scenarios with ecological thermal insulation (Bs) perform better in environmental criteria than their respective scenario with conventional thermal insulation (As). They also have a much more positive effect on ozone depletion potential than scenarios 'A', as can be observed in Table 3.

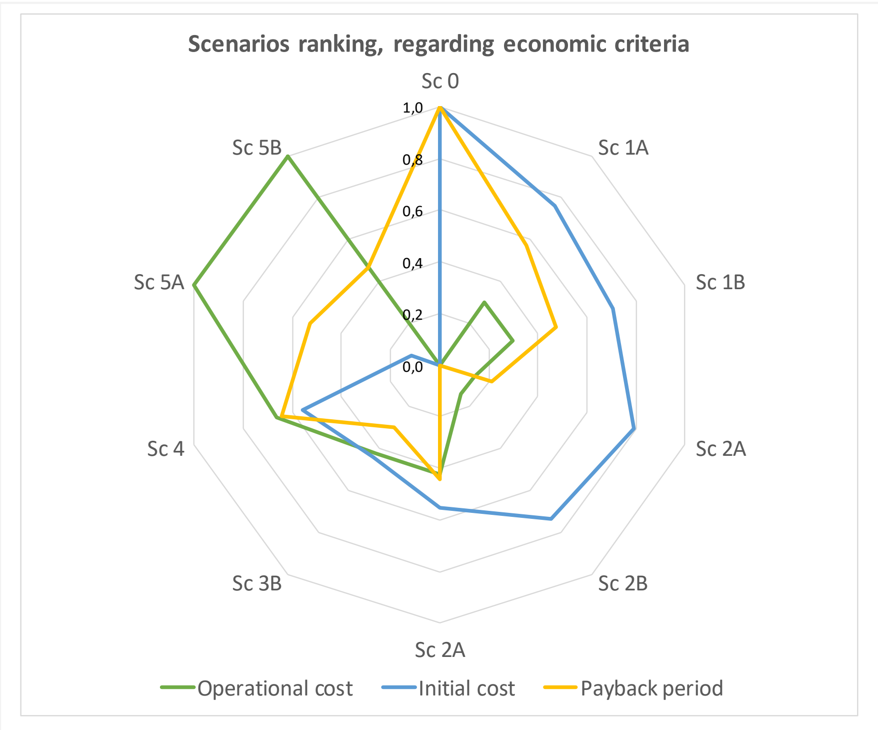

Figure 6: Scenarios ranking for the three economic criteria.

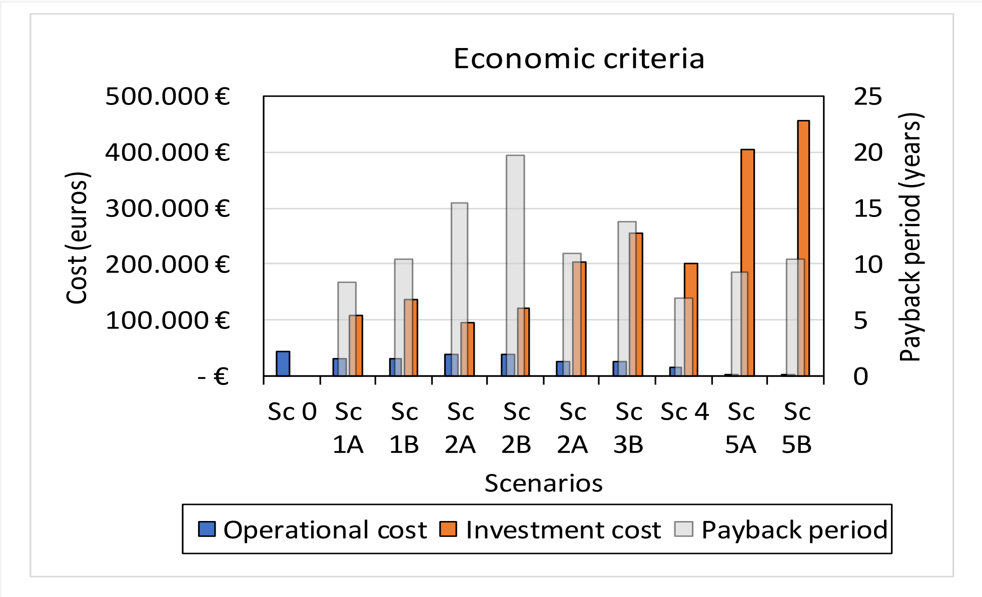

Figure 7: Annual operational cost, investment costs and payback period for the ten examined scenarios.

The synergy scenario 5B has the optimal environmental effects, managing to lower global warming potential and acidification potential by 99.9%, human health particulate and the city's climate change mitigation by 99.8%, eutrophication potential by 99.6% and smog potential by 99.5%.

Regarding the environmental performance of the rest of the energy upgrade scenarios, the poorest is observed in Scenarios 2A and 2B (placing thermal insulation only on the horizontal elements), ranging from a reduction of 13.7% for smog potential (Scenario 2A) to 14.0% for eutrophication potential, human health particulate and acidification potential. The reduction of CO_2 emissions from Scenario 4 (photovoltaic panels) is also significant (66.2%). Similar reduction is achieved also for fine particulate matter equivalent (67.8%) from this Scenario. Gustafsson M. et al. (2017) concluded that photovoltaic systems are beneficial worldwide from an environmental point of view throughout their life cycle. The effect of photovoltaic systems on this criterion strongly depends on the resources used for the production of electricity; if lignite is also used, as in the case of Greece (NIR, 2019), the placement of photovoltaic panels on buildings for the production of electricity can be beneficial also for this criterion.

6. Scenarios hierarchy

Combining all these criteria with the Multi Attribute Utility Theory and the weighting factors presented in Table 3, the hierarchy of scenarios that is depicted in Figure 8 and the first column of Table 2 is reached. It can be observed, that according to the selected criteria, indicators and weighting factors Scenario 5A is the optimal option, which, quite astonishingly, means that the addition of conventional, non-ecological thermal insulation (expanded polystyrene) on the building envelope, in combination with photovoltaic panels on the roof of the building is the most sustainable option. The second-best option is Scenario 5B (also synergy scenario, but with ecologic thermal insulation blown cellulose). Thus, the most effective scenarios, from a sustainability point of view of energy upgrading have been found to be the synergetic ones. Chidiac S. E. et al. (2011) have also come up to the conclusion that the synergies of multiple measures for the energy upgrade of office buildings, is crucial in order to reduce their energy consumption more effectively. Nonetheless, it should be taken into consideration that the effectiveness of the chosen energy upgrading synergies is significantly influenced by the typology of the building, the climate of the area where it is located, as well as on the technologies that will be implemented (ibid).

The installation of the photovoltaic systems on the roof (Scenario 4) ranks third, higher than Scenarios 3A and 3B (insulation of the building envelope with conventional and ecological material, respectively), which rank 4th and 5th, respectively. Scenarios 1A and 1B (insulation on the vertical components of the building envelope), rank 6th and 7th, respectively, managing to lower the environmental and energy effect of the building quite marginally, with high economic cost and small effect on the energy classification (upgrade the building to energy class 'C', from 'D').

It is interesting to compare the 'conventional' scenarios (1A, 2A, 3A and 5A) with their respective 'ecological' scenarios (1B, 2B, 3B and 5B); 'conventional' ones are more efficient in terms of the sustainability criteria examined, than 'ecological' ones. This occurs, because the criteria examined were not only environmental, but also economic; as the cost of environmental-friendly materials is much higher and their payback period is longer, they have been placed lower in the final rankings.

In the case that the criteria were exclusively environmental, then the exact opposite would be observed, as will be examined below.

Scenarios 2A and 2B rank 9th and 10th, being less effective, than leaving the building as is (Scenario 0), which ranks 8th. These scenarios request high initial costs, with disproportionately small energy and environmental benefits, as well as relatively high payback periods and low decrease in operational costs, causing them to be less preferable, than leaving the building operate as is (Scenario 0). A similar conclusion has been reached by Afshari A. et al. (2014), where after several energy upgrade scenarios for a 15-floor building in Abu Dhabi, they found out that adding thermal insulation on the roof did not significantly increase the efficiency of the building. However, the placement of thermal insulation on the horizontal components of a low storey building may prove beneficial (ibid). Indeed, Chidiac S. E. et al. (2011) concluded that smaller buildings tend to benefit to a greater extend in comparison to larger buildings, from the thermal insulation of their roof. However, for the three-floor building that has been examined here, it is concluded that it is more sustainable that it remains as is, rather than placing thermal insulation only on its horizontal components.

7. Sensitivity analysis

A sensitivity analysis is also carried out, in order to assess the uncertainty regarding the weighting factors incorporated in this research (Figure 10). For this reason, three more cases are examined; equal weighting factors for all criteria, prioritisation to all environmental and energy criteria with a weighting factor '5' and '3' for economic criteria and finally '5' to all criteria and '0' to economic ones. The results are the same when equal weighting factors are placed for all criteria, as with the originally used weighting factors (Table). However, hierarchy changes as the weighting factor of economic criteria lowers;

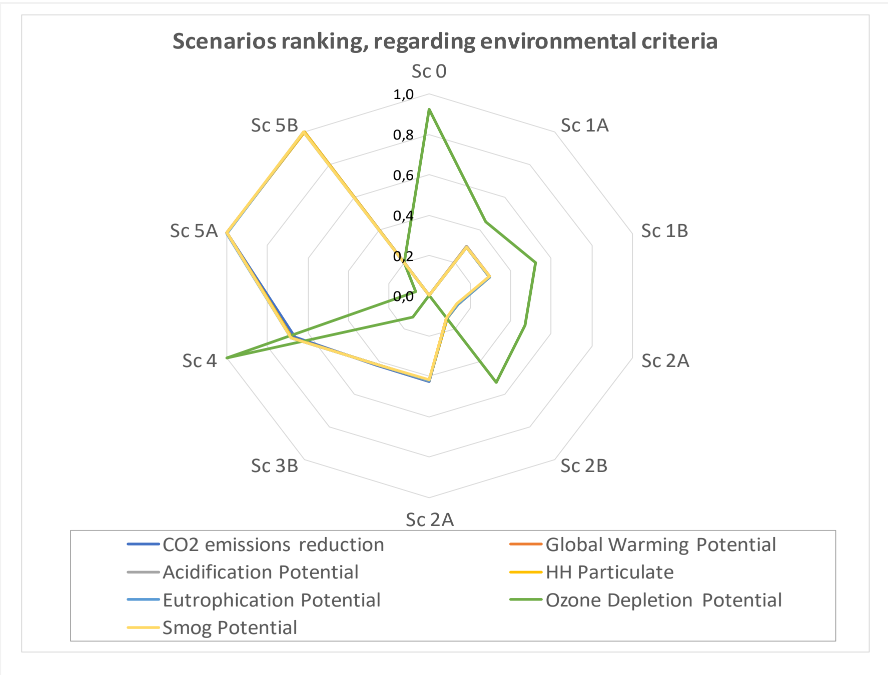

Figure 8: Scenarios ranking for the seven environmental criteria.

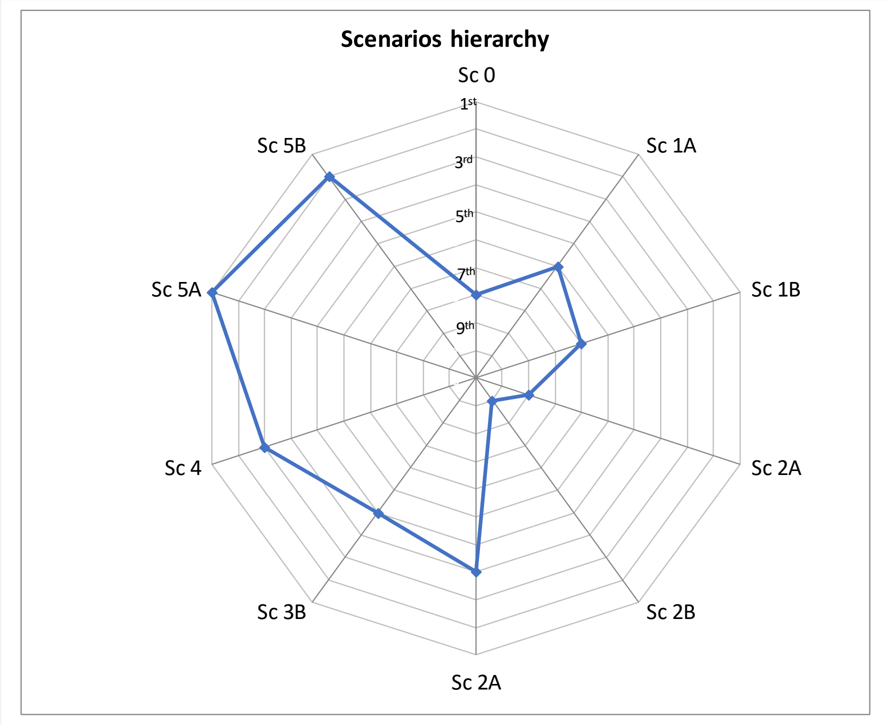

Figure 9: Scenarios hierarchy.

Table 2: Scenarios hierarchy for: WF1 – weighting factors as described in Table 3; WF2 – weighting factors are set to '5' for environmental and energy criteria and are set to '3' for economic criteria; WF3 – all weighting factors are equal; WF4 – weighting factors are set to '0' for economic criteria and to '5' for environmental and energy criteria.

Scenario	WF1	WF2	WF3	WF4
Sc 0	8	10	8	10
Sc 1A	6	6	6	7
Sc 1B	7	7	7	6
Sc 2A	9	8	9	9
Sc 2B	10	9	10	8
Sc 3A	4	4	4	5
Sc 3B	5	5	5	4
Sc 4	3	3	3	3
Sc 5A	1	2	1	2
Sc 5B	2	1	2	1

Scenario 0, with its largest energy consumption ranks last, while ecological scenarios (Bs) excel conventional scenarios (As) in Scenarios 5 and 2. When economic criteria are taken out of the decision-making process, Scenarios 'B' (ecologic thermal insulation) rank higher than scenarios 'A' (conventional thermal insulation). Yet again, the synergy scenario 5 of the upgrade of the building envelope and the application of photovoltaic panels is the optimum solution, followed by the photovoltaic panels (Scenario 4), then by improving the building envelope (Scenario 3B and then 3A), followed by placing insulation on the vertical, opaque elements (Scenarios 1B and 1A). Interestingly enough, in this case, it also seems better to only insulate the roof (Scenarios 2B and 2A), than to let the building as is (Scenario 0), which ranks last. When economic criteria are taken out of the equation, the environmental and energy small benefits of the energy upgrade of building elements, is much better than not taking any action at all. Yet again, as sustainability is built on the three pillars of environmental protection, social equity and economic growth (UN, 1987), taking only energy and environmental criteria into consideration leads to false estimations. As some of the greatest motivations (and also disincentives) are economic ones, it is not realistic not to take economic criteria into consideration, when technical works are considered. In the instance of Scenario 2B, it needs a payback period of 19.7 years, while it only offers 14.1% energy savings; common sense prescribes that it is better to seek other energy upgrade investments or not to take action at all, than to invest money and resources on something with such trivial results.

Thus, the weighting factors that have been used in this analysis, seem appropriate for describing the prioritisation of the examined scenarios.

8. Conclusions

This paper has used energy, economic and environmental criteria for examining energy improvement techniques of a heritage, office building in Athens, so as to assess which are sustainable and which are not. This is achieved with multicriteria analysis, so as to prioritise the examined energy upgrade scenarios. It has been found out that the most effective scenario for the energy upgrade of the examined heritage, office building is a synergetic one (thermal insulation of the building envelope and placement of photovoltaic panels), either with conventional or ecological thermal insulation (Scenarios 5A and 5B, respectively), in relation to the weighting factors placed on economic criteria. Therefore, applying measures that aim at different energy consumption sectors is vital for more effectively reducing its energy consumption and converting it to a near Zero Energy Consumption Building. With the implementation of this scenario the building has turned into a nZEB, with energy classification 'A+'.

The initial cost of Scenario 5A has been estimated at 404,689.10€, while its payback period is 9.3 years. These two criteria are the ones in which Scenario 5B scores worse values than Scenario 5A (457,330.90€ and 10.5 years, respectively), which turn out to be fatal, with the assumed weighting factors; Scenario 5A outweighs 5B (same scenario, but with eco-friendly insulation materials), due to the increased cost of ecological materials, which affects these economic criteria. If environmental and energy criteria are given a significantly higher weighting factor, then Scenario 5B ranks 1st and Scenario 5A follows as the 2nd option, as has been shown in the sensitivity analysis, due to the fact that it depicts much better values in all environmental and embodied energy criteria.

It is worth noting that the application of renewable energy sources of large capacity and more specifically of photovoltaic systems on the building envelope is extremely important, as their implementation not only reduces the

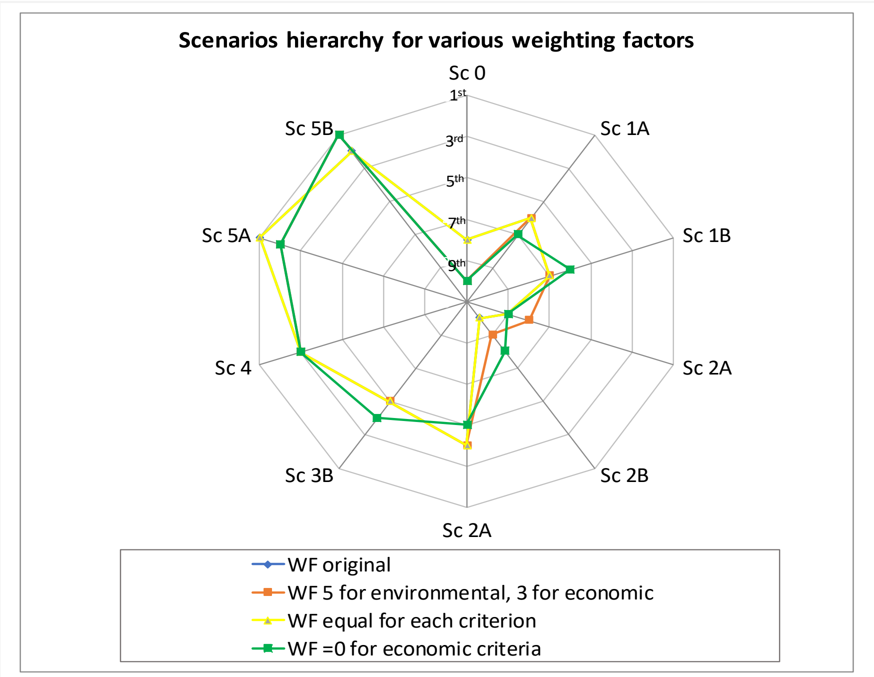

Figure 10: Sensitivity analysis – changes in scenarios hierarchy.

Table 3: Results for the 13 examined criteria and their respective indicators for the 10 examined scenarios. Scenarios that lead to nZEB, according to Decision 85251/242/2018 are highlighted with grey.

Type of criterion	Energy			Economic			Environmental						
Criterion	Reduction of energy consumption	Total Primary Energy	Added energy value	Life cycle costs	Capital construction	Cost benefit	Global Warming Potential	Acidification Potential	Human Health Particulate	Eutrophication Potential	Ozone Depletion Potential	Smog Potential	Climate change mitigation at city level
Indicator	Energy savings (%)	Embodied and operational energy (TJ)	Energy classify-cation	Operational cost (€)	Investment cost (€)	Payback period (years)	Carbon dioxide equivalent (tn CO_2 eq))	Sulfur dioxide equivalent (kg SO_2 eq)	Fine Particulate Matter equivalent (kg PM2.5 eq)	Nitrogen equivalent (kg N eq)	Trichloro-fluorome-thane equivalent (gCFC-11 eq)	Ozone equivalent (tn O_3 eq)	Operational CO_2 emissions reduction (%)
Weighting factors	4.65	4.59	3.64	4.55	4.00	4.01	4.68	4.53	4.73	4.49	4.52	4.68	3.79
Scenario 0 (building as is)	0.0%	706690541.2	D	43628.6	0.0	0.0	41590494.5	333493.5	36874.6	2865.5	1.74E-05	1193579.8	0.0%
Scenario 1A	29.8%	496805144.4	C	30645.6	108434.4	8.4	29247827.3	234461.0	25944.4	2021.8	8.90E-05	842921.9	29.7%
Scenario 1B	29.8%	496527019.6	C	30645.6	135543	10.4	29233442.8	234379.5	25940.4	2019.1	7.75E-05	841667.0	29.7%
Scenario 2A	14.1%	607563998.6	D	37488.0	95187.2	15.5	35765959.8	286735.1	31724.0	2470.2	8.51E-05	1029631.2	14.1%
Scenario 2B	14.1%	607341884.2	D	37488.0	120720.4	19.7	35754456.2	286669.7	31720.8	2468.1	7.64E-05	1028625.3	14.1%
Scenario 3A	42.4%	407816972.8	B	25122.1	203621.6	11.0	24019960.9	192486.9	21322.8	1667.7	1.57E-04	696096.6	42.4%
Scenario 3B	42.4%	407316733.5	B	25122.1	256263.4	13.8	23994072.8	192340.1	21315.7	1662.8	1.37E-04	693835.9	42.4%
Scenario 4	67.8%	227422094.6	B+	14758.3	201067.5	7.0	13384355.4	107322.5	11866.7	922.2	5.61E-06	384109.3	66.2%
Scenario 5A	100.1%	899628.2	A+	98.6	404689.1	9.3	71863.9	459.0	90.2	17.7	1.47E-04	8825.0	99.8%
Scenario 5B	100.1%	399388.9	A+	98.6	457330.9	10.5	45975.9	312.2	83.0	12.8	1.27E-04	6564.3	99.8%

overall environment impact of the building, but also is the only option for a significant change in its energy classification and its characterisation as 'nZEB' (Scenarios 4, 5A and 5B). The application of only photovoltaic panels on the building's roof and atriums ranks 3rd in all cases, despite the changes in the weighting factors.

Scenario 4 outperforms Scenarios 3A and 3B (thermal insulation on the building envelope with conventional and ecological materials, respectively) in all economic, energy and also environmental criteria. More specifically, the building has changed from energy class 'D' to energy class 'B' for Scenarios 3A and 3B and to "B+" (nZEB), for Scenario 4; thus ranking 4th and 5th, respectively, when economic criteria are not taken into consideration and 5th and 4th, respectively, when they are not. These scenarios are followed by Scenarios 1A and 1B, (thermal insulation on the vertical opaque elements, with conventional and ecological materials, respectively), which rank 6th and 7th respectively and 7th and 6th, respectively, when economic criteria are not considered. These scenarios perform poorly for most criteria and manage to upgrade the certification of the building from energy class 'D' to 'C'. Scenarios 2A and 2B (insulating only horizontal elements), in overall, perform worse than leaving the building as is (Scenario 0). Due to their high initial costs and their poor performance in the rest of the criteria, they rank 9th and 10th, respectively, when economic criteria are taken into consideration, with Scenario 0 raking 8th. Therefore, with the assumptions of this research and the 13 environmental, economic and energy criteria that have been taken into consideration, it is more sustainable to leave the building as is, than to only apply thermal insulation on its horizontal elements, despite of the materials used.

It is concluded that synergetic energy upgrade actions should be put forward, while resources consuming ones with small energy savings result should be avoided. The application of RES on the building is capable of turning it into a nZEB and not just the thermal protection of the building envelope. Yet again, the existing definition of 'nZEB' (based on comparative and not absolute values) can lead to the paradox of quite high energy consuming buildings (98.7kWh/m^2/year, in this case) to be characterised as 'nZEBs'.

Undoubtedly, the synergetic energy saving measures that offer energy savings to more than one sectors lead to larger energy savings, more efficient environmental protection, in a cost-effective way; these energy upgrade techniques should be put forward, despite their high initial cost. For the sake of environmental protection, it is important that the price of ecological materials is not as high as that of conventional ones. With the internalisation of externalised costs, these differences may be alleviated, making ecological materials financially more attractive, thus putting them forward for the energy upgrade of the building stock.

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A case study of the energy refurbishment of a public building: Assessment of the current situation and evaluation of retrofit solutions

Dr. Aimilios MICHAEL[1], Assistant Professor
Andreas KYRIAKIDIS[1], PhD candidate
Dr. Apostolos MICHOPOULOS[1], Senior Researcher
Eirini KYRITSI[1], PhD student
Dr. Dimitrios STIMONIARIS[2], Assistant Professor
Dr. Dimitrios TSIAMITROS[2], Associate Professor
Dr. Theodoros KOTTAS[2], Senior Researcher

[1] Department of Architecture, University of Cyprus
[2]Department of Electrical and Computer Engineering, University of Western Macedonia

Contact details of corresponding author
e-mail: kyriakidis.andreas@ucy.ac.cy
Address: University of Cyprus, Department of Architecture,
P.O. Box 20537, 1678 Nicosia, Cyprus

Abstract

Buildings are responsible for the 40% of the total energy consumption in Europe. Most of the energy consumed by buildings is associated with heating and cooling needs mostly due to high heat losses and gains during the heating and cooling period, respectively. It is widely accepted that building energy refurbishment can offer significant reduction in energy consumption. The present study is part of the funded research program *"Autonomous intelligent buildings of Zero Energy consumption connected to sustainable transport systems"* that aims to address the challenge of a novel and innovative concept of public buildings, i.e. the creation of Zero Emission Buildings. The project is co-funded by the European Regional Development Fund (ERDF) and national funds of Greece and Cyprus through the cooperation programme Interreg VA Greece-Cyprus 2014-2020. The outputs of the project include pilot buildings of high energy efficiency, integration of renewable energy sources and charging stations that promote sustainable mobility. Moreover, the outcomes include the creation of an electronic platform for the building's energy performance monitoring and for remote real-time controlling. Finally, the project will allow the publication of technical guidelines and good practices for future energy upgrades of public buildings within the Mediterranean region, as well as in Europe. In the present study an analysis of the energy behaviour of a pilot building is presented. This analysis takes into consideration the climatic conditions of the area, the orientation of the building and the surrounding urban environment, the building envelope, the electromechanical equipment and the use of the building. Based on that, an evaluation of the possible retrofit measures in terms of their applicability and potential, is also performed. The results show that the pilot building has high potential to be upgraded into a Zero Emission Building.

Keywords: Zero emission buildings; Building interventions; Energy efficiency; Cyprus.

1. Introduction

Built environment is responsible for the 40% of world's primary energy consumption (IEA, 2009). European Union, and other international organizations (IEA, 2019), have introduce Directives and Guidelines regarding the Energy Efficiency in the Building sector (EPBD recast, 2010). The Directive 2010/31/EU of the European Parliament states that Member States shall ensure that by 31 December 2020 all new buildings are nearly zero energy buildings and after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings (EPBD, 2010). Nearly Zero Energy Building is defined as "a building that has a very high energy performance as determined in accordance with Annex I of the Directive 2010/31/EU. The required energy of an NZEB building should be covered by renewable energy sources, produced on-site or nearby" (EPBD, 2010). The revised Energy Performance of Buildings Directive (EU) 2018/844 (European Parliament, 2018), includes even more measures for energy refurbishment of buildings, while also it introduces the Smart Readiness Indicator (SRI) for buildings in order to promote smart building technologies.

Nonetheless, apart from the regulations concerning new constructions, it is essential to consider actions for improving the energy efficiency of the existing building stock. Most of these buildings were built during the postwar reconstruction decade and therefore did not abide by any environmental principles or energy efficiency regulations. More specifically, in Cyprus the 40% of the building stock was constructed before 1981, while the 54% from 1981 to 2006, before any regulations for energy efficiency were established (Zingheri P., 2016). Therefore, actions need to be taken towards the energy refurbishment of existing buildings. Several studies indicate that there is great potential for energy saving through the energy refurbishment of existing buildings (Lidberg T. et al., 2018; Ascione F. et al., 2019; Corrado V. et al., 2016; Gaglia A.G. et al., 2019). Moreover, numerous studies argue that, retrofit measures regarding proper insulation of the building envelope and integration of energy efficient mechanical systems are essential for the increase of energy efficiency of existing buildings (Rabani M. et al., 2017). Furthermore, the integration of renewable energy sources would increase the energy autonomy of the building, limiting the demand from the electrical grid, aiding towards the goal of creating Zero Energy Buildings.

A considerable percentage of the existing building stock represents Public Buildings. In the case of Cyprus, where the present study is conducted, the 2-3% of total inland energy consumption is consumed by Public buildings, while the respective electricity consumption is 8% (Energy Service, 2019). Moreover, Cyprus National obligations include the renovation of 3% of the total area of heated and / or cooled buildings owned and used by government authorities (Law no. 149(1)/2015), in order to comply with the obligations of EU Directive 2012/27/EU (European Union, 2012). Public buildings are an important factor to achieving energy efficiency in the building sector, not only for the significant energy savings that can be achieved, but also for their high visibility in public life. Therefore, through the upgrade of these buildings to Zero Energy Buildings, good practices and retrofit actions can be discussed and presented to the public, through several seminars in order to disseminate the produced knowledge and to increase the environmental awareness and eco-consciousness (Michael A., Phocas M.C., 2012; Phocas M.C. et al., 2011).

The present paper deals with the energy refurbishment of a Public building and its upgrade to an "intelligent" Zero Emission Building. An analysis of the energy behaviour of the pilot building, namely the Aradippou Police Station, and the evaluation of the possible retrofit measures in terms of their applicability and potential are presented. The study is part of the research program *AYTONOMΩ "Autonomous intelligent buildings of Zero Energy consumption connected to sustainable transportation systems"*. The project is co-funded by the European Regional Development Fund (ERDF) and national resources of Greece and Cyprus through the cooperation programme Interreg VA Greece-Cyprus 2014-2020. The energy upgrade of a pilot building can contribute significantly towards the development of good practices and methods for the Public buildings of Cyprus and other areas of the Mediterranean basin, since studies have been shown that the appropriate retrofit actions for the efficient upgrade of buildings depend on the climate conditions, building typology and occupancy (Chidiac S.E. et al., 2011).

2. Background on energy refurbishment

Energy refurbishment can be a challenging process in terms of selecting the most appropriate retrofit actions for each case (Ma Z. et al., 2012; Asadi E. et al., 2012). In 2011, Xing Y. G. et al. proposed a hierarchical pathway towards to zero carbon building through retrofitting the building envelope, install more efficient building equipment and on-site integration of renewable power generation systems. Michael A. et al. in 2011, investigates the benefits of architectural integration of active solar systems on the facades and roofs of existing buildings, while Savvides A. et al. (2014), introduces a taxonomy and evaluation methodology for the building integration of photovoltaic and solar thermal systems. Moreover, Aksamija (Aksamija A., 2015) investigate the potential of an existing commercial building in Holyoke, Massachusetts, to be upgraded to a zero-energy one. He found that a comprehensive method considering adaptive design, building envelope treatment, passive design, appropriate HVAC systems and integration of renewable energy sources was needed to achieve that goal.

Therefore, the process of energy refurbishment should be addressed with a holistic view that includes retrofit actions towards reducing the energy demand, integrating renewable energy production systems to meet the energy requirements, implementing “intelligent” energy management systems for increasing the efficiency in building energy use and finally, actions that promote sustainable mobility.

2.1 Retrofit actions for decreasing energy demand

Numerous studies argue that the envelope retrofitting constitutes one of the most important stages of the refurbishment process (Ardente F. et al., 2011; Ali H., Hashlamun R., 2019). The insulation of the building envelope can significantly reduce the cooling and heating demands of the relevant buildings. In the case of the hot, arid climate conditions of Cyprus, roof insulation is considered as the most beneficial, followed by the wall insulation and window upgrade (Cyprus Ministry of Commerce, Industry and Tourism, 2013). Nonetheless energy retrofitting actions on the building envelope must be effectively coupled to the use of more efficient HVAC systems (Ascione F. et al., 2019). Furthermore, Ardente F. et al. (2011) conducted an evaluation of different retrofit actions implemented in six public buildings in six different European cities. The outcomes of the study showed that, the most significant benefits were achieved after improving the thermal insulation levels of the building envelope and the renovation of HVAC plants and lighting systems.

2.2 Implementing Renewable Energy Sources

As mentioned before, the integration of renewable energy sources is essential in order to meet the concept of a zero-energy building. Several studies deal with renewable energy production technologies (Li X. et al., 2019; Harkouss F. et al., 2019; Antony A., 2019), including studies focusing on renewable integrated technologies implemented on buildings (Mutani G. et al., 2018; Savvides A. et al., 2019; Vassiliades C., 2015). In areas with high available solar radiation like Cyprus solar technologies are considered as the most appropriate (Kalogirou S.A., 2001). Specifically, Larnaca, the area in which this study takes place, has an annual sunshine duration per day of 9,2 hours (Department of Meteorology of Cyprus, …) and less than 5% of cloudy days for the whole year (Pashiardis S. et al., 2017). Pashardis S. et al. in 2017 found that the constant and intense solar radiation in Cyprus is most suitable for solar energy conversion systems.

2.3 “Intelligent” building technologies

One of the main characteristics of Nearly Zero Energy Buildings is that, apart from minimizing the energy consumption, active renewable energy production systems are installed in order to balance the energy requirements. To accurately measure the actual energy consumption and production, several parameters that differ during operational conditions need to be taken under consideration. Such parameters include the user’s actions, i.e. unnecessary operation of lighting or HVAC systems, irrelevant use of windows, high or low setting of the thermostat temperature, and the prevailing weather conditions, i.e. their effect on the energy availability on a “weather-basis” rather than a “need-basis” through renewable energy sources (Kolokotsa D. et al., 2011). Therefore, a system that manages the energy production and energy requirements in real-time operation could yield significant benefits (Kolokotsa D. et al., 2011).

The installation of a Building Management System (BMS) offers a series of benefits towards to the efficient use of the electrotechnical equipment and long-term monitoring of indoor environmental quality (Guillemin A. and Morel N., 2002). For example, Kolokotsa D. et al., in 2005 developed and tested a fuzzy controller for a BMS in two buildings in Greece. Though this application, energy consumption was reduced up to 20% for heating and cooling, and up to 50-70% for lighting. Therefore such “intelligent” systems for monitoring and managing the building energy use will be a key factor in creating Zero Energy Buildings.

2.4 Sustainable mobility

Urban mobility is an aggravating factor in environmental issues as it is responsible for the increase of greenhouse emissions due to the use of the fossil fuels in the majority means of transport. For this purpose, the European Union targets for 2020 include a 10% renewable energy share in road transportations (Directive 2009/28/EC). Therefore, many urban areas are trying to adopt sustainable mobility strategies, such as the promotion of electric vehicles. Furthermore, systems, based on Renewable Energy Sources, can be installed for power generation and charge of the electric cars, limiting the greenhouse emissions related to electricity produced by fossil fuel power plants. Thus, several studies analyzed issues concerning the use of electric vehicles and the integration of renewable sources for providing transport services (Sujitha N. and Krithiga S., 2017; Croce A.I. et al., 2019; Calise F. et al., 2019). Additionally, the creation of charging stations by public authorities, where free renewable power for electric vehicles can be provided, could promote and increase the electric vehicle use. Finally, authors in (Zacharaki V. et al., 2016) gives a study of a photovoltaic charging-station (parking lot) for electric mini-buses.

3. Methodology

The present paper deals with the energy upgrade of an existing public building to a Zero Emission Building. This chapter describes the pre-survey of the building and its environment, required for the selection of the retrofit actions. The collected data included architectural drawings, existing studies—thermal insulation information, structural, electrical and mechanical studies—, building operation hours, building uses, number of occupants, electricity consumption and electromechanical equipment. Moreover, information concerning the climatic conditions of the area, the orientation of the building and the surrounding urban environment were also collected.

3.1 Climatic conditions

Cyprus has a Mediterranean climate marked by cold, wet winters and hot, dry summers. Aradippou is a municipality in Larnaca district, the third populated district of the island, and it is located at latitude 34°57’ N and longitude 33°35’ E. Larnaca district belongs to climatic zone 1 as all the coastal areas of the island. The meteorological data for Larnaca are recorded at the Larnaca International Airport, which is located about 10 km from the case study building. According to the relevant meteorological data between 1991 and 2005 (Department of Meteorology, 2019), the mean temperatures reach their highest value, i.e. 27.6 °C, during July and August, while the mean maximum temperature during the same period reach 32.7 °C. Similarly, the lowest mean temperatures, i.e. 11.8 °C, are recorded during January and February, while the mean minimum temperature for the same period is 6.9 °C. Diurnal temperature ranges between 9 and 12 °C during the summer period and between 8 and 10 °C during the winter period. The mean annual precipitation is 351.51mm.

3.2 The case study building and its environment

The present study deals with the energy refurbishment of a public building, i.e. the Aradippou Police Station, located in the district of Larnaca and more specifically in Aradippou municipality. The aim is to create a pilot Zero Emission Building which will serve as a demonstration project for other public buildings of Cyprus and potentially of any other area with similar climatic conditions and building constructions. The selected pilot building is located near the Rizoelia highway junction which connects four major districts of Cyprus, i.e. Nicosia, Limassol, Larnaca and Famagusta. Next to the selected plot is the Aradippou Lyceum and, in a close distance, the Aradippou Town Hall. Thus, the specific location attracts a significant number of passengers daily, making the location ideal for a demonstration pilot project aiming to increase environmental awareness. Furthermore, the location is also ideal for the placement of the charging station for electric cars as it attracts high car traffic.

The surrounding area of the building is characterized by a very low-density urban fabric with the largest portion of the land being green area. The high traffic road is located at the North-east side of the plot while the lyceum is located at the southern side. It is noted that there are no high buildings around the selected plot to block the sunlight or the air flow. The Police Station building is located on the south-eastern side of the case study plot, while there is a small covered parking area on the western side and another uncovered parking area on the northern side (Figure 1). The Police Station is a single-story building with a basement. The ground floor accommodates working and auxiliary spaces, a lecture hall, a kitchen, an infirmary and the detention cells for men, women and minors, while the basement accommodates parking spaces, storage rooms and areas for electromechanical installations. The entrance of the building, which leads into a closed, covered atrium, is located on the north side of the Police Station along with the lecture hall and the kitchen (Figure 2a). The detention centers are in the south-west side, where another closed atrium serves as an enclosed courtyard.

Finally, the south-east area accommodates working and auxiliary spaces arranged around another small enclosed courtyard (Figure 2b). The building under study is relatively new but poorly insulated. One of the indicators for the evaluation of the energy performance of the building is the Energy Performance Certificate. This certificate is mandatory by the law in cases of intense renovation of buildings. The Energy Performance Certificate is issued through the software SBEMcy which simulates the Cyprus National Methodology for Calculating the Energy Performance of Buildings. The Certificate places the existing building in Energy class C since the calculated yearly energy consumption of the building was 367 kWh/m^2/yr, while the CO_2 emissions were calculated to be 107.88 kgCO_2/m^2/yr (Figure 3).

The indoor area of the building is 610.32 m^2, with the 182.58 m^2 accommodating the detention cells and the 427.74 m^2 all the other uses. The external wall area is 413.65 m^2 while the windows/doors area is 70.89 m^2. Thus, the window-to-wall ratio is only 17% limiting the amount of natural lighting entering the building spaces. The external wall of the building envelope is 0.30 m thick and consists of reinforced concrete load-bearing structure and hollow ceramic bricks plastered with cement-based mortar. The U-values of the load-bearing structure is 3.00 W/m^{2}K while the U-value of the brick walls is 1.40 W/m^{2}K.

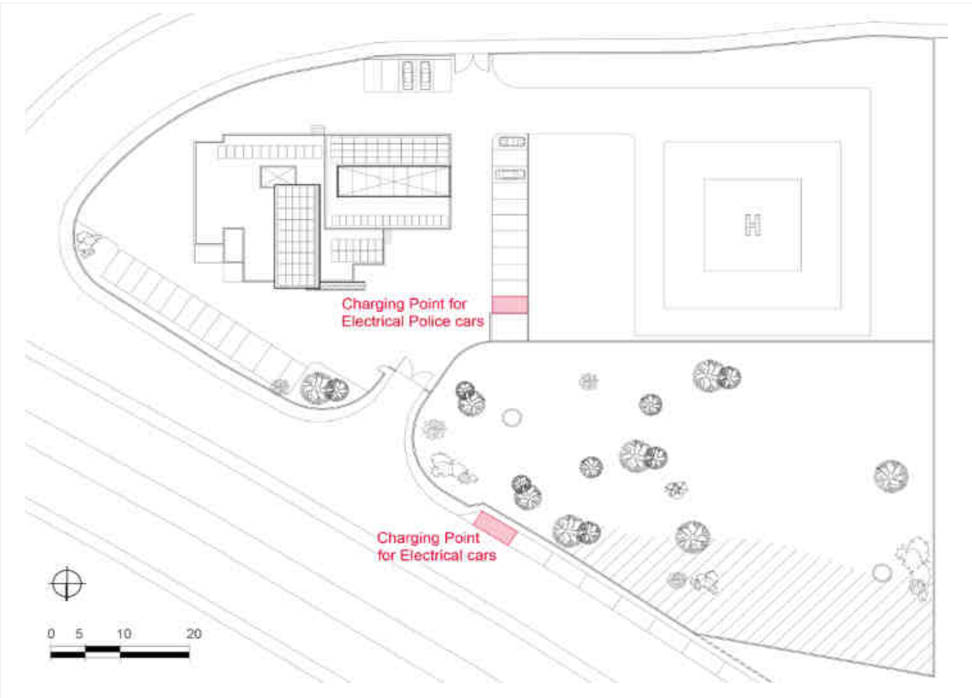

Figure 1: Plan view of the case study building plot, where the charging points for the electric cars are marked in red color.

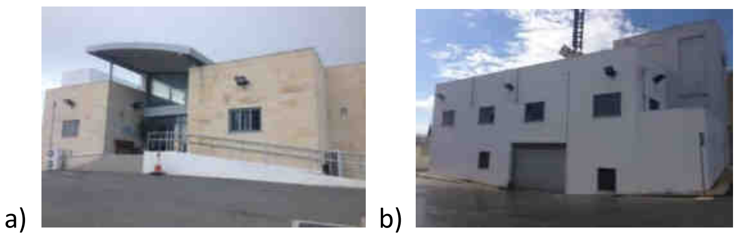

Figure 2: a) View of the entrance of the case study building, b) view of the east side of the building.

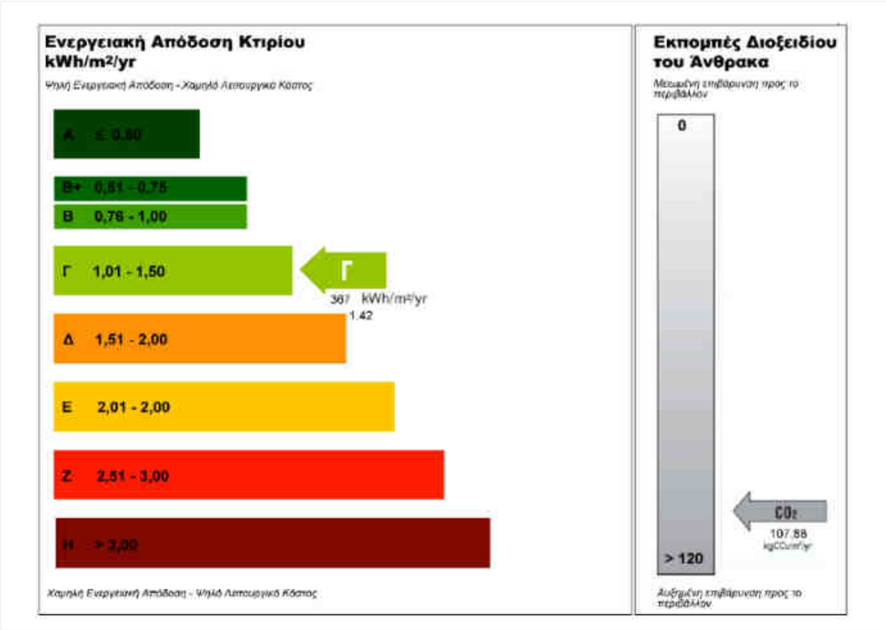

Figure 3: Energy Performance Certificate of the case study building.

The building has a flat roof with an area of 428 m^2 which consists of 25 cm thick reinforced concrete, 5 cm thick extruded polystyrene insulation and concrete paving tiles. The U-value of the existing roof is 0.513 W/m^{2}K. The upper concrete slab is covered by suspended ceiling tiles made of mineral wool, except for the detention cells where no false ceiling is applied. The lower concrete slab is 35 cm thick and consists of reinforced concrete, floor screed and ceramic tiles, with a U-value of 2.60 W/m^{2}K. As mentioned previously, there are two enclosed courtyards and the entrance atrium. The entrance atrium is covered by a separate higher metal roof and is accessed by a glazed wall, while glazed windows are positioned on the rest of the surrounding walls. The other courtyards are also covered but exposed to the external conditions. The windows are double glazed aluminum-framed with a U-value of 3.7 W/m^{2}K. Thus, significant cooling losses are observed as well as poor natural lighting levels. Regarding the HVAC systems, there is an existing air-source Variable-Refrigerant Flow heat pump (VRF) system for heating and cooling the building. Additionally, two air-source split type heat pumps are installed.

Besides the characteristics of the building construction components and equipment, there are some particularities regarding the building use that should be taken into consideration. More specifically, the building, needs to be working at a 24-hour basis. Therefore, the needs for artificial lighting as well as the use of the heating and cooling systems are higher than common office buildings. Furthermore, due to the existence of detention cells issues concerning security, as for example the installation of products which meet specific requirements concerning possible vandalism, must be considered. Moreover, the building, needs to remain open during the energy refurbishment process. This is an issue that probably will apply to many Public buildings and not only to this specific project. Finally, as the case study is a Public building and thus freely accessible to people, it is ideal for the dissemination of the retrofit measures and good practices applied to the case study building to the public.

3.3 Intervention measures

After recording the existing building condition, several retrofit measures were proposed taking into consideration the best applicable improvement in the energy efficiency and the relevant cost. Specifically, in order to meet the requirements for upgrade the existing Public building into a Zero Emission Building, several retrofit methods were evaluated. The retrofit methods aimed both to the reduction of the energy demand of the building and to the production of energy, through the integration of renewable energy sources.

Figure 4: Installation of thermal insulation on walls where stone cladding is applied.

Table 1: Retrofit actions on the building envelope.

Retrofit action	**Existing U-value (W/m^2K)**	**Max U-values allowed be national regulation (W/m^2K)**	**U-value after refurbishment (W/m^2K)**	**Thermal insulation Improvement (%)**
Insulation of load-bearing walls	3.00	0.4	0.31	90.0
Insulation of Brick walls	1.40	0.4	0.28	80.0
Roof Insulation	0.51	0.4	0.31	40.0
Basement roof slab insulation	2.59	0.4	0.30	88.0
Replacement of existing Windows	3.70	2.25	1.30	65.0

The intervention actions include improvement of the insulation levels of the building fabric, upgrading of the existing heating/cooling and lighting equipment through the addition of new high efficiency components, use of renewable energy sources, use of "intelligent" electronic platform for monitoring and remote real-time controlling of the energy performance of the building and integration of charging stations that promote sustainable mobility.

4. Retrofit solutions

4.1 Description of retrofit solutions

Descriptions of the retrofit actions that will be implemented in the case study building are provided in the present chapter.

4.1.1 Building Fabric

Regarding the improvement of the insulation characteristics of the building fabric, thermal insulation will be installed on the building envelope and new windows with lower U-value will replace the existing ones. More specifically, external thermal insulation will be installed on the load bearing components and brick walls. The insulation will consist of 10 cm thick rock mineral wool slabs. With the addition of the insulation slabs the U-value of the load-bearing walls will decrease from 3.00 W/m^2K to 0.31 W/m^2K, improving the existing insulation level by 90 %. Moreover, the U-value of the brick walls will decrease from 1.40 W/m^2K to 0.28 W/m^2K, improving the existing insulation level by 80 %. It should be noted that on the walls where stone cladding is applied, the insulation will be installed using aluminum systems as shown in Figure 4.

Moreover, 10 cm thick Spray Polyurethane Foam (SPF) will replace the existing insulation on the roof, decreasing the U-value from 0.51 W/m^2K to 0.31 W/m^2K improving the insulation level by 40 %. Insulation will be also applied under the roof slab of the unconditioned basement area. The insulation will consist of 10 cm thick rock mineral wool slabs. With the addition of the insulation slabs the U-value of the basement roof slab will decrease from 2.59 W/m^2K to 0.30 W/m^2K, improving the existing insulation level by 88 %.

Finally, the existing windows will be replaced by new triple glazed (Ug-value < 0.7 W/m^2K) aluminum framed windows with thermal break, 50 mm, with a U-value of 1.3 W/m^2K. The replacement of the existing windows will improve the window insulation level by 65 %. Concluding, the improvement of the insulation level of the building fabric is expected to reduce the energy demand by 68 %. The retrofit actions on the building envelope are summarized in Table 1.

4.1.2 HVAC system and artificial lighting

After improving the insulation of the building envelope that will result to the reduction of the heat gains and losses, the HVAC system will be upgraded with a more energy efficient one. Firstly, a heat recovery ventilation system with efficiency at least 76% in heating mode will be installed. The ventilation system will refresh the indoor air keeping the CO_2 levels in lower concentrations and removing odors from the indoor space, increasing the productivity and comfort of the occupants. Secondly, the two air-source split type heat pump units and the existing VRF piping and communication wiring will be removed from the building. The renovated heating and cooling system will be consisting of the existing VRF units in combination with three new high efficient water-cooled heat pumps (COP > 6.0), new piping and new communication wiring. The heat pumps will provide space cooling and heating as well as Domestic Hot Water (DHW). Each indoor unit will be able to operate independently in both heating and cooling mode. Furthermore, the HVAC systems, including all the indoor and outdoor VRF units and the DHW, will all be equipped with Konnex (KNX) interface for complete connectivity and control of all unit parameters by the building's "intelligent" monitoring system. Finally, a central KNX control unit with a touch screen located in a selected position in the working space area will give the users the ability to control the operation of each indoor unit, i.e. to turn some or all of them ON or OFF.

Regarding the artificial lighting, the existing lighting system will be replaced be new A+ LED lights. It is noted that inside the detention cells the new LED lights will also be vandal-resistance. The vandal-resistance lights have mechanical properties that increase their resistance to damage and, thus, are designed for areas such as prisons, psychiatric hospitals, gyms and underground pedestrian streets.

4.1.3 Renewable Energy Sources

Regarding the integration of Renewable Energy Sources, the refurbished building will use both a solar thermal system for Domestic Hot Water production, and a PhotoVoltaic (PV) system that will partially cover the power demand of the building The solar thermal system consisted of 12 solar thermal panels covering an area of 30 m^2, will be placed on the south side of the building's flat roof (Figure 5), and it is going to be in operation during the winter period in order to assists the operation of the VRF heat pumps. Although, during the summer period the solar collectors will be fully cover by protector sleeves as no heating loads are foreseen. Additionally, a PV system of 19.25 kWp capacity will be installed on the roof. The PV system will consist of 3 arrays of PV panels. One array, of 40 PV panels, will be placed on the south-west side of the roof. One smaller array, of 16 PV panels, will be placed northward of the roof of the west courtyard, the one located between the detention cells, but at a distance of approximately 3 m in order to avoid the shadow of the courtyard roof. Finally, the fourth array, of 14 PV panels, will be placed on the north-west side of the roof (Figure 5). It is noted that there are no surrounding high buildings or trees to drop shadow on the roof of the building. The generated power from the PV system will be stored in lithium-ion batteries with a capacity of 39.6 kWh. The system will be connected to the central electrical grid for energy supply in the case of low solar radiation. The Solar Thermal System and the PV system will be connected to the building monitoring system.

4.1.4 Charging Station for electric cars

One of the main objectives of the present study is the promotion of sustainable mobility. For this purpose, a charging station for electric cars connected to the PV system will be installed in the building plot. The charging station will have two charging points as shown in Figure 1. The charging station will require a PV system of 12 kWp capacity, in order to cover its energy needs. The PV system will consist of 1 array of 45 PV panels placed on the metal roof of the entrance atrium. Also, the station will be able to store up to 26.4 kWh. Finally, the station will be able to fully charge a 36 kWh vehicle with an average electric car range of 300 km. It is noted that the charging system and power generation systems in the building will be fully interconnected and will be treated as one.

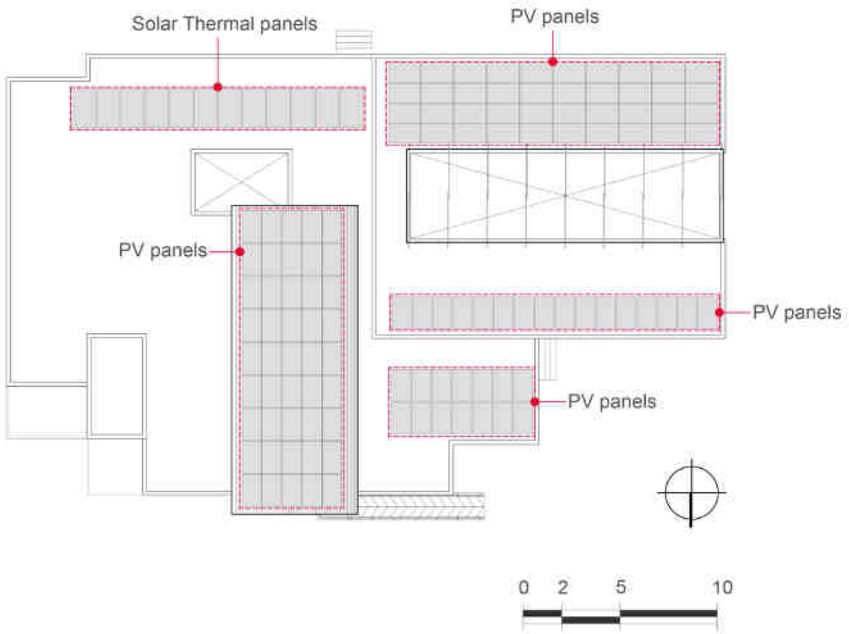

Figure 5: Roof plan presenting the Solar Thermal panels and the Photovoltaic panels.

4.1.5 Building "intelligent" monitoring system

To increase the energy efficiency of the building, an appropriate "intelligent" energy management system will be applied in the case study building. Thus, an appropriate electronic data recording system will be installed in the building in a designated area. The "intelligent" system will have features for surveillance, control and metering of the building energy use and will consist of units for collecting, processing and storing information from locally installed sensors and measuring instruments and controls. The in-situ measurements will include temperatures, heat inflow and outflow, heat absorbed by the building structure, surface temperatures etc. These units will record, store, transmit and illustrate data on a 24-hour basis. Additionally, the system will limit wasted energy through intelligent algorithms, i.e. fuzzy cognitive networks, neural networks, genetic algorithms etc., for regulating the operation of the HVAC units. Furthermore, a relevant application for portable devises, like smartphones and tablets, will satisfy the need for remote control of the system. Moreover, energy data, as for example the energy output from the PV panels or the carbon footprint of the building, will be able to be exported and displayed on a projection screen. The projection screen will be installed in an accessible and visible to the public area, in order to increase environmental awareness.

4.2 Expected outcome

The energy refurbishment of the case study Public building aims to be the starting point to the creation of Zero Emissions Public Buildings that will address issues concerning reduction of energy consumption, renewable energy generation and "intelligent" energy management. The Aradippou Police Station will become a model of energy and technologically advanced Public building. After the building refurbishment the energy consumption is expected to be reduced by 68% while the energy demand will be covered by renewable energy sources. Moreover, the "intelligent" monitoring system will manage the energy use of the building reducing even more the energy demand.

The public will also benefit from the project since a manual for the upgrading of existing buildings to "intelligent" Zero Emission Buildings will be issued to disseminate the produced knowledge. Moreover, people owning electric cars will be able to charge their vehicles in the new charging station. Furthermore, training seminars addressing several environmental issues will be organized for users of public buildings, i.e. people working in or visiting the buildings. The seminars will address issues of energy design, energy saving and renewable energy sources.

Apart from the seminars, educational tours for students will be organized in order to be informed for the good practices and technologies installed in the building and increase their environmental awareness. Thus, having in mind the use of the specific building as a Police station, this will be a perfect opportunity for the police to address the public with issues concerning the environment or CO_2 emissions issues and technology issues.

5. Conclusions

The present paper deals with the energy refurbishment of a Public building and its upgrade to an "intelligent" Zero Emission Building. An analysis of the energy behaviour of the pilot building, namely the Aradippou Police Station, and the evaluation of the possible retrofit measures in terms of their applicability and potential are presented. The study is part of the research program *ΑΥΤΟΝΟΜΩ "Autonomous intelligent buildings of Zero Energy consumption connected to sustainable transport systems"*. The project is co-funded by the ERDF and national funds of Greece and Cyprus through the cooperation programme Interreg VA Greece-Cyprus 2014-2020. The program aims to address the challenge of a novel and innovative concept of public buildings, i.e. the creation of Zero Emission Buildings. The outputs of the programme include pilot buildings of high energy efficiency, integration of renewable energy sources and charging stations that promote sustainable mobility.

The pre-survey of the building and its environment showed that the location is ideal for a demonstration pilot project aiming to increase environmental awareness as it attracts a significant number of people and cars daily. Furthermore, the location is also ideal for the placement of the charging station for electric cars as it attracts high car traffic daily. Regarding the existing building, it is found that it suffers from poor insulation of the building envelope, resulting significant heat gains and losses. Moreover, the existing HVAC system could not provide independent operation in both heating and cooling mode for each indoor unit which, taking into consideration the different uses, the many enclosed offices as well as the 24hour operation of the building, caused problems in the HVAC use and efficiency. Additionally, keeping in mind the 24-hour operation of the building, the existing low efficiency artificial lighting required significant energy consumption. It is noted that due to the existence of detention cells, issues concerning security, like the installation of vandal-resistance products, were considered. No renewable energy source was found in the building. Thus, the Energy Performance Certificate placed the existing building in Energy class C.

After recording the existing building condition, several retrofit measures were proposed taking into consideration the best applicable improvement in the energy efficiency and the relevant cost. The proposed retrofit methods include addition of thermal insulation on the external walls, roof and basement roof slab. Also, replacement of the existing windows by new triple glazed high efficiency aluminum windows. The improvement of the insulation level of the building fabric is expected to reduce the energy demand by 68%. Regarding the HVAC system, it will be upgraded to a more efficient version which will permit independent operation of each indoor unit in both heating and cooling mode. Moreover, a heat recovery ventilation system will be installed in order to improve the indoor air quality. The existing artificial lights will be replaced by new high efficiency vandal-resistance LED lights.

Two Renewable Energy Sources will be integrated into the refurbished building, a Solar Thermal system and a Photovoltaic (PV) power generation system. An electric car charging station with two charging points will be connected to the PV system. Finally, an appropriate "intelligent" energy management system will be applied in the case study building in order to increase the energy efficiency of the building. The management system will be connected to all HVAC, lighting and renewable energy sources components, as well as other measuring sensors and controls. Furthermore, a relevant application for portable devises, like smartphones and tablets, will satisfy the need for remote control of the system and energy data will be able to be exported and displayed on a projection screen which will be installed in an accessible and visible to the public area, in order to increase environmental awareness.

The expected outcomes of the study include the reduction by 68% of the building energy demand which will be covered by renewable energy sources. Moreover, the "intelligent" monitoring system will manage the energy use of the building reducing even more the energy demand. The public will also benefit from the project since a manual for the refurbishment will be issued, electric car owners will be able to charge their vehicles in the new charging station, training seminars and educational tours for students will be organized to inform about the good practices and technologies installed in the building and increase environmental awareness.

The case study building has high potential to be upgraded into a pilot Zero Emission Building which will serve as a demonstration project for other public buildings of Cyprus and potentially of any other area with similar climatic conditions and building stock.

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Computational Investigation to the Design Method of Centrifugal Fan Volute with the Aim of Increasing Energy Efficiency

M.Sc. Ardit GJETA[1], PhD candidate*
M.Sc. Albert SHIRA, PhD candidate*
Prof. Dr Andonaq LAMANI, Full Professor*
Prof. As. Altin DORRI, Head of Energy Department*

*Mechanical Engineering Faculty, Polytechnic University of Tirana, Albania

[1] *Contact details of corresponding author*
Tel: +355 69 26 49 501
e-mail: agjeta@fim.edu.al
Address: “Mother Teresa” Square, Nr. 4, Tirana, Albania

Abstract

Industrial fans are subject to EU energy labeling and Ecodesign requirements. By using more efficient industrial fans, Europe will save 34 TWh and avoid 16 million tones of CO_2 emissions annually by 2020 (Commission Regulation No. 327/2011). In this article, we will present some other alternative methods of external volute design shape and evaluate these methods by performing numerical simulations using open source CFD software OpenFOAM (Eck B., 1973). An automized loop with RANS and data post-processing is set up using Matlab, for allowing a large number of parameter variations (Carolus Th., 2013). We conducted numerical analysis for all operating points, where starting points are optimal impellers for the whole range of specific speeds (Bamberger K. et al., 2015). The effect of volute shape in the centrifugal fan performance and efficiency are presented. A qualitative understanding of the effects of volute shape will enable the performance of a real product to be improved.

Keywords: CFD Software OpenFOAM, Centrifugal fan, Volute, efficiency.

1. Introduction

European regulations put into force standards for energy-efficiency of fans, with increasing requirements in the near future (Commission Regulation No. 327/2011). Studies concerning centrifugal fans have investigated the impeller, but only to a smaller extend the spiral casing (volute) (Bamberger k. et al., 2016; Atre Pranav C. and Thundil Karuppa Raj R., 2012; Shah K.H. et al., 2003). An impeller is a mechanical device that supplies mechanical energy to the fluid and is a key component of the fan. The volute may take up a substantial part of the fan's hydraulic loss. Currently, minimization of energy loss is dependent on the characteristics of the spiral casing. Hence, appropriate design of the fan volute has significant meaning to centrifugal fan performance.

Following a current and nearly finished study on aerodynamic optimization of centrifugal fan impellers using CFD-trained meta-models, where a method for optimization of impellers of the whole class of centrifugal fans has been developed, an extension to the volute is envisaged (Yukun Lv. et al., 2012; Ayder E., Braembussche Van den R., 1993). For that, this study of volutes is carried out which should lead to advanced best practice recommendations for the volute design shape.

2. Climate and Energy Policy

In March 2007, the EU’s leaders endorsed an integrated approach for climate and energy policy. They committed to transforming EU into a highly energy-efficient, low carbon economy starting with demanding climate and energy targets to be met by 2020, ie[20]:

[20] https://ec.europa.eu/clima/policies/strategies/2020_en

- 20% reduction in greenhouse emissions; compared to 1990 level;
- 20% increase in renewable energy resources;
- 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency.

The Energy related Products Directive (ErP) was enforced, with the aim to reduce energy across the supply chain of energy related products, introducing efficiency standards for the installation of electric motors and fans. The European Directives that are now applicable to electric motor and fan efficiency are:

- Ecodesign Directive (2005/32/EC) energy using products (EuP);
- *Commission Regulation (EC) No 640/2009 - Ecodesign requirements for electric motors.*
- Ecodesign Directive (2009/125/EC) extension to energy related products (ErP)
- *Commission Regulation (EU) No 327/2011-* Ecodesign requirements for fans driven by motors with an electric output between 125 W and 500 kW.

More specifically for:

Legislative requirements for HVAC[21] systems, machines components and motor assemblies, such as fans and electric motors used in different engineering applications are the object of: i) Ecodesign Directive (2005/32/EC; 2009/125/EC); Energy Using Products (EuP); Commission Regulations (EC) (No. 640/2009; 327/2011).

Fans Efficiency: Fan Motor Efficiency Grade (FMEG) started in January 1st 2015. Motors with rated output 7.5-375kW shall not be less efficient than the IE3 efficiency level or shall meet the IE2 efficiency level. It should be used with a variable speed drive. The basis of the FMEG is the optimum or maximum efficiency of the fan, calculated as:

$$Fan\ Efficiency\ [\%] = \frac{Air\ flow\ [m^3/\mathrm{s}]\ x\ Pressure\ [\mathrm{Pa}]}{Motor\ input\ power\ [Watts]}$$

The pressure can be either static or total (depending on the fan test method used). There are three important exemptions to ErP compliance:

- Motors with less than 125 watts
- Fans used to move air or gases at temperatures exceeding 100 °C
- Placed on the market before 1st January 2015 as a replacement for identical fans integrated in products which were placed on the market before 1st January 2013

It is the responsibility of the manufacturer to ensure that the finalised fan motor assembly complies with legislation and meets the required efficiency level. The two main components that have a large effect are: i) The motor and ii) The transmission.

The formula to calculate the FMEG grade for a forward curved fan in a housing is:

$$N = 2.74\ x\ ln(P) - 6.33 - \eta_e$$

And to calculate the FMEG grade for a backwards curved fan with no housing is:

$$N = 4.56\ x\ ln(P) - 10.5 - \eta_e$$

Where:

N, is the FMEG grade;

P[kW], is the input power in kW;

$\eta_e[\%]$, is the optimum or maximum efficiency percentage.

The Commission Regulation (EU) No 327/2011 refers to the following: Total electricity consumption of fans driven by motors with an electric input power between 125 W and 500 kW is 344 TWh per year, rising to 560 TWh in 2020 if current Union market trends persist. The cost- efficient improvement potential through design is about 34 TWh per year in 2020, which corresponds to 16 Mt of CO_2 emissions. Consequently, fans with an electric input power between 125 W and 500 kW represent a product for which Ecodesign requirements should be established. The preparatory study showed that fans driven by motors with an input power between 125 W and 500 kW are placed on the Union market in large quantities, with their use-phase energy consumption being the most significant environmental aspect of all life-cycle phases. Improvements in the energy efficiency of fans driven by motors with an electric input power between 125 W and 500 kW should be achieved by applying existing non- proprietary

[21] Heating, Ventilation, and Air Conditioning

cost-effective technologies that can reduce the total combined costs of purchasing and operating them. Ecodesign requirements for industrial fans are mandatory for all manufacturers and suppliers wishing to sell their products in the EU. These requirements cover product information and efficiency (Commission Regulation No. 327/2011). At the time of adoption of this Regulation, the best available technology on the market for fans is as indicated in Table 1. These benchmarks may not always be achievable in all applications or for the full power range covered by the Regulation.

Exemptions from the regulation: All standard fans are subject to ErP regulations. However, there are several fan applications that are exempt from ErP Regulations. These are listed below:

- Fans in vehicle applications for the transportation of people or goods;
- Fans with an optimum efficiency at speeds of 8,000rpm or higher;
- In applications for which the 'specific ratio' is over 1.11;
- Fans used in the conveyance of non-gaseous substances in industrial applications;
- "Smoke-extract" type fans.

3. Volute shape design method

3.1 Constant circulation method

The spiral housing in radial fans has the task of collecting the fluid in a low-loss manner and converting kinetic energy into static pressure.

Table 1: Minimum energy efficiency requirements for fans from 1 January 2017 (Commission Regulation No. 327/2011).

Fan types	Efficiency category (static or total)	Efficiency grade (N) 2017 (%)	Maximum achievable efficiency	Power range P in kW	Target energy efficiency (%)
Centrifugal backward curved fan with housing	static	61	72	$0.125 \le P \le 10$	$\eta_t = 4.56 \cdot ln(P) - 10.5 + N$
				$10 < P \le 500$	$\eta_t = 1.1 \cdot ln(P) - 2.6 + N$
	total	**64**	**75**	$0.125 \le P \le 10$	$\eta_t = 4.56 \cdot ln(P) - 10.5 + N$
				$10 < P \le 500$	$\eta_t = 1.1 \cdot ln(P) - 2.6 + N$

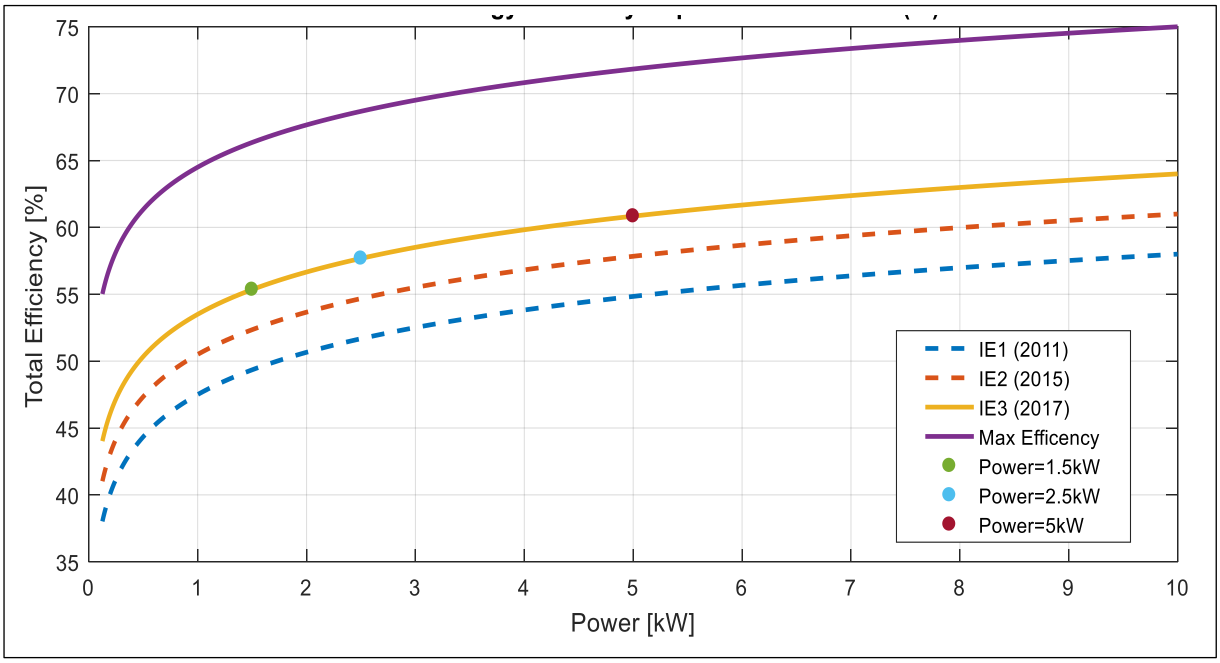


Figure 1: Minimum energy efficiency requirements for fans [by the authors].

Constant circulation method (Eck B., 1973) is a method to draw volute based on that the velocity circulation is a constant

$$r \cdot c_u = const$$

In practice, this rule is valid with the restriction that one spiral must be so far displaced from the impeller that deflections conditioned by the consideration of a finite number of blades can be ignored. This rule constitutes the basis for the dimensioning of a volute for the case where friction has been ignored. The velocity c at an arbitrary place can be calculated from its components c_m and c_u ,

$$r \cdot c_u = r_2 \cdot c_{u2} \rightarrow c_u = c_{u2} \cdot (r_2 / r).$$

From the condition that the same volume flow must flow (continuity equation) through all the streamline in volute it gives the relationship,

$$\bar{V} = 2\pi \cdot r_2 \cdot b_2 \cdot c_{m2} = 2\pi \cdot r \cdot B \cdot c_m,$$

from which follows $r_2 \cdot b_2 \cdot c_{m2} = r \cdot B \cdot c_m$,

from this we obtain the following inclination α of the streamlines:

$$\tan(\alpha) = \frac{c_m}{c_u} = \frac{c_{m2}}{c_{u2}} \frac{b_2}{B} \quad (1)$$

Because we obtain the boundary of the volute from the streamline, again it yields, $\tan(\alpha) = \frac{dr}{rd\varphi}$

$$\frac{dr}{r} = d\varphi \tan(\alpha) = d\varphi \tan(\alpha_2)\frac{b_2}{B} \quad (2)$$

The solution states,

$$\ln\frac{r}{r_2} = \varphi \tan(\alpha_2)\frac{b_2}{B} = \varphi \frac{c_{m2}}{c_{u2}}\frac{b_2}{B} \quad (3)$$

Accordingly, the trajectory of fluid particles in the volute is as follows (Carolus 2013)

$$r_{(\varphi)} = r_2\, \mathrm{e}^{\varphi \tan(\alpha)} = r_2\, \mathrm{e}^{\varphi \tan(\alpha_2)\frac{b_2}{B}} \quad (4)$$

where

$r_{(\varphi)}$ [m], is the radius of the volute at angle φ,

r_2 [m], is the outer radius of impeller that is equal to 150mm in this case;

α [°], is the angle that absolute velocity vector makes with the peripheral direction $\tan(\alpha) = c_m / c_u$

b_2 [m], width of outlet impeller

B [m], width of volute

3.2 Archimedes helix method

The following equation will give the Archimedes shape of volute (Eck B., 1973):

$$r = r_2 + \frac{H}{2\pi}\varphi, \mathrm{H} = \frac{Q}{B \cdot c_u} \quad (5)$$

r_2,[m] is the outer radius of impeller
H [m], is the maximum aperture of the casing. In spiral case design, to ensure its exit outlet nozzle for $\varphi > 2\pi$, the spiral is replaced by a straight line, while on the other side of the spiral case is the tongue. The tongue divides the fluid stream coming from the rotor into two parts, the first part goes directly to the exit nozzle, while the rest before leaving the exit nozzle, it must circulate on the rotor (Eck B., 1973). Spiral case designed by this method limit the fan's radial size, experience shows that it is more suitable for the fan with low and medium specific speed.

3.3 Structure square method

The following equations will give the structure square method (Yukun Ln. et al., 2012) shape of volute (Figure 2).

The drawing procedure: Make a square in the impeller center, its side length $a = H/4$. Then take the square four vertexes as the centers, start from $\varphi = 0°$, followed by the radius of circular to draw four arcs, R_d, R_c, R_b and R_a, it that way its obtain the desired helical line.

Lines drawn by this method and the logarithmic spiral line have a certain gap. If specific speed is higher, the error is larger. In order to make the volute line drawn by this method approximate for the logarithmic spiral.

3.4 Performance of the volute

The overall performance of the volute is affected mainly by the following geometric parameters (Ayder E., Braembussche Van den R., 1993): area of the cross-section, shape of the cross-section, radial location of the cross-section, location of the impeller and tongue geometry. The overall performance of the volute can be analyzed by using:

$a = \frac{H}{4}$ H [m] is the maximum aperture of the casing

For angle $\varphi = \frac{3}{2}\pi \div 2\pi \rightarrow R_a = R_2 + 3.5 \cdot a$ For angle $\varphi = \pi \div \frac{3}{2}\pi \rightarrow R_b = R_2 + 2.5 \cdot a$

For angle $\varphi = \frac{1}{2}\pi \div \pi \rightarrow R_c = R_2 + 1.5 \cdot a$

For angle $\varphi = 0 \div \frac{1}{2}\pi \rightarrow R_d = R_2 + 0.5 \cdot a$

(6)

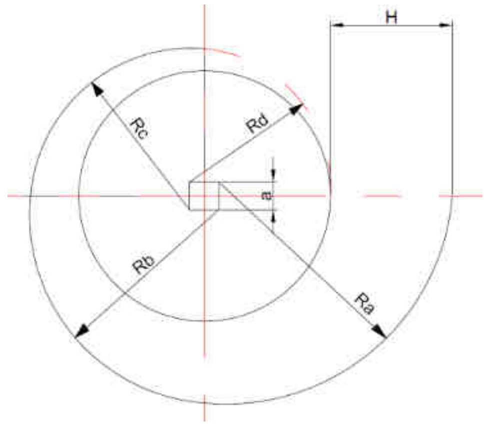


Figure 2: The schematic plot of structure square method [by the authors].

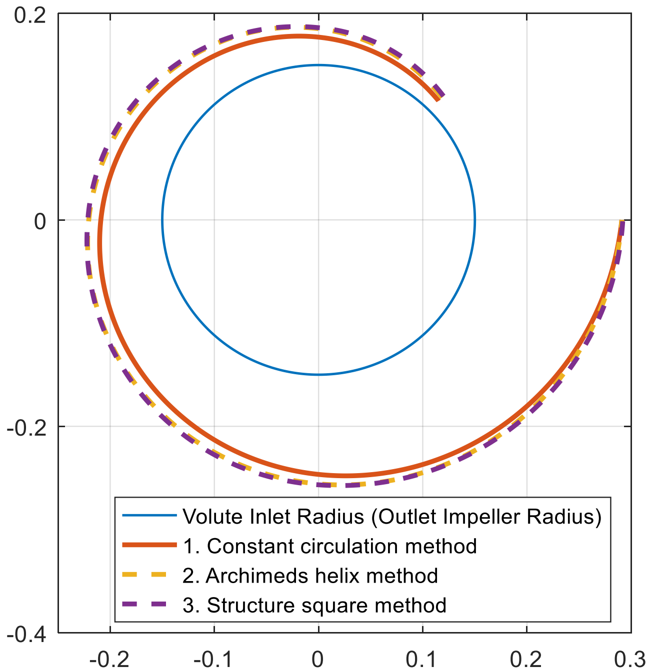


Figure 3: Comparison of volute shape for different shape method [by the authors].

- Total Efficiency of volute $\eta_t = \frac{p_{t3}}{p_{t2}}$ (6)
- Static pressure recovery coefficient of volute:

  $$C_p = \frac{p_3 - p_2}{p_{t2} - p_2} = \frac{p_3 - p_2}{\frac{\rho}{2} c_2^2} \quad (7)$$

  C_p, is defined as the ratio between the static pressure recovered in the volute to the dynamic pressure at the impeller exit.
- Total pressure loss coefficient of volute:

  $$K_p = \frac{p_{t2} - p_{t3}}{p_{t2} - p_2} = \frac{p_{t2} - p_{t3}}{\frac{\rho}{2} c_2^2} \quad (8)$$

  where

K_p is defined as the ratio between the total pressure losses in volute to the dynamic pressure at the impeller exit.

From equation (7, 8) becomes:

$$\frac{c_3^2}{c_2^2} = 1 - K_p - C_p \quad (9)$$

Where $\frac{c_3^2}{c_2^2}$ is the ratio of volute outlet/inlet kinetic energy.

4. Numerical analysis

For the simulations it is accepted one optimized impeller with the design flow coefficient $\phi = 0.07 \div 0.14$, which correspond to flow rate of $Q = 0.23 \div 0.47 m^3 / s$, since the diameter of the impeller is $D_2 = 0.3m$ and the rotational speed is $n = 3000 rpm$. The detailed flow field at the impeller's outlet from preceding RANS simulations is used as boundary conditions for a RANS of the flow in the volutes. Numerical simulations were performed using the Open Source CFD software, OpenFOAM v3.0.x (OpenFOAM, 2015).

Three-dimensional, incompressible, steady-state flow computations were carried out. This solves discretized forms of the Reynolds-averaged Navier–Stokes equations for turbulent flow using the finite volume method (Ferziger J. H., Perić M., 2002). The unstructured grid solution procedure is based on a variant of the SIMPLE pressure correction technique (Patankar S. V., 1980). The iterative solution was deemed to be converged when the normalized absolute error over the mesh had reduced to 10^{-5} for each variable. OpenFOAM supports the standard k–ω model by Wilcox (1998), and Menter's SST k–ω model (1994) (Menter F. R. & Esch T., 2001). The k-ω SST turbulence model was employed for these calculations, with near-wall conditions supplied by the 'wall function' conditions of Launder and Spalding, 1974 (Launder B. E. and Spalding D. B., 1974). K–ω models have gained popularity mainly because can be integrated to the wall without using any damping functions. This is the most widely adopted turbulence model in the aerospace and turbo-machinery communities.

5. Boundary and initial conditions

The inflow boundary conditions were based on known flow rates and the flow direction (Bamberger K. et al., 2016). Non uniform velocity profiles were prescribed at the volute inlet (fan impeller outlet) by implementing radial and tangential velocity components, also axial velocity is included (Gjeta A. et al., 2018). The front and back side of the impeller as the rotating wall, the other parts wall with no slip condition and for the outlet ambient pressure is used. Turbulent kinetic energy is $k = 3 \cdot m^2 s^{-2}$, and the specific turbulence dissipation rate is $\omega = 4000 \cdot s^{-1}$.

Since we have a set of geometric parameters with a wide range of values it is necessary that the process of generating the geometry and then mesh creating to be carried out automatically.

The geometry of volutes is generated from MATLAB code as a stereo-lithography (.stl file), than cfMesh v1.1.2 software is used to create mesh. Grid resolution is made according to $y+$ value $(30 < y+ < 200)$.

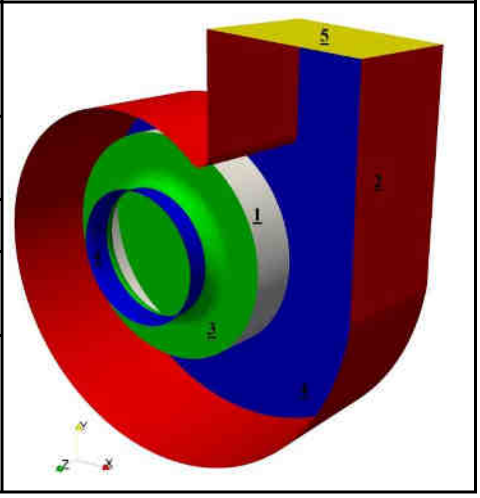
6. Results of simulations

For this set of simulations some parameters will be kept constant, e.g. tongue angle, tongue radius, and volute width. In this study we have changed the angle of the logarithmic spiral and based on the maximum volute opening value, we have constructed by other methods as well. All fan performance points were studied and we compared the results in terms of total efficiency, static pressure recovery coefficient and total pressure loss coefficient. The first parameter to be observed is the total efficiency of the volute. From graph of figure 4 we can observe that:

- For the alpha angle 12 degree, Archimedes helix method has the highest total efficiency value. For the flow coefficient $\phi = 0.07 \div 0.10$, efficiency from the constant circulation method is higher than the structured squares method, while in the interval of flow coefficient $\phi = 0.10 \div 0.14$, is the structured square method the one that has the highest total efficiency value.
- For the alpha angle 16 degrees the results of the Archimedes helix method and the structured squares are almost identical and result in higher value compare to the constant circulation method.
- For the alpha angle 20 degrees, the higher values of total efficiency are provided by the volute shape according to the structured square method and then the Archimedes helix method and in the end the constant circulation method.

In terms of the static pressure recovery coefficient on the volute, the value is almost the same for the constant circulation and Archimedes helix method. This is the advantage of the Archimedes helix method, having a higher value of total efficiency without sacrificing the static pressure recovery coefficient, which is one of the main reasons why volute is used in the centrifugal fans.

Table 2: Boundary conditions used in simulations in the OpenFOAM software [by the authors].

Color	Name	Boundary and Initial Condition		Schematic view of volute geometry
1	Inlet	Constant mass flow rate	Radial, tangential and axial velocity	
2	Spiral Casing (Volute)	No slip condition	fixedValue 0;	
3	FrontAndBackInlet	Rotating wall	omega;	
4	FrontAndBackVolute	No slip condition	fixedValue 0;	
5	Outlet	Ambient Pressure	zeroGradient;	

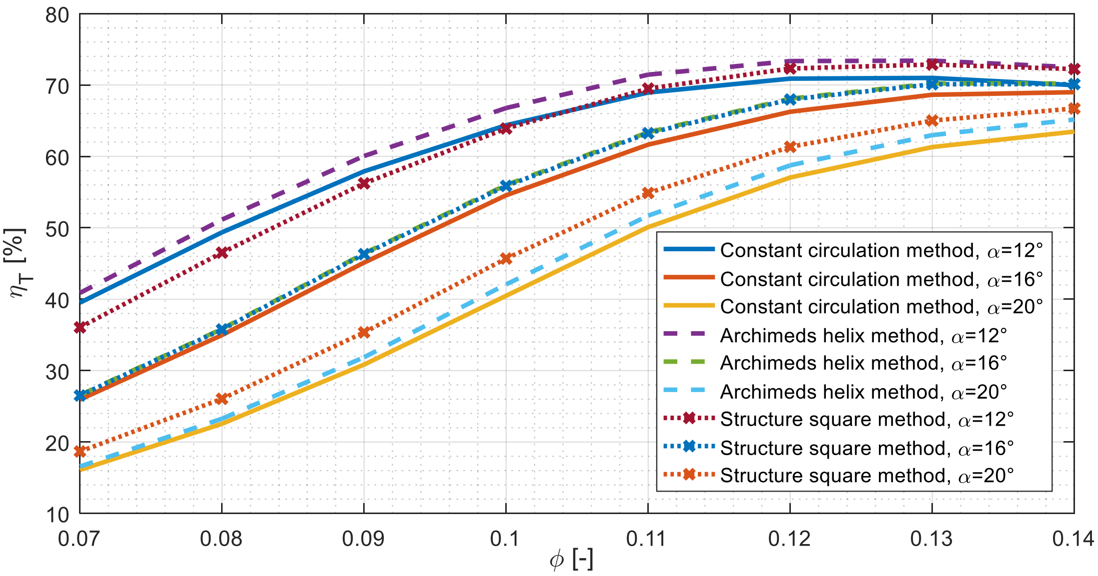


Figure 4: Total efficiency of volute function of flow coefficient [by the authors].

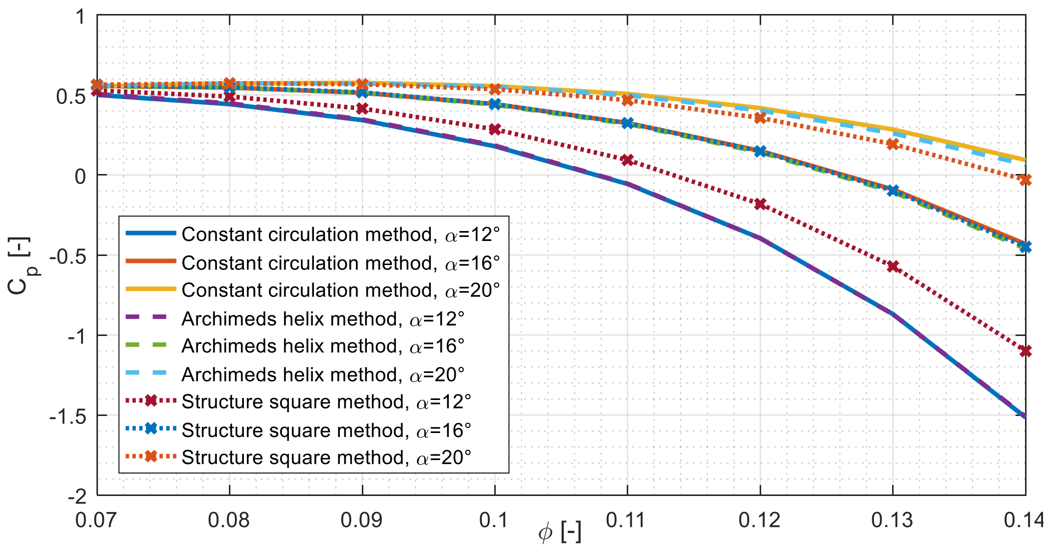


Figure 5: Static pressure recovery coefficient as a function of flow coefficient [by the authors].

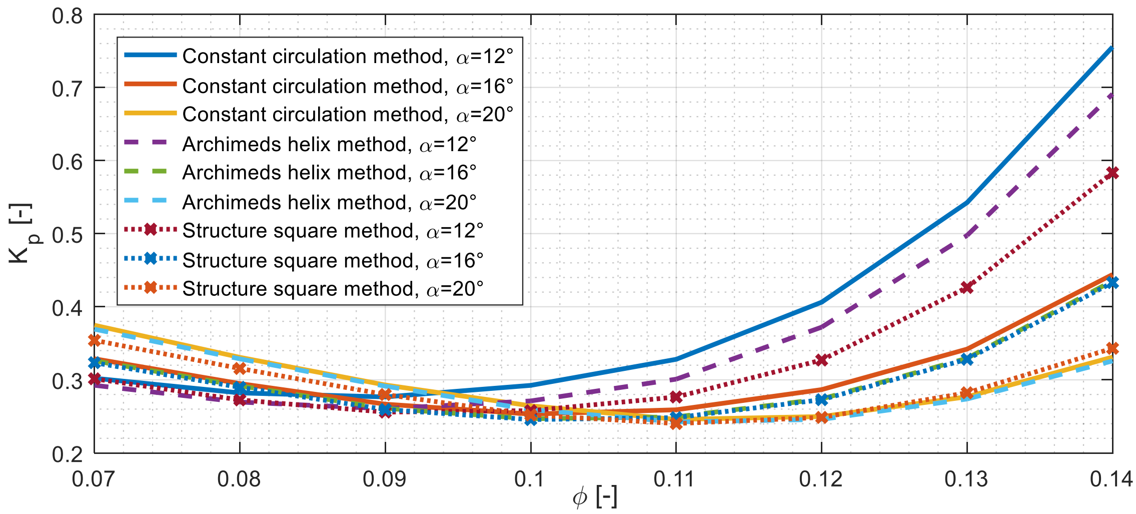


Figure 6: Total pressure loss coefficient as a function of flow coefficient [by the authors].

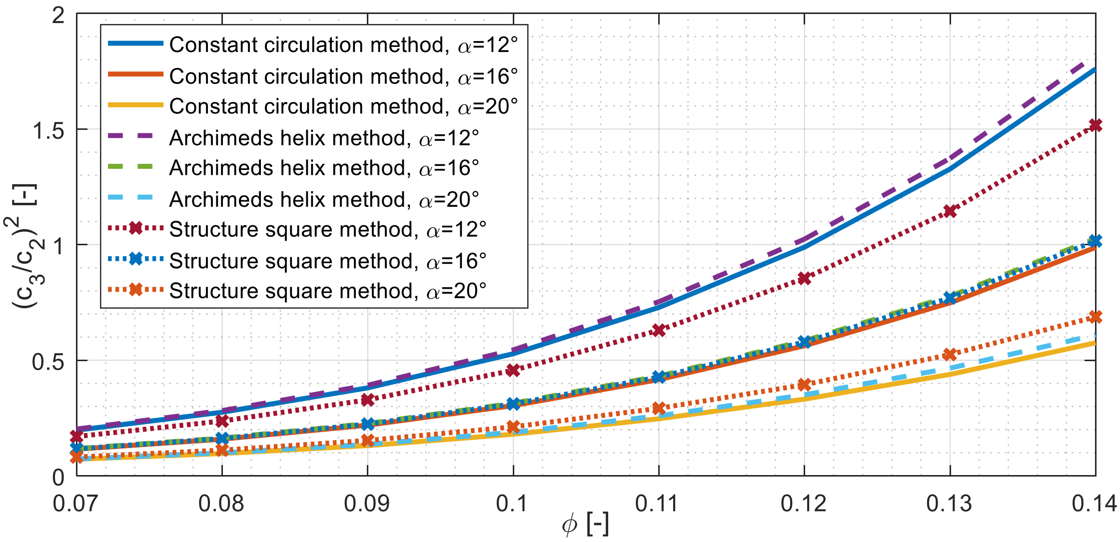


Figure 7: Outlet/inlet kinetic energy ratio as a function of flow coefficient [by the authors].

As for the structured squares method, we can observe that for the alpha angle 12 degrees for each of fan operation point provides a higher value of the static pressure recovery coefficient, while for the alpha angle 20 degrees a slightly smaller value but not significant is seen. For compact volutes in dimensions, we can say that the structured square method can be recommended as the best volute shape design method, dedicated to recovering static pressure since these volutes also have high a value of efficiency.

The other parameter to be addressed is the total pressure loss coefficient in the volute.

The results obtained from the graph in Figure 6, reinforce the conclusion that for compact volutes, the structured squares method, in addition to increasing the static pressure recovery coefficient in the volute, also provides a lower value of the total pressure loss coefficient. This is also true for volute with the alpha angle 16 degrees, but at lower values, while for large volutes, the results are not distinguishable from one another.

The last parameter is the outlet/inlet kinetic energy ratio, as one parameter which is a function of both the static pressure recovery coefficient and the total pressure loss coefficient, according to the equation (9). Since this parameter shows the ratio of outlet/inlet kinetic energy of the volute, which means the ratio of volute outlet velocity c_3 and inlet velocity c_2, the tendency for this indicator is as low as possible.

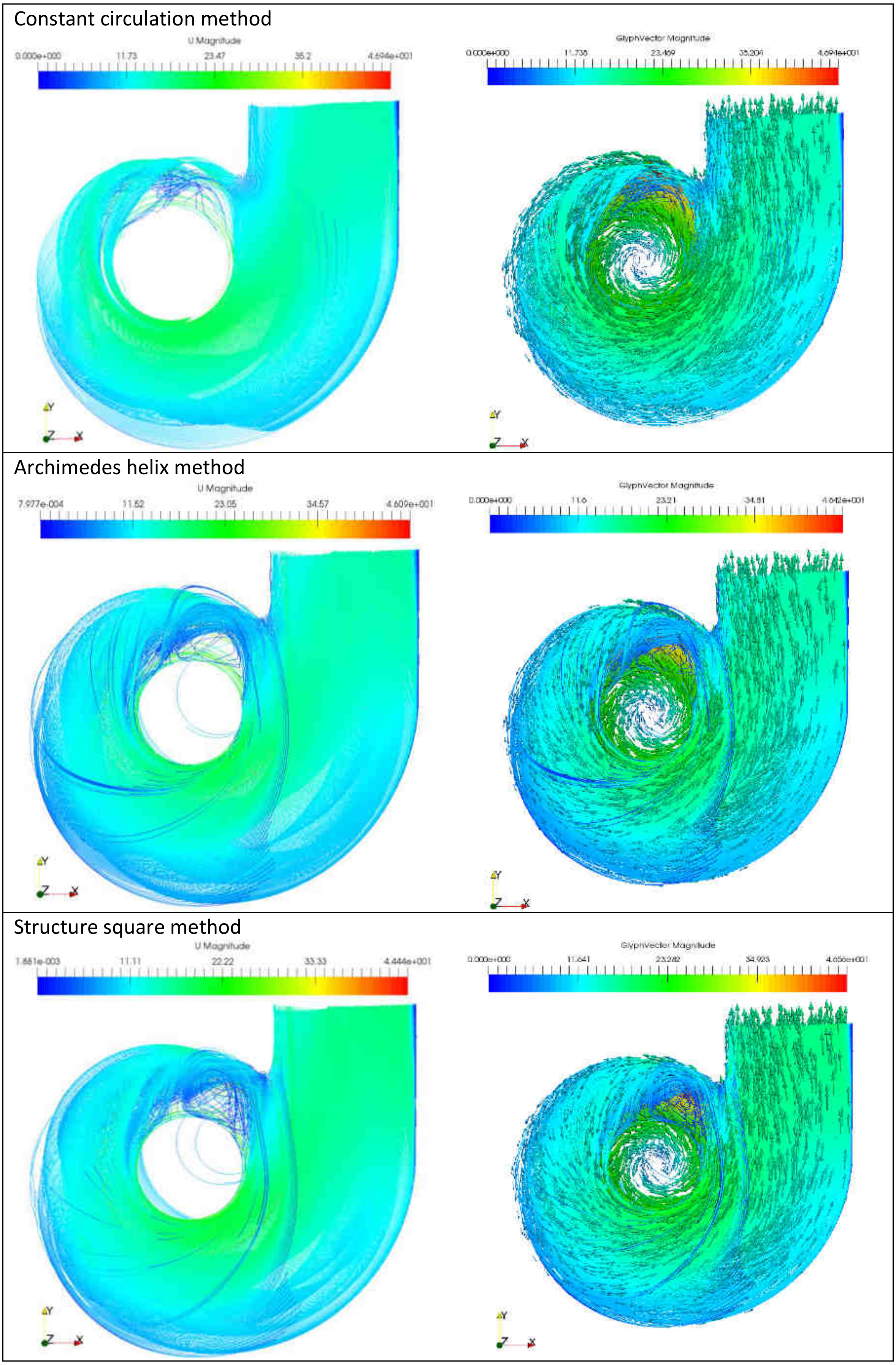


Figure 8: Velocity magnitude streamlines comparison between volute shape methods [by the authors].

For compact volutes, the structured square method provides minimum value, while with increasing volute size, the lower value of this ratio is ensured by the constant circulation method.

7. Conclusions

In this study, 3 methods of volute design shape of the centrifugal fan are examined. Based on the results of numerical solutions we have estimated the method of design shape of volute which is more efficiently as a function of the way that the centrifugal fan is used. Evaluation is carried out by analyzing the performance of the volute, based on the static pressure recovery coefficient as well as the total pressure loss coefficient.

From the simulation results we can summarize the following conclusions:

- The constant circulation method, like the more traditional way to design a spiral case, does not provide a high value of efficiency and static pressure recovery coefficient
- The Archimedes helix method, unlike the constant circulation method, provides a higher value of efficiency without sacrificing the value of the static pressure recovery coefficient
- For compact volutes, although the structured square method has a lower value of total efficiency than the Archimedes helix method, it is this method that should be used as it provides higher static pressure recovery coefficient values as well as minimum values of total pressure loss coefficient
- For medium-sized volutes, we can recommend the Archimedes helix method and the structured squares method, since the results are almost the same, but significantly more positive results than the constant circulation method.

While for large volutes, although higher efficiency of the method is for structured square method, since the main focus is on a high value of the static pressure recovery coefficient the constant circulation method is recommended.

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Nomenclature

Indices	
1	impeller inlet
2	volute inlet
3	volute outlet
opt	optimal
min	minimum
max	maximum
Abbreviations	
CFD	Computational Fluid Dynamics
RANS	Reynolds Averaged Navier-Stokes
SST	Shear stress transport
FOAM	Field Operation And Manipulation
ErP	Energy related Products
EuP	Energy using Products
IE	International Efficiency
FMEG	Fan Motor Efficiency Grade
Greek Symbols	
ϕ	flow coefficient
η	efficiency
ρ	air density

The role of behavioral barriers in the natural gas penetration for the Hellenic building sector

Dr. Popi KONIDARI [1], Research Fellow of KEPA, National and Kapodistrian University of Athens (NKUA)

Prof. Dimitrios MAVRAKIS, Director of KEPA, NKUA

Ioannis NTROUKAS, PhD candidate, NKUA

[1] *Contact details of corresponding author*
Tel: +30 210 7275830
Fax: +30 210 72 75828
e-mail: pkonidar@kepa.uoa.gr
Address: KEPA Building, University Campus – Ilissia, Athens - Greece

Abstract

The National Energy and Climate Plan of Greece that was submitted to the European Commission in January 2019, has three main components: the promotion of energy efficiency, the further penetration of natural gas in the energy mix and the support of renewable energy sources. The second component is significant for the transformation of the energy systems to cleaner ones, but the penetration rate is slower than expected due to a set of barriers part of which is linked with the behaviour of end-users.

This paper maps these barriers for the building sector through bibliographic desktop work using action plans, official reports, papers and outcomes of funded projects. The barriers are presented and grouped into five main categories (social, cultural, educational, economic and institutional). The Decision Support Tool (DST), HERON-DST, is used to quantify the importance of each barrier in prevailing the gas penetration in buildings and to provide the Impact factor of the barrier.

The discussion focuses on the impact of the most important barriers in the implementation of relevant policies and their relation to the effort to increase the ambition to achieve the 7th Sustainable Development Goal.

Keywords: Behavioral barriers, Decision Support Tool, HERON-DST.

Acknowledgement: Research is funded by the Municipality of Moschato-Tavros

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12th International Conference on "Energy and Climate Change"
9-11 October 2019, Athens - Greece

The role of behavioural barriers in the natural gas penetration for the Hellenic building sector

Dr. Popi KONIDARI
Research Fellow
KEPA of NKUA

1

Structure

- National framework
- Methodological approach
- Mapped barriers
- Impact factors
- Discussion
- Conclusions

2

National target for 2030

3

Main components

- Achievement of energy savings in final consumption
- Increased penetration of natural gas in energy mix
- Increase the RES share in final energy consumption

Source:National Energy and Climate Plan of Greece, 2019, At: https://ec.europa.eu/energy/sites/ener/files/documents/greece_draftnecp.pdf

4

Main priorities for Natural Gas

- Promotion of Natural Gas (NG) as intermediary fuel for the decarbonization of the energy system
- Improvement of energy efficiency in infrastructures of electric energy and NG
- Reinforcing competitiveness in the markets of electric energy and NG
- Promotion of infrastructures for transfer, distribution and storage of NG

5

NG in final consumption

- Target
  - Increase in NG use sectors of final consumption by 50% compared to year 2016
- Reasoning
  - Intermediary fuel for moving towards a low GHG emission model for these sectors
- Results
  - Improved energy efficiency
  - Lower energy cost

6

Penetration rates for NG

	Έτη				
	2013	2014	2015	2016	2017
	% NG in final energy consumption (national, sectoral)				
Country	6,21	5,66	6,18	6,62	7,35
Households	6,17	6,13	8,09	7,68	8,17
Tertiary sector (commercial and public sector)	6,86	7,30	8,86	7,27	6,88

(1) Source: Eurostat, 2019 - https://ec.europa.eu/eurostat/documents/3217494/9172750/KS-EN-18-001-EN-N.pdf/474c2308-002a-40cd-87b6-9364209bf936
(2) https://ec.europa.eu/eurostat/web/energy/data/energy-balances
(3) 2013 - https://ec.europa.eu/eurostat/documents/3217494/6898731/KS-EN-15-001-EN-N.pdf/e5851c73-9259-462e-befc-6d037dc8216a

7

Barriers

Forces or theoretical mechanisms observed during the function of the market and prevent behaviours or investments that could increase the use of NG in final energy consumption of the building sector

8

Methodology

- Four steps – based on Analytical Hierarchy Process (AHP)
  - *Step 1:* Mapping, categorization and merging behavioral barriers
  - *Step 2:* Development of the AHP tree and matrices
  - *Step 3:* Calculation of weight coefficients
  - *Step 4:* Definition and calculation of Impact Factors (I) of barriers

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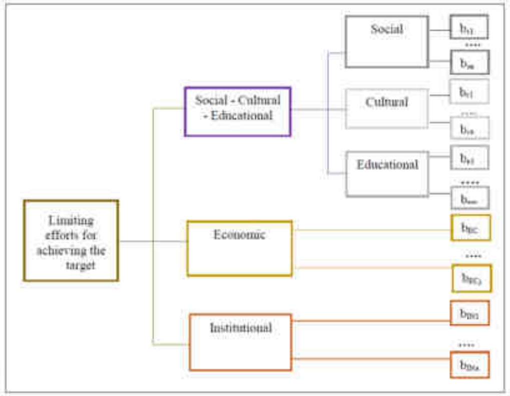
Steps 1 & 2

AHP tree and matrices



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Steps 3 & 4

Weight coefficients and Impact factors

$$I_{S1} = W_{S\text{-}C\text{-}E} * W_S * W_{S1}$$

Type	Name of barrier	Function
Social	Social group interactions and status considerations	$I_{S1} = W_{S\text{-}C\text{-}E} * W_S * W_{S1}$
Social	Socio-economic status of building users	$I_{S2} = W_{S\text{-}C\text{-}E} * W_S * W_{S2}$
Social	Strong dependency on the neighbors in multi-family housing	$I_{S3} = W_{S\text{-}C\text{-}E} * W_S * W_{S3}$
Social	Inertia	$I_{S4} = W_{S\text{-}C\text{-}E} * W_S * W_{S4}$
Social	Commitment and motivation of public social support	$I_{S5} = W_{S\text{-}C\text{-}E} * W_S * W_{S5}$
Social	Rebound effect	$I_{S6} = W_{S\text{-}C\text{-}E} * W_S * W_{S6}$
Cultural	Lack of interest/low priority/Undervaluing use of NG	$I_{C1} = W_{S\text{-}C\text{-}E} * W_C * W_{C1}$
Cultural	Customs, habits and relevant behavioural aspects	$I_{C2} = W_{S\text{-}C\text{-}E} * W_C * W_{C2}$
Cultural	Bounded rationality/Visibility of using NG	$I_{C3} = W_{S\text{-}C\text{-}E} * W_C * W_{C3}$
Cultural	Missing credibility/mistrust of technologies and contractors	$I_{C4} = W_{S\text{-}C\text{-}E} * W_C * W_{C4}$
Educational	Lack of trained and skilled professionals/ trusted information, knowledge and experience	$I_{E1} = W_{S\text{-}C\text{-}E} * W_E * W_{E1}$
Educational	Lack of awareness/knowledge on savings potential/information gap on NG technologies	$I_{E2} = W_{S\text{-}C\text{-}E} * W_E * W_{E2}$

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Steps 3 & 4

Weight coefficients and Impact factors

Economic	Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance)	$I_{EC1} = W_{EC} * W_{EC1}$
Economic	High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users	$I_{EC2} = W_{EC} * W_{EC2}$
Economic	Payback expectations/investment horizons	$I_{EC3} = W_{EC} * W_{EC3}$
Economic	Relatively cheap energy and fuel prices/ misleading Tariff system not reflecting correct prices for energy use of NG/EE	$I_{EC4} = W_{EC} * W_{EC4}$
Economic	Unexpected costs (Hidden costs/ Costs vary regionally (Fragmented ability))	$I_{EC5} = W_{EC} * W_{EC5}$
Economic	Financial crisis/Economic stagnation	$I_{EC6} = W_{EC} * W_{EC6}$
Economic	Embryonic markets	$I_{EC7} = W_{EC} * W_{EC7}$
Institutional	Split Incentive	$I_{I1} = W_I * w_{I1}$
Institutional	Legislation issues (Lack of relevant legislation/Lack of regulatory provision /Change of legislation for local/regional administrative division/ Complex/inadequate regulatory procedures)	$I_{I2} = W_I * w_{I2}$
Institutional	Building stock characteristics/aging stock/ Historical preservation	$I_{I3} = W_I * w_{I3}$
Institutional	Poor compliance with efficiency standards or construction standards/ Technical problems/ Performance gap/mismatch	$I_{I4} = W_I * w_{I4}$
Institutional	Lack of data/information-diversion of management	$I_{I5} = W_I * w_{I5}$
Institutional	Barrier to behavior change due to problematic Implementation Network (IN)/governance framework (Inadequate IN/governance framework /inadequate implementation of policy measures / poor Policy coordination across different levels/cooperation of municipalities)	$I_{I6} = W_I * w_{I6}$
Institutional	Disruption/Hassle factor	$I_{I7} = W_I * w_{I7}$
Institutional	Security of fuel supply	$I_{I8} = W_I * w_{I8}$

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Software HERON Decision Support Tool

Version 1.1.5

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Impact Factors - 1

Type	Name of barrier	Impact Factor
Social	Social group interactions and status considerations	0.055
Social	Socio-economic status of building users	0.098
Social	Strong dependency on the neighbors in multi-family housing	0.034
Social	Inertia	0.029
Social	Commitment and motivation of public social support	0.090
Social	Rebound effect	0.018
Cultural	Lack of interest/low priority/Undervaluing use of NG	0.015
Cultural	Customs, habits and relevant behavioural aspects	0.053
Cultural	Bounded rationality/Visibility of use of NG	0.016
Cultural	Missing credibility/mistrust of technologies and contractors	0.049
Educational	Lack of trained and skilled professionals/ trusted information, knowledge and experience	0.014
Educational	Lack of awareness/knowledge on savings potential/information gap on NG technologies	0.041

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Impact factors - 2

Economic	Lack of any type of financial support (lack of financial incentive (Public and Private sector)/ Lack of funds or access to finance)	0.133
Economic	High capital costs/Financial risk/ Uncertainty on investment/ High cost of innovative technologies for end-users	0.076
Economic	Payback expectations/investment horizons	0.035
Economic	Relatively cheap energy and fuel prices/ misleading Tariff system not reflecting correct prices for energy use of NG/EE	0.034
Economic	Unexpected costs (Hidden costs/ Costs vary regionally (Fragmented ability))	0.015
Economic	Financial crisis/Economic stagnation	0.052
Economic	Embryonic markets	0.015
Institutional	Split Incentive	0.012
Institutional	Legislation issues (Lack of relevant legislation/Lack of regulatory provision /Change of legislation for local/regional administrative division/ Complex/inadequate regulatory procedures)	0.014
Institutional	Building stock characteristics/aging stock/ Historical preservation	0.008
Institutional	Poor compliance with efficiency standards or construction standards/ Technical problems/ Performance gap/mismatch	0.006
Institutional	Lack of data/information-diversion of management	0.042
Institutional	Barrier to behavior change due to problematic implementation Network (IN)/governance framework (Inadequate IN/governance framework /Inadequate implementation of policy measures / poor Policy coordination across different levels/cooperation of municipalities)	0.022
Institutional	Disruption/Hassle factor	0.016
Institutional	Security of fuel supply	0.008

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Discussion - 1

- Most important barriers
  - Economic: Lack of any type of financial support - 13.3%
  - Social: Socio-economic status of building users – 9.8%
  - Social: Lack of public social support – 9.0%
- Less important barriers
  - Institutional: Poor compliance with efficiency standards or construction standards – 0.6%
  - Institutional: Building stock characteristics – 0.8%
  - Institutional: Security of fuel supply: - 0.8%

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Discussion - 2

- Rationality behind important barriers
  - Socio-economic characteristics of Hellenic end-users
  - Indicator for progress on SDG7 in Greece
  - Indicators for energy poverty

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Socio-economic characteristics of end users -1

Demographic indicators for time period 2006-2017												
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Age dependence ratio	50.0	50.0	50.0	50.4	51.0	51.8	52.8	53.7	54.5	55.2	55.9	56.5
Ageing ratio	125.0	126.8	127.9	129.0	130.7	132.9	135.4	138.3	141.8	145.5	148.3	150.3

*the ratio of the number of economically non-active persons (aged 0 - 14 and 65 years and over) compared with the number of economically active persons (aged 15 - 64 years).
**the number of persons aged 65 years and over per hundred persons under the age of 15.

Source: Hellenic Statistical Authority, 2019. Living Conditions in Greece.
At: http://www.statistics.gr/documents/20181/14479704/LivingConditionsInGreece_0919.pdf/76f3206f-fcff-4be9-2a58-f64da216ab1f?t=1567769493076

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Socio-economic characteristics of end-users -2

Population aged 15 years and over by employment status, 2007 - 2018												
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Employment rate	48.5	48.9	48.3	46.7	43.3	39.5	37.7	38.1	39.0	39.9	40.9	41.9
Unemployment rate	8.4	7.8	9.6	12.7	17.9	24.4	27.5	26.5	24.9	23.5	21.5	19.3

*Employment rate represents persons in employment as a percentage of the total population.

Source: Hellenic Statistical Authority, 2019. Living Conditions in Greece.
At: http://www.statistics.gr/documents/20181/14479704/LivingConditionsInGreece_0919.pdf/76f3206f-fcff-4be9-2a58-f64da216ab1f?t=1567769493076

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Barriers, energy poverty and SDG7

- Energy Poverty Observatory
  - Inability to keep home adequately warm
  - Arrears on utility bills
- Eurostat for progress on SDG7
  - Inability to keep home adequately warm

Goal 7:
Ensure access to affordable, reliable, sustainable and modern energy for all.

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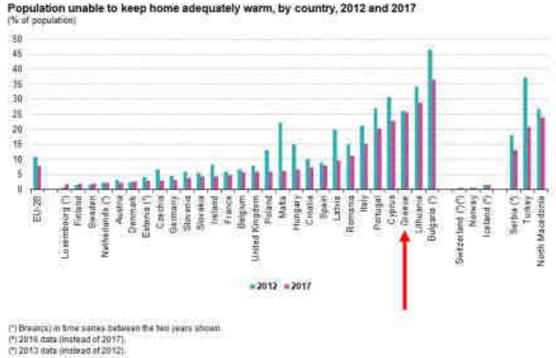
Inability to keep home adequately warm (2012-2017)



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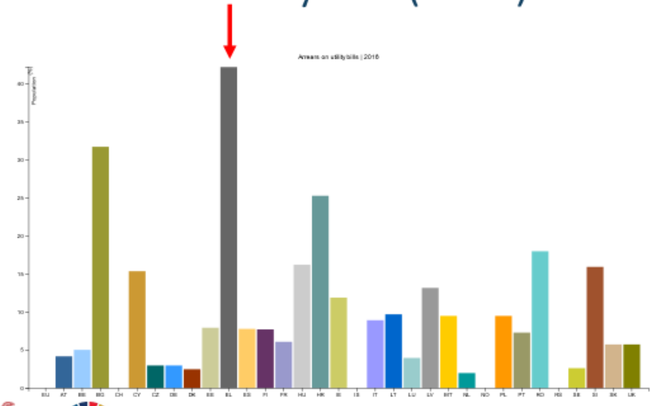
Arrears on utility bills (2016)



Source: https://www.energypoverty.eu/indicator?primaryId=1462#

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Conclusions

- Important barriers in NG penetration
  - Lack of any type of financial support
  - Socio-economic status of building users
  - Lack of public social support
- Financial policy instruments
  - Tax exemptions
  - Subsidies

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Thank you

Dr. Popi KONIDARI
Tel.: 0030 210 72 75 830
e-mail: pkonidar@kepa.uoa.gr

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Session D: Renewable Energy Sources

Towards non-carbon energy production: Technical and environmental assessment of enhanced strategies in CO_2 purification for geothermal power plant

Andrea HERNÁNDEZ PEDRERO[1*], Researcher
Maryori C. DÍAZ-RAMÍREZ[1,2], Technology Project Manager
Víctor J. FERREIRA[1,2], Reseacher
Ana M. LÓPEZ-SABIRÓN[1,2], Researcher
Ana MARTÍNEZ SANTAMARÍA[1,2], Researcher
[1]Research Centre for Energy Resources and Consumption (CIRCE)
[2]Instituto Universitario de Investigación CIRCE – (Fundación CIRCE - Universidad de Zaragoza)

**Corresponding author:*
e-mail: ahernandez@fcirce.es
Address: Research Centre for Energy Resources and Consumption (CIRCE), Parque Empresarial Dinamiza, Avda. Ranillas 3D, 1ª Floor, Zaragoza, 50018, Spain

Abstract

Geothermal energy is envisaged as an untapped renewable resource which attains more flexible operation and a lower environmental impact compared to conventional power production based on fossil fuels. However, most geothermal power plants release the non-condensable gases dissolved in the geothermal fluid. This gaseous emission usually includes CO_2, N_2, CH_4, H_2S and H_2 in different proportions depending on the reservoirs. CO_2 purification provides a value-added product and may contribute to minimize the environmental impact of geothermal power generation.

An enhanced, two-stage CO_2 purification technology is considered within this research work. In the first step, H_2S is selectively absorbed by amine-based solvent. The second stage aims to separate the CO_2 from the other more volatile compounds by condensation, which requires an intermediate dehydration process. The potential uses of the purified gas strongly depend on its purity, being the reduction of the H_2S content to negligible values the most important target. In addition, the amount of recovered CO_2 defines the economic viability of the process. The environmental impact will depend on the burdens attributed to the processes involved in the value chain of the by-products following a life cycle thinking. To do that, relevant key environmental impact categories are determined and characterized by the Life Cycle Assessment (LCA) methodology application.

In this study, the effect of key operating parameters of the purification system on CO_2 purity and CO_2 recovery efficiency is analysed by computer simulation. Based on these results, the environmental impacts of the feasible strategies are evaluated using the LCA perspective.

Keywords: Geothermal energy, CO_2 purification, LCA, Environmental impact.

1. Introduction

Geothermal technologies can provide renewable energy from underground reservoirs (hot rocks, aquifers, brines, etc.) for base-load generation of electricity and heating (or cooling) without weather or seasonal variations, as opposed to other renewable sources. In addition, geothermal technologies produce lower greenhouse gas emissions than conventional technologies based on fossil fuels; thus, they can play an important role in climate change mitigation for sustainable development (IEA, 2011).

Nevertheless, emission of geothermal gases is an inevitable part of high temperature geothermal utilization and usually one of the main environmental problems associated with geothermal power production. The main components of geothermal gas emissions are CO_2, H_2S, H_2, CH_4, N_2 and Ar, with different concentrations depending on geological settings, temperature and composition of the geothermal reservoir (Gunnarsson I. et al., 2015).

One option to improve environmentally the system is to treat this stream by means of purification processes so as to convert the waste gas stream emitted by geothermal power plants into value-added products (purified CO_2). In this vein, a two-stage purification technology is considered. Firstly, H_2S is removed from the geothermal gases by absorption in order to obtain a gas stream with a very low content of H_2S. Then, this sweet gas mixture produced is dehydrated and the CO_2 is separated from the Non-Condensable Gases (NCG) by condensation at cryogenic conditions. A purified CO_2 stream is obtained, which can be used in different applications. Depending on the type of power plant and the fuel used, the CO_2 product stream may contain different impurities, such as O_2, H_2O, NO_x, SO_x, CO, etc. The chemical solvents used for H_2S or CO_2 separation and their degradation products can be also carried over into the CO_2 stream and result in another impurity (Porter R.T.J. et al., 2015).

This work focuses particularly on the second purification stage proposed to obtain a high purity CO_2 stream from the waste gas emitted. The second purification stage aims at separating the CO_2 from the sweet gas obtained in the first stage. Cryogenic separation is suitable when the CO_2 concentration in the gas stream is high (usually above 50%). The process involves the compression and refrigeration of the gas mixture to conditions at which the CO_2 can condense. The major benefit of this technology is the fact that no chemical sorbent is required. However, cryogenic separation requires substantial power to operate the refrigeration unit. In addition, dehydration of the feed gas is required to remove the water that would result in hydrate formation and plugging of valves, fittings or even gas lines (Abu-Zahra M. R. M. et al., 2016). Consequently, dehydration is a point for improving the purified CO_2 stream.

The objective of this work is to analyse, select and design the appropriate dehydration technology to remove water from the sweet gas and allow for the cryogenic separation of CO_2 from the NCG. A comparison between the standard and the advanced dehydration is performed based on process simulations. Additionally, the environmental impacts associated are evaluated.

2. Methodology

2.1 First purification stage: sweet gas production and properties

The first purification stage aims to reduce the H_2S content in the gas stream to levels of zero to low ppm. The removal of H_2S is important to avoid corrosion problems in the gas transport pipeline and to minimize environmental impacts. In a typical amine-based gas treating unit, the sour gas is fed to the bottom of the absorber column and flows upward, counter-current to the lean amine introduced from the top. The sweet gas exits the top of the column and the solvent with the absorbed acid gas is discharged from the bottom. In a distillation column, the acid gas is desorbed, and the amine is regenerated by means of heating. Make up streams are used to account for the loss of amine and water in the absorber and the regenerator. The lean amine is recycled back to the absorber.

In absorption processes where selective H_2S removal is desired, an appropriate amine selection is of great importance. When H_2S dissolves in amine solutions, it dissociates instantaneously in the solvent. However, as opposed to primary and secondary amines, tertiary amines do not react directly with CO_2 and thus they require a very long time to absorb CO_2. For this reason, tertiary amines are kinetically selective towards H_2S. The tertiary amine most commonly used is N-methyl diethanolamine (MDEA) because of its several advantages, such as very low vapor pressure, which prevents from high evaporation losses, or very low heat of reaction with CO_2 and H_2S, which reduces the energy penalty in the amine regenerator (Alvis R. S., 2013).

In addition, selectivity towards H_2S can be increased by conveniently choosing the tower internals. Considering that tertiary amines absorb H_2S more rapidly than CO_2, operating at short contact times (low interfacial areas, small tray counts, short packed beds) makes the process kinetically controlled and selective towards H_2S. This is provided by unstructured packing (Alvis R.S., 2013).

The selective absorption of H_2S with an aqueous MDEA solution was simulated in a previous work (Martinez-Santamaria A. et al., 2020) in Aspen HYSYS using a typical geothermal gas stream as feed to the absorber column, according to the characteristics of

NCG from six geothermal power plants in Iceland (Mamrosh D. et al., 2014). After optimization of the operating conditions, a sweet gas with the composition presented in Table 1 was obtained. It can be seen that the sweet gas is a CO_2-rich stream and NCG, such as H_2, N_2 and CH_4, are the main impurities, followed by water. Other impurities are present in small quantities (tenths of ppmw or less). For the purpose of using the CO_2 in the sweet gas for storage or industrial applications, a purified CO_2 stream needs to be produced. In this work, a second purification stage for CO_2 separation from the other NCG is proposed.

2.2 Second purification stage: cryogenic separation of CO_2

This paper focuses particularly in the second purification stage proposed to obtain a high purity CO_2 stream from the waste gas emitted by geothermal power plants. The second purification stage aims at separating the CO_2 from the sweet gas obtained in the first stage.

Cryogenic separation is suitable when the CO_2 concentration in the gas stream is high (usually above 50%). The process involves the compression and refrigeration of the gas mixture to conditions at which the CO_2 can condense. The major benefit of this technology is the fact that no chemical sorbent is required. However, cryogenic separation requires substantial power to operate the refrigeration unit. In addition, dehydration of the feed gas is required to remove the water that would result in hydrate formation and plugging of valves, fittings or even gas lines (Abu-Zahra M. R. M. et al., 2016).

2.3 Dehydration technology selection

Different technologies are available for gas dehydration, such as absorption, adsorption, membranes, etc. The main parameter considered when selecting a technology is the level of required dehydration. Figure 1 shows the water dew point that can be achieved by different dehydration technologies. This work aims to obtain a purified CO_2 stream at -55ºC (-67ºF), thus the water dew point or hydrate formation temperature must be sufficiently lower, i.e. 5-10ºC (9-18ºF) below the stream temperature. Consequently, Figure 1 shows that either molecular sieves, silica gel or advanced glycol technologies are required.

Enhanced glycol dehydration is selected to remove water from the sweet gas presented and allow for cryogenic separation of CO_2. Economics frequently favour absorption technology with liquid desiccants (i.e. glycols) when they can achieve the required dehydration specification. In addition, absorption equipment is simple to operate and maintain, and it can be easily automated for unattended operation (Gas Processors Association, 2004). For these reasons, glycol dehydration is the most commonly used by gas processing facilities. Glycols present the following advantages: unusually high hygroscopicity, excellent stability to thermal and chemical decomposition, low vapor pressures, easily regenerated for reuse, noncorrosive and nonfoaming at normal conditions and readily available at moderate cost (Stewart M. and Arnold K., 2011).

Glycols are effective for sour gas dehydration at subcritical conditions, but additional precautions in the design are needed due to the solubility of the acid gas in the desiccant solution. Glycol losses in CO_2 dehydration systems can be significantly higher than in natural gas systems due to the solubility of TEG in dense phase CO_2 (Gas Processors

Table 1: Feed gas properties.

Sweet gas properties	
Temperature (ºC)	11.70
Pressure (bar)	5.70
Flowrate (kg/s)	5.86
CO_2 (%mol)	56.30
H_2 (%mol)	35.10
N_2 (%mol)	7.84
CH_4 (%mol)	0.56
H_2O (%mol)	0.23
H_2S (ppm)	0.72
MDEA (ppm)	0.01

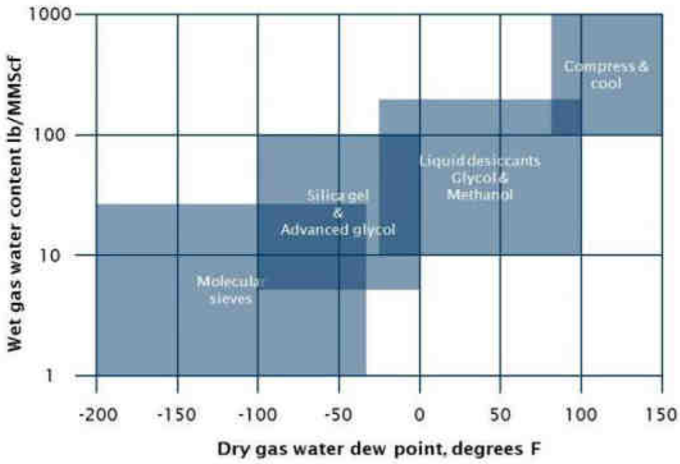


Figure 1: Dehydration technology selection chart (Olijhoek J. and Leeuw B., 2015).

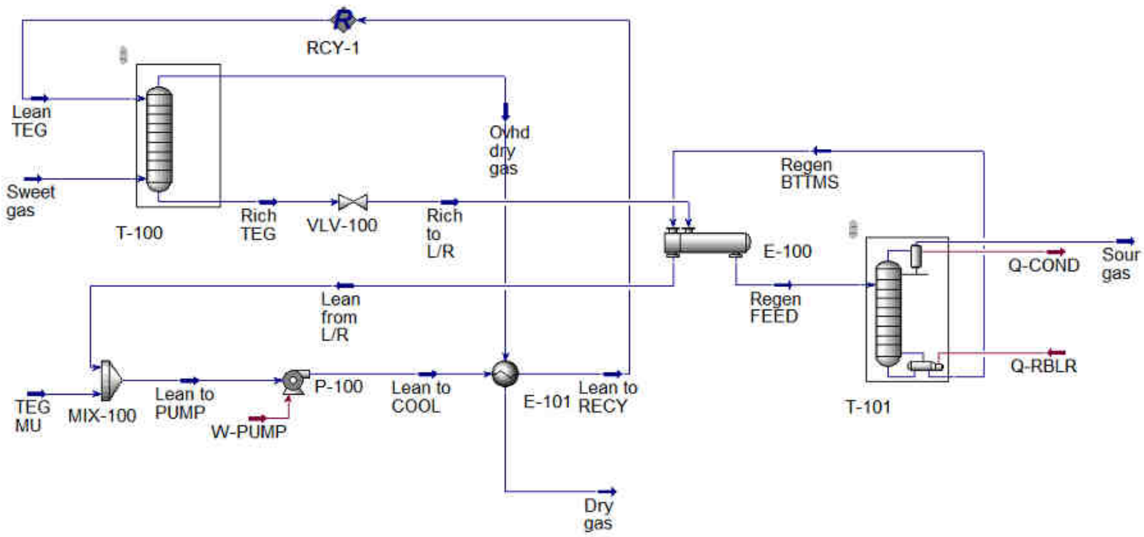


Figure 2: Standard glycol dehydration process flow diagram.

Association, 2004; Kohl A. L. and Nielsen R. B., 1997).

The selection of the glycol typology depends on the application process and conditions. Diethylene Glycol (DEG) is preferred when the process temperature is below 15°C because of the high viscosity of TEG in this temperature range, whereas Tetraethylene Glycol (TTEG) is recommended for contact temperatures above 50ºC to minimize vapor losses (Kohl A. L. and Nielsen R. B., 1997). In case of applications focused on gas dehydration, the Triethylene Glycol (TEG) is more effective.

2.4 TEG dehydration description: standard and enhanced strategies

In standard glycol dehydration processes, the regenerated glycol is pumped to the top of the contactor. The glycol absorbs the water as it flows down through the contactor counter current to the gas flow. Water-rich glycol is removed from the bottom of the contactor and flows through the lean/rich heat exchanger before entering the regenerator. TEG regeneration takes place by fractional distillation at near atmospheric pressure, since water and glycol have widely varying boiling points (100ºC for water vs. 288ºC for TEG). This allows for a very sharp separation with a relatively short column. The regenerated lean glycol exits the bottom of the column, is partly cooled in the lean/rich exchanger and is pumped through the glycol cooler before being recirculated to the contactor (Gas Processors Association, 2004; Kohl A. L. and Nielsen R. B., 1997). The standard process flow diagram is represented in Figure 2.

The level of dehydration that can be achieved by standard glycol absorption is primarily dependent on the amount of water that can be removed from the solvent in the regenerator. Atmospheric water distillation is limited by the glycol degradation temperature, which is about 204ºC for TEG. In that case, TEG can be concentrated up to 98.5-99.0% purity. When significantly higher concentrations are needed, enhanced stripping technology is required. All methods for enhanced stripping are based on the principle of reducing the partial pressure of water vapor in the gas phase, and hence obtaining a higher glycol concentration at the same temperature (Gas Processors Association, 2004; Kohl A. L. and Nielsen R. B., 1997).

One of the most common and simplest methods for enhancement of the glycol concentration is the injection of stripping gas in the reboiler. This allows for TEG concentrations up to 99.2-99.9wt% and water dew point depressions of 55ºC to 80ºC. However, to prevent from excessive glycol losses when stripping gas is used, a cool glycol condenser coil in the stripper is typically used (Gas Processors Association, 2004; Kohl A. L. and Nielsen R. B., 1997).

The straightforward modification to convert a standard process into an advanced process is to split and reinject part of the dry gas as stripping stream into the reboiler. The standard and advanced configurations are modelled and compared in order to determine the level of dehydration achieved, the energy requirements and the environmental impacts associated.

2.5 Equilibrium model for glycol dehydration

Process simulation software Aspen HYSYS® is used to design and optimize the dehydration and cryogenic separation of CO_2. The Cubic-Plus-Association (CPA) property package available in Aspen HYSYS® v11 is used. It represents the CPA equation of state and is suitable for modelling vapor-liquid and vapor-liquid-liquid equilibrium of mixtures containing hydrocarbons, non-hydrocarbons such as CO_2, H_2S and N_2, and polar/associating chemicals such as water, alcohols, glycols, esters and organic acids (Aspen Technology Inc, 2019).

Glycol dehydration modelling presents some unique challenges. It requires an equation of state that takes into account the interactions between the polar molecules of the aqueous/glycol liquid solution as well as the interactions between water, acid gases (CO_2 and H_2S) and hydrocarbons present in the gas phase (Hatcher N. A. et al., 2010). In addition, species forming hydrogen bonds often exhibit unusual thermodynamic behaviour. The strong attractive interactions between molecules of the same species (self-association) and between molecules of different species (cross-association) may strongly affect the thermodynamic properties of the fluids. Thus, the chemical equilibria between clusters should be taken into account in order to develop a reliable thermodynamic model (Derawi S., 2002; Hartono A. and Kim I., 2004).

The CPA model combines the cubic Soave-Redlich-Kwong (SRK) equation of state and an association (chemical) term. While the SRK model accounts for the physical interaction contribution between species (attractive and repulsive forces), the association term considers hydrogen bonding contributions (Derawi S., 2002; Hartono A. and Kim I., 2004). The CPA property package in Aspen HYSYS® can be also used to analyse hydrate formation. That is, at the given stream temperature, the hydrate formation pressure is calculated, and at the stream pressure, the hydrate formation temperature is calculated (Aspen Technology Inc, 2019).

To convert from equilibrium stages to actual trays, an overall tray efficiency of 25-30% can be assumed. Also, when extremely low dew points are required (-40˚C and below), structured packing is preferred in the contactor over traditional bubble cap trays because they attain more theoretical stages at significantly smaller contactor diameter and a slightly smaller contactor height (Gas Processors Association, 2004; Kohl A. L. and Nielsen R. B., 1997).

2.6 Process simulation and parametric analysis

The second purification stage aims at separating the CO_2 from the sweet gas obtained in the first stage by cryogenic separation. However, prior dehydration of the sweet gas is required in order to remove the water that would result in hydrate formation and plugging of fittings under cryogenic conditions. Deep level of dehydration using glycols can be only reached by advanced process. The enhanced glycol dehydration allows to regenerate the TEG to purities above 99wt%, and thus removing more water from the gas stream and achieving lower hydrate formation temperatures.

The second purification stage is simulated in Aspen HYSYS based on an enhanced dehydration process injecting dry gas in the reboiler, which is the straightforward advanced configuration. A set of initial conditions based on typical guidelines are selected and further optimized by a parametric analysis of different process variables. The parametric analysis is performed to study the effect of different process variables on the composition of the purified CO_2 stream, and particularly on its level of dehydration. The parameters evaluated are presented in Table 2.

Table 2: Process variables evaluated.

Absorber	Regenerator
Number of stages	Stripping stream flowrate
Pressure	
Solvent flowrate	

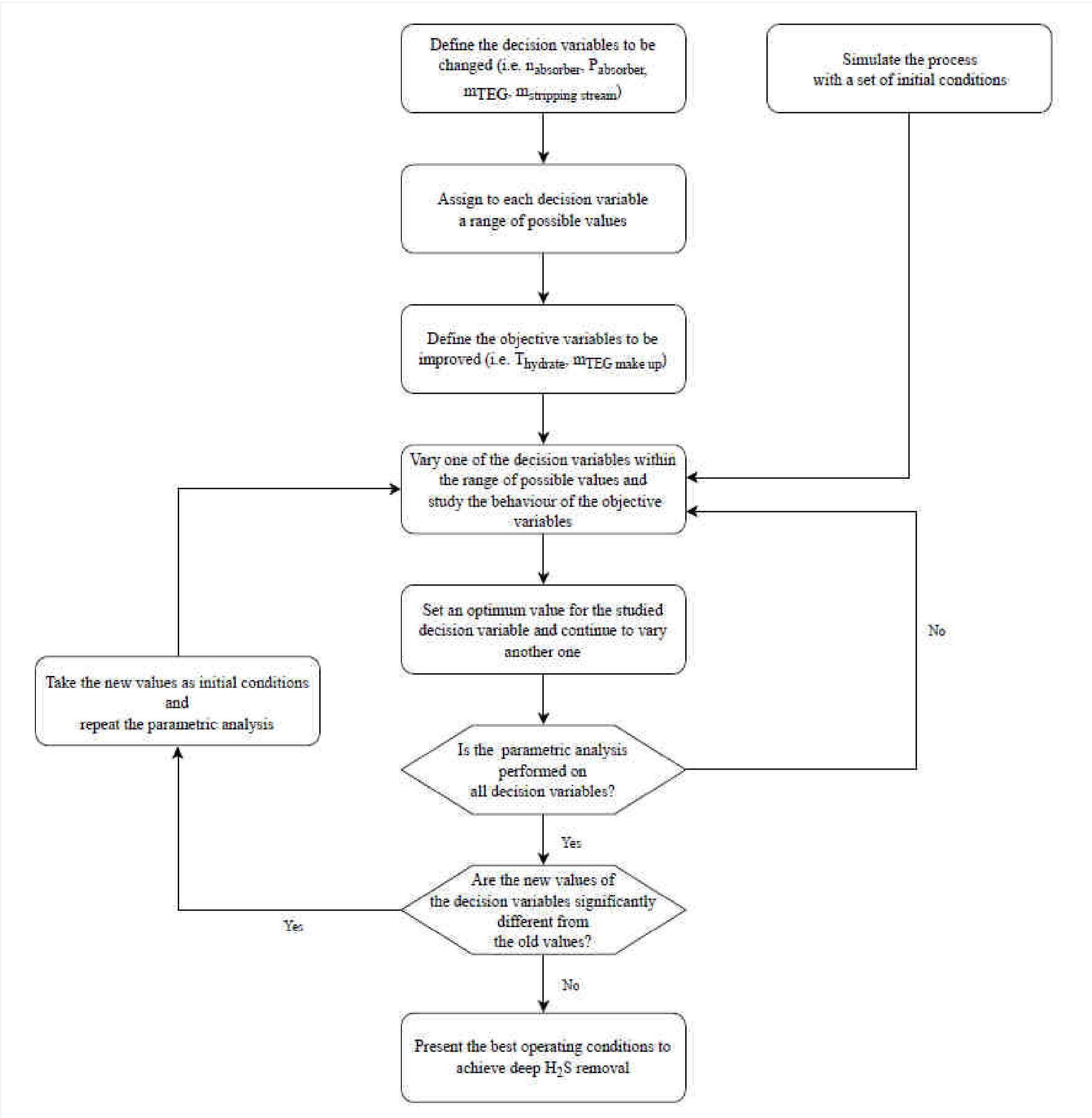


Figure 3: Decision flowchart for iterative parametric analysis.

Following the iterative in-house created approach represented in Figure 3, the parametric analysis provides a set of optimized values that prevent from hydrate formation. The two different configurations of the second purification stage, based on standard and advanced dehydration, are modelled using the CPA property package. The sweet gas presented in Table 1 is fed to the process. The absorption and regeneration columns of the dehydration section are assumed to have structure packings and thus an overall tray efficiency of 30% in order to convert from equilibrium to real stages.

2.7 Life Cycle Assessment (LCA)

LCA methodology is recognized as a powerful tool due to its applicability to evaluate industrial processes sustainability. The LCA methodology attempts to associate the emissions, resources extraction and processes (inputs and outputs along the value chain) into potential environmental impact categories applying four interrelated phases: goal and scope definition, inventory analysis, impact evaluation and interpretation of results, according to the standards ISO 14040:2006 and ISO 14044:2006 (Ferreira G. et al., 2015).

In this study, standard dehydration and enhanced dehydration using dry gas as stripping stream are characterised in order to quantify the magnitude of environmental burden related to the purification of CO_2. As mentioned before, dehydration using dry gas is the straightforward configuration for an enhanced glycol dehydration and thus it is chosen as the reference case.

To perform the technology comparison, one kilogram per hour of water absorbed by the purification unit has been considered as a functional unit to evaluate the environmental impact of the processes and one hour has been selected as timescale. Impacts were quantified for the two contaminants CO_2 and H_2S content in the sour gas. Accordingly, the amount of these gases was quantified and normalised regarding the functional unit and timescale. Environmental burden associated to volatiles fraction was excluded due to their depictable amount in the output stream. In addition, effects related to rich H_2 and CO_2 product streams were excluded from this study since they are considered as not emitted gases.

Similar material characteristics for column internals are assumed for the two dehydration technologies, and therefore, it was not evaluated in this LCA. Finally, energy consumption was also excluded from the analysis due to it is to be produced by renewable sources within the system plant boundaries. Based on these considerations, data gathered from the life cycle inventory is included in Table 2.

The environmental analysis is developed with SimaPro software version Analyst 8.5.0.0, in-house databases complemented by the Ecoinvent 3.0, and CML IA baseline as the selected method of evaluation. This approach allows to calculate impact categories or environmental indicators related to CO_2 and H_2S, which are the relevant impacts for this study. In this vein, effects concerning the optimal configuration are assessed for global warming (kg CO_2 eq) and human toxicity (kg 1,4 dichlorobenzene (1,4-DB) eq) indicators.

3. Results and Discussion

3.1 Second purification stage simulation based on enhanced TEG dehydration using dry gas

The second purification stage based on an enhanced TEG dehydration using dry gas as stripping stream is initially simulated and represented in Figure 4. The sweet gas is fed to the process at moderate pressure (5.7 bar), thus a multistage compression with intercooling is required prior to dehydration, although in Figure 4 it is represented as a single-stage process for simplicity. After compression, the sweet gas enters a two-phase separator so that free water can be removed from the sweet gas. The still wet gas then enters the bottom of the absorber column of the dehydration process, described in section 2.4.

The dry gas obtained from the top of the absorber column is split into two streams, the stripping stream and the gas product. The stripping stream is decompressed down to the reboiler pressure and preheated before reinjection. With the advanced dehydration process, the partial pressure of water vapor in the gas phase in the reboiler is reduced, thus enhancing the TEG regeneration.

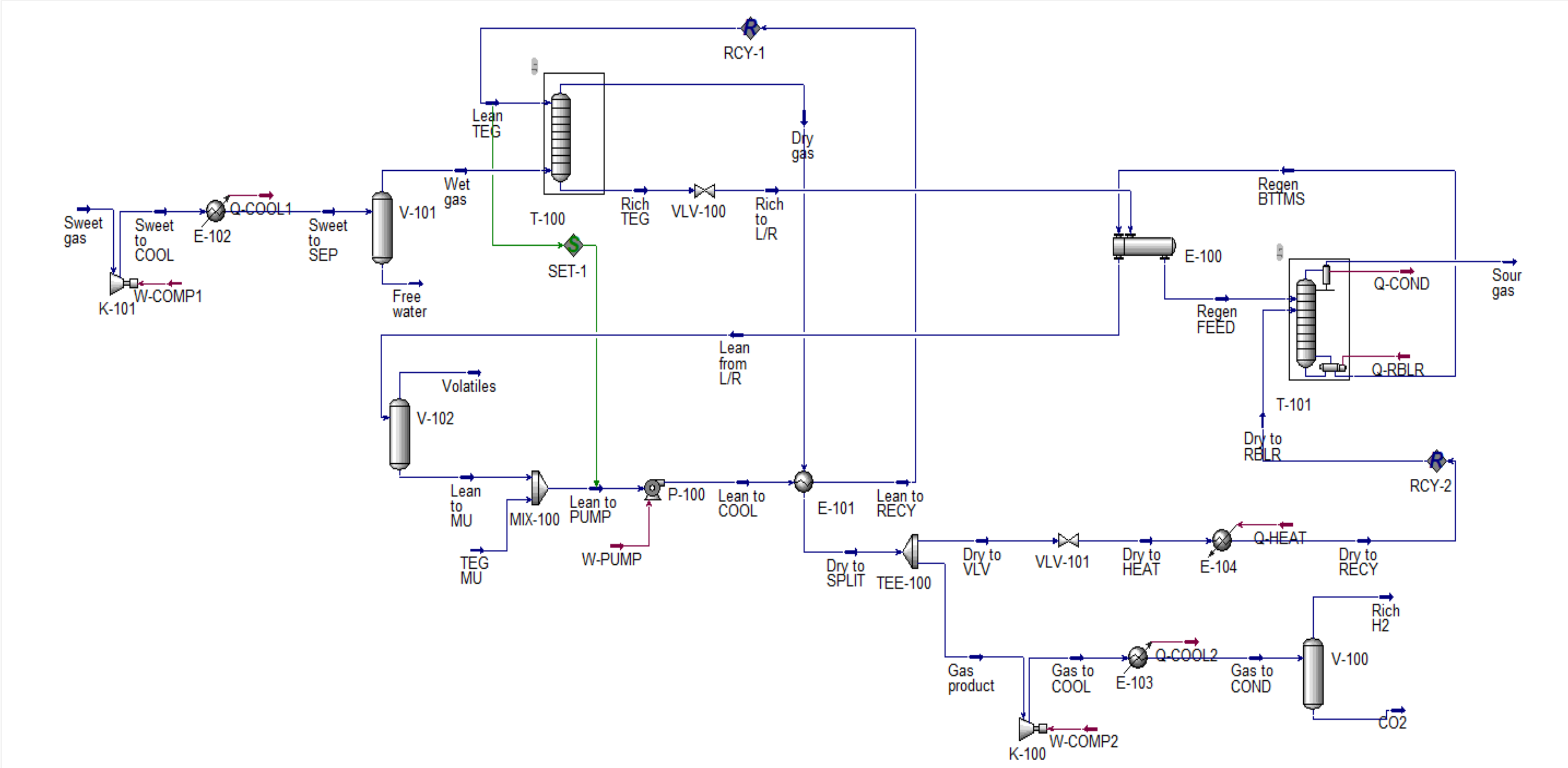


Figure 4: Process flow diagram of the second purification stage based on an enhanced dehydration using dry gas as stripping stream.

Table 3: Life cycle inventory.

Stream	Standard	Dry gas
Water absorbed (kg/h)	7.30	8.25
CO_2 (kg/h)	0.062	0.02003
H_2S (kg/h)	0.000041	0.00023

On the other hand, the gas product is sent to a refrigeration unit where the desired cryogenic conditions are achieved. This section is represented in Figure 4 as a single heat exchanger for simplicity. The cryogenic stream at -55ºC and 60 bar enters a two-phase separator where the liquified CO_2 is separated from the NCG. The level of impurities depends on the composition of the dry gas and the cryogenic conditions.

The most important factors that have been carefully considered during the process simulation are explained below:

- The columns are simulated assuming an overall tray efficiency of 30% to convert from equilibrium to actual stages. This is necessary because the process is modelled with the equilibrium-based CPA property package.
- The temperature of the wet gas entering the absorber column is adjusted so that the temperature of the rich TEG glycol is always above 16ºC in order to avoid problems due to the increased TEG viscosity at lower temperatures.
- The regenerator is operated at atmospheric pressure to minimize the boiling temperature of the rich glycol/water mixture. Although pressures below atmospheric would increase the lean glycol concentration, reboilers are rarely operated in vacuum due to the added complexity and the fact that air leaks may result in glycol dehydration (Stewart M. and Arnold K., 2011).
- The temperature at the top and at the bottom of the regenerator is set to 105ºC and 204ºC, respectively. The condenser temperature should not fall too low to avoid too much water reflux to the regenerator. On the other hand, the reboiler temperature is limited by the maximum temperature that can be tolerated without excessive decomposition of glycol (Kohl A. L. and Nielsen R. B., 1997).

3.2 Parametric analysis and optimization

The model of the purification stage based on an enhanced TEG dehydration using dry gas as stripping stream is utilized to carry out a parametric analysis on different process variables. The aim is to study the influence of different process variables on the level of dehydration of the product CO_2 stream and to optimize the parameters in order to minimize the energy consumption and to minimize the solvent loss.

3.2.1 Number of stages and pressure in the absorber

The variation of the hydrate formation temperature with the number of stages in the absorber at different pressures is represented in Figure 5. The higher the number of stages, the more water is absorbed by the TEG, thus the water content in the product CO_2 stream decreases as well as the hydration formation temperature. The variation of the hydrate formation temperature with the number of stages in the absorber is best represented by a linear trend with a slightly decreasing slope as pressure increases, thus dehydration is also favoured at higher pressures.

The dehydration level should provide a hydrate formation temperature sufficiently lower than the stream temperature, i.e. 5ºC below the stream temperature. To consider the deviations of the simulations from reality due to the utilization of an equilibrium model, the selected conditions should provide a hydrate formation temperature 10ºC below the product CO_2 temperature. Therefore, a hydrate formation temperature of -65ºC is achieved by absorber columns with 20 stages and pressures around 60 bar.

3.2.2 TEG flowrate

The relation between the hydrate formation temperature and the TEG flowrate is represented in Figure 6 at different pressures. The figure shows that increasing the TEG flowrate and the pressure, favours water absorption and reduces the hydrate formation temperature, specially at 60 bar. The selected TEG flowrate and pressure to achieve a dehydration level that provides a hydrate formation temperature of -65ºC are 0.15 kg/s and 60 bar.

3.2.3 Stripping stream flowrate

Figure 7a) shows the effect of the dry gas flowrate injected into the reboiler on the hydrate formation temperature. For stripping stream flowrates below 0.5 kg/s, the amount of water absorbed is progressively lower, and thus the hydrate formation temperature rapidly increases. Conversely, stripping stream flowrates above 0.5 kg/s do not affect dehydration and therefore the hydrate formation temperature does not significantly change.

In addition, Figure 7 b) shows the effect of the dry gas flowrate injected into the reboiler on the TEG make up flowrate. As opposed to the other parameters studied, the stripping stream flowrate greatly affects the amount of solvent loss in the regenerator. While reducing the partial pressure of water in the gas phase in the reboiler, and thus enhancing the solvent regeneration, the injection of a stripping stream drags some TEG that finally leaves the regenerator dissolved in CO_2.

A dry gas flowrate of 0.5 kg/s is required to achieve a hydrate formation temperature of -65ºC. A flowrate of 5.4 kg/h of TEG is necessary to make up for the glycol dragged by the injected stripping and loss in the sour gas.

3.3 Optimized parameters and simulation results for different process configurations

The second purification stage based on an enhanced TEG dehydration using dry gas as stripping stream is simulated and optimized by following the iterative parametric analysis represented in Figure 5. The final operating conditions are summarized in Table 4.

The optimized operating conditions for the enhanced TEG dehydration are implemented as well in the based on standard glycol dehydration configuration. The process flow diagram is represented in Figure 8. Table 5 presents the simulation results for the two different process configurations using the optimized operating conditions presented in Table 4.

The purification configuration based on enhanced dehydration achieves glycol regeneration to significantly higher purities than the standard dehydration. As a result, the standard process produces a purified CO_2 stream with a higher amount of water, and thus hydrates form at -55ºC and 60 bar. Consequently, the standard dehydration configuration is not a suitable option. Nonetheless, the purification process based on enhanced dehydration has much more TEG losses associated due to injection of the stripping stream into the reboiler.

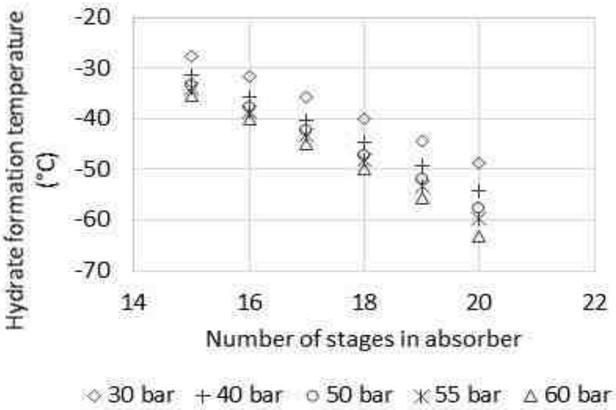


Figure 5: Analysis of the number of stages in the absorber at different pressures.

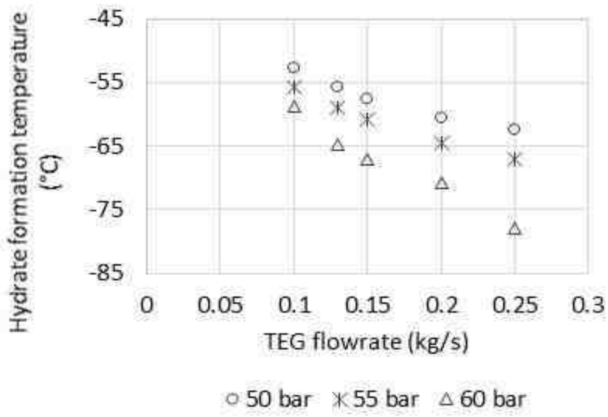
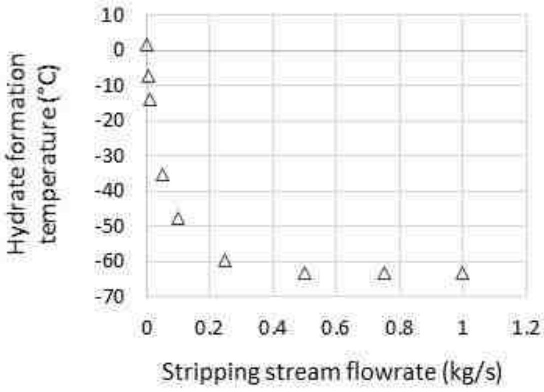
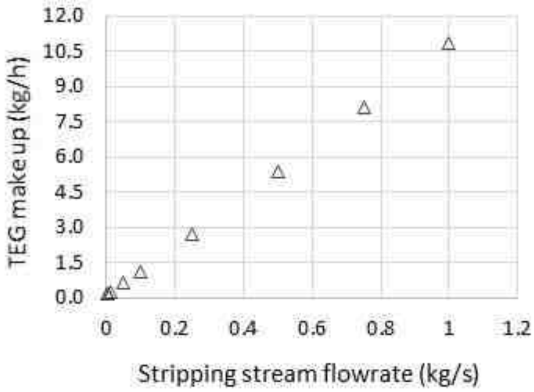


Figure 6: Analysis of the TEG flowrate at different pressures.



a)



b)

Figure 7: Analysis of the dry gas flowrate when used as stripping stream. a) effect of stripping stream flowrate on hydrate formation temperature; b) effect of stripping stream flowrate on TEG make up flowrate.

Table 4: Optimized operating conditions.

Absorber	
Number of real stages	20
Equilibrium tray efficiency (%)	30
Pressure (bar)	60
TEG flowrate (kg/s)	0.15
Lean TEG temperature (ºC)	30
Wet gas temperature (ºC)	23.5
Regenerator	
Number of stages	3 (n+2)
Equilibrium tray efficiency (%)	30
Pressure (bar)	1.0
Condenser temperature (ºC)	105
Reboiler temperature (ºC)	204
Stripping stream flowrate (kg/s)	0.5

Table 5: Comparison of simulation results.

Process stream	**Enhanced dehydration**	**Standard dehydration**
Lean TEG		
TEG (%mass)	99.94	97.64
CO_2		
Temperature (ºC)	-55	-55
Pressure (bar)	60	60
Flowrate (kg/s)	4.2	4.6
CO_2 (%mass)	99.0	99.2
H_2S (ppmw)	0.98	0.98
H_2O (ppmw)	0.57	54.7
Hydrate formation temperature (ºC)	-64.9	4.94
TEG MU		
Flowrate (kg/h)	5.4	0.08

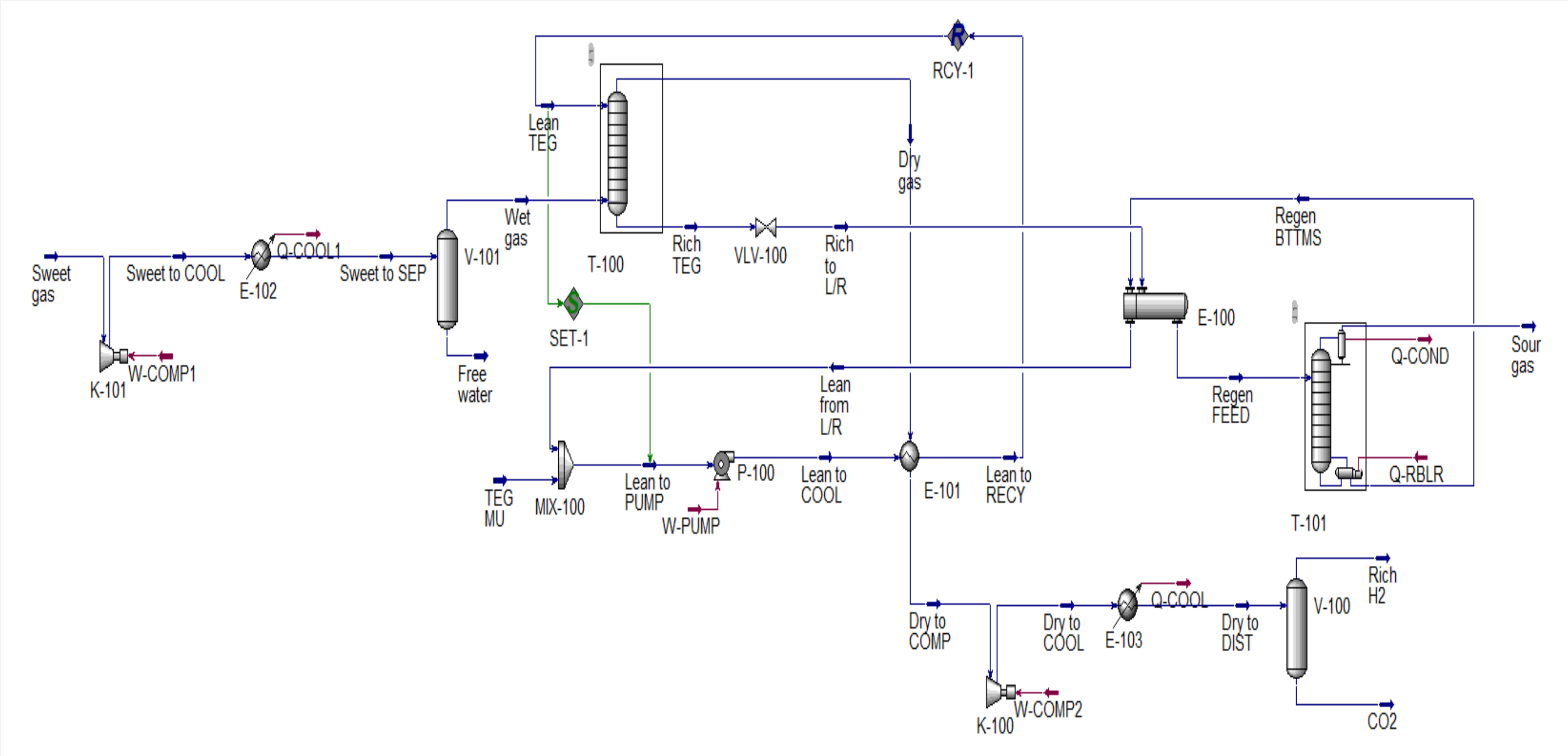


Figure 8: Process flow diagram of the second purification stage based on standard dehydration.

Table 6: Energy requirements comparison.

Energy requirements	Enhanced dehydration (dry gas)	Standard dehydration
Heating (MJ/kg)	95	23
Cooling (MJ/kg)	1,829	2,100
Work (MJ/kg)	920	1,040

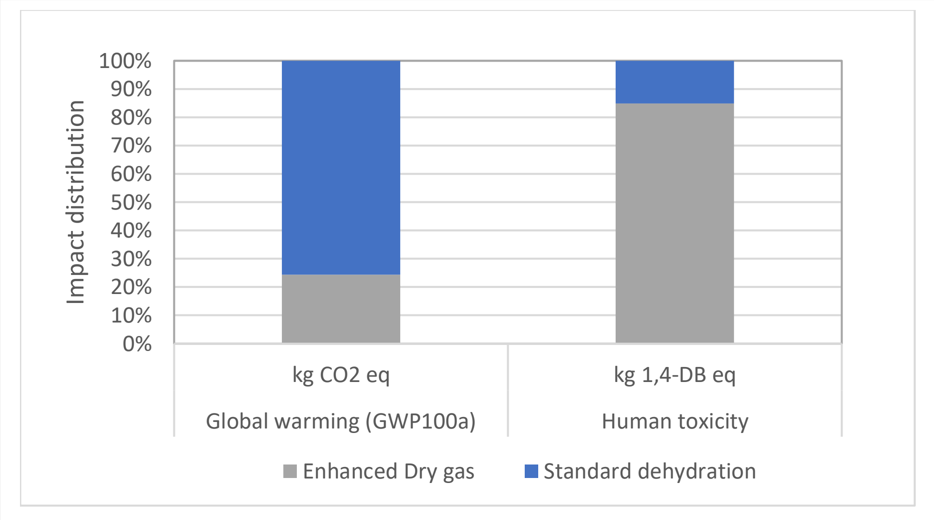


Figure 9: Environmental impact distribution among the purification technologies.

Table 6 shows the energy requirements relative to the amount of water absorbed for the two different purification configurations.

The energy required for heating is higher for the purification process based on enhanced dehydration due to the dry gas conditioning prior injection into the reboiler. However, the relative cooling and compression needs of the purification process based on standard dehydration are higher.

3.4 Environmental impact analysis

Results quantified to the two purification technologies are showed in Figure 8. As it is depicted, the purification technology using dry gas as stripping stream contributed to reduce CO_2 emissions (kg/h) around 70% in comparison with the standard technique. In terms of the H_2S emissions, the higher environmental burden is attributed to the dry gas technique. Nevertheless, due to the rather low amount of the contaminant in the sour gas the effect is depictable. Based on these results, it seems that the dry gas technology shows a better environmental performance than the standard technique considering one kilogram per hour of water absorbed by the purification unit as reference.

4. Conclusions

This work presents a two-stage purification technology to convert waste gaseous emissions from geothermal power plants into value-added products. The first stage aims to reduce H_2S content in the gas mixture in order to produce a purified CO_2 stream at -55ºC and 60 bar in the second stage. To obtain CO_2 at cryogenic conditions, prior dehydration is required in order to avoid hydrate formation. Therefore, this study particularly focuses on the modelling, simulation and optimization of the second purification stage. A comparison of two different technologies based on standard and enhanced glycol dehydration prior cryogenic separation is performed.

Simulation results confirm that second purification stage should involve an enhanced glycol dehydration in order to achieve deep water removal (0.57 ppmw) and hydrate formation temperatures below the liquified CO_2 stream temperature (-64.9ºC). In contrast, the standard glycol dehydration would provide a purified CO_2 stream with higher water content (54.7 ppmw) and higher hydrate formation temperature (4.9ºC).

The analysis of the energy requirements reports higher heating needs for the enhanced dehydration due to the preheating of the dry gas before injecting in the reboiler. However, the cooling needs and the power required for compression are about 12-13% lower.

The environmental assessment suggests that the enhanced dehydration has a better performance in terms of global warming achieving a reduction of 70% of the total CO_2 eq impact.

Acknowledgements

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Nomenclature

CPA	Cubic Plus Association
DEG	Diethylene glycol
EOR	Enhanced Oil Recovery
IDHL	Immediately Dangerous to Life or Health
LCA	Life Cycle Assessment
MDEA	N-methyl diethanolamine
NCG	Non-Condensable Gas
n	Number of real stages
TEG	Triethylene Glycol
TTEG	Tetraethylene Glycol
SRK	Soave-Redlich-Kwong

The application of ArcGIS for assessing the potential of solar energy in urban area: The case of Vranje

Boban PAVLOVIĆ [1]
Junior researcher, Faculty of Mining and Geology, University of Belgrade
Milica PEŠIĆ-GEORGIADIS
Teaching assistant, Faculty of Mining and Geology, University of Belgrade
[1] *Contact details of corresponding author*
Tel: +381654071990
E-mail: boban_pavlovic@hotmail.rs
Address: Djusina 7, 11000 Belgrade

Abstract

In order to determine the solar energy potential for a specified location, it is crucial to consider the latitude, altitude, slope, terrain morphology, atmospheric conditions, etc. Such a complex calculation and mapping of solar energy can be done using the ArcGIS geoprocessing tool, named Area Solar Radiation (ASR). By using the ASR tool, supported with the adequate input data, it is possible to calculate the maximum solar radiation energy (irradiation) for a defined area and for a specified time interval. This paper presents a methodology for the application of the ASR tool for the determination of solar energy potential in urban areas. The focus of the research was urban residential areas, where solar panels (for heat and electricity production) can be installed on rooftops. The methodology was tested for the city of Vranje, located in the Southern Region of Serbia. The extraction of the urban area was carried out using the CORINE Land Cover Open Data – the product of the visual interpretation of high-resolution satellite imagery. According to the ASR calculation, the maximum irradiation for a selected part of the urban area is 1,373 kWh/m^2 annually, and the average for a total urban area is 1,227 kWh/m^2, annually. The obtained result can be used as an input for further technical and economic analysis of the cost-effectiveness of the usage of solar energy. The presented methodology can be applied to any other area with an appropriate digital elevation model (DEM), which is the main precondition to ensure the appropriate topographic parameters.

Keywords: Renewable energy, solar potential, GIS, solar mapping.

1. Introduction

Solar radiation is the primary source of energy for many physical and biological processes on Earth and it is one of the basic preconditions for the existence of the living world. In essence, energy received from the Sun is in the form of light and thermal energy. When considering the total impact of the solar radiation, it should in mind that solar radiation is also a precondition for the existence of wind energy, marine energy, and energy in biomass and fossil fuels, captured through photosynthesis.

For the purpose of heating and electricity production, the application of solar panels (solar thermal panels for heating water and PhotoVoltaic (PV) solar panels for electricity production) and the construction of solar thermal power plants is commonly used.

Setting aside a technical characteristic of photovoltaic cells within the solar panels, the amount of electric energy that will be produced depends on many factors. Certainly, one of the most important is the insolation/solar irradiation, defined as the solar radiation energy received from the Sun per unit area of the Earth's surface (kWh/m^2).

The solar irradiation in a specific area depends on latitude (geographic coordinate that specifies the north-south position of a point on the Earth's surface) because it determines the duration of daily solar radiation and annually. Apart from latitude, factors as air temperature, humidity, cloudiness should be also considered.

For the optimal use of solar panels, the morphology of the terrain is also crucial. The variability of morphological factors, such as altitude, slope, and aspect, affects the length of direct solar radiation. In addition, the morphology also affects the level of shading of the area, which certainly reduces the period of direct solar radiation. All the above are essential preconditions for appointing the specific location as a potentially favorable one for panel placement.

When estimating the solar energy potential for the specific location, it is highly recommended to have ground measured data from the meteorological stations. Such data can provide better precision in the evaluation of the solar energy potential.

However, high costs of installation and maintenance of the meteorological stations promoted the development of different methods to estimate the global solar irradiation from the available data. There are several models - available to be used by the public - for creating the solar maps. These models are usually connected with computer software applications, with most of them using ESRI's ArcGIS as their base system (Sarmiento N. et al., 2019). ESRI's ArcGIS can provide the appropriate modeling platform for the estimation of solar radiation energy. Many of the necessary capabilities are now widely accessible from GIS platforms, including abilities to construct or import digital elevation models, to integrate diverse databases for input and output, to access viewshed analysis algorithms that permit assessment of sky obstruction and reflectance etc (Dubayah R., Rich P.M., 1995).

Solar Analyst Tool (SAT) is an extension module of ArcGIS, which derives a solar radiation map based on the input Digital Elevation Model (DEM) (Dubayah R., Rich P. M., 1995). Using the input parameters, such as atmospheric conditions, geographical location, and terrain morphology, the ArcGIS SAT enables the calculation of solar energy potential over a given space and for a specified time interval. The output is a solar map which contains information regarding the quantity of insolation/solar radiation energy for a specified area. Such solar resource calculation and mapping integrated into the SAT is developed by Fu P. and Rich P.M. (in 2000). This tool, which is based on solar geometrical theory, counts incoming solar radiation for each pixel of a DEM. The DEM provides information about the morphology of the area (elevation, slope, and orientation).

In this paper, the developed methodology is tested and analyzed for the urban area of the city of Vranje, located in the southeastern part of Serbia.

2. The state of Renewable Energy Sources in Serbia

Potentials of Renewable Energy Sources (RES) of the Republic of Serbia are significant and estimated at 5.65 Mtoe (Million tonnes of oil equivalent) per annum (Republic of Serbia, 2016). The largest part of the current usage of the RES refers to a traditional way of using biomass and large hydropower plant (Republic of Serbia, 2016).

Other areas in renewable energy, potentially with lower levels of environmental impact, show low levels of development. The utilization of other renewable sources of energy, such as wind, solar, and geothermal, is marginal (Lewis M., 2018).

The estimated potential can have a considerable contribution to the lesser utilization of fossil fuels, as well as the improvement of the environment. The biomass potential amounts to approximately 3.4 Mtoe per year (2.3 Mtoe per year is unused, and 1.1 Mtoe is used), 1.7 Mtoe lies in hydropotential (0.8 Mtoe per year is unused, and 0.9 Mtoe per year is the used hydropotential), 0.2 Mtoe per year in geothermal energy, 0.2 Mtoe per year in geothermal energy, 0.1 Mtoe per year in wind energy, 0.2 Mtoe per year in solar energy and 0.04 Mtoe per year in biodegradable part of waste (Republic of Serbia, 2013).

Total primary energy production from RES in Serbia in 2018 was 2.069 Mtoe (Ministry of Mining and Energy, Republic of Serbia, 2018). In the total domestic production of primary energy from renewable energy sources, the largest share has biomass (56%), then hydropower (38%), wind power (5%), while biogas, solar energy, and geothermal energy participate with 1% in total share (Republic of Serbia, 2018).

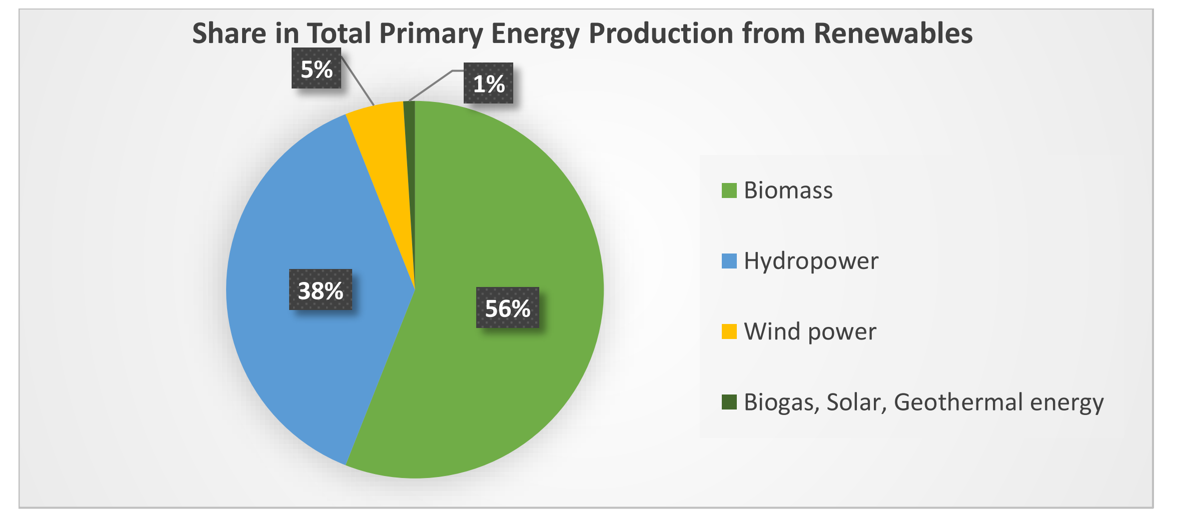

Figure 1: Total production of primary energy from RES in Serbia per energy source (Republic of Serbia, 2018).

3. Potential of solar energy in Serbia

Serbia has an average of 272 sunny days and about 2,300 sunny hours, which is more than the European average (Pavlovic T. et al., 2011).

Annually, the average value of the overall solar radiation energy for the territory of the Republic of Serbia ranges from 1,200 kWh/m^2, in northwest Serbia, to 1,550 kWh/m^2, in southeast Serbia (Pavlovic T. et al., 2011).

For instance, the average value of the annual solar radiation energy in Germany, between 1981 and 2010, fluctuates from approximately 950 kWh/m^2 and 1,260 kWh/m^2 according to a specific location (ISE, 2019). According to the statistics, provided by the International Energy Agency (IEA), solar PV electricity generation in Germany in 2016 was 38,098 GWh (IEA, 2019a). For the same year, solar PV electricity generation in Serbia was 12 GWh (IEA, 2019b)

As can be seen from the comparison with Germany, the discrepancy between the solar potential in Serbia and the utilization of solar radiation energy for electricity generation in Serbia is noticeable. Therefore, it is clear that there is an opportunity for further improvements in using solar energy in Serbia, and consequently, for increasing the share of RES in the gross final consumption of energy.

Existing share of RES in gross final consumption in 20.1%. As a candidate state for future membership of the European Union (EU), Serbia needs to take significant measures towards increasing consumption of RES and more sustainable energy consumption. In accordance with Directive 2009/28/EC of the EU, Serbia adopted the National Action Plan for RES as a framework for promotion of energy generated from RES and set mandatory national goals for share of renewable energy in gross final consumption of energy (27%) as well as the share of energy from RES in transport (10%) by 2020 (Republic of Serbia, 2016).

Considering all the aforementioned, it can be concluded that the installation of new capacities for use of solar energy and its conversion into thermal and electrical energy may contribute to the fulfillment of the goals from Serbia's National Action Plan for RES.

4. Overview of The Solar Analyst Tool

The Solar Analyst Tool (SAT) allows the analysis of the effects of solar radiation. The algorithm which is implemented in the SAT is developed and later upgraded by the authors – Paul Rich and Pinde Fu (1999). As the authors of the SAT point out, the calculation and mapping which are enabled by this tool are very useful for the area for which there is no direct measurement data of solar irradiation/insolation (Fu P., Rich P.M., 2000).

Basically, two types of analysis can be distinguished within the SAT. The first one involves the analysis of a specific area, named "Area Solar Radiation" (ASR), and the second one, is for the analysis of the specific points determined by the x and y coordinates, named "Points Solar Radiation" (PSR) (ESRI, 2019).

In this specific case, the ASR calculation is used for the calculation of the total solar radiation (direct and diffuse) over a time period at the selected geographical area. The calculation is repeated for each pixel of the available DEM. The obtained result of the calculation is given in the form of a raster with values of energy, expressed in Wh/m^2.

5. Data processing

The total amount of solar radiation that reaches the Earth's surface is the sum of direct, diffuse, and the reflected radiation (Figure 2). Generally, direct radiation has the largest share in total solar radiation, and in the second place is diffuse radiation. Reflective radiation has the smallest share in total solar radiation, but it is not negligible in the area with reflective surfaces, such as the area covered with snow. However, the SAT does not include reflected radiation in the calculation, so in this case, the total amount of solar radiation is calculated as the sum of direct and diffuse radiation.

The SAT calculation involves four steps (ESRI, 2019):

1. The calculation of an upward-looking hemispherical viewshed based on topography;
2. Overlay of the viewshed on a direct sun map to estimate direct radiation;
3. Overlay of the viewshed on a diffuse sky map to estimate diffuse radiation;
4. Repeating the process for every location of interest to produce an insolation map.

The SAT generates an upward-looking hemispherical viewshed. A hemispherical viewshed is similar to upward-looking hemispherical (fisheye) photographs, which view the entire sky from the ground up, similar to the view in a planetarium (ESRI, 2019). The hemispherical viewsheds are used to calculate the insolation for each location and produce an accurate insolation map (Fu P., Rich P.M., 2000). Figure 3 shows the layout of the hemispherical viewshed. As it can be seen, such a layout also provides a view of the surrounding topography, where it is possible to observe how topography can prevent direct solar radiation. The resultant viewshed characterizes whether the sky directions are visible (shown in white) or obstructed (shown in gray).

The direct solar radiation originating from each sky direction is calculated using a sun map in the same hemispherical projection as the viewshed. A sun map is a raster representation that displays the sun track or apparent position of the sun as it varies through the hours of the day and through the days of the year. The sun map consists of discrete sectors defined by the sun's position at particular intervals during the day (hours) and time of year (days or months).

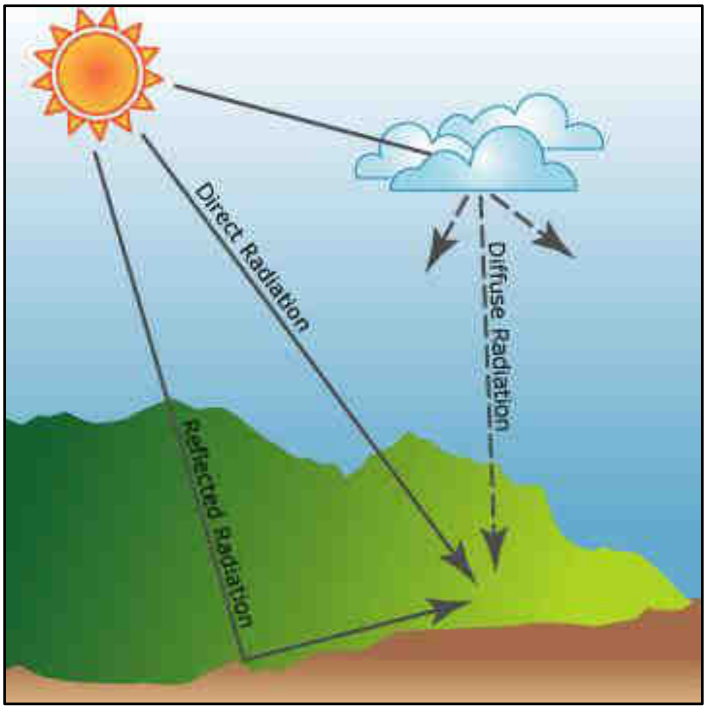

Figure 2: Solar radiation (ESRI, 2019).

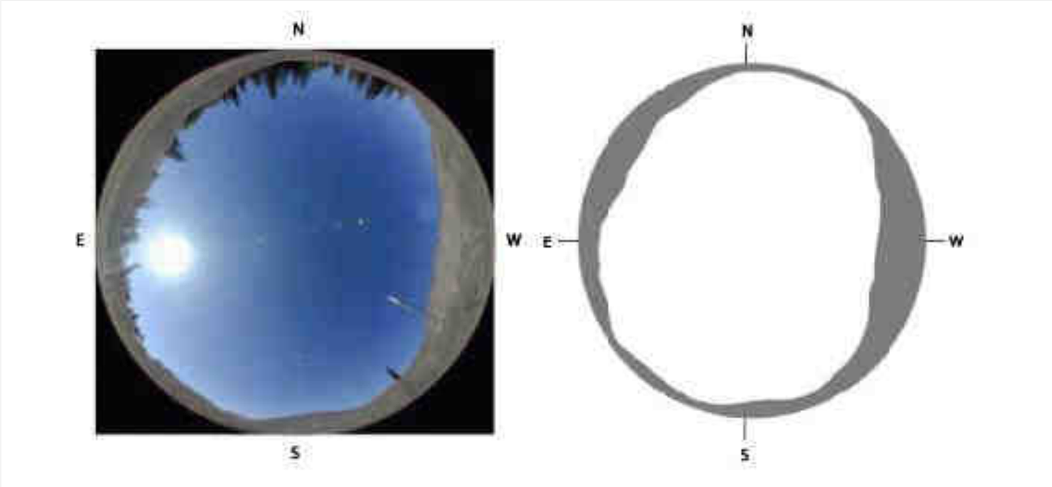

Figure 3: The viewshed of the visible and obstructed sky from a particular point on the surface (ESRI, 2019).

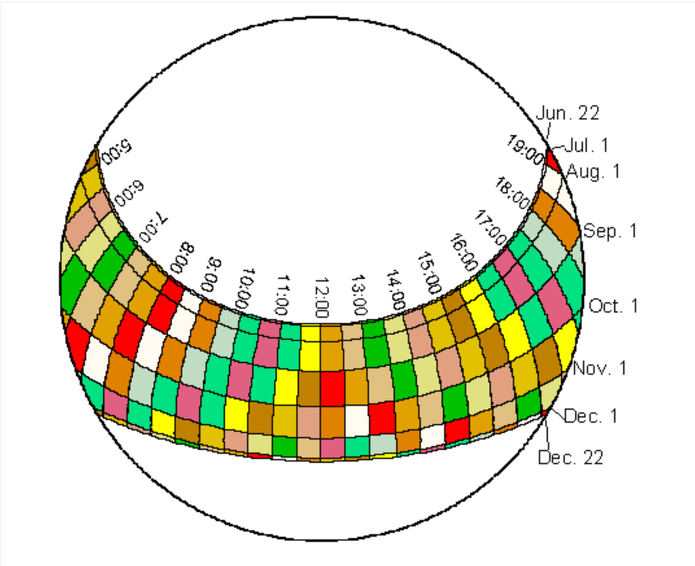

Figure 4: The map of the direct solar radiation (Rich P.M., Fu P., 1999).

Thus, the map of direct solar radiation will represent the Sun's trajectory, which depends on the latitude of the exploration area or points and the specified time interval. Each sector displayed on the map will have a unique value, along with its azimuth and zenith. Figure 4 shows an example of a direct solar radiation map (also called a sun map) that can be found in the literature (Republic of Serbia, 2018). Precisely, this is a map relating to 39° North latitude for the period between the summer and winter solstice (the 22nd of June - the 22nd of December), i.e. between the period when the Sun reaches the highest and lowest point in the sky above the horizon.

Unlike the direct solar radiation, which totally depends on the position and distance of a given area/point relative to the Sun, the diffuse solar radiation can originate from any direction. The diffuse solar radiation is scattered in different directions by clouds, particles in the air, etc.

For this reason, the diffuse solar radiation map (also called sky map) shows a hemispherical view of the entire sky above the observed location, divided into separate sectors with unique diffuse radiation values. The number of sectors depends on the required accuracy in the calculation (ESRI, 2019).

Figure 5 shows a sky map with sky sectors defined by 8 zenith divisions and 16 azimuth divisions. Each color represents a unique sky sector, or portion of the sky, from which diffuse radiation originates (Rich P.M., Fu P., 1999).

In order to obtain a final result, (e.g. the quantity of solar energy for a specific area), the viewshed raster is overlaid with the sun map and sky map rasters to calculate diffuse and direct radiation received from each sky direction. The proportion of visible sky area in each sector is calculated by dividing the number of unobstructed cells by the total number of cells in each sector (ESRI, 2019) (Figure 6).

It is important to note that solar radiation maps and layout of hemispherical viewshed previously shown in this section, are internally used from the SAT and it is not an output of the SAT application. Summarizing the main advantages of the SAT over previously developed models, the authors emphasize the following (Fu P., Rich P.M., 2000):

- Versatile output: calculates direct, diffuse, global radiation, and direct radiation duration, sun maps and sky maps, and viewsheds;
- Simple input: requires only DEM, atmospheric transmissivity, and diffuse proportion;
- Flexibility:
  - calculates insolation for any: i) specified period (instantaneous, daily, monthly, weekly, etc.); ii) region (whole DEM, restricted areas, or point locations);
  - allows the specification of the receiving surface orientation (from DEM, field survey, or orientations of surfaces such as sensors or leaves) and height offsets for ground features;
- Fast and accurate calculation: uses advanced viewshed algorithm for calculations;

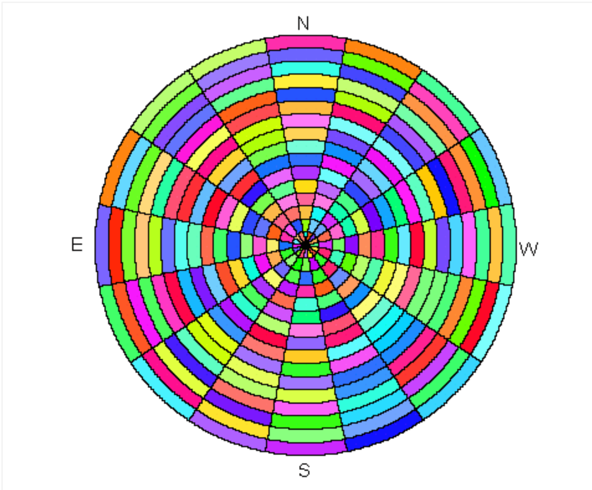

Figure 5: The map of the diffuse solar radiation (Rich P.M., Fu P., 1999).

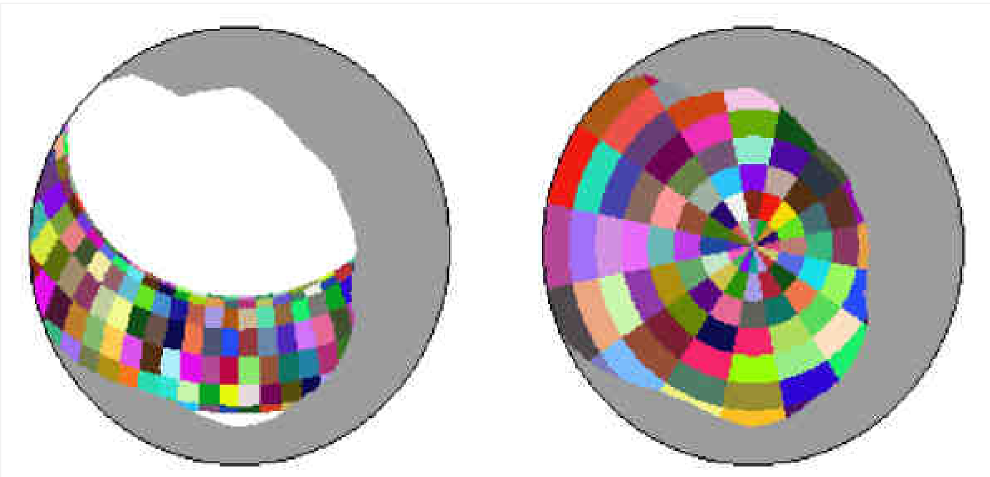

Figure 6: The examples of the overlay of viewshed with maps of direct and diffuse solar radiation (Rich P.M., Fu P., 1999).

- Broad accessibility: the Solar Analyst runs within ArcView and does not require expensive, high–end GIS software;
- User-friendly interface: implements user interface with ArcView Dialog Designer and ArcView Avenue; benefits from ArcView's mapping, query, graphing, & statistics functions;
- Programmable capabilities: improves user efficiency by allowing task automation.

Calculation of solar energy

The total amount of solar radiation, entitled in the SAT as Global radiation ($Global_{tot}$), is calculated as the sum of direct (Dir_{tot}) and diffuse (Dif_{tot}) radiation of all sun map (map of direct solar radiation) and sky map (map of diffuse solar radiation) sectors, respectively (Fu P., Rich P.M., 2000):

$$Global_{tot} = Dir_{tot} + Dif_{tot} \quad (1)$$

Direct solar radiation

Total direct insolation (Dir_{tot}) for a given location is the sum of the direct insolation ($Dir_{\theta,\alpha}$) from all sun map sectors respectively (Fu P., Rich P.M., 2000):

$$Dir_{tot} = \Sigma\ Dir_{\theta,\alpha} \quad (2)$$

The direct insolation from the sun map sector ($Dir_{\theta,\alpha}$), with a centroid at zenith angle (θ) and azimuth angle (α), is calculated using the following equation (3):

$$Dir_{\theta,\alpha} = S_{Const} * \beta^{m(\theta)} * SunDur_{\theta,\alpha} * SunGap_{\theta,\alpha} * \cos(AngIn_{\theta,\alpha}) \quad (3)$$

where:

$\mathbf{S_{Const}}$ = The solar flux outside the atmosphere at the mean earth-sun distance, known as solar constant. The solar constant used in the analysis is 1367 W/m^2. This is consistent with the World Radiation Center (WRC) solar constant;

β = The transmissivity of the atmosphere (averaged over all wavelengths) for the shortest path (in the direction of the zenith);

m(θ) = The relative optical path length, measured as a proportion relative to the zenith path length;

$\mathbf{SunDur_{\theta,\alpha}}$ = The time duration represented by the sky sector. For most sectors, it is equal to the day interval (for example, a month) multiplied by the hour interval (for example, a half-hour (0.5)). For partial sectors (near the horizon), the duration is calculated using spherical geometry;

$\mathbf{SunGap_{\theta,\alpha}}$ = The gap fraction for the sun map sector;

$\mathbf{AngIn_{\theta,\alpha}}$ = The angle of incidence between the centroid of the sky sector and the axis normal to the surface (see equation 4 below).

Relative optical length, **m(θ)**, is determined by the solar zenith angle and elevation above sea level. For zenith angles less than 80°, it can be calculated using the following equation (ESRI, 2019):

$$m(\theta) = EXP(-0.000118 * Elev - 1.638*10^{-9} * Elev^2) / \cos(\theta) \quad (4)$$

where:

- **θ** = The solar zenith angle;
- **Elev** = The elevation above sea level in meters.

The effect of surface orientation is taken into account by multiplying by the cosine of the angle of incidence. The angle of incidence ($AngInSky_{\theta,\alpha}$) between the intercepting surface and a given sky sector with a centroid at zenith angle and azimuth angle is calculated using the following equation (ESRI, 2019):

$$AngIn_{\theta,\alpha} = acos(Cos(\theta) * Cos(G_z) + Sin(\theta) * Sin(G_z) * Cos(\alpha-G_a)) \quad (5)$$

where:

$\mathbf{G_z}$ = The surface zenith angle;

Note that for zenith angles greater than 80°, refraction is important;

$\mathbf{G_a}$ = The surface azimuth angle.

Diffuse radiation calculation

For each sky sector, the diffuse radiation at its centroid (**Dif**) is calculated, integrated over the time interval, and corrected by the gap fraction and angle of incidence using the following equation (Fu P., Rich P.M., 2000):

$$Dif_{\theta,\alpha} = R_{glb} * P_{dif} * Dur * SkyGap_{\theta,\alpha} * Weight_{\theta,\alpha} * \cos(AngIn_{\theta,\alpha}) \quad (6)$$

where:

$\mathbf{R_{glb}}$ = The global normal radiation (see equation 6 below).

$\mathbf{P_{dif}}$ = The proportion of global normal radiation flux that is diffused. Typically, it is approximately 0.2 for very clear sky conditions and 0.7 for very cloudy sky conditions.

Dur = The time interval for analysis.

SkyGap$_{θ,α}$ = The gap fraction (proportion of visible sky) for the sky sector.

Weight$_{θ,α}$ = The proportion of diffuse radiation originating in a given sky sector relative to all sectors (see equations 7 and 8 below).

AngIn$_{θ,α}$ = The angle of incidence between the centroid of the sky sector and the intercepting surface.

The global normal radiation (**R$_{glb}$**) can be calculated by summing the direct radiation from every sector (including obstructed sectors) without correction for the angle of incidence, then correcting for proportion of direct radiation, which equals **1-P$_{dif}$** (ESRI, 2019):

$R_{glb} = (S_{Const}\ \Sigma(\beta^{m(\theta)})) / (1 - P_{dif})$ (7)

For the uniform sky diffuse model, **Weight$_{θ,α}$** is calculated as follows (ESRI, 2019):

$Weight_{\theta,\alpha} = (\cos\theta_2 - \cos\theta_1) / Div_{azi}$

where:

θ_1 and θ_2 = The bounding zenith angles of the sky sector.

Div_{azi} = The number of azimuthal divisions in the sky map.

For the standard overcast sky model, **Weight$_{θ,α}$** is calculated as follows:

$Weight_{\theta,\alpha} = (2\cos\theta_2 + \cos2\theta_2 - 2\cos\theta_1 - \cos2\theta_1) / 4 * Div_{azi}$ (9)

Total diffuse solar radiation for the location (Dif_{tot}) is calculated as the sum of the diffuse solar radiation (Dif) from all the sky map sectors (3):

$Dif_{tot} = \Sigma\ Dif_{\theta,\alpha}$ (10)

Case of Vranje

Vranje is the administrative center of Pcinja district. The DMS coordinates of Vranje are **42°33'5" N 21°54'1" E.** The city is located in the southeastern part of Serbia (Figure 7). The total area of Vranje is 860 km^2, and according to the estimation of the Statistical Office of Republic of Serbia from 2017, the population of the city administrative area is 80,961 people (SORS, 2018).

Vranje is selected for the case study based on available literature on solar energy potential in Serbia, where the southeastern part of Serbia is pointed out as an area with good potential for the usage of solar energy (University of Belgrade, 2004; Stamenkovic Lj., 2009).

The average daily solar radiation energy for a flat surface during winter ranges between 1.1 kWh / m^2 in Northern Serbia and 1.7 kWh / m^2 in Southern Serbia, and in the summer between 5.4 kWh / m^2 in Northern Serbia and 6.9 kWh / m^2 in Southern Serbia (University of Belgrade, 2004). It should be noted that the data were obtained based on data measured at meteorological stations University of Belgrade, 2004). Figure 8 shows two maps with the average daily energy of solar radiation on a horizontal surface. The map on the left shows the average daily energy of solar radiation in January and the map on the right shows the average daily energy of solar radiation in July. The black-colored circle shows the position of Vranje on the map of Serbia.

In this case study, the focus is on the estimation of solar radiation energy in urban area of the city for the reason that most people live in there and also, there is a large number of buildings that are potentially suitable for installation of solar panels.

For the purpose of representing the topographic surface (three-dimensional terrain) of the urban area of the city of Vranje, a Digital Elevation Model (DEM) is used. The DEM can be represented as a raster. Raster data is made up of pixels (or cells), and each pixel has an associated value. In case of the DEM, each cell has a value corresponding to its elevation (PBC GIS, 2019). For the generation of the DEM generally data issued from different sources can be used (Taud H. et al., 1999):

- Contour lines (from existing maps),
- Photogrammetric (aerial photography or digital satellite imagery),
- Field data.

In this work, the DEM which is generated from the contour lines and its resolution is 10 m is used. This DEM originates from the University of Belgrade, (Faculty of Forestry, 2018).

For the optimal usage of the Solar Analyst Tool, it is important to point out that the resolution of a DEM affects the results of the estimation of solar energy potential.

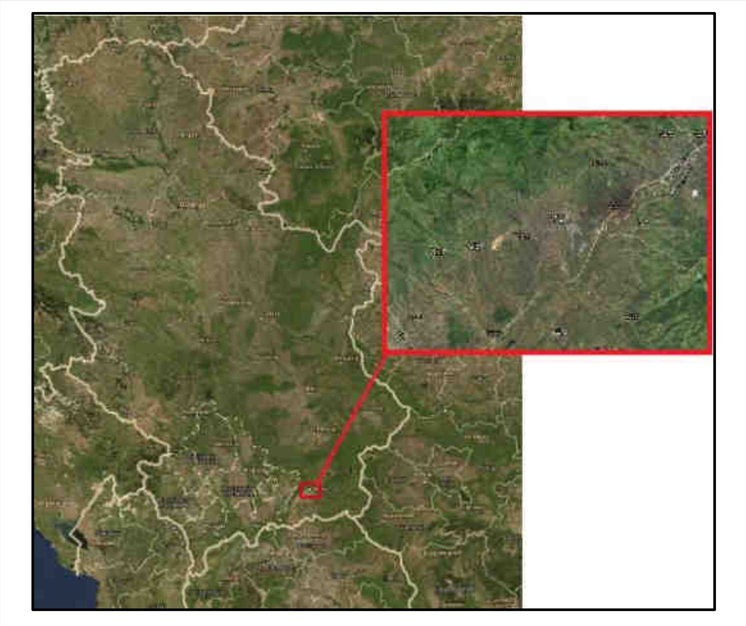

Figure 7: The geographical position of the city of Vranje.

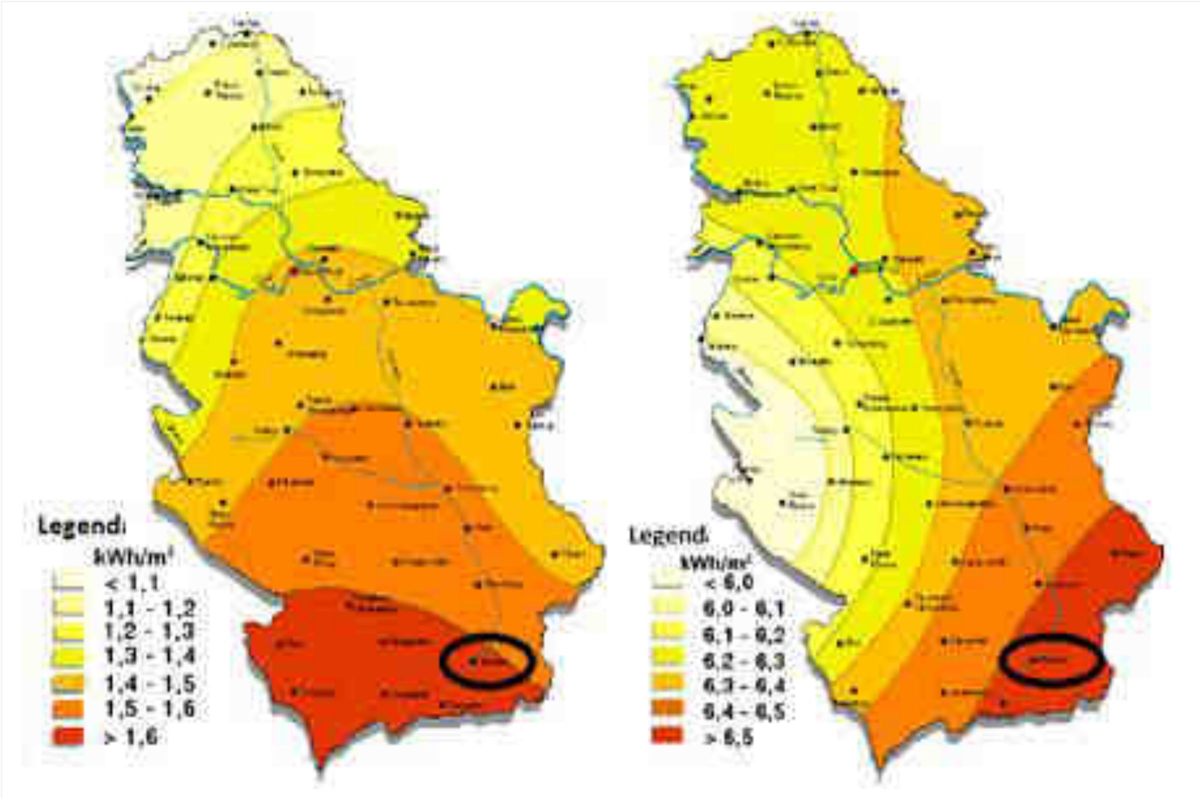

Figure 8: Average daily solar irradiation to the horizontal surface for January (left) and July (right) (15) (University of Belgrade, 2004).

The higher resolution provided, the better information regarding the suitability of the location for the installation of solar panels it is.

The extraction of the urban area of the city of Vranje is carried out using the CORINE Land Cover Open Data – the product of the visual interpretation of high-resolution satellite imagery (Copernicus land Monitoring Service, 2019a). Corine means “coordination of information on the environment” and it is a prototype project working on many different environmental issues. As described on the website, Copernicus Land Monitoring Service (CLMS) provides geographical information on the land cover to a broad range of users in the field of environmental terrestrial applications (Copernicus land Monitoring Service, 2019b).

Data from CORINE Land Cover (CLC) is generated by the processing of high-resolution satellite images and they provide information about land cover changes in the major part of Europe. Polygonal entities represent a state of land cover differentiated in 44 classes, divided into a 3-level hierarchical classification system (Stojkovic S., 2017). The COPERNICUS website includes CLC datasets for different years with the corresponding land cover changes (Copernicus land Monitoring Service, 2019a).

Regarding the object of this study, using the ArcGIS software (ArcMap) it is possible to extract the urban area from CLC, originally defined as a class of Urban fabric, which is consisting of the next subclasses (20):

- No. 111 - Continuous urban fabric, and
- No. 112 - Discontinuous urban fabric, which is the object of interest for this case study.

In the case of Vranje, it possible to extract only the class No. 112 – Discontinuous urban fabric, showed in Figure 9.

Using ArcMap's option **"Select Features"** it is possible to export the selected class of the land cover and make the new shape file which contains only the urban area of Vranje. For clipping the DEM to the dimension of the urban area of Vranje, it is used the Clip Tool in ArcMap. In the Clip Tool in the field named **"Input Raster", it is necessary to load the specified DEM from the Introduction.** After that, in the field named **"Output Extent",** the shape file which contains the urban area of Vranje is loaded.

The Clipping tool will clip the inserted DEM for the required area, as it can be seen in Figure 10 below. When the DEM of the urban area of Vranje is defined, the next step is the implementation of the tool Area Solar Radiation. The ASR is used to calculate the total insolation/solar radiation energy over a selected period of time for the urban area of Vranje.

Required data to complete the calculation includes the following:

- DEM;
- **Latitude for the site area** - based on input DEM. The analysis is designed only for local landscape scales, so it is generally acceptable to use one latitude value for the whole DEM.
- Sky size - the resolution of the viewshed, sky map, and sun map rasters that are used in the radiation calculations (units: cells per side). These are upward-looking, hemispherical raster representations of the sky and do not have a geographic coordinate system. These rasters are square (equal number of rows and columns). The recommended sky dimension value for a daily interval greater than 14 days is 200 (ESRI, 2019).
- Time configuration - there are 4 options (ESRI, 2019).
  - Calculation of solar radiation energy for winter and summer solstice,
  - Calculation within one day,
  - Multi-day,
  - Within one year.

  In this particular case, the calculation is made for the whole year and for July and December.
- Day interval - data required to analyze the position of the Sun over time. The auto-set interval is 14 days. The interval can be set to be shorter, but it is not recommended to be shorter than 3 days since the Sun's trajectory overlaps at shorter intervals (ESRI, 2019).
- Hour interval - Time interval through the day (units: hours) used for calculation of sky sectors for sun maps. In this case, the accepted default value is -0.5.
- Topography parameters:
  - Z factor - used to adjust the calculation in cases where the units of measurement for the z coordinate are not the same as for the x, y coordinates. If the x, y units, and z units are in the same units of measure, the z-factor is 1. This is the default.
  - Slope and aspect - The slope and aspect rasters are calculated from the input surface raster. This is the default.
  - **Number of azimuth directions** - Valid values must be multiples of 8 (8, 16, 24, 32, and so on). The recommended number for complex topography, such as in the case of the topography of the city of Vranje, is 32.

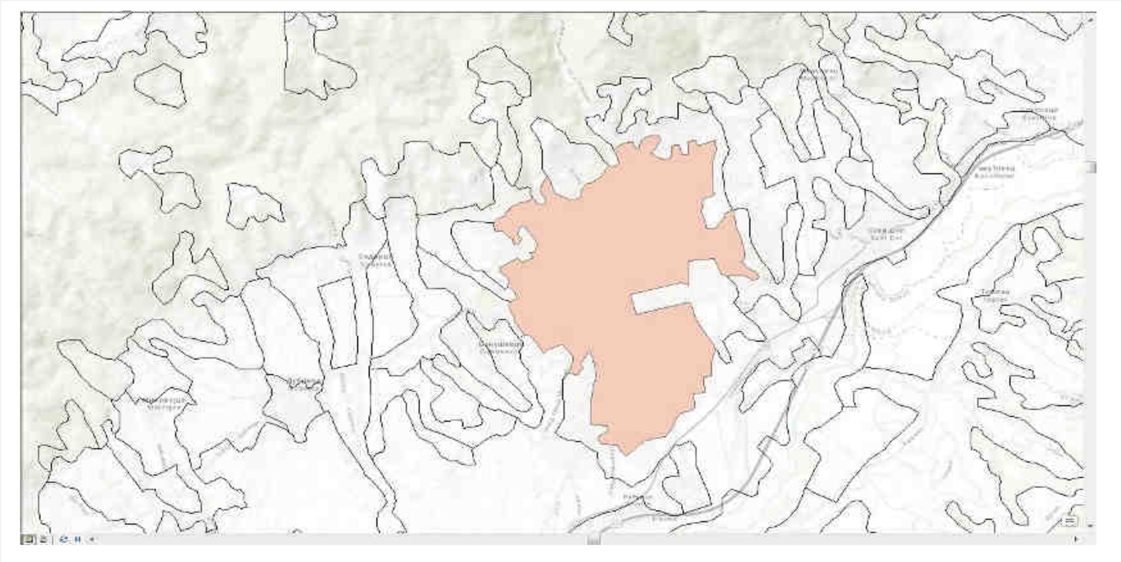

Figure 9 : The Urban area of Vranje in Corine Land Cover (CLC) Open Data.

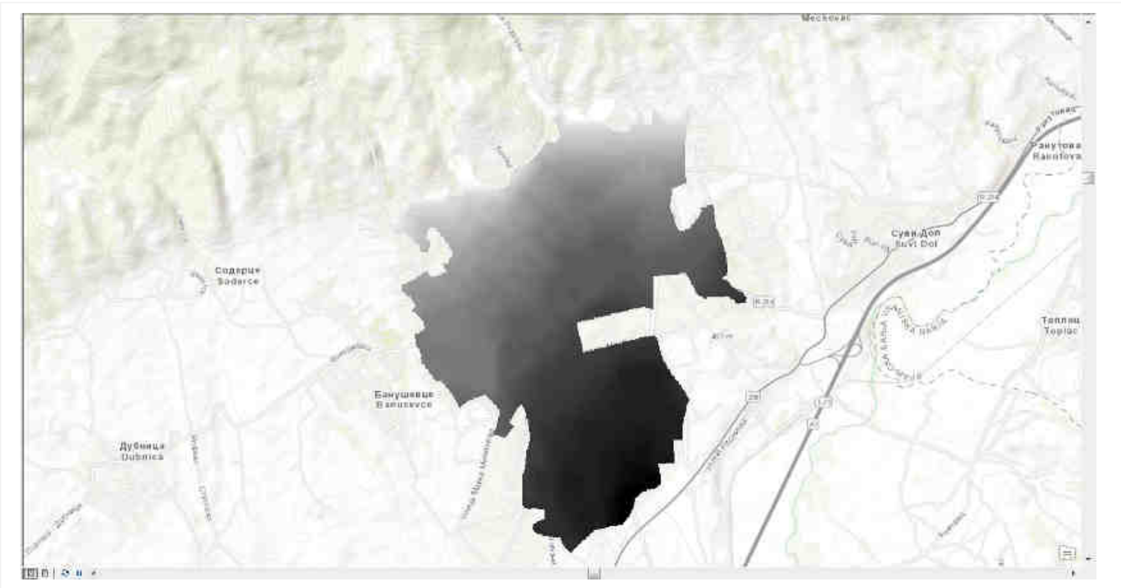

Figure 10 : The clipped DEM of the urban area of Vranje.

- Solar radiation parameters:
  - Zenith and Azimuth divisions - represents the number of sectors in the diffuse solar radiation map (sky map) from which diffuse radiation can originate. In this case, the accepted default value is 8.
  - Diffuse model type - there is a choice between two models: UNIFORM_SKY and STANDARD_OVERCAST_SKY. In this particular calculation, the first model is chosen, which considers the diffuse radiation as uniform from all directions.
  - Diffuse proportion - represents the share of diffuse radiation in total (global) radiation. The typical value for mostly clear sky conditions - 0.3.
  - Transmittivity - The fraction of radiation that passes through the atmosphere (averaged over all wavelengths). Values range from 0 (no transmission) to 1 (all transmission). The default is 0.5 for a generally clear sky.

6. Results and Discussion

Previously shown calculation is repeated for each pixel of the input DEM. The output raster representing the global radiation energy or the total amount of incoming insolation (direct and diffuse) calculated for each location of the input DEM (urban area of the city of Vranje).

The result of the SAT calculation is originally represented in units of watt-hours per square meter (Wh/m^2), but considering the aim of this paper, the output values in this work are displayed in kWh/m^2.

Figure 11 shows the amount of solar radiation energy/insolation during the year for the subject area. As it can be seen, the maximum amount of solar energy in certain parts of the area reaches a value of 1,373 kWh / m^2 annually. Dividing that value by 365 days the quotient of the average daily solar radiation energy for the area with the highest value of solar radiation energy is calculated, and the resulted daily solar radiation energy is 3.76 kWh/m^2.

Figure 12 shows the histogram with the insolation values for the studied area. In addition to this histogram, ASR tool also provides the basic statistics, according to which it is possible to get the mean value of the insolation for the studied area, which is 1,227 kWh / m^2.

Due to seasonal trends, solar radiation varies throughout the year. The Sun is higher in the sky in summer months than in winter months at the equivalent time of the day. It results in higher solar energy absorption by solar panels during summer months. In the case of PV panels, the longer days of summer allow PV cells to generate more energy than in the wintertime.

For that reason, as already mentioned in a previous section, the ASR is also used for the calculation of monthly solar radiation in January (winter time) and July (summertime).

Figure 13 shows two maps of the subject area. The left one represents the amount of solar radiation energy/insolation during January, and the right one represents the amount of solar radiation energy/insolation during July. As it can be seen, the maximum amount of solar energy in January for certain parts of the area reaches a monthly value of 42 kWh/m^2, and in July it reaches a monthly value of 181 kWh/m^2.

Figure 14 shows the histograms with the insolation values for the analyzed months, with the basic statistics, according to which it is possible to get the mean value of the insolation for the studied area and period of time, which is near 29 kWh / m^2 in January and near 175 kWh / m^2 in July.

By dividing the mean value of the monthly insolation with the number of days in months, the average daily solar radiation energy is calculated. The average daily solar radiation energy is 0.94 kWh / m^2 for January and 5.65 kWh / m^2 for July.

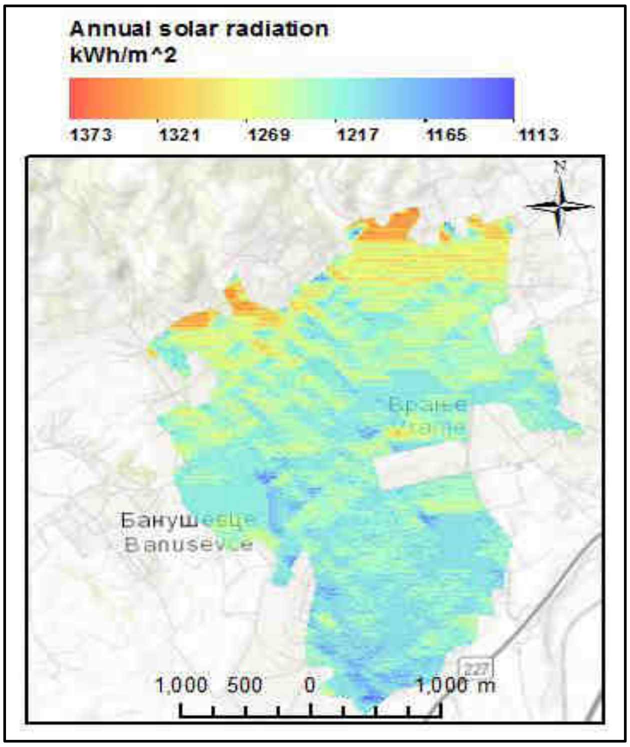

Figure 11: The annual map of the solar radiation energy/insolation.

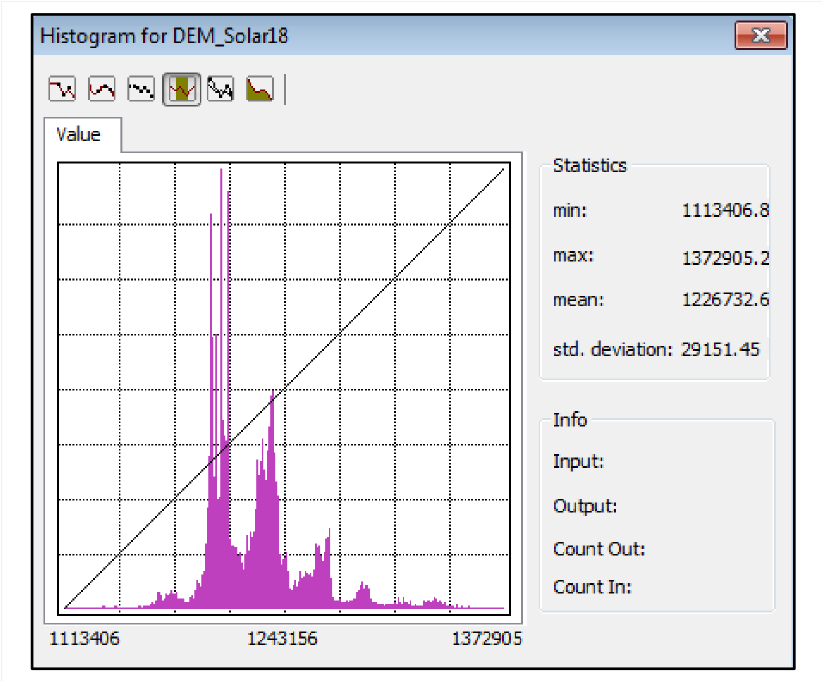

Figure 12: Histogram of the annual solar radiation energy/insolation.

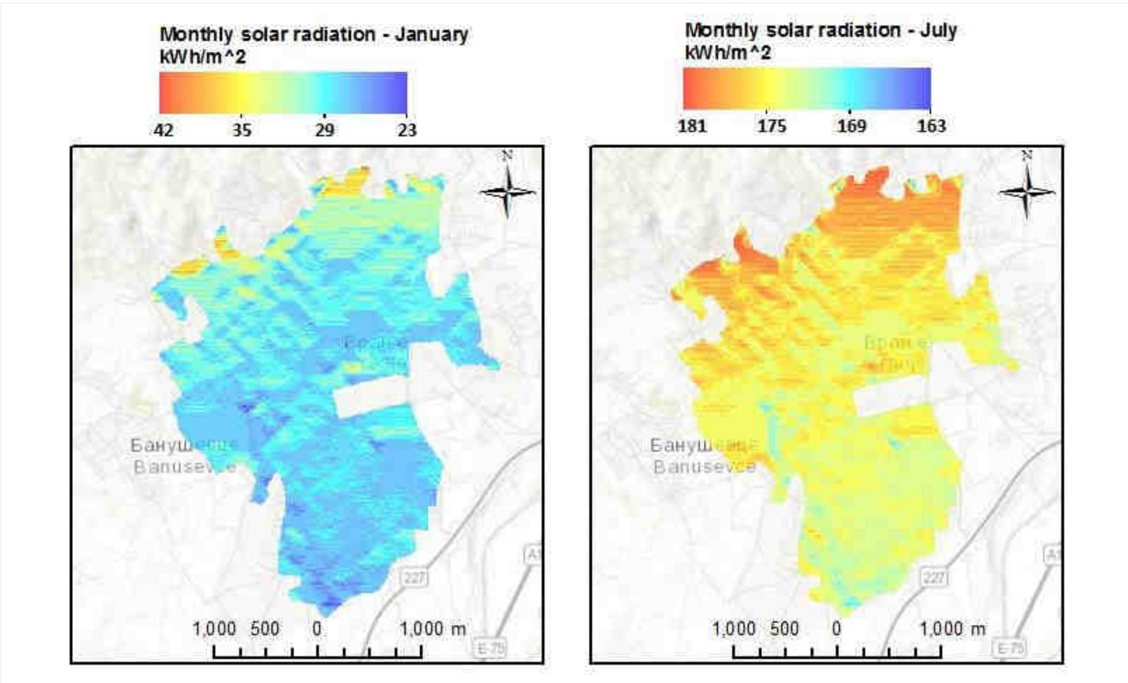

Figure 13: The monthly map of the solar radiation energy/insolation for January (left) and July (right).

The obtained results of the solar radiation energy are one of the most important parameters for estimating electricity production from PV panels. In practice, the output of the PV electricity production is often estimated for the reason that the exact value of the output electricity depends on a large number of factors (type of PV cells, temperature of PV cells, effect of dust on PV cells, losses in the inverter, etc.). For the purpose of the estimation of the annual electricity production generated from a PV system, the equation retrieved from the website of United States Environmental Protection Agency (US EPA) is used:

$$E = A * r * H * PR \quad (11)$$

in which:

E = Energy (kWh);
A = Total solar panel Area (m^2);

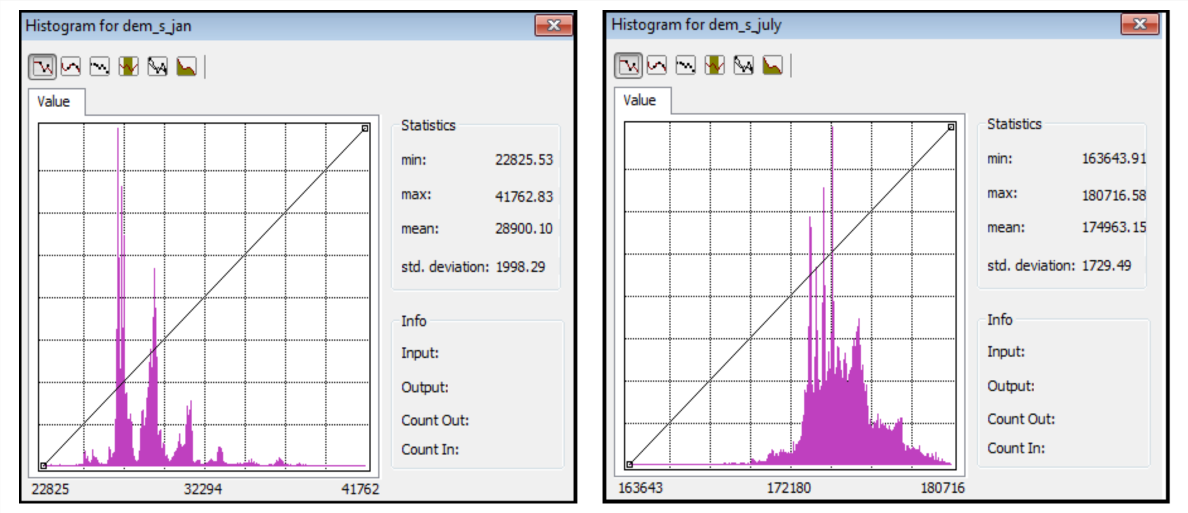

Figure 14: Histogram of the monthly solar radiation energy/insolation for January (left) and July (right).

r = Solar panel efficiency (%);
H = Annual average solar radiation on tilted panels (shadings not included);
PR = Performance ratio, coefficient for losses (range between 0.5 and 0.9).

The factors for this equation were determined in consultation with experts at the National Renewable Energy Laboratory (NREL) based upon conservative best estimates and utilization of NREL's Annual Technology Baseline (ATB) tool and PVWatts Calculator (US EPA, 2019). Based on these resources, NREL recommends these factors (US EPA, 2019):

r = 15% solar panel efficiency of PV module, and
PR = 86% performance ratio.

Accepting the recommended values for “r” and “PR”, and assuming that the solar panel area is 1 m^2, the energy output from PV cells is:

$E = 1 * 15\% * 1373 \text{ kWh/m}^2 * 86\% = 177.12 \text{ kWh}$ (12)

As it can be seen from the proposed calculation above, the estimated annual electricity output would be 177.12 kWh for the installed panel area of 1 m^2.

7. Conclusions

Nowadays, there are many advanced software tools for the calculation of solar energy potential. In this work, it is proposed a methodology that combines ArcGIS software tool Area Solar Radiation (ASR) and the CORINE Land Cover (CLC) inventory for the identification of urban areas.

The advantage of this methodology is that it can give a quick estimation of solar energy potential for a specific space which there is no data about.

The results obtained from the ASR tool can be compared with the cited data in this work, which is based on the available literature. According to the ASR calculation, the maximum energy that can be annually expected on a certain location in the urban area of Vranje is 1,373 kWh / m^2, and according to aforementioned literature source (8), the estimated energy of solar radiation is around 1,550 kWh/m^2 for the southeast part of Serbia.

Also, comparing the results for the average daily solar energy in July to the map given in the introduction (15), it is noticeable that results obtained with the ASR (5.65 kWh / m^2 / day) for the analyzed space, are lower than the average daily solar energy for the south of Serbia (6.9 kWh / m^2 / day), based on the cited study in the introduction section.

In the end, it can be concluded that the proposed methodology for the determination of the solar radiation can be a good basis or a starting point for further technical and economic evaluations of the cost-effectiveness of using solar panels to generate electricity or for heating.

In this respect, the practical application of this methodology may be found in the initial part of one comprehensive feasibility study. A more detailed analysis would certainly include direct measurements of solar irradiation/insolation in the area, cost estimation, return on investment, analysis of land use and other factors affecting the use of renewable energy sources, i.e. solar radiation energy.

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The RES AUCTIONS in Greece 2016-2019 - Results and Perspectives

Dr. Dionysios PAPACHRISTOU*[1], Electrical Engineer, Scientific Expert, Coordinator of RES Auction Team, Director of Press & Public Relations Office

Mrs. Alexandra GOURZI[1], Head of Unit Legal Advisors

Mr. Apostolos GIZAS[1], Scientific Expert, Head of Units RES Development & Energy Storage Policy, Electricity Networks & Smart Grids Technologies

Mr. Ilias DOULOS[1], Dipl. Mechanical & Aeronautical Engineer, M.Sc., Markets and Competition Monitoring

Mr. Panagiotis DALIOURIS[1], Automation Engineer, Member of RES Auction Team

Panagiota KAPETANA[1], Electrical Engineer, Member of RES Auction Team

Mr. Aggelos CHANTZIGIANNIS[1], Electrical Engineer, Member of RES Auction Team

Mrs. Chrysoula RIGA[1], Dipl. Applied Mathematics and Physical Sciences, MBA

Mrs. Efstathia KOUTSOPOULOU[1], Lawyer, Member of RES Auction Team

Mrs. Eleftheria PALLA[1], Lawyer, Member of RES Auction Team

Mrs. Aggeliki PANAGIOTAKOPOULOU[1], Lawyer, Member of RES Auction Team

Mr. Thanassis PETMEZAS[2], CEO

[1]Regulatory Authority for Energy,

[2]cosmoONE Hellas Marketsite S.A., 26 Olympias Str, GR-141 22 Attika

** Contact details of corresponding author*
Tel.: +30 210 3727409
Fax: +30 210 3464407
e-mail: papachristou@rae.gr
Address: [1]Regulatory Authority for Energy, 132, Pireos Str., GR-11854, Athens, Greece

Abstract

In line with the "Guidelines on State aid for environmental protection and energy (2014-2020)" (2014/C 200/01), Greece run a pilot tender in 2016 for a 5% of the total Renewable Energy Sources' (RES) capacity which was to be installed within the period 2015-2016. This first PV pilot tender laid the foundation for a generalized tender scheme for all RES technologies that followed. According to Ministerial Decision 04/2018 (Official Government Gazette B'1466 / 27.04.2018) a cumulative capacity of 2.600MW will be auctioned in Greece for wind and Photovoltaic (PV) power plants during the period 2018 to 2020, in order to achieve the RES deployment and CO_2 reduction targets of the country for the next decade, through the increase of the competition and the reduction of the cost of renewable energy for the consumers in accordance to the European Guideline. The first step made within this new regulatory framework for RES development was the design and implementation by the Regulatory Authority for Energy of the first competitive auction for new wind and PV projects from the entire territory of Greece, for a maximum power of 300 MW for each of these technologies. The auctions were carried out successfully on July 2018 (278 MW is awarded) and on December 2018 (221 MW is awarded). The first technology neutral auction for 600 MW was conducted on April 2019 and was offered for large wind (above 50MW) projects and large PV projects (above 20 MW). The final auction of 2019 was conducted in July, for PV projects (143MW is awarded) and wind projects (179MW is awarded). This paper provides a detailed analysis of the procedure and results of the all eleven (11) RES auctions with a tender total capacity of almost 1.3GW, which took place in Greece from 2016 to 2019. The results presented in this paper show that a significant reduction in prices is achieved and that a new era in the RES sector has begun. The EU Court of Auditors presents the RES Auction in Greece held by Greek Regulatory Authority for Energy (RAE) as best practice.

Keywords: Photovoltaic, PV Market, RES Tenders.

1. New Support Scheme for RES – From Pilot to Permanent RES Auctions

In accordance with the Greek legal framework and specifically Law 4414/2016 "*New support scheme for Renewable Energy Sources (RES) power plants and high efficiency combined heat and power plants. - Provisions on the legal and functional separation of the supply and distribution branches in the natural gas market and other provisions*" (referred as "Law" hereafter), Greece implemented a new RES support mechanism, in compliance with the Guidelines on State aid for environmental protection and energy (2014-2020) (European Commission, 2014).

One of the main purposes of the Law was the development of an adequate support scheme for power generation from RES in the context of a common European Member States' policy on fighting climate change, reducing greenhouse gas emissions and achieving the target of RES participation in gross final energy consumption. Feed in Tariff (FiT) is replaced by Sliding Feed-in-Premium scheme and Competitive Tenders that can be technology-specific, neutral or regional, hence Producers will have to return their excess income to the system if market price exceeds Reference Price. In this legislation framework, specific provisions took place for the planning, organization and execution of a pilot tender. The legislation stated that "*RAE shall be responsible for carrying out competitive bidding processes and certifying their results*".

Technology based tenders are at first considered for Greece, because PV projects are more cost competitive than wind power plants. This policy was subjected to the permission of the EU, and in January 2018 Directorate-General for Competition (DG Comp) approved the National scheme for the permanent auction procedures (SA. 48143[22]). RAE decided to perform also neutral competitive auctions, but only for large photovoltaics (PV stations > 20 MW) and wind stations (Wind stations > 50 MW), to analyze the results of the competition between the two technologies.

The proposed specific terms and conditions of the technology specific auctions were announced in an open workshop day organized on the 24th of January 2018 in Athens by RAE for all stakeholders (Figure 1), followed by a broad public consultation procedure, which was completed at the end of March 2018.

Taking into consideration all the comments of the broad public consultation procedure for the auctions and the opinions expressed during the workshop, RAE issued by decision of the Board (RAE Decision 321/2018 – Government Gazette B' 1466/27.04.2018) the terms and conditions for participation and described the process (RAE's call for tender) and conducted the first permanent competitive auction.

Additional workshops were organized during the submission of applications period, in Thessaloniki (8th of May), in Athens (10th of May) and in Ioannina (15th of May, 2018), in order to make completely clear the obligations of the applicants and the required documents for a complete and successful application: all with participations that exceeded all expectations (Figures 2 and 3).

Figure 1: Workshop in Athens, January 2018

•Public Consultation – Athens, 24th of January	•Workshop – Thessaloniki, 8th of May
•Workshop/Training – Athens 10th of May	•Workshop – Ioannina 15th of May
•Virtual Auctions Training – 28-29th of June	•Workshop – Athens 10.02.2019

Figure 2: Workshops.

[22] http://europa.eu/rapid/press-release_IP-18-5461_en.htm

Figure 3: Snapshots from workshops in various cities.

A two day preparatory event prior to the auctions was held with continuous virtual actions and helpdesk support for the better familiarization of the participants.

2. Conduct of the Competitive Bidding Process

2.1 Procedure

2.1.a The Pilot Tender

RAE was obliged, according to the "Law", to conduct a pilot tender on photovoltaic power plants within the year 2016. This was also used as an opportunity for collecting information that would facilitate the introduction of a generalized tendering scheme for all RES technologies that were to take place in the following years.

According to the "Law", Article 7, paragraph 9, the pilot tender on photovoltaic plants should have the following main characteristics:

- the tendered capacity should be at least 40 MW,
- the PV-Plants should be divided into two Categories, according to the installed capacity of each installation (Category I for PV-Plants ≤ 1MW and Category II for PV-Plants > 1MW), whereas the tendered capacity of Category I could not exceed 20% of the overall auctioned power.

The maximum allowed bidding price in accordance to the legislation was set at 104 €/MWh for Category I and 94 €/MWh for Category II. In compliance to the main legislative guidelines, two competitive bidding processes took place online on the 12th of December 2016, in cooperation with a Greek company specialized in B2B online auctions. Instead of the traditional competition procedure (submission of heavy hard copy application files and an unnecessary load of paperwork), the online application procedure allowed the participants to upload all the necessary technical and legal documents that had to be sent for participation in the tender, minimizing workload and simplifying the procedures in whole, with both, participants and RAE benefiting from this simplicity.

A **rule of a minimum level of competition equal to 40%** was decided by RAE, ensuring competition between participants in each category. This rule determined that the capacity of each category sum must be equal or exceed 140% of the auctioned capacity.

A rule, for the letter of guarantee at the level of 1% of the total investment cost per project was imposed to all the participants in order to participate in the auction procedure. In addition, after the success in each category, each participant had the obligation to cover **a rule of "4% guarantee of proper performance".** This means that each participant must submit to RAE an additional letter of guarantee, only if the sum of all letters of guarantee which were submitted to all the operators (Grid or System operator) does not equal or exceeds the amount defined by the **4% rule** of the total investment cost for each project.

For Category I, the auctioned capacity must be commissioned within 18 months and for Category B within 24 months (art.7 par. 9e, Law 4414/2016). Auctioned capacity and participation terms for the 1st Pilot Auction are presented in Table 1.

2.1.b First Cycle Auction, Technology Specific, July 2018.

The preparation steps of the first regular tenders were carefully designed, based on the experience gained from the implementation of the first pilot tender for 40 MW PV plants in 2016. The auctions following, concern mature projects with completed licensing procedure and with final connection/binding offer. In July 2018, according to 321/2018 RAE's decision, the first technology specific auction cycle was conducted.

This was the first auction for wind plants and consisted of three (3) categories with the following characteristics:

1. Category I for PV-Plants ≤ 1MW

Table 1: Auctioned capacity and participation terms for the 1st Pilot Auction, Technology Specific, December 2016

1st Pilot Auction, Technology Specific, December 2016		
	Category I PV – Plants PPV ≤ 1 MW	Category II PV – Plants PPV > 1 MW
Auctioned Capacity (max)(MW)	5	35
Fee for participation (€)	500	500
Ceiling Price (€/MWh)	104	94
Level of competition	40%	40%
Letter of Guarantee for participation in the auction	1%	1%
Letter of Guarantee for proper performance	4%	4%
Timetable for Connection (months)	18 months	24 months

2. Category II for PV-Plants between 1MW and 20 MW

3. Category III for Wind-Plants between 3MW and 50MW.

The maximum tendered total capacity for the two categories of PV-Plants was 300MW equal to the total tendered capacity of Category III for Wind-Plants whereas the ceiling (starting) price was set at 85 €/MWh for Category I, 80 €/MWh for Category II and 90 €/MWh for Category III. The whole procedure by using the electronic Registration & Auction Platform was innovative, fully transparent, simplified and reliable.

The level of competition follows the **75% rule of a minimum level of competition** instead of the 40% rule imposed by RAE for the pilot tender**.** This means that a minimum competition threshold was set, in order to secure conditions for healthy and effective competition. For this competitive procedure, the deadlines for commissioning the auctioned capacity were set as follows:

- For Category I, 12 months after the announcement of tender results
- For Category II, the deadline for PV-Plants 1 MW < P_{PV} ≤ 5 MW is set at 15 months and for PV-Plants >5MW is set at 18 months. Moreover, 6 months are added if PV-Plant is connected to the Transmission System via a substation.
- For Category III, the deadline for Wind-Plants 3 MW < P_{WIND} ≤ 10 MW is set at 24 months and for Wind-Plants >10MW is set at 36 months. Moreover, 6 months are added if Wind-Plant is connected to the Transmission System via a substation.

Aligned with RAE's decision 321/2018, all other requirements remain the same as imposed in the pilot tender. Table 2 shows the main characteristics of the July's 2018 auctions.

2.1. c Second Cycle Auction, Technology Specific, December 2018.

In accordance with RAE's decision 1230/2018, three (3) more auctions took place in December 2018. More specifically, two (2) auctions for PV-Plants (Category I for PV Plants≤ 1MW and Category II for PV-Plants 1MW < P_{PV} ≤ 20 MW) and one (1) auction for wind projects (Category III for Wind-Plants 3MW < P_{Wind} ≤ 50 MW). The ceiling prices for PV-Plants categories were set at 81,71 €/MWh and 71,91 €/MWh respectively. For Wind-Plants, Category III, the ceiling price was set by RAE at 79,77 €/MWh considering the worldwide prices trend and also the financing conditions in Greece (Table 3).

2.1.d First Cycle Technology Neutral Auction, April 2019

The first technology neutral auction took place in Greece in April 2019 for a total of 600MW which was offered for large wind (above 50MW) and large PV projects (above 20 MW).

The auctioned capacity of 600MW is the sum of the entire capacity offered in 2018, since no neutral auction was conducted in that year, and half of the capacity offered in 2019 according to Ministerial Decision ΑΠΕΕΚ/Α/Φ1/ οικ. 180215/15.10.2018 (Government Gazette B' 4528/17.10.2018).

Technological neutrality in principal means that all renewable technologies compete on an equal footing and the most competitive technologies are awarded a support entitlement[23]. The ceiling price was set at 64,72 €/MWh and the competition rate at 40% (Table 4).

2.1.e 2nd Cycle Technology Specific Auction, July 2019

The last competitive procedure for 2019 was conducted by RAE in July 2019 in alignment to 441/2019 RAE's Decision. The Regulator calls for bids in the tender scheme for solar PV with an installed capacity of less than 20 MW and for wind plants with an installed capacity of less than 50MW. As it is shown in Table 5, the ceiling price for PV plants was set at 69,26 €/MWh and for wind plants at 69,18 €/MWh. The **40% rule of a minimum level of competition** was imposed.

2.2 Electronic Platform

A specific electronic platform was developed in order to serve all procedures of the pilot tender. The algorithm was also custom developed for the electronic auctions which took place. Important steps were added in the platform's algorithm for improvement and innovation of the whole process, as well as for the proper implementation of the procedural part of the competition, i.e. posting, processing, submission, evaluation, and local storage of supporting documents via an online platform.

In this way, the applications of the interested parties, as well as the supporting legal and technical documents, were submitted online. Each company had to create a unique profile through which all necessary files could be uploaded. Then, RAE evaluated all applications and the projects, which passed successfully through phase A (administrative check), had the opportunity to participate in the competitive tendering procedure (phase B) using this specific electronic platform. The pattern used for the execution of the process is shown in Figure 4.

Available on line user guides included all the important steps via visual examples for registering in the platform, applying and taking part in the tenders. In addition, all participants were called upon training through dry runs in order to make them acquainted with the platform hosting the tenders.

In this way, an innovative auction, which was never used before in the field of RES plants, became accessible and understandable to all participants, independent of the profile of the company - varying from full Societe Anonyme (S.A.)(Public Limited Company – PLC) to individuals.

2.3 Online Auctions

The final tenders took place online on the same electronic platform with an absolute success for participants, RAE and end-consumers.

Table 2: Auctioned capacity and participation terms for the 1st Cycle Auction, Technology Specific, July 2018.

1st Cycle Auction, Technology Specific, July 2018			
	Category I PV – Plants PPV ≤ 1 MW	Category II PV – Plants 1MW < PPV ≤ 20 MW	Category III Wind – Plants 3MW < PPV ≤ 50MW
Auctioned Capacity (max)(MW)	70	230	300
Fee for participation (€)	500	1000	1000
Ceiling Price (€/MWh)	85	80	90
Level of competition	75%	75%	75%
Letter of Guarantee for participation in the auction	1%	1%	1%
Letter of Guarantee for proper performance	4%	4%	4%
Timetable for Connection (months)	12 months	a. 15 months- 1MW < PPV ≤ 5MW b. 18 months - PPV>5MW c. 6 months added if connected to the Transmission System via a substation	a. 24 months- 3MW < PWIND ≤ 10MW b. 36 months -PWIND >10MW c. 6 months added if connected to the Transmission System via a substation

[23] https://www.ceer.eu/documents/104400/-/-/167af87c-5472-230b-4a19-f68042d58ea8

Table 3: Auctioned capacity and participation terms for the 2nd Cycle Auction, Technology Specific, December 2018.

2nd CycleAuction, Technology Specific, December 2018			
	Category I PV – Plants PPV ≤ 1 MW	Category II PV – Plants 1MW < PPV ≤ 20 MW	Category III Wind – Plants 3MW < PPV ≤ 50MW
Auctioned Capacity (max)(MW)	90	100	229
Fee for participation (€)	500	1000	1000
Ceiling Price (€/MWh)	81,71	71,91	79,77
Level of competition	75%	75%	75%
Letter of Guarantee for participation in the auction	1%	1%	1%
Letter of Guarantee for proper performance	4%	4%	4%
Timetable for Connection (months)	12 months	a. 15 months- b. 1MW < PPV ≤ 5MW c. 18 months - PPV>5MW d. 6 months added if connected to the Transmission System via a substation	d. 24 months- 3MW < PWIND ≤ 10MW e. 36 months -PWIND >10MW c. 6 months added if connected to the Transmission System via a substation

Table 4: Auctioned capacity and participation terms for the 1st Cycle Neutral Auction, April 2019.

1st Cycle Technology Neutral Auction, April 2019	
	Technology Neutral
Auctioned Capacity (max)(MW)	600
Fee for participation (€)	5000
Ceiling Price (€/MWh)	81,71
Level of competition	40%
Letter of Guarantee for participation in the auction	1%
Letter of Guarantee for proper performance	4%
Timetable for Connection (months)	36 months PPV > 20 MW 36 months PWIND > 50 MW 36 months for each technologyin wind and solar energy facilities. 6 months added in case a new substation construction is needed 12 months added in case an ultra high voltage center construction is needed.

Table 5: Auctioned capacity and participation terms for the 2nd Cycle Auction, Technology Specific, July 2019

2nd Cycle Auction, Technology Specific, July 2019		
	Category I PV – Plants, 1MW < PPV ≤ 20 MW	Category II Wind – Plants, PWind ≤ 50MW
Auctioned Capacity (max)(MW)	300	300
Fee for participation (€)	500	1000
Ceiling Price (€/MWh)	69,26	69,18
Level of competition	40%	40%
Letter of Guarantee for participation in the auction	1%	1%
Letter of Guarantee for proper performance	4%	4%
Timetable for Connection (months)	a. 12 months- PPV ≤ 1MW b. 15 months – 1MW <PPV ≤ 5MW c. 6 months added if connected to the Transmission System via a substation	a. 24 months-PWIND ≤ 10MW b. 36 months -PWIND >10MW c. 6 months added if connected to the Transmission System via a substation

The used auctions were a variation of the Yankee auction type. The basic "RULE" of this auction was that: all accepted bids are registered in ascending order with criterion the submitted price. In case of equal prices, the bid which relates to the smaller quantity of PV prevails. In case of bids with equal price and quantity, the bid that was submitted earlier prevails. In that way, it is never possible to have in the system two totally equal bids. The allocation of the financial aid starts from top to bottom, till it exceeds the available PV quantity. The algorithm followed during these procedures is shown in Figure 5. It consists of the following steps:

1. Auction set up: It includes all actions that need to be done, in order to set up the YANKEE auction type, according to the specific requirements of RAE pilot tenders.
2. Set up of bidders' info: The auction Service provider (cosmoONE) as administrator of the platform, "invites" in the system the eligible bidders by constructing a list of companies that can have access to the specific auction. Companies that are not invited have neither access to the auction nor information that the specific auction exists and takes place.
3. Set up of PV capacities and related info: The auction Service provider inputs the initial values of the installed PV capacity per participating company/user in the auction, the total available capacity, the opening value per Unit of measurement and the bid increment.
4. Set up of Time and date related info: The auction Service provider inputs the date and time of the auction opening, the auction duration, the provision of time extensions, the rule, duration and number of extensions, etc. There were no extensions in the case of the pilot tender, as decided by RAE.
5. Auction Opens: The auction opens and the time clock starts counting down the time. Any bidder can submit its bid as long as the auction is still open.
6. Based on the market situation, bids can be submitted or not.
7. If no bid is submitted till the time of auction closing, the auction closes with no bids (path 5-6-9-6-9-….-30).
8. If a bid is submitted, there is the first control point and the system checks if the auction is still open. In case that the duration (either the initial planned or with time extensions) of the auction has passed, the bid is rejected, the auction changes status to 'close' and no more bids are accepted (path 5-6-7-8-30).
9. The auction results are automatically generated at closing time. The system produces an analytical list of all bids from all bidders with their outcome (accepted, quantity, value, rejected, reason for rejection etc.) and the winners' list that indicates the final allocated quantities and the respected values on the measure of unit (path 30-31).
10. If a bid is submitted and the auction is still open, there is the second control point. The system checks the value (per unit of measure) against the opening price (path 6-7-10).
11. In case that the submitted value is greater than the opening price, the bid is rejected and the system allows the bidder to improve its bid (path 10-13-20).
12. If the submitted value is equal or less than the opening price, the system performs the third check about the quantity that is linked with the specific bidder, against the available (not already temporary allocated) quantity. If the available quantity is equal or greater than the requested one, the system grands the bid and temporary allocates this quantity to the bidder (path 10-11-14).
13. If the available quantity is less than the requested, the system makes a comparison of the bid against the existing bids that have already allocated quantity. In case that the bid is "better" that the existing accepted bids according to the "RULE", the system grabs the quantity from one or more bidders with the lowest current ranking and temporary allocates the quantity to the specific bidder (path 10-11-12-14). Bidders who lose their quantity are immediately notified by the system. If the bid is "worse" that the existing accepted bids, according to the "RULE", the bid is not granting quantity to the bidder, it is registered in the system, and the system allows the bidder to improve its bid (path 10-11-12-13).
14. Check for time extensions: Whenever a bid is accepted, the system checks if the bid has been submitted within the time window, where the time extensions can be activated. In case that the submission time is within this period, the system grands a time extension (path 14-15-16).

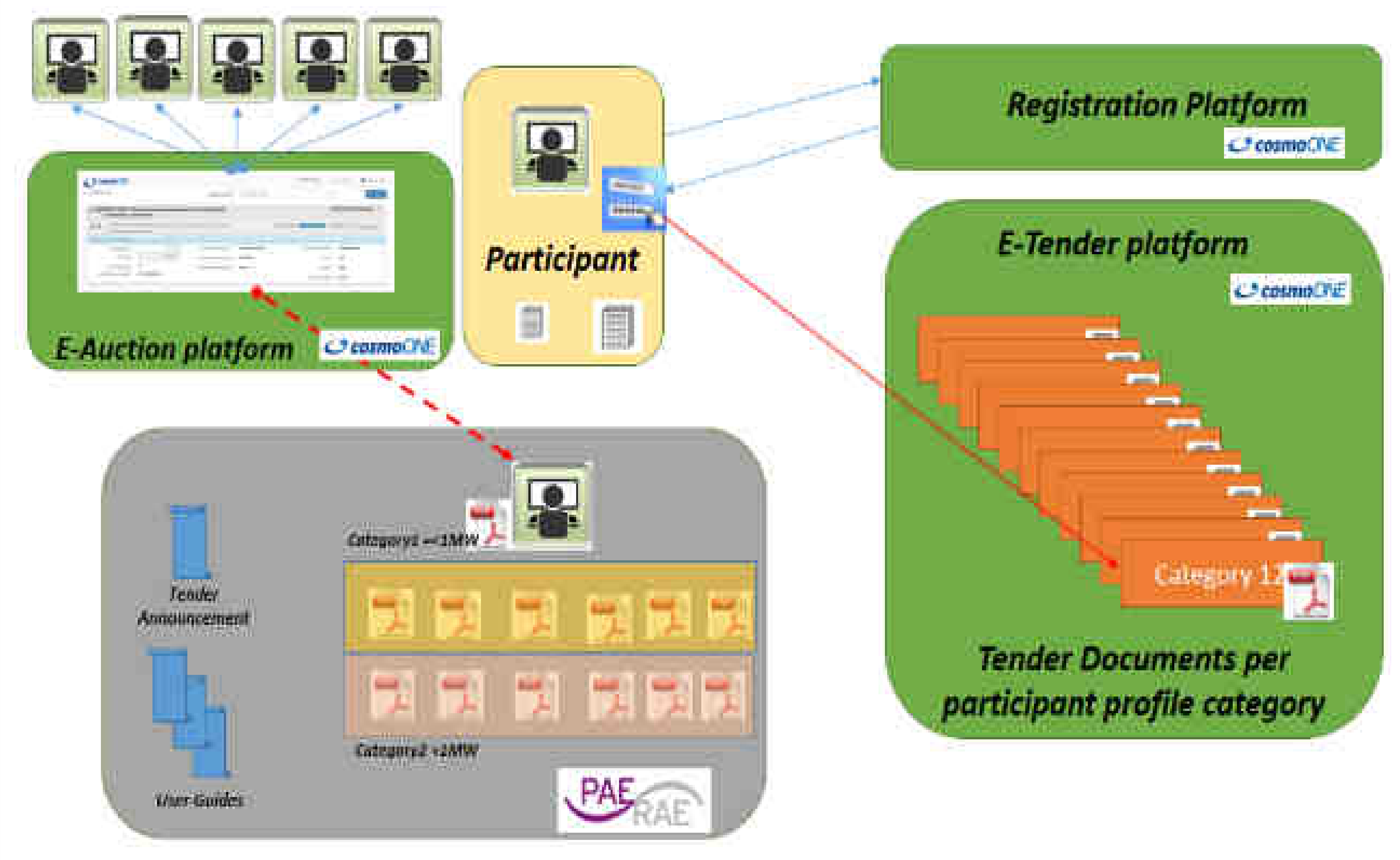

Figure 4: The procedure of the participants' registration and application onto the online platform.

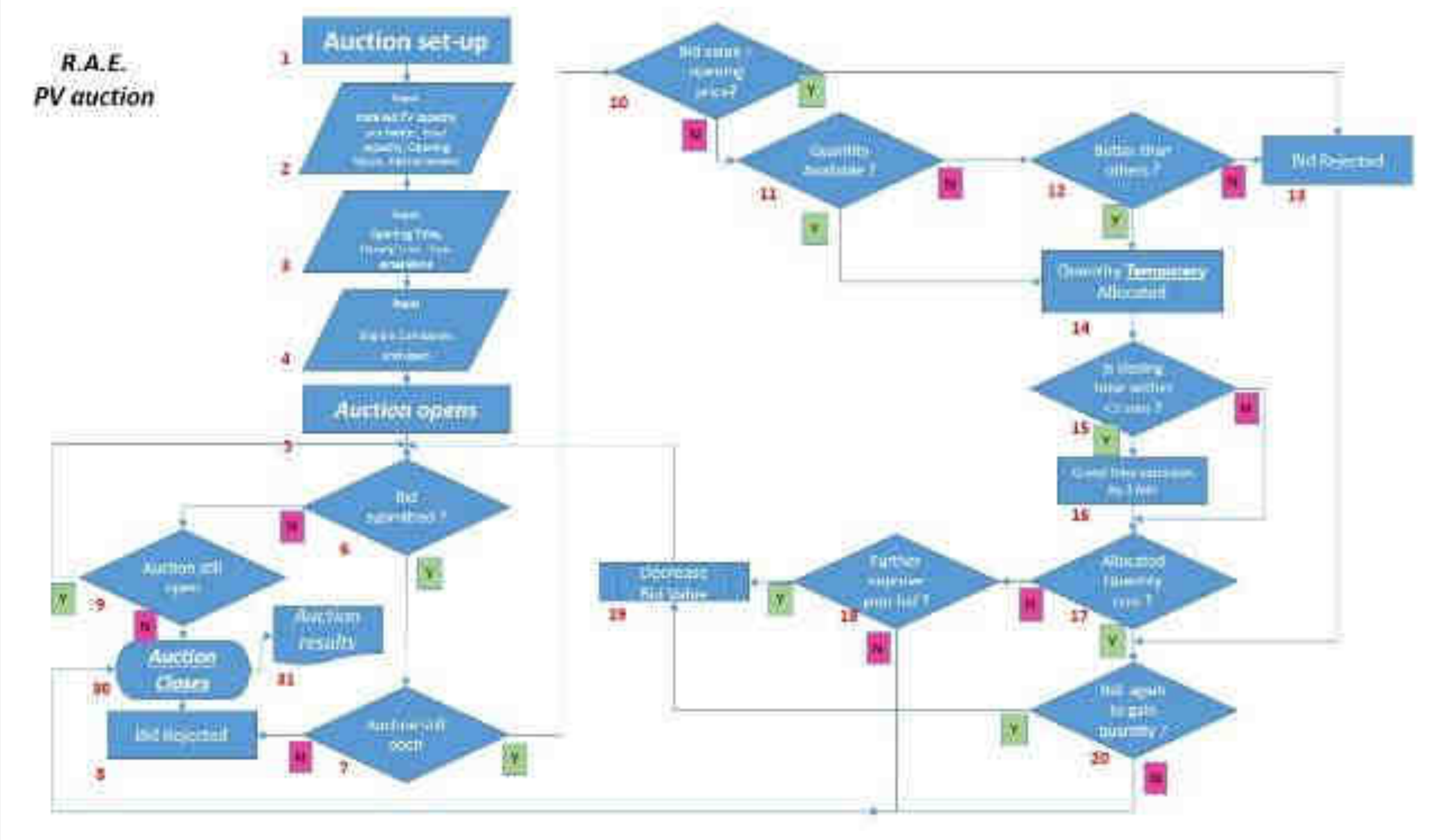

Figure 5: The algorithm for the Yankee type of auctions conducted by RAE

15. (Temporarily) allocated quantity is lost: During the auction, every bidder can lose its quantity due to the submission of a better bid by another bidder. This is indicated in screen and the bidder has the right to bid again to regain the quantity.

16. Allocated quantity is lost and the bidder does not want to improve its bid and bids again. The bidder does not submit any further bids and waits till the auction closes, as he/she can still gain his/her quantity under certain conditions that derive from the "RULE" (path 17-20-30-31).

17. Quantity is lost and the bidder wants to improve its bid and bids again. The bidder improves the bid by decreasing the bid value and submits the bid again (path 17-20-19-6).

18. Quantity is not lost, but the bidder wants to improve its bid. If the bidder wants to strengthen his/her position in the auction and be in a better position against the other bidders according to the "RULE", he/she is eligible to submit a new bid. To do so, he/she must improve the bid value and submit the bid (path 17-18-19-6).

3.Results and Conclusions

3.1 Results of the Pilot Tender

Beginning with the pilot tender, the participants in the first Category I (≤ 1 MW) were fourteen (14) and the photovoltaic power plants that successfully achieved a price in the tender were nine (9). The weighted average price of the successful bids was 98,78 €/MWh. Under the second Category II (> 1 MW), fourteen (14) participants applied and seven (7) acquired a price; the weighted average price of the successful bids was 83,3 €/MWh (Table 6). Participants were informed in every step whether their bid was valid or had to make a new price offer. At the end, there was a decrease of the starting price by about 15%, (important outcome for end-consumers whose benefit was one of RAE's primary goals).

The thirty (30) minute processes were observed in real time by the committee of RAE specially called upon the evaluation of the applications and the completion of tenders. In each auction of the pilot tender, a different bidding pattern was observed. More specifically, during the Category I auction, in the total sum of 35 bids the minimum bidding price was 94,97 €/MWh and the maximum one was 104 €/MWh (Figure 6), as indicated by Law 4414/2016. For Category II, in the total sum of 446 bids, the minimum bidding price was 79,97 €/MWh and the maximum one was 88 €/MWh (Figure 7).

After the procedure is determined, participants are allowed to raise objections for the results. Since the procedure was objective, described in great detail at the tender invitation, also conducted by RAE, and clarified through the dry runs and the users' guides available to all participants, there were no objections which were not clarified by the publication of RAE's decision on the final results, which was accepted by RAE's Board.

3.2 Results of the 1st Cycle Auction, Technology Specific, July 2018

In July 2018, all the competitive procedures took place on the same date, 02.07.2018. As shown in Table 8, in PV Plants Category I (≤ 1MW) of the procedures, the applied capacity was 105,54 MW over one hundred seventy seven (177) submitted applications. After imposing the 75% rule of minimum competition, the final auctioned capacity was 53,52 MW. The awarded capacity covered almost the 100% of the offered capacity. The minimum price was 75,87 €/MWh and the maximum one 80 €/MWh. The weighted average price of the successful bids was 78,42 €/MWh. The ceiling price was set at 85 €/MWh and a reduction of 7,74% was calculated.

During the auction, 1527 bids were made and it took 1' and 30'' for the lowest price to drop from 79 €/MWh to 76 €/MWh (Figure 8).

In Category II (1MW < PPV ≤ 20 MW) thirty-four (34) applications were submitted with corresponding PV-Plants of 197,21 MW in total. The final auctioned capacity was 53,4 MW and the total capacity awarded was 52,92 MW, this means that the awarded projects covered 99,1% of the auctioned capacity. The maximum bidding price was 71 €/MWh and the lowest one 62,97 €/MWh (Table 9). The weighted average price of the successful bids was 63,81 €/MWh and the ceiling price was set at 80 €/MWh.

The last five (5) minutes, ninety four (94) bids were submitted and that is the 33, 6% of the total bids. This fact leads to a decrease of the starting price of about 20,24%. (Figure 9).

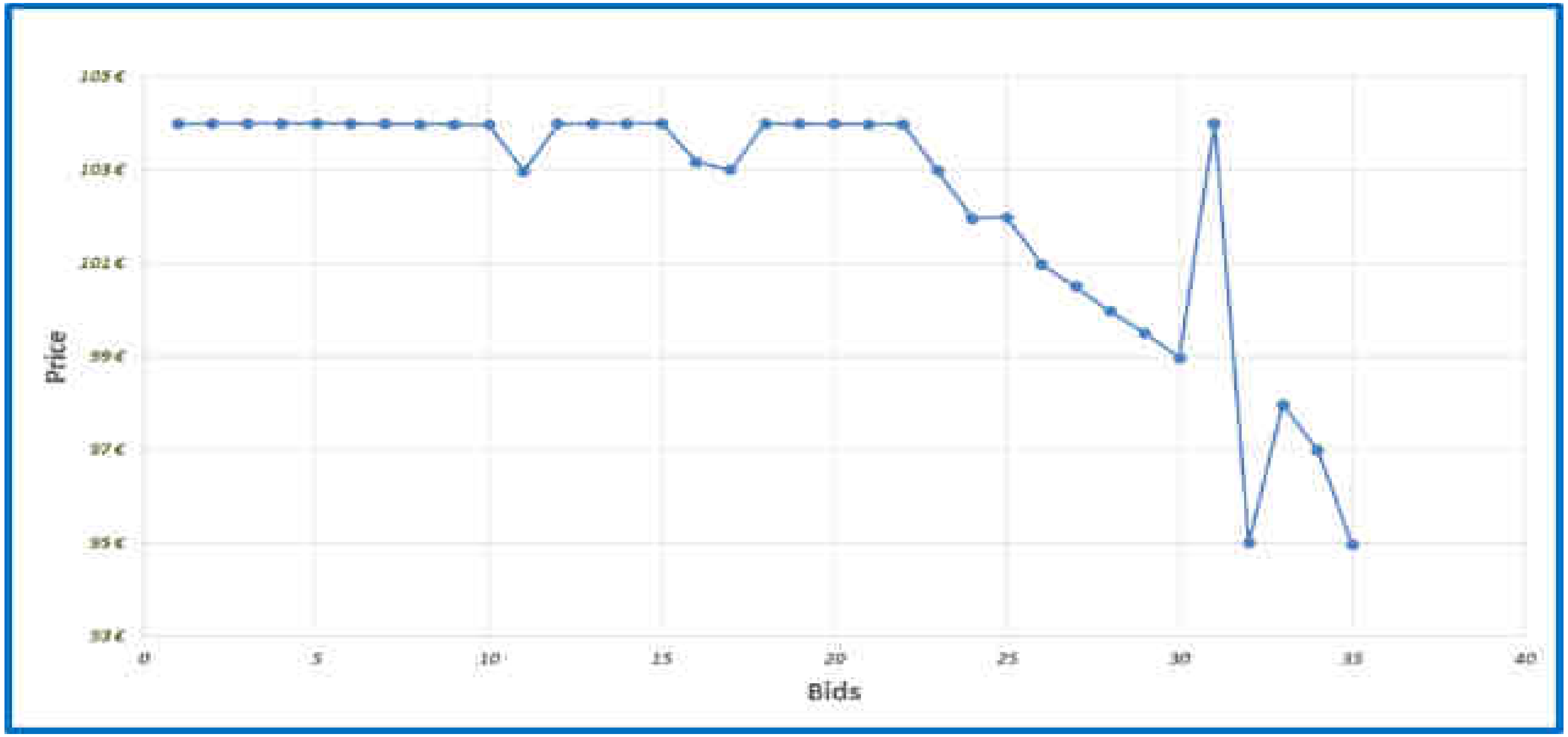

Figure 6: Timetable of the bids of the first pilot tender for Category I (installed capacity ≤ 1MW) July 2018.

Table 6: Table of Results for the 1st Pilot Auction, PV - Technology Specific, December 2016.

				Project Application (No/MW)						Auction				
Competitive Procedure	Category	Auctioned Capacity (max)(MW)	Final Auctioned Capacity (MW)	Applied		Approved		Granted		Bids	Ceiling price (€/MWh)	Highest Bid (€/MWh)	Lowest Bid (€/MWh)	Weighted Price (€/MWh)
1st Pilot Auction, PV – Technology Specific, December 2016	PV stations PPV ≤ 1MW	5	4,8	14	6,89	13	6,8	9	4,8	35	104	104	94,97	98,78
	PV Stations 1MW<PPV≤ 50MW	35	35,2	13	53,17	12	50,21	7	35,12	446	94	88	79,97	83,3

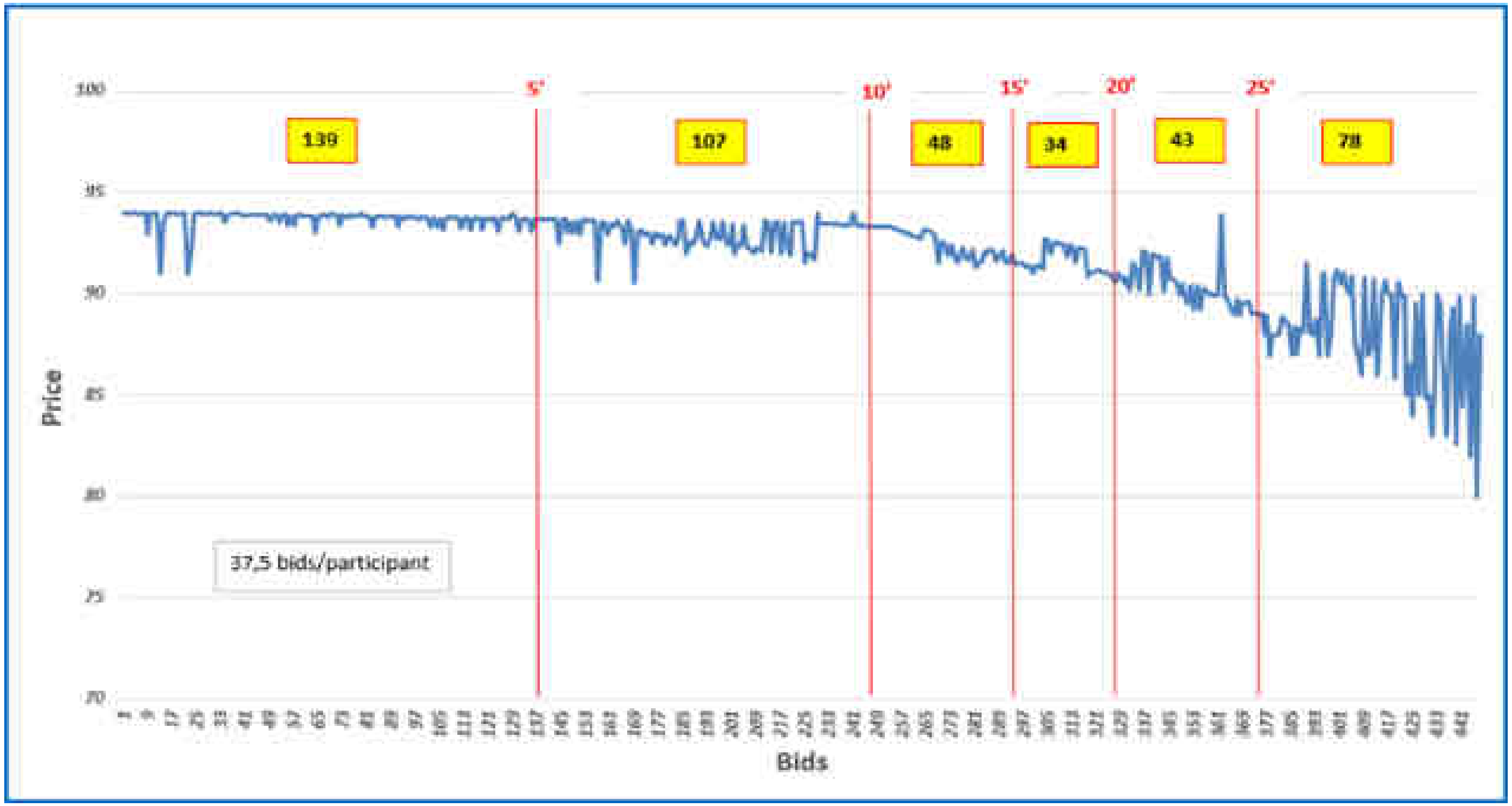

Figure 7: Timetable of the bids of the first pilot tender for Category II (installed capacity > 1MW).

Table 7: Table of Results for the 1st Cycle Auction, Technology Specific, Category I (PPV ≤ 1MW).

				Project Application (No/MW)						Auction				
Competitive Procedure	Category	Auctioned Capacity (max)(MW)	Final Auctioned Capacity (MW)	Applied		Approved		Granted		Bids	Ceiling price (€/MWh)	Highest Bid (€/MWh)	Lowest Bid (€/MWh)	Weighted Price (€/MWh)
1st Cycle Auction, Technology Specific, July 2018	PV stations PPV ≤ 1MW	70	53,52	177	105,54	155	94,07	83	53,48	1527	85	80	75,87	78,42

Table 8: Table of Results for the 1st Cycle Auction, Technology Specific, Category II (1MW < PPV ≤ 20 MW), July 2018.

				Project Application (No/MW)						Auction				
Competitive Procedure	Category	Auctioned Capacity (max)(MW)	Final Auctioned Capacity (MW)	Applied		Approved		Granted		Bids	Ceiling price (€/MWh)	Highest Bid (€/MWh)	Lowest Bid (€/MWh)	Weighted Price (€/MWh)
1st Cycle Auction, Technology Specific, July 2018	PV stations 1MW < PPV ≤ 20MW	230	53,4	34	197,21	13	93,44	8	52,92	280	80	71	62,97	63,81

Table 9: Table of Results for the 1st Cycle Auction, Technology Specific, Category III (3MW < PWind ≤ 50 MW), July 2018.

				Project Application (No/MW)						Auction				
Competitive Procedure	Category	Auctioned Capacity (max)(MW)	Final Auctioned Capacity (MW)	Applied		Approved		Granted		Bids	Ceiling price (€/MWh)	Highest Bid (€/MWh)	Lowest Bid (€/MWh)	Weighted Price (€/MWh)
1st Cycle Auction, Technology Specific, July 2018	Wind stations 3MW <PWind ≤ 1MW	300	176,39	14	308,68	14	308,68	7	170,93	336	90	71,93	68,18	69,53

Table 10: Table of Results for the 2nd Cycle Auction, Technology Specific, Category I (PPV ≤ 1MW), December 2018.

				Project Application (No/MW)						Auction				
Competitive Procedure	Category	Auctioned Capacity (max)(MW)	Final Auctioned Capacity (MW)	Applied		Approved		Granted		Bids	Ceiling price (€/MWh)	Highest Bid (€/MWh)	Lowest Bid (€/MWh)	Weighted Price (€/MWh)
2nd Cycle Auction, Technology Specific, December 2018	PV stations PPV ≤ 1MW	90	61,95	204	114,62	192	108,4	95	61,94	3907	81,71	68,99	63	66,66

Table 11: #bids of the December 2018 Auction for Category I (installed capacity PPV ≤ 1MW).

Category I, PPV ≤ 1MW	**December 2018**	**July 2018**
Total number of valid bids	3907	1527
Last 5 minutes number of bids	1221	483
Last minute number of bids	477	

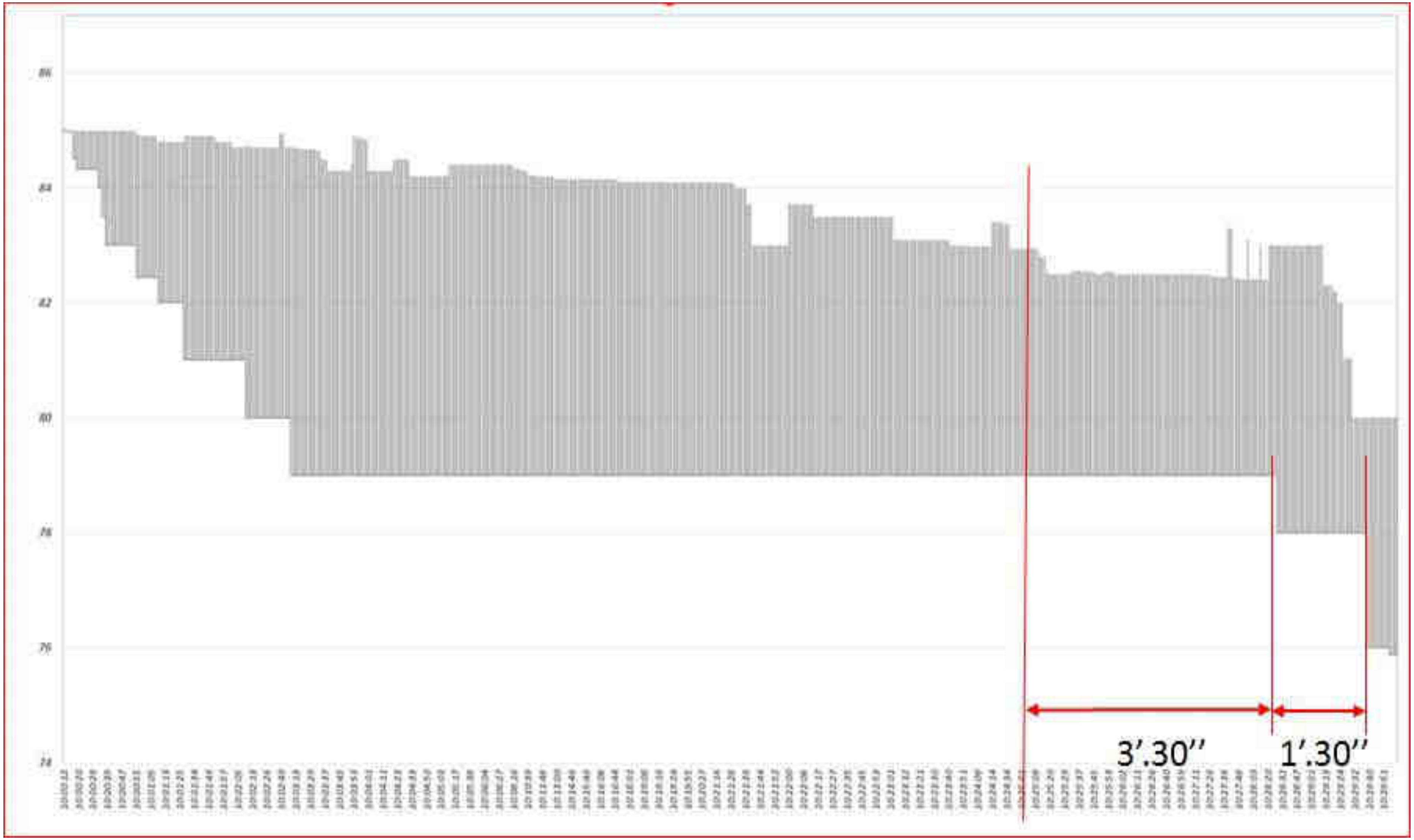

Figure 8: Evolution of highest and Lowest Price for Category I, PV ≤ 1MW.

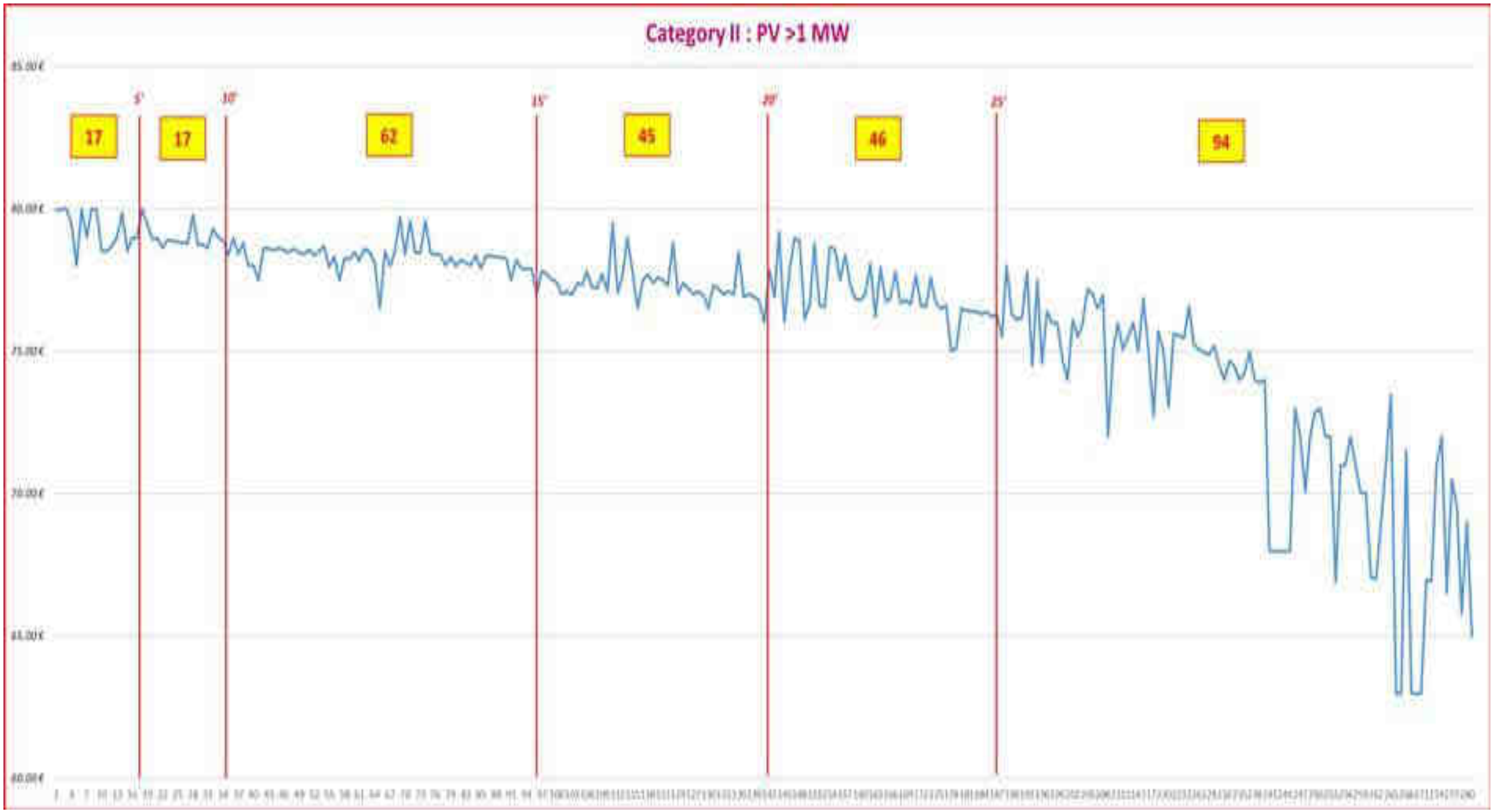

Figure 9: Timetable of the bids of the July 2018 Auction for Category II (installed capacity 1MW < PPV ≤ 20 MW).

Table 12: Table of Results for the 2nd Cycle Auction, Technology Specific, Category III (3MW < PWind ≤ 50 MW), December 2018.

				Project Application (No/MW)						Auction				
Competitive Procedure	Category	Auctioned Capacity (max)(MW)	Final Auctioned Capacity (MW)	Applied		Approved		Granted		Bids	Ceiling price (€/MWh)	Highest Bid (€/MWh)	Lowest Bid (€/MWh)	Weighted Price (€/MWh)
2nd Cycle Auction, Technology Specific, December 2018	Wind stations 3MW<PWind ≤ 50MW	229	160,94	14	281,65	14	281,65	8	159,65	362	79,77	65,37	55	58,58

Table 13: Table of Results for the 1st Cycle Auction, Technology Neutral, April 2019.

				Project Application (No/MW)						Auction				
Competitive Procedure	Category	Auctioned Capacity (max)(MW)	Final Auctioned Capacity (MW)	Applied		Approved		Granted		Bids	Ceiling price (€/MWh)	Highest Bid (€/MWh)	Lowest Bid (€/MWh)	Weighted Price (€/MWh)
1st Cycle Auction, Technology Specific, April 2019	Technology Neutral	600	455,56	8	637,78	8	637,78	7	437,78	56	64,72	64,72	53	57,03

Table 14: Table of Results for the 2nd Cycle Auction, Technology Specific, July 2019.

				Project Application (No/MW)						Auction				
Competitive Procedure	Category	Auctioned Capacity (max)(MW)	Final Auctioned Capacity (MW)	Applied		Approved		Granted		Bids	Ceiling price (€/MWh)	Highest Bid (€/MWh)	Lowest Bid (€/MWh)	Weighted Price (€/MWh)
2nd Cycle Auction, Technology Specific, July 2019	PV station PPV ≤ 20MW	300	143,04	68	200,26	68	200,26	24	142,88	275	69,26	67,7	61,95	62,77
	Wind Stations PWind ≤ 50MW	300	186,96	12	261,75	12	261,75	9	179,55	37	69,18	69,18	59,09	67,31

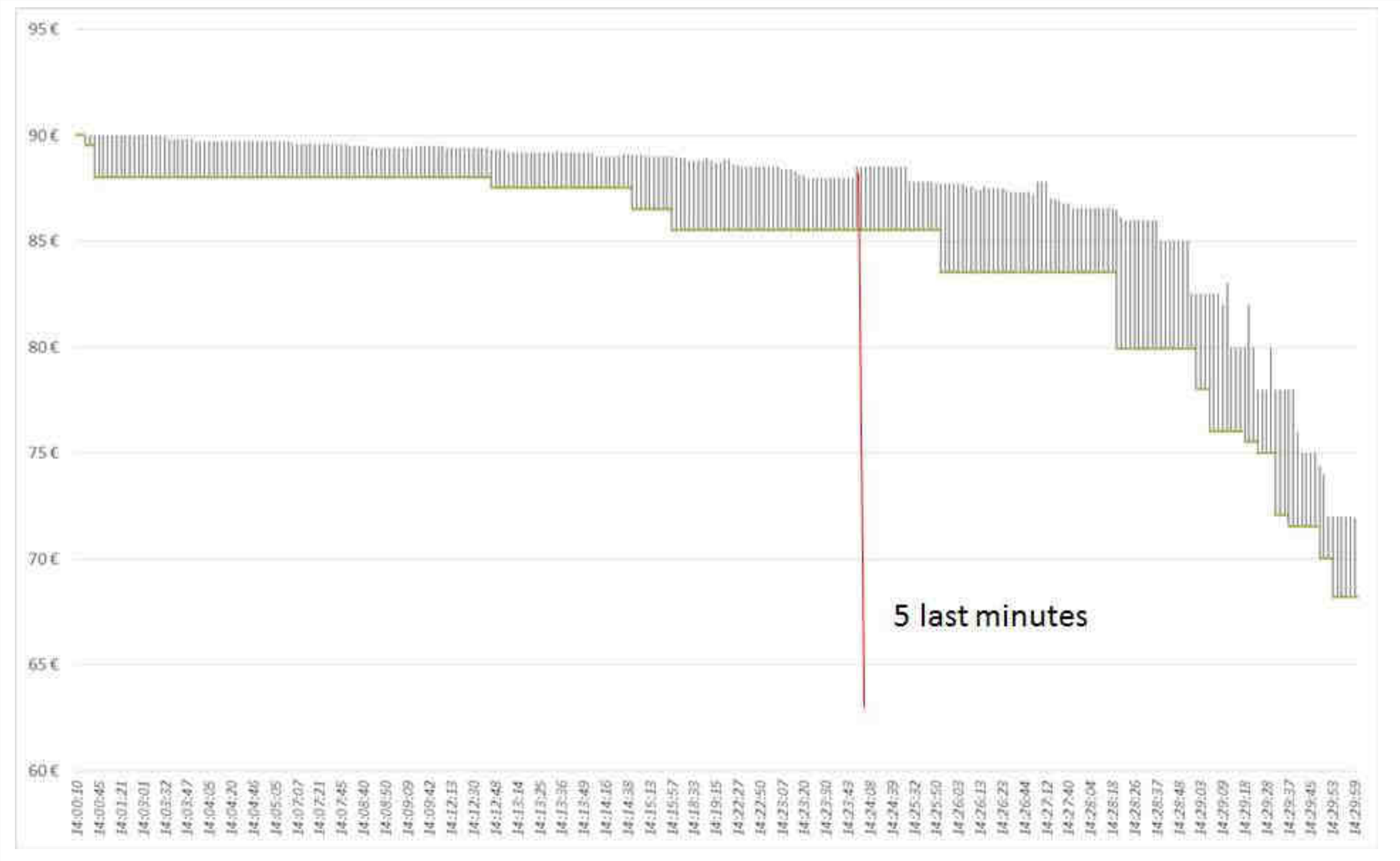

Figure 10: Evolution of Highest and Lowest price during the wind projects tender period.

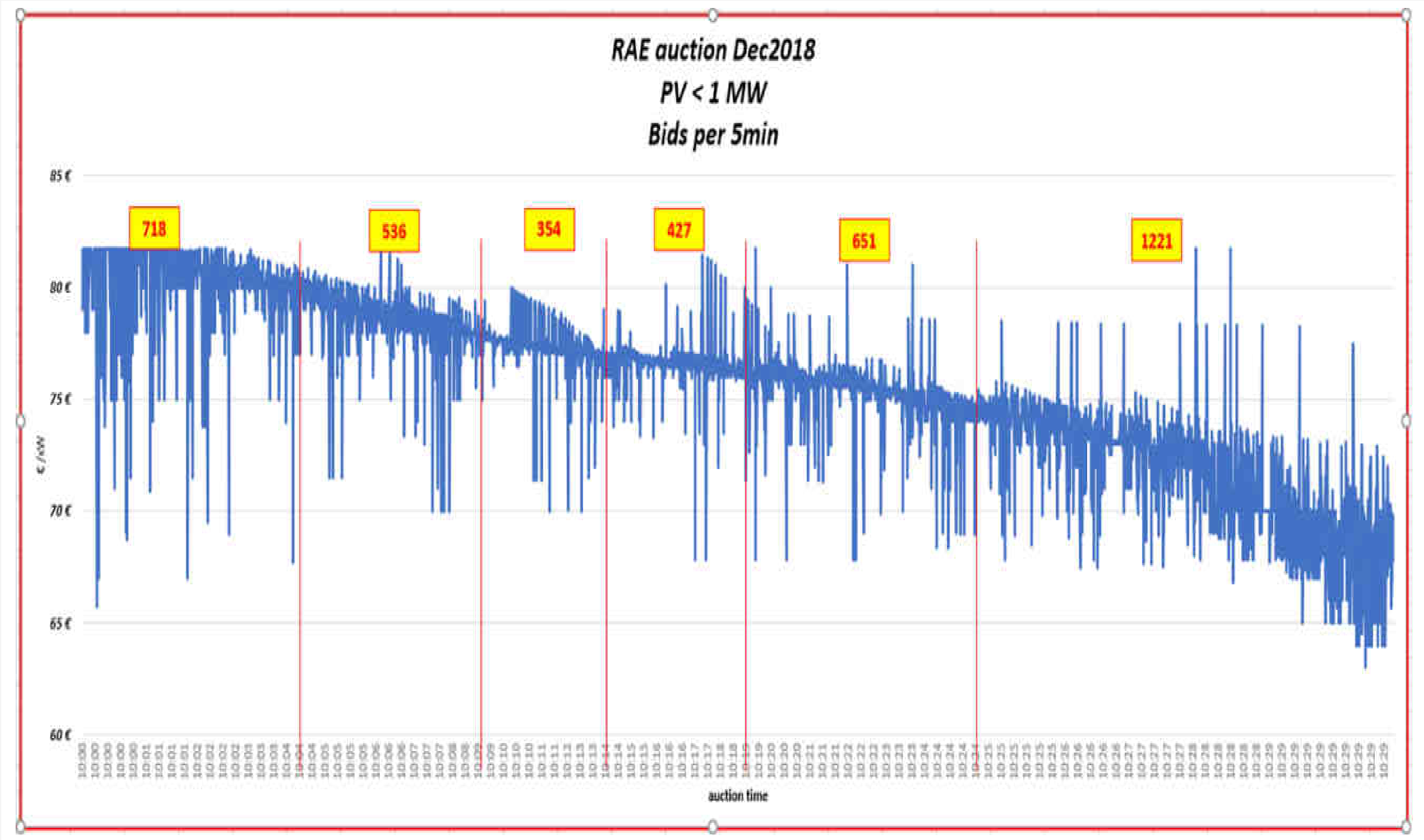

Figure 11: Timetable of the bids of the December 2018 Auction for Category I (installed capacity PPV ≤ 1MW).

In Wind-Plants auction, **Category III ($3MW < PWind \leq 50$ MW)**, the highest bid was 71,93 €/MWh and the lowest 68,18 €/MWh. Fourteen (14) applications were submitted for the wind power tender, with corresponding projects of 308,7 MW in total. As a result, the finally auctioned capacity, after imposing the completion rule of 75%, was 176 MW. Half of the 14 participations in the auction were successful, and the awarded projects covered almost completely the auctioned capacity. The weighted average price of the successful bids was 69,53 €/MWh, hence there was a remarkable decrease of the starting price of about 22,74% (Table 10).

During the wind projects' auction, a number of 336 bids was made. The bidding prices remained high, above 85 €/MWh during the first 25 minutes of the auction. However, strong competition took place during the last 5 minutes' period, which was further increased in the last minute of the electronic auction (Figure 10). This behavior of the participants resulted in significantly reduced weighted average price of 69.5 €/MWh, which is almost 23% lower than the initial ceiling price of 90 €/MWh. The entire procedure was successfully executed, and there was no objection to the whole application and auction steps or to the finally announced results by the Regulator.

3.3 Results of the 2nd Cycle Auction, Technology Specific, December 2018

According to RAE's Decision 1026/2018 (included in Government Gazette B' 4784/25.10.2018[24]), the second Cycle RES Auctions took place at the 10th of December 2018. In **Category I ($PPV \leq 1MW$)**, as shown in **Table 11**, two hundred and four (204) applications were submitted with corresponding projects of 114,62 MW in total. After imposing the 75% rule of minimum competition, the final auctioned capacity was 61,95 MW. In this auction, the awarded projects covered the 100% of the auctioned capacity. The maximum bidding price was 68,99 €/MWh and the minimum one 63 €/MWh. The ceiling price was set at 81,71 €/MWh and the weighted average price of the successful bids was 66,66 €/MWh.

In this category, the total number of bids offered were 3.907 of which 1.221 were offered in the last five (5) minutes of the auction. It is notable that during the last minute of the auction, 477 bids were submitted, i.e. almost equal to the total last 5' minutes bids (483) of the July auction (Table 11, Figure 11)!

The PV-Plant auction **Category II** (for PV stations $1MW < PPV \leq 20$ MW), was cancelled as the number of total capacity of the participants was bellow of the auctioned capacity and this led to "zero" competition. More specifically, twenty-seven (27) applications of a total capacity 151,32 MW passed to the second phase but only 12 participated in the electronic auction with bids of 85,99 MW total capacity which was below the auctioned one (86,47 MW).

The second wind technology auction, **Category III,** took place in December 2018 and included Wind Stations of installed capacity $3MW < PWind \leq 50$ MW. After RAE's opinion, 1/3 of the auction capacity of 2019 was brought infront, meaning that the auctioned capacity in December was finally (129+100=229MW). Fourteen (14) applications were submitted for the wind power tender, with corresponding projects of 281,65 MW in total. After imposing the rule of 75%, the final auctioned capacity was 160,94 MW. Eight (8) of the participants in the auction were successful, and 159,65 MW was awarded – 99% of the auctioned capacity. The weighted average price of the successful bids was 58,58 €/MWh (Table 12).

The highest bid was 65,37 €/MWh and the lowest one 55 €/MWh while the ceiling price was 79,77 €/MWh. During the auction, significant competition took place among the participants and 362 bids were made. As a result, a decrease of the starting price of about 27% occurred. This was an important outcome for end-consumers, whose benefit is one of RAE's primary goals.

3.4 Results of the 1st Cycle Auction, Technology Neutral, April 2019

The first technology neutral auction was announced by RAE in February 2019 (RAE's Decision 230/2019) and included PV projects of installed capacity $PPV > 20MW$ and Wind projects of installed capacity $PWind > 50$ MW. There were eight (8) applications with corresponding projects of 637.78 MW in total

24 http://www.rae.gr/site/file/categories_new/about_rae/actions/decision/2018/1026?p=files&i=0

and seven (7) of them were granted (granted capacity 437,78 MW). After imposing the 40% rule of minimum competition the final auctioned capacity was 455,56 MW. The ceiling price was set at 64,72 €/MWh and the maximum and minimum bidding price was 64,72 €/MWh and 53 €/MWh respectively (Table 13). The weighted average price of the successful bids was 57,03 €/MWh, hence the reduction of the starting price is 11,88%.

3.5 Results of the 2nd Cycle Auction, Technology Specific, July 2019.

The final auctions for year 2019 which were conducted by RAE, were technology specific and concerned PV stations **(Category I, PPV ≤ 20MW)** and wind plants **(Category II, PWind ≤ 50 MW).** The participants in the first **Category I** were sixty-eight (68) and the photovoltaic power plants that successfully achieved a price were twenty four (24). The weighted average price of the successful bids was 62,77 €/MWh; the highest bid price was 67,7 €/MWh and the minimum one 61,95 €/MWh. The ceiling price was set at 69,26 €/MWh (Table 14). As for the second **Category II,** the total number of applications was twelve (12) with corresponding wind projects of 261,75 MW in total. After imposing the 40% rule of minimum competition, the final auctioned capacity was 186,96 MW. Nine (9) projects successfully achieved a price in the tender. The weighted average price of the successful bids was 67,31 €/MWh and the ceiling price was set at 69,18 €/MWh. Finally, the highest bidding price during the auction was 69,18 €/MWh while the lowest one 59,09 €/MWh (Table 14)**.**

A significant reduction of initial prices is stated in each of the eleven (11) auctions and in each category of technology. As shown **Figure 13**, **in Category I** for PV-stations with capacity **PPV ≤ 1MW**, the weighted average price for the auction of December 2018 was 18,41% lower than the initial ceiling price due to the strong competition (192 applications and 3.907 bids). For the pilot auction of December 2016 and the auction of July 2018, the reduction was 5,1% and 7,74% respectively. Out of the total capacity of 120,22MW that was awarded to 187 projects, 4,8MW was awarded in 2016 pilot auction, 53,48MW in July 2018 auction and 61,94MW in December 2018 auction (Figure 14).

For **Category II: PV stations 1MW < PPV ≤ 20 MW** a remarkable decrease of the starting price of about 20,24% was stated in July's 2018 Auction. Significant was the decline in the 2016 pilot auction of 11.4%. The auction of December 2018 stated a decrease of 2.11% while in July 2019 for the same category, the decrease was 9.37% (**Figure 18**) and the relevant total capacity awarder was 230,92 MW (**Figure 19**).

For **Category III: Wind Stations 3MW < PWind ≤ 50 MW significant reduction took place** (**Figure 17**) and a total capacity of 510,13MW awarded via the auctions until July 2019 (**Figure 18**)(Papachristou D., 2018).

Figure 12: max-min Prices of the December 2018 Auction for Category III, 3MW < PWind ≤ 50 MW.

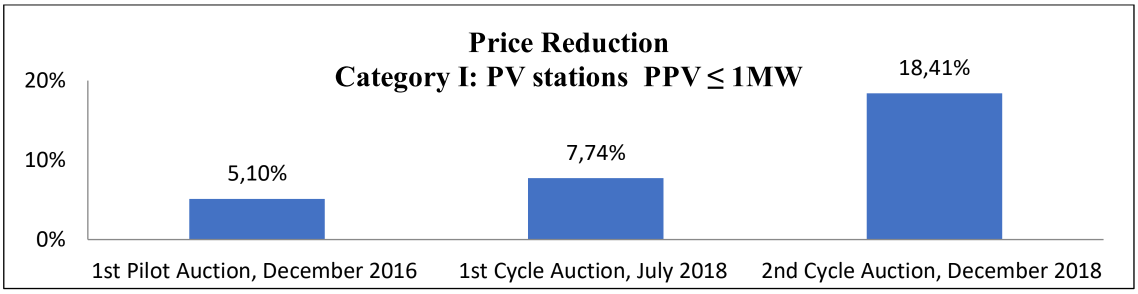

Figure 13: Percentage of Price Reduction in Category I: PV stations PPV ≤ 1MW.

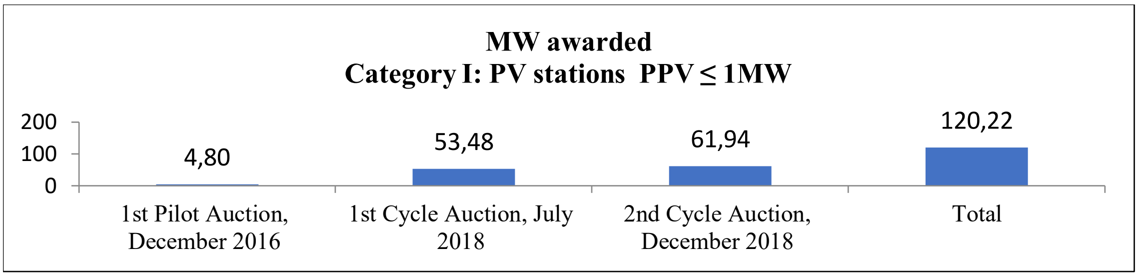

Figure 14: MW awarded in Category I: PV stations PPV ≤ 1MW.

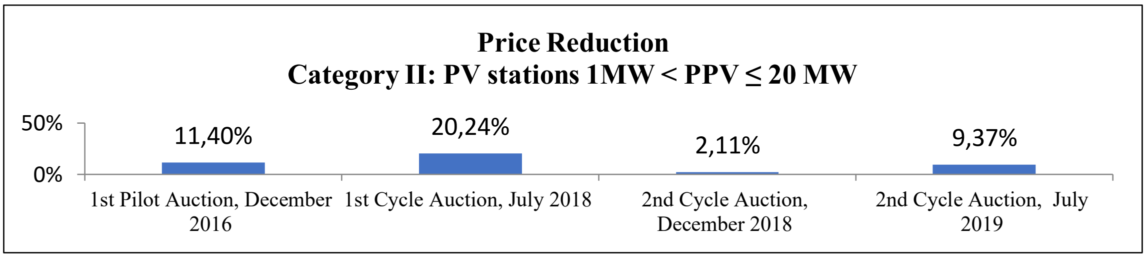

Figure 15: Percentage of Price Reduction in Category II: PV stations 1MW < PPV ≤ 20 MW.

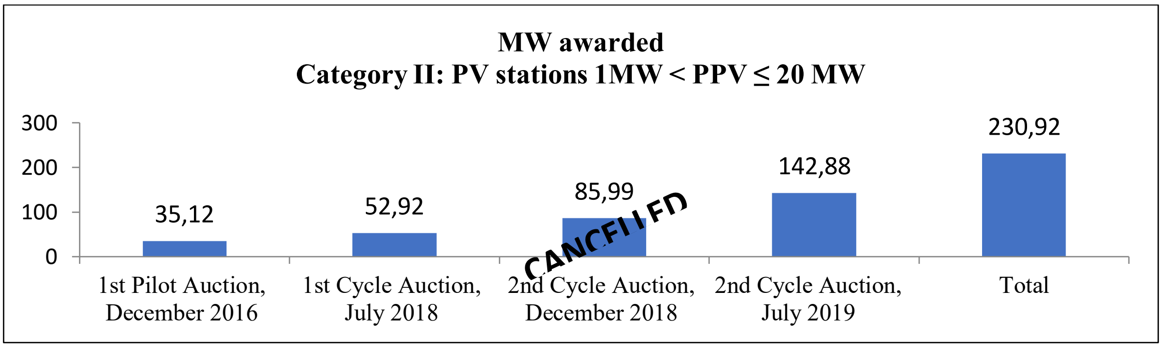

Figure 16: MW awarded in Category II: PV stations 1MW < PPV ≤ 20 MW.

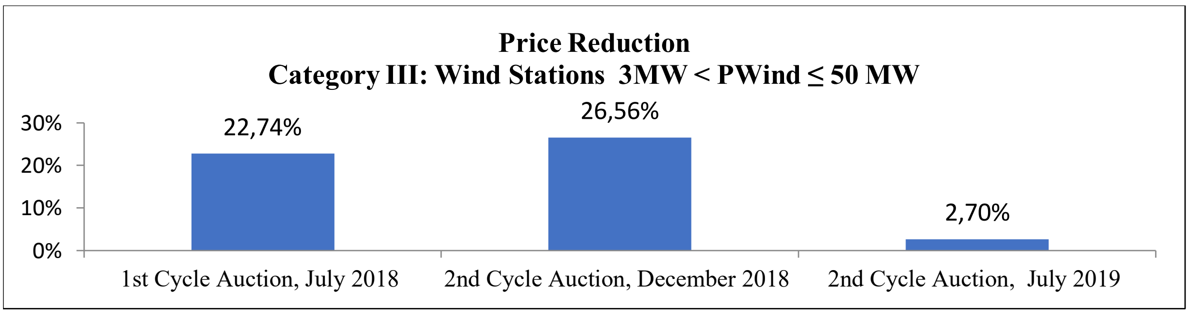

Figure 17: Percentage of Price Reduction in Category III: Wind Stations 3MW < PWind ≤ 50 MW.

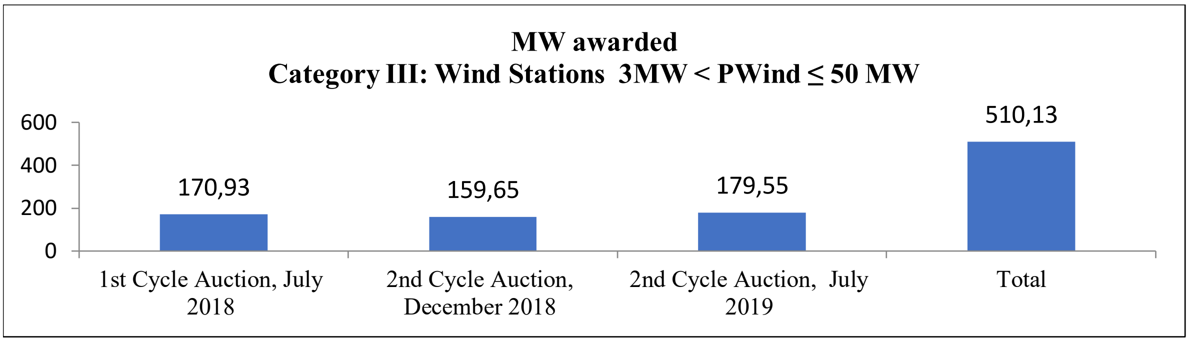

Figure 18: MW awarded in Category III: Wind Stations 3MW < PWind ≤ 50 MW.

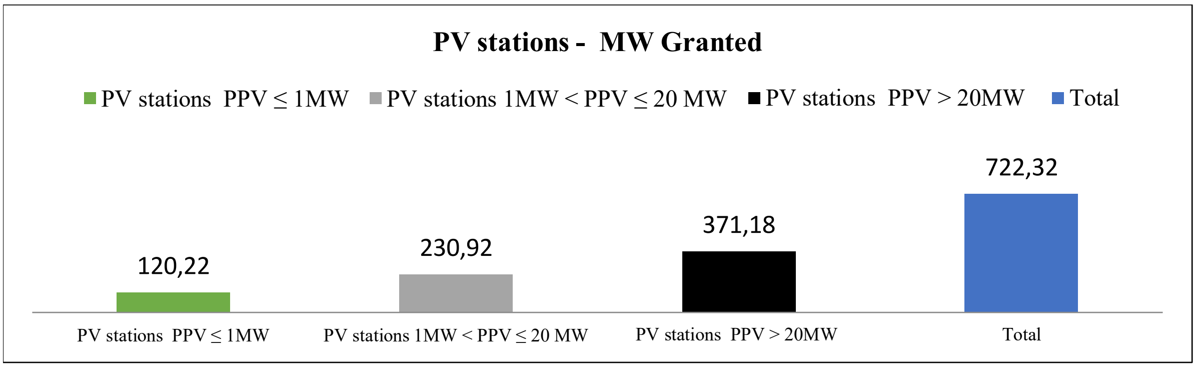

Figure 19: Total MW Granted for PV stations.

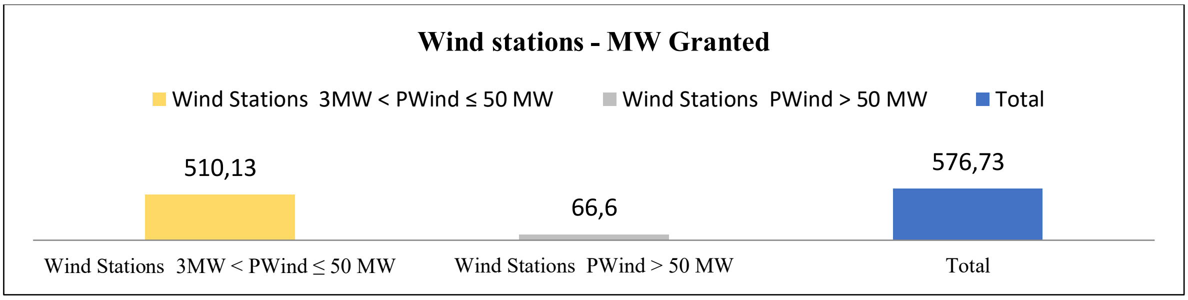

Figure 20: Total MW Granted for Wind stations.

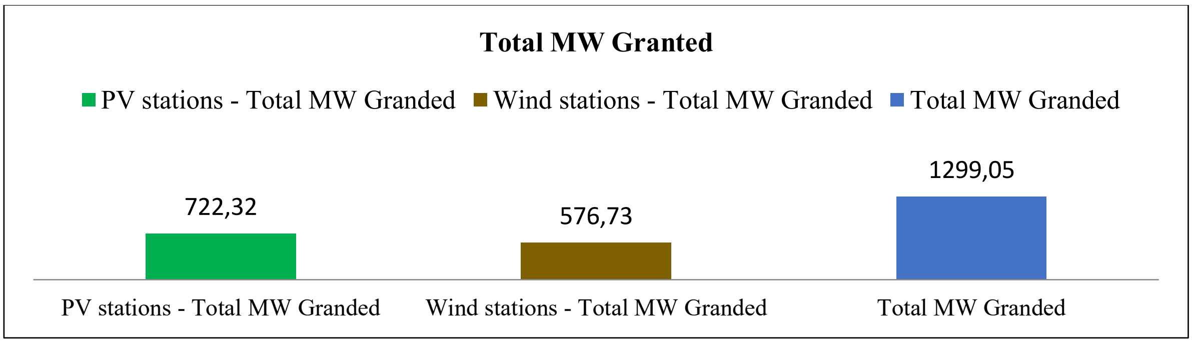

Figure 21: Total MW Granted.

Table 15: Results of the eleven (11) RES Auctions in Greece during the period 2016-2019.

				Project Application (No/MW)						Auction				
Competitive Procedure	Category	Auctioned Capacity (max)(MW)	Final Auctioned Capacity (MW)	Applied		Approved		Granted		Bids	Ceiling price (€/MWh)	Highest Bid (€/MWh)	Lowest Bid (€/MWh)	Weighted Price (€/MWh)
1st Pilot Auction, PV -Technology Specific, December 2016	PV stations PPV≤ 1MW	5	4,8	14	6,89	13	6,8	9	4,8	35	104	104	94,97	98,78
	PV stations 1MW <PPV≤ 20MW	35	35,2	13	53,17	12	50,21	7	35,12	446	94	88	79,97	83,3
1st Cycle Auction, Technology Specific, July 2018	PV stations PPV≤ 1MW	70	53,52	177	105,54	155	94,07	83	53,48	1527	85	80	75,87	78,42
	PV stations 1MW <PPV≤ 20MW	230	53,4	34	197,21	13	93,44	8	52,92	280	80	71	62,97	63,81
	Wind Stations 3MW < PWind ≤ 50MW	300	176,39	14	308,68	14	308,68	7	170,93	336	90	71,93	68,18	69,53
2nd Cycle Auction, Technology Specific, December 2018	PV stations PPV≤ 1MW	90	61,95	204	114,62	192	108,4	95	61,94	3907	81,71	68,99	63	66,66
	PV stations 1MW <PPV≤ 20MW	100	86,47	27	151,32	27	151,32	12	85,99	30	71,91	71,91	63	70,39
	Wind Stations 3MW < PWind ≤ 50MW	229	160,94	14	281,65	14	281,65	8	159,65	362	79,77	65,37	55	58,58
1st Cycle Auction, Technology Neutral, April 2019	Technology Neutral	600	455,56	8	637,78	8	637,78	7	437,78	56	64,72	64,72	53	57,03
2nd Cycle Auction, Technology Neutral, July 2019	PV stations PPV ≤ 20 MW	300	143,04	68	200,26	68	200,26	24	142,88	275	69,26	67,7	61,95	62,77
	Wind Stations PWind ≤ 50 MW	300	186,96	12	261,75	12	261,75	9	179,55	37	69,18	69,18	59,09	67,31

In Figure 19 a total capacity of 722,32MW of PV installations was awarded via auctions until July 2019 (including the neutral auction).

Currently a total capacity of 1,3 GW is under development and estimated to connect to the grid latest on 2021. On the following (Figure 20) a total capacity of 576,73MW of Wind installations was awarder via the auctions until July 2019 (including the neutral auction).

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The Renewable Energy Dimension of Energy Security

Nikoletta KONTOULIS, *Ph.D. Candidate,*
Department of International and European Studies, University of Piraeus
Georgia-Maria D. POLYMEROPOULOU
Department of International and European Studies, University of Piraeus
John A. PARAVANTIS [1] , *Associate Professor*
Department of International and European Studies, University of Piraeus

[1] Contact details of corresponding author
Tel: +30 210 4142771
e-mail: jparav@unipi.gr & paravantis@gmail.com
Address: 80 Karaoli & Dimitriou Street, Piraeus, 18534 Greece

Abstract

This research contributes to the cause of addressing climate change in an era of increasing global geopolitical uncertainties by reviewing how renewable energy enters the dimensions, components and metrics used in measuring energy security; the scope of the discussion is such that the contribution of renewable energy to energy security may be understood across a wide spectrum of geographical, socio-political, economic and technological conditions. The evolving definition and geopolitics of energy security during the 20th and early 21st century are presented. The state-of-the-art of the energy security and renewable energy literature is reviewed, with a focus on eminent energy milestones. The dimensions, components and metrics of energy security are presented and discussed, along with quantitative indicators and indexes. The role of the different types of renewable energy (including solar and wind) is highlighted and discussed in the context of the following novel components of energy security: physical availability; technology; economic affordability; social accessibility; governance; unconventional threats; and natural environment. The impact of renewable energy on patterns of energy-security-related co-opetition among states is assessed and the role of international institutions is mentioned. Barriers to renewable energy projects as well as the socioeconomic and environmental disadvantages of renewable energy are discussed, with references to EU countries with a high share of renewables, such as Norway, Sweden, Latvia, Finland, Austria, Portugal and Denmark. The social acceptance of renewable energy projects and technologies is examined and related to the context of energy security at a time of a geopolitical transition under climate change policies.

Keywords: energy security, renewable energy, climate change, energy transition, consumers, producers, transit countries

1. Introduction

Energy has been crucial for economic growth throughout human history, the *"precondition of all commodities, a basic factor equal with air, water, and earth"* (E. F. Schumacher, Nobel laureate economist, 1977). The International Renewable Energy Agency (IRENA)(IRENA, 2019) underlines that fossil fuels have been the foundation of the global energy system, and their role is deeply embedded in the relations among countries and regions.

The ability of a country to access the energy resources needed to maintain its national power without compromising foreign policy, economic, social and environmental objectives, is referred to as energy security. Energy security is paramount to human security (Sovacool B.K. & Mukherjee I., 2011) and has become an increasingly popular concept. There is no universal definition of energy security (Kruyt B. et al., 2009; APERC, 2007), which Chester L. (2010) has been aptly described as *"slippery"* and *"polysemic"*. Consequently, energy security has become an umbrella term for different policy goals (Winzer C., 2012). This ambiguity is affirmed by the many existing definitions of energy security. A few years back, Sovacool B.K. (2011a) reported that there were at least 45 different and Ang B.W. et al. (2015) identified 83 definitions in the existing literature. In a most recent study, Matsumoto K. et al. (2018)

confirmed that there are no uniform definitions or evaluation methods for assessing energy security.

Recently, a strong interest has emerged in favor of the integration of renewable energy in the energy mix as a priority measure in support of energy security and against climate change (Hache E., 2018). Energy security planning is increasingly geared towards establishing a low-carbon economy and achieving climate mitigation goals (Hamed T.A. & Bressler L., 2019). Article 2 of the Paris Agreement (UN, 2019) requires countries to implement their nationally determined contributions, and to increase their ambitions over time, necessary for keeping the rise in global mean temperature below 2°C (Rogelj et al., 2016).

At a time when society is increasing its demands for an accelerated transition to a low carbon energy system, the energy data for 2018 paint a worrying picture, with both energy demand and carbon emissions growing at the fastest rates seen for years (BP, 2019). Renewables and energy efficiency offer a safe, reliable and affordable way of achieving massive decarbonisation, in line with keeping the rise in global temperatures below 2°C (IRENA, 2018).

This is a particularly exciting time to study the renewable energy dimension of energy security: the global energy landscape is in the middle of a game-changing revolution in source rock resources; consumer countries have turned into producers; producer countries have turned into consumers; and transit countries have turned into new players. The main goal of this paper is to shed light on the role and the impact of renewables in energy security by examining how renewable energy sources enter the dimensions, components and metrics used in measuring energy security, across a wide spectrum of geographical, socio-political, economic and technological conditions.

2. Energy security and renewable energy

Since the turn of the 21st century, climate change and its link to fossil fuels have attracted the attention of political and industrial actors, academic researchers and society, thus moving to the forefront of the political discourse (Moe E., 2015). This has happened against a backdrop of geopolitical turmoil caused by a series of issues of energy significance including:

- the second Gulf War (2003 to 2011);
- the crises between Ukraine and Russia (2005 to 2009);
- the Arab Spring upheaval (2010);
- the Fukushima Daichi nuclear accident (2011);
- the cyber attack on 35,000 computers of Aramco (the Saudi Arabia oil company that supplied 10% of global demand for oil);
- the Tigantourine gas plant hostage crisis in Algeria (2013) with 39 fatalities of expatriates, the first major terrorist strike on a big energy facility;
- the adoption of the European Union (EU) Energy Union (2015), a project of immense scope and significance;
- the signing (2015) and later the unraveling (2018) of a nuclear deal between Iran, the five permanent members of the United Nations (US, UK, China, Russia, and France), Germany and the EU, aiming to limit Iran's enrichment of uranium (2015);
- the lifting of the 1975 US oil export ban (2015);
- and Yemeni rebel attacks on two Saudi pumping stations with armed drones, the first such terrorist attack on energy installations (2019).

With the turn of the 21st century, the price of oil (arguably the world's most important commodity) climbed to record highs and exhibited fluctuations that were difficult to predict. A barrel of crude oil, which in average annual OPEC[25] prices, costs $2.70 in 1973, jumped to over $10 by 1978; further jumped and fluctuated around $30 until 1985; fell to around $20 or less until 1999; climbed to an unprecedented high of $94.10 in 2008, shocking the global economy; fell to just over $60 and climbed to a new high of $109.45 in 2012; and fell to just over $40 and back up to $69.52 in 2018. These ups and downs in the price of oil, especially the unpredictability after 2008, underscore that the world has entered a prolonged era of peak oil no matter for how many decades shale oil and gas continue to supply the world.

The climate is a chaotic system which, considering the Ice Ages (the last of which

[25] Organization of the Petroleum Exporting Countries

ended just 12,000 years ago), has exhibited wide variability even in the recent past. Nevertheless, all evidence at this point shows that global warming and its effects will intensify during the rest of the 21st century, so climate change will become a more concrete and tangible target (Moe E., 2015). Intensifying geopolitical tensions are also likely, mainly between the US and China (with its expanding territorial claims in southeast Asia), with other emerging powers such as India (with its own territorial issues with neighboring countries), Indonesia (with its expanding population), Brazil (host of the world's most important ecosystem), Japan and Germany, all of which the Economist Intelligence Unit has predicted to be among the countries with the highest nominal Gross Domestic Product (GDP) per capita by 2050.

The need to address climate change as well as emerging geopolitical tensions will make energy policy a field of paramount importance in international relations, with energy security constituting the most important aspect of energy policy. The need to address climate change is perceived as urgent: 2018 carbon emissions grew by 2% which is the fastest growth in seven years (BP, 2019). Signs of a shift away from fossil fuels have become clearer (Moe E., 2015), e.g. since the 2011 Fukushima nuclear accident, Japan and Germany have moved towards ending their dependence on nuclear energy, while the Danish parliament has decided that Denmark be fossil fuel free by 2050.

As new energy alternatives need to be less polluting, renewable energy moves naturally to center stage. Renewable energy is at least four decades old, but it has gained increasing currency as a conceptual alternative to centralized energy sources, such as coal and nuclear power, which are perceived as environmentally destructive and dehumanizing (Harjanne A. & Korhonen J. M., 2019). Yet, renewable energy is not free of impacts on natural ecosystems, the economy, society and politics:

- Wind and solar energy are dilute fuels, requiring large expanses of land. The construction of onshore wind farms in particular necessitates clearing land areas, with impacts on species such as tortoises, birds and bats.
- Wind turbines have a lifespan of around 20 to 26 years, after which steel, cement and other materials used in their construction must be recycled or properly disposed of as solid waste.
- Large renewable energy projects oftentimes are opposed by society on the grounds of visual aesthetics and other intrusions into the way of life.
- The intermittent nature of wind and sunlight means that the energy they capture must be stored if they are to serve as the main energy source.
- Finally, although renewable energy is becoming more inexpensive, it continues to rely on state budgets.

For the transition to renewable energy to succeed, environmental impacts must be minimized, and the profile of renewable energy projects must be made more attractive to society. Most importantly, concerns about energy security (Gökgöz F. & Güvercin M.T., 2018) and the political economy of renewables must be addressed.

The International Energy Agency (IEA) was founded in 1974, with the objective of helping countries coordinate a collective response to major disruptions in the supply of oil with the establishment of mandatory strategic petroleum reserves[26]. IEA defines renewable energy as *"energy derived from natural processes that are replenished at a faster rate than they are consumed"*. The main renewable energy sources are wind, solar, biomass, hydropower, geothermal, and wave. Wind and solar have grown at an unprecedented rate and are arguably the most significant sources, with electric utilities buying into wind power almost without hesitation. Yet, they are called variable renewable energy sources because they share a unique problematic characteristic: the amount of power they generate varies with the weather and the time of day (IRENA, 2019).

Considering that renewable technologies have the potential to contribute to energy security while meeting environmental objectives at the regional, national and global level (Ölz S. et al., 2007), IRENA (an official United Nations observer) was founded in 2009 to serve as a platform for international

[26] https://www.iea.org/about/ourmission

cooperation on the technologies, policies and financial know-how of renewable energy[27]. At the time being, renewable energy was only a marginal contributor to global primary energy and electricity supply (Scholten D. & Bosman R., 2016). Now renewable energy is growing rapidly in installed capacity and investments. The global awareness about renewables is shown by numbers: By the end of 2018, renewable energy targets had been adopted in 169 countries at the national, state or provincial level. Moreover, 135 countries have power regulatory policies (REN21, 2019).

Decreasing the dependence on fossil fuels and increasing the amount and percentage of renewables (and nuclear energy) will help mitigate climate change (Matsumoto K. & Andriosopoulos K., 2016). Domestic renewable energy may reduce the need of countries for energy imports (Scholten D. & Bosman R., 2016) and, consequently, their dependence on exporter countries (Gökgöz F. & Güvercin M. T., 2018). So, renewable energy is considered the most secure way to minimize energy supply risks by exploiting domestically controllable energy supplies (Bang G., 2010).

3. Defining energy security

Energy security is a contested and complex term (Valentine S. V., 2011) which encapsulates concepts such as security of supply, reliability of infrastructures, affordability and environmental friendliness (García-Gusano D. et al., 2017). Energy security means different things to different countries, depending on: their geographical location; their natural resource endowment; their economic disposition (Luft G. & Korin A., 2009); their status as producer/exporter, consumer/importer or transit (Johansson B., 2013), their vulnerability to energy supply disruptions; their political system; their ideological views and perceptions (Marquina A., 2008); and the status of their international relations, e.g. reliance on Russian gas depends on historical experiences during the Cold War (Leonard M. & Popescu N., 2007).

Examined over different historical time frames, the concept of energy security is dynamic and fluid, with evolving energy policy challenges (Winzer C., 2012; Månsson A. et al., 2014). The oil crises of 1973 and 1979 transformed oil supply from a military to a socio-political and economic issue for importing countries. The gas crises of 2006 and 2009 between Russia and Ukraine raised concerns about transit countries and brought back the use of energy as a geopolitical weapon (Overland I., 2019). As pointed out by Cherp A. and Jewell J. (2014), a classic definition of energy security has been provided by Yergin D. (1988), who visualized energy security as the assurance of *"adequate, reliable supplies of energy at reasonable prices"*, adding a geopolitical component by qualifying that this assurance must be provided *"in ways that do not jeopardize national values or objectives"*.

The IEA defines energy security as the *"uninterrupted availability of energy sources at an affordable price"*, and considers it to have a long-term and a short-term aspect. The IEA has restated the definition through the years, to characterize energy security as the adequate, affordable and reliable supply of energy. Long-term energy security relates to *"timely investments to supply energy in line with economic developments and environmental needs"*. Short-term energy security relates to *"the ability of the energy system to react promptly to sudden changes in the supply-demand balance"* (IEA, 2011; Jewell J., 2011; Kisel E. et al., 2016; Hache E., 2018).

Countries have different energy security objectives depending on their role in the energy market: producer/exporter countries aim to ensure reliable demand for their commodities; consumer countries commonly aim towards diversity of energy supply, so as to minimize their dependence and maximize their security; and transit states try to make the best of their role as bridges connecting producers/exporters with their markets (Luft G. & Korin A., 2009). For consumer and transit countries, security of supply is important; for producer/exporter countries, security of demand is possibly as important as security of supply (Johansson B., 2013).

3.1. Dimensions and components of energy security

The conceptualization and formulation of the dimensions of energy security is a necessary step for its analysis with the aim of highlighting the role of renewable energy in it. Energy

[27] https://www.irena.org

security is considered to be composed of a small number of dimensions, e.g. technical, social, environmental, political, geological, and economic (Sovacool B. K., 2016); each dimension contains components; and each component may be measured by metrics, i.e. quantitative or qualitative indicators. When all metrics, components and dimensions are aggregated, an energy security index may be calculated based on available data.

In an extension to the original IEA definition of energy security, the Asia Pacific Energy Research Centre (APERC, 2007) highlighted the so-called four As of energy security: (1) availability of the supply of energy resources; (2) affordability of the price of energy resources so that economic performance is not affected adversely; (3) accessibility to all social actors; and (4) acceptability from a sustainability standpoint. The first two As (availability and affordability) constitute the classic approach to energy security (20th century), while the latter two (accessibility and acceptability) reflect contemporary environmental concerns, such as climate change, as well as sociopolitical issues such as fuel poverty.

Ang B.W. et al. (2015) argued that the most important dimension of energy security is availability, as this is taken into account in 99% of related studies. The term availability is also used to imply stable and uninterrupted supply of energy (IEA, 2007; EC, 2000; Yergin D., 2006), while some authors use the term reliability to refer to the role of energy infrastructure (Jun E. et al., 2009; WEC, 2016) and the production of electricity and heat (Augutis J. et al., 2014). As for accessibility, it has been at the center of energy security debates and policy approaches into the 21st century (Kopp S.D., 2014). Goldthau A. and Sovacool B. K. (2012) talked about the following three key energy challenges: energy security, energy justice, and a low carbon transition, highlighting the need to consider energy security as a democracy issue, equity as an important aspect of accessibility, and global climate change as an important aspect of acceptability.

A similar set of four dimensions of energy security has been proposed by Sovacool B. K. and Rafey W. (2011): (1) availability, i.e. diversifying fuels, preparing for disruption recovery, and minimizing dependence on foreign supplies; (2) affordability, i.e. providing affordable energy services, and minimizing price volatility; (3) efficiency and development, i.e. improving energy efficiency, altering consumer attitudes, and developing energy infrastructure; and (4) environmental and social stewardship, i.e. protecting the natural environment, communities and future generations.

Alhajji A. F. (2008), a global energy expert, differentiated among six dimensions of energy security: economic, environmental, social, foreign policy, technical and security. Vivoda V. (2010) listed seven salient energy security dimensions: environment, technology, demand side management, socio-cultural or political factors, human security, international elements like geopolitics, and the formulation of energy security policy; and 44 attributes of energy security. Knox-Hayes J. et al. (2013) extracted the following dimensions of energy security: (1) availability, indicating security of supply and affordability; (2) welfare, indicating equity and environmental quality; (3) efficiency, representing various factors including low energy intensity and small-scale energy (with some overlap with welfare); (4) affordability, indicating (among other factors) price affordability and small-scale energy; (5) environment, appearing to be very similar to welfare; (6) transparency, standing for equity, transparency and education; (7) climate, connected to global climate change and having significant overlap with welfare and environment; and (8) equity, overlapping with other dimensions.

Sovacool B. K. and Mukherjee I. (2011) presented the following dimensions with corresponding components: (1) availability, i.e. security of supply and production, dependency and diversification; (2) affordability, i.e. price stability, access and equity, decentralization and affordability; (3) technology development and efficiency, i.e. innovation and research, safety and reliability, resilience and adaptive capacity, efficiency and energy intensity, and investment and employment; (4) environmental and social sustainability, i.e. land use, water, climate change, and pollution; and (5) regulation and governance, i.e. governance, trade and regional interconnectivity, competition and markets, and knowledge and access to information as well. Regarding energy independence, self-sufficiency may be a more pragmatic target since even a producer/exporter country cannot really extricate itself from the global energy markets and their vulnerabilities (Zhao H., 2019).

3.2. Metrics of energy security

There is a multitude of energy security indicators: Sovacool B. K. and Mukherjee I. (2011) assembled 320 simple indicators and 52 complex indexes of energy security. Kruyt B. et al. (2009) differentiated among simple indicators (such as reserves-to-production ratios, import dependence, energy prices, political stability and demand-side requirements) and aggregated indices. Sovacool B. K. and Brown M. A. (2009) considered energy security to be defined according to the following criteria (i.e. dimensions): *availability*, measured by: oil and natural gas import dependence; availability of alternative fuels; *affordability,* measured by: retail electricity, gasoline and petrol prices; *energy and economic efficiency,* measured by: energy intensity; electricity use per capita; average fuel economy of passenger vehicles; *environmental stewardship,* measured by sulfur dioxide (SO_2) and carbon dioxide (CO_2) emissions.

In a paper evaluating the energy security performance of 18 countries from 1990 to 2010, Sovacool B. K. et al. (2011) presented a more detailed list of dimensions, components and corresponding metrics, adding: regulation and governance, measured by energy exports; competition, measured by energy subsidies per capita; and information, measured by the completeness of energy data. Ang B. W. et al. (2015) confirmed governance and added other dimensions such as infrastructure and energy efficiency.

An even more detailed definition of energy security involved the following dimensions, components and corresponding metrics (Ren J. & Sovacool B.K., 2014):

1. *Availability*, measured by: security of supply, equal to

$$\frac{\text{total production energy}}{\text{total consumed energy}};$$

self-sufficiency, equal to

$$\frac{\text{imported energy}}{\text{total consumed energy}};$$

diversification, measured by a diversity index such as the Shannon-Wiener; renewable energy, equal to

$$\frac{\text{renewable energy}}{\text{total consumed energy}};$$

and technological maturity, a qualitative metric.

2. *Affordability*, measured by: price stability, equal to the deviations of price about a global mean value; dependency, equal to

$$\frac{\text{total imported energy}}{\text{population}};$$

market liquidity, a qualitative metric; decentralization, equal to

$$\frac{\text{total energy by distributed and small scale generation}}{\text{total energy production}};$$

electrification, equal to the percentage of population with reliable access to grid; and equity, equal to the percentage of households depending on wood, straw, etc. for cooking and heating.

3. *Accessibility*, measured by the following qualitative metrics: import stability, trade, political stability, military power, and safety and reliability, all qualitative metrics.
4. *Acceptability*, measured by the following qualitative metrics: environment, a composite of several *"micro aspects"* that are *"measured individually"*; social satisfaction, national governance, international governance, transparency, and investment and employment.

Renewable energy is a factor in much of the research that aims to conceptualize, define and measure energy security.

3.3 Synthesizing an energy security index

Having reviewed the dimensions, components, metrics and methods of energy security, a novel energy security index will now be proposed. The following seven dimensions and components are proposed:

1. *Physical availability*, the historical bedrock of energy security (Kruyt B. et al., 2009; Luft G. & Korin A., 2009; IEA, 2007; Narula K. & Reddy S., 2015), accounting for: security of supply; self-sufficiency (affected by oil and gas import dependence, and boosted by renewable energy); Strategic Petroleum Reserves (SPR, acting as a buffer and a deterrent); energy diversification (accounting for the

contribution of small-scale distributed renewable energy installations).

2. *Technology development*, accounting: (state and maturity of) infrastructure, e.g. matching of available oil to refinery infrastructure; energy (grid) efficiency (the "fifth fuel"), onshore and offshore wind farms; energy consumption and conservation in the building sector, transportation systems and the industry; smart grids; decentralization, i.e. diffusion of small scale and prosumer systems (mostly renewable energy); research (intensity), development and innovation (with a sizeable portion related to renewable energy).
3. *Economic affordability*, perhaps the second most important energy security dimension historically, accounting for: affordability of electricity and gasoline prices (expressed in Purchasing Power Parity); stability (i.e. lack of volatility) and predictability of prices; competition, subsidization (per capita), profitability; energy intensity (i.e. electricity use per capita and monetary unit of GDP); fuel economy of passenger vehicles (also related to technology). This dimension has been favorably affected by the price of wind power, which has fallen to about 2 cents/kWh, down from a maximum of 9 cents/kWh in 2009.
4. *Social accessibility*, i.e. social stewardship, accounting for: dependency (expressed as imported energy per capita); electrification, i.e. percent of the population with (reliable) access to the electricity grid (potentially improved by resorting to renewable sources); energy democracy, e.g. percent of households that are fuel poor (also likely to be improved by the use of small-scale renewables); social equity, e.g. percent of households relying on traditional energy sources (such as wood) for cooking and heating; consumer awareness, knowledge and attitudes, e.g. towards renewable energy (Stigka E. et al., 2014; Paravantis J. et al., 2018).
5. *Governance*, taking into account: quality of governance, measured by, e.g. the Worldwide Governance Indicators (WGI) of the World Bank[28] that rate "voice" (i.e. citizen participation) and accountability, political stability (which may be measured by the number of years since the previous regime change) and absence of violence, government effectiveness, regulatory quality, rule of law, and control of corruption (i.e. transparency and accountability, no crony capitalism); type of polity (democracy or otherwise); military power (possibly a qualitative variable); data quality and intelligence; good regulatory policies (e.g. avoiding overregulation, setting reasonable and objective performance criteria, avoiding picking winners and losers) and adoption of "fit" energy policies, i.e. catering to all societal energy tribes (Caputo R., 2009; Thomson M., 1984).
6. *Unconventional threats*, including asymmetric, paramilitary or nonconventional threats to energy infrastructure, such as: revolutions (e.g. Iranian revolution, Arab Spring); accidents caused by human error (likely to be less severe with renewable energy installations); durability and safety (of infrastructure, likely to be more favorable with distributed small scale prosumer systems based on renewable technologies); terrorism incidents, including cyberwarfare (also likely to be of a less severe nature with renewables).
7. *Natural environment*, accounting for: (existence of) tragedy of the commons (i.e. overexploitation of resources that are public goods, and may be depleted unlike renewable energy sources), resource curse (i.e. presence of abundant energy and natural resources in poor countries); (mitigation of) environmental pollution, e.g. SO_2 emissions (per capita); (mitigation of) global climate change, e.g. CO_2 emissions (per capita), affected favorably with more use of renewable energy; forest cover; land use (management), probably the most important negative impact of onshore wind farms; water availability, i.e. quality and quantity, water stress and scarcity, population access to improved water; environmental (sustainability) management; health problems caused by environmental threats, e.g. (high concentration of toxic

[28] https://info.worldbank.org/governance/wgi

substances; (impacts of) black-swan type of natural disasters.

How are the dimensions of energy security covered by the research literature? In a paper examining 40 years of energy security trends, Brown M. A. et al. (2014) found that 91 peer-reviewed academic articles covered the dimensions of energy security differently. In particular, availability was covered by 82% of the examined articles; affordability by 51% of the articles; energy and economic efficiency by 34% of the articles; and environmental stewardship by 26% of the articles. As to the precise nature of these dimensions of energy security, a Factor Analysis carried out by the authors concluded that: availability was mostly a function of oil import dependence, road fuel intensity, and natural gas import dependence (in decreasing order of importance); affordability was a function of electricity and gasoline retail prices; energy and economic efficiency was a function of electricity use per capita, and energy per GDP intensity; and environmental stewardship was a function of CO_2 and SO_2 emissions.

How are the different dimensions of energy security perceived by different economic actors? In a paper examining seven suppositions about energy security in the United States, Sovacool B. K. (2011b) presented the following expert suppositions pertaining to energy security issues: (1) security of supply and trade; (2) energy democracy; (3) energy research; (4) energy efficiency; (5) affordability; (6) environmental pollution; and (7) climate change. Empirical research carried out by the author concluded that the different dimensions of energy security are indeed rated differently by those working in different sectors of the economy:

- The private sector considered the following four energy security dimensions to be the most important (with a rating over 4.5 out of five): (1) conducting research and development on new and innovative energy technologies (which encompasses renewable energy); (2) providing available and clean water; (3) minimizing the destruction of forests and the degradation of land and soil; and (4) minimizing air pollution.
- Among government occupations, more (i.e. eight) dimensions were rated over 4.5, including the four of the private sector plus the following: (5) reducing greenhouse gas emissions; (6) minimizing the impact of climate change; (7) assuring equitable access to energy services to all of its citizens (favorably affected by small scale renewable energy systems); and (8) informing consumers and promoting social and community education about energy issues.
- With universities, even more dimensions were rated over 4.5, including the four of the private sector plus the following: (5) reducing greenhouse gas emissions; (6) minimizing the impact of climate change; (7) informing consumers and promoting social and community education about energy issues; (8) assuring equitable access to energy services to all citizens (favorably affected by small scale renewable energy systems); (9) ensuring transparency and participation in energy permitting, siting, and decision making (related to the nature of renewable energy); and (10) having low energy intensity.
- The non-profit sector rated the following dimensions over 4.5: (1) providing available and clean water; (2) minimizing air pollution; (3) conducting research and development on new and innovative energy technologies (which includes renewable energy); (4) minimizing the destruction of forests and the degradation of land and soil; (5) reducing greenhouse gas emissions; (6) minimizing the impact of climate change; (7) informing consumers and promoting social and community education about energy issues; (8) assuring equitable access to energy services to all citizens (favorably affected by small scale renewable energy systems); (9) ensuring transparency and participation in energy permitting, siting, and decision making (related to the nature of renewable energy); and (10) having a secure supply of coal, gas, oil and/or uranium.
- Finally, those working in intergovernmental occupations rated the first two dimensions of the private sector and the following dimensions with a score over 4.5: (3) minimizing air pollution; (4) having a secure supply of coal, gas, oil and/or uranium; (5) promoting trade in energy products; technologies, and exports; (6) reducing greenhouse gas emissions; (7) informing consumers and promoting social and community education about

energy issues; (8) assuring equitable access to energy services to all citizens (favorably affected by small scale renewable energy systems); and (9) having low energy intensity.

4. The role of renewable energy in the dimensions of energy security

Having reviewed the dimensions, components and some metrics of key literature definitions of energy security, and having presented a novel energy security index containing seven dimensions, this work is now concluded with recapping and highlighting the role of renewable energy in the dimensions of energy security.

Although renewable energy has a much better greenhouse gas emissions profile, it has environmental impacts like any other technology. Wind and solar energy are dilute fuels, requiring large expanses of land. The construction of onshore wind farms in particular necessitates clearing land areas with impacts on species such as tortoises, birds and bats. The intermittent nature of wind and sunlight means that the energy they capture must be stored if they are to serve as the main energy source. Wind turbines have a lifespan of around 20 to 26 years, after which steel, cement and other materials used in their construction must be recycled or properly disposed of. These impacts mean that the participation of renewable energy in the energy mix of a country creates additional negative environmental impacts that are offset by the positive environmental impact of the reduction in fossil fuel usage.

Looking back at the dimensions of energy security proposed by Sovacool B. K. and Rafey W. (2011), the components of fuel diversification, disruption recovery, minimization of dependence on foreign supplies, reduction of price volatility, and support of sustainability (although with the introduction of aforementioned environmental impacts) are all served by the use of renewable energy for electricity production. Renewable energy improves at least three of the four dimensions of energy security defined in that work.

Recalling the definition of energy security by Knox-Hayes J. et al. (2013), it is argued that (further to the obvious connection of renewable energy to availability) the components of environmental quality (especially climate change) and small-scale energy production are also improved by the use of renewable energy.

Turning to Sovacool B. K. and Mukherjee I.'s work (2011), the following components of security of supply and production are favorably affected by increased penetration of renewable energy: dependency and diversification; price stability (regardless of the level of prices); decentralization and affordability (achieved with distributed small-scale installations); innovation and research (inherent in renewable energy); investment and employment (as new jobs are created in the renewable energy industry); environmental quality, especially climate change (with the aforementioned negative impacts of renewable energy); trade and regional interconnectivity (e.g. with onshore wind farms and distributed small scale systems). Renewable energy probably provides the best opportunity for a country to become more independent of the vulnerabilities of global energy markets and approach the goal of energy self-sufficiency (Zhao H., 2019) irrespective of its endowment in fossil fuel resources or its access to expensive nuclear energy technology.

Considering Ren J. and Sovacool B.K.'s more detailed presentation of an energy security index (2014), renewable energy enters the dimensions of: availability, as the percentage that represents the total consumed energy; affordability, influencing the total energy produced by distributed and small scale generation (a characteristic of renewable installations); accessibility, by improving the outlook of safety and reliability (as a secondary source); and acceptability, by helping with investment and employment.

The social acceptability of renewable energy has been reviewed by Stigka E. et al. (2014) with empirical research carried out in a later work (Paravantis J. et al., 2018). The socioeconomic and environmental disadvantages of renewable energy were discussed, and the 2014 renewable energy performance was presented for EU countries, with Norway, Sweden, Latvia, Finland, Austria, Portugal and Denmark having high renewable energy usage and being near their targets (Stigka E. et al., 2014). The same source also pointed out that a number of social actors including local communities, local agencies, investors, Non-Governmental

Organizations (NGOs), and local information networks, are involved in renewable energy projects. Opposition to projects is not uncommon, per the NIMBY (Not In My BackYard) phenomenon, which led the authors to review the following barriers to renewable energy projects:

- Economic and institutional factors, such as economic conditions in a region, issues with public or private ownership, lack of financial incentives, high investment costs (compared to fossil fuel alternatives), inefficiencies in the existing legal framework, complex licensing procedures and bureaucratic problems.
- Technical and planning factors, such as local geography and geomorphology, issues with the process of selecting an appropriate site (especially related to its previous usage), and planning problems.
- Environmental and quality of life issues, such as landscape deterioration, visual instruction, noise pollution and vibrations (depending on the distance of residents from the renewable energy installations), disruption of nearby ecosystems, impacts on the quality of life in the area.
- Factors related to public perceptions, such as lack of information or knowledge of renewable energy technologies, mistrust (which ignorance intensifying anxiety), lack of impartiality, and suspicion towards investors.

The latter empirical research (Paravantis J. et al., 2018) found out that income and awareness of renewables are strong determinants of the willingness to accept renewable energy. Although it could be considered that aesthetics would be more of a problem near tourist destinations, where economic, social and cultural factors become involved (Stigka E. et al., 2014), it was found that considerations related to tourism were low in the list of factors affecting the willingness to pay for renewable energy projects. All in all, although renewable energy greatly improves the outlook on greenhouse gas emissions, reduces dependence on fossil fuels, and increases the safety and reliability of the energy supply, steps must be taken to be accepted by local communities. Education and an improvement of the financial situation of families will help build trust, so that the fear of uncontrolled development profits at the expense of the public good is addressed.

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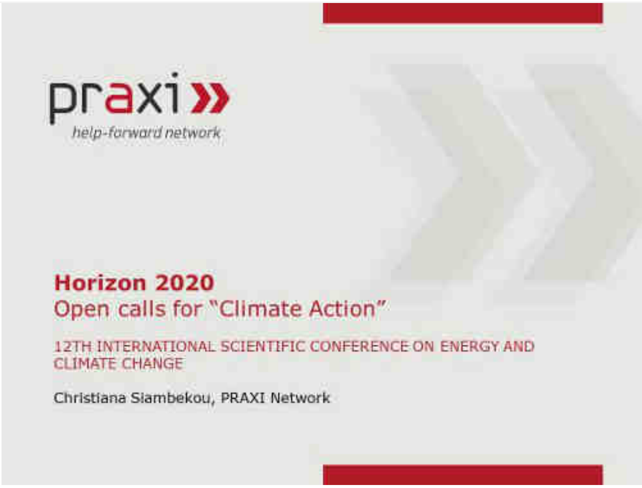
DAY 3: BROKERAGE EVENT

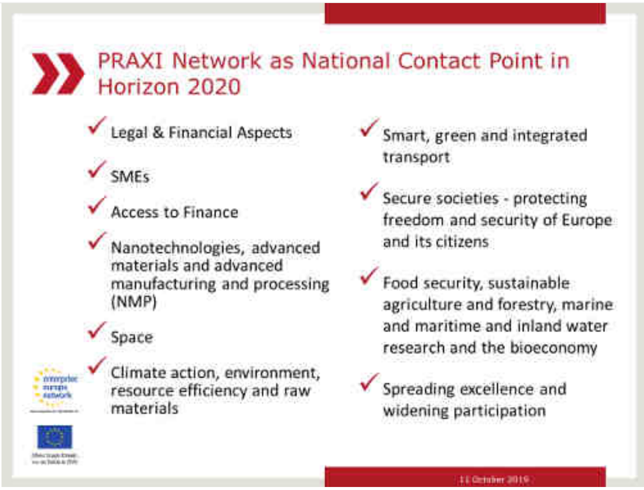
Session A: Funding Opportunities

Horizon 2020 Open calls for “Climate Action”

Mrs. Christianna SIAMBEKOU

PRAXI Network, Greece





Next Framework Programme on Research and Innovation

- Will cover the period 2021-2027
- Indicative budget: 100 billion euros
- Adoption timeline: will be launched by January 2021

➢ For more information, visit the site of EU:

Horizon Europe - the next research and innovation framework programme

11 October 2019

Societal Challenge 5: Climate action, environment, resource efficiency and raw materials

Work Programme 2018-2020

Focus:

- ✓ moving to a greener, more resource efficient and climate-resilient economy in sync with the natural environment
- ✓ demonstrating a strong commitment to supporting the UN's Sustainable Development Goals (SDGs) and the targets of the COP21 Paris Agreement

2 multiannual calls:

"Building a low-carbon, climate resilient future: climate action in support of the Paris Agreement"

"Greening the economy in line with the Sustainable Development Goals (SDGs)"

- Total indicative budget 2018-2020: €1.1bn
- budget for 2020: €391.18m

European Commission

Call "Building a low-carbon, climate resilient future: climate action in support of the Paris Agreement"

- ✓ **Decarbonisation**
- ✓ **Climate adaptation, impacts and services**
- ✓ ***Inter-relations between climate change, biodiversity and ecosystem services***
- ✓ ***The Cryosphere***
- ✓ **Knowledge gaps**
- ✓ ***Earth observation***

➢ **Budget in 2020:** €189.5 million

European Commission

Call "Greening the economy in line with the Sustainable Development Goals (SDGs)"

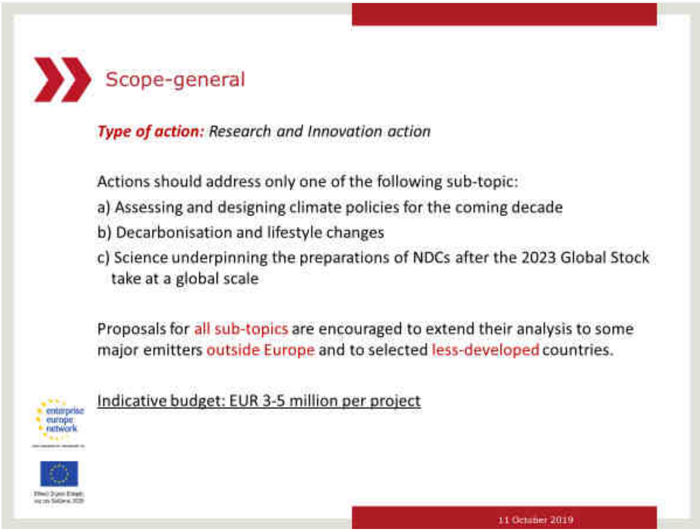
- ✓ **Connecting economic and environmental gains - the circular economy**
- ✓ **Raw materials**
- ✓ **Water for our environment, economy and society**
- ✓ **Innovating cities for sustainability and resilience**
- ✓ **Protecting and leveraging the value of our natural and cultural assets: Earth observation; nature-based solutions, disaster risk reduction and natural capital accounting; heritage alive**

➢ **Budget in 2020:** €128.86 million

European Commission


Call (2020) - Building a low-carbon, climate resilient future: climate action in support of the Paris Agreement
Topic
Type of action
Decarbonisation
LC-CLA-10-2020 RIA
LC-CLA-11-2020 IA
Climate adaptation, impacts and services
LC-CLA-12-2020 RIA
LC-CLA-13-2020 RIA
LC-CLA-23-2020 CSA
Inter-relations between climate change, biodiversity and ecosystem services
LC-CLA-14-2020 RIA
LC-CLA-15-2020 RIA
LC-CLA-16-2020 RIA
The Cryosphere
LC-CLA-17-2020 RIA
LC-CLA-21-2020 CSA
Knowledge gaps
LC-CLA-18-2020 RIA
LC-CLA-22-2020 CSA
Earth Observation
LC-CLA-19-2020 RIA
LC-CLA-20-2020 RIA
11 October 2019


LC-CLA-10-2020: Scientific support to designing mitigation pathways and policies
Specific Challenge:
In the context of the Paris Agreement, all Parties including the EU were invited to submit by 2020 both an update of the Nationally Determined Contributions (NDCs) regarding short term actions up to 2030 as well as long-term greenhouse gas emission development strategies up to 2050. These strategies are expected to underpin the EU's commitment to the Paris Agreement. A reliable policy framework is needed for business and consumers enabling low-carbon consumption, lifestyle and investment decisions. Furthermore, the EU does not act in isolation and cannot achieve the Paris Agreement goals by its own mitigation efforts. Achieving the goals of the Paris Agreement will require a very significant increase of ambition and swift implementation at the global scale. Actions under this topic should provide scientific evidence, analysis and support for these processes and reinforce the link between the latest climate science, mitigation pathways and underlying policies.
11 October 2019


Scope-general
Type of action: Research and Innovation action
Actions should address only one of the following sub-topic:
a) Assessing and designing climate policies for the coming decade
b) Decarbonisation and lifestyle changes
c) Science underpinning the preparations of NDCs after the 2023 Global Stock take at a global scale
Proposals for all sub-topics are encouraged to extend their analysis to some major emitters outside Europe and to selected less-developed countries.
Indicative budget: EUR 3-5 million per project
11 October 2019


Expected impacts
The project results are expected to contribute to:
providing measurable support to the EU's long term strategyon greenhouse gas emission reductions;
providing national and global pathways towards the Paris Agreement's global temperature goal and insights into how these can inform countries' next NDCs;
supporting the Stock take Exercise by taking stock of collective progress towards the Paris Agreement goals and investigating how progress can be accelerated;
demonstrating how the latest climate science can be converted into practical advice for national mitigation action;
11 October 2019

Call (2020) - Greening the economy in line with the Sustainable Development Goals (SDGs)

Topic	Type of action
Connecting economic and environmental gains - the circular economy	
CE-SC5-24-2020	RIA
CE-SC5-25-2020	**RIA**
CE-SC5-28-2020	IA
CE-SC5-29-2020	CSA
CE-SC5-30-2020	RIA
CE-SC5-31-2020	IA
Row materials	
CE-SC5-07-2020	IA
CE-SC5-08-2020	CSA
SC5-10-2020	IA
SC5-26-2020	CSA
Innovating cities for sustainability and resilience	
SC5-27-2020	RIA
Protecting and leveraging the value of our natural and cultural assets: Nature-based solutions, disaster risk reduction and natural capital accounting	
SC5-32-2020	RIA
SC5-33-2020	CSA
Specific support and implementation aspects	
SC5-34-2020	ERA-NET Cofund
SC5-35-2020	ERA-NET Cofund
SC5-36-2020	ERA-NET Cofund

11 October 2019

CE-SC5-25-2020: Understanding the transition to a circular economy and its implications on the environment, economy and society

Specific challenge:

The transition to CE entails a systemic transformation of entire value chains. The understanding of this transition will be important for the development of CE approaches and targeted policy measures. Best practices will serve as an inspiration for projects and inform new and adapted policies and policy tools.

Scope:

Assess current state of CE transition in relevant sectors and analyse possible transition scenarios. Sectors identified in CE Action Plan or others if justified according to environmental footprint etc. Social, economic and environmental aspects. Role of public awareness and acceptance and other social aspects; gender. Attention to the issue of hazardous materials in CE. Policy recommendations at local, national, European and global levels.

Supports European Plastics Strategy → envisage joint activities

Type of action: *Research and Innovation Action, Two-stage*

Indicative budget: EUR 10 million; EUR 3-4 million per project

11 October 2019

Expected impacts

- ✓ *more systemic policy decisions to further facilitate the transition to a safe, environmentally friendly, efficient and effective circular economy in selected sectors*
- ✓ *efficient and effective use of both primary and secondary resources in Europe, reducing waste generation, negative health impacts, environmental pollution and greenhouse gas emissions*
- ✓ *new business opportunities for European industries and SMEs*
- ✓ *creating new tools and methodologies oriented to companies, to consider social, environmental and economic aspects when they design circular business models*
- ✓ *creating incentives and support the development of strategic governance mechanisms that enable the transition to a Circular Economy and contribute to the effective implementation of the Sustainable Development Goals in Europe*
- ✓ *supporting the achievement of climate commitments and specific quantitative targets on resources efficiency, recycling rates or waste disposal quotas*

11 October 2019

Climate Action: Work Programme 2018-2020

2020 topics open:
12 Nov 2019

Call deadlines:
13 Feb 2020 (single/first stage)
3 Sep 2020 (second stage)

11 October 2019

Horizon 2020 SC5 Climate Action - Infoday 2019

Information Day and Brokerage Event

16-17 September 2019, Brussels

More information:
https://ec.europa.eu/easme/en/section/horizon-2020-environment-and-resources/2019-information-days-calls-2020

(All presentations and webstreams are available)

11 October 2019

NCPs CaRE project
http://www.ncps-care.eu

Network of National Contact Points

- Information and networking events
- Support in partner search

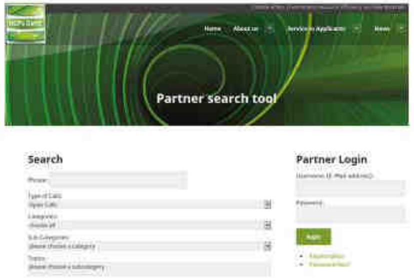
NCPs CaRE

11 October 2019

NCPs CaRE – Partner search tool

Register on the online platform to:

- ✓ Create partnership profiles
- ✓ Search collaboration opportunities



11 October 2019

How can PRAXI Network support you as NCP?

Information

- Dissemination of general information on funding opportunities in H2020
- Organization of info-days and seminars
- Dissemination of partner searches to our clients from consortia around the world
- Dissemination of the information on planned info-days, seminars and workshops organised in Greece and abroad

11 October 2019

How can PRAXI Network support you as NCP?

Provision of support, consulting and training

- Identification of the right call
- Rules and procedures for participation
- Evaluation criteria
- Horizontal issues (e.g. innovation management, commercialization, IPR, legal and financial issues)

11 October 2019

How can PRAXI Network support you as NCP?

Mediation

- With the appropriate members of the Commission responsible for the respective thematic area
- For partner searches to create the best consortia
- With NCPs and partners around the world to promote client profiles
- To signpost you to the right experts for specialized issues outside our scope/expertise

11 October 2019

Explore other EU projects in the field

- CORDIS -EC dissemination platform on FP funded research projects: https://cordis.europa.eu/projects/home_en.html
- EASME data hub -SC5 projects, partners and demonstration sites: https://sc5.easme-web.eu
- Horizon dashboard -data discovery: https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/horizon-dashboard
- Innovation radar: www.innoradar.eu

11 October 2019

Finding partners

- Participant Portal Partner Search https://ec.europa.eu/research/participants/portal/desktop/en/organisations/partner_search.html
- NCPs CaRE Portal for SC5 http://partnersearch.ncps-care.eu
- LinkedIn group "Environment projects & partner search –EASME" https://www.linkedin.com/groups/7001906
- The Enterprise Europe Network: https://een.ec.europa.eu

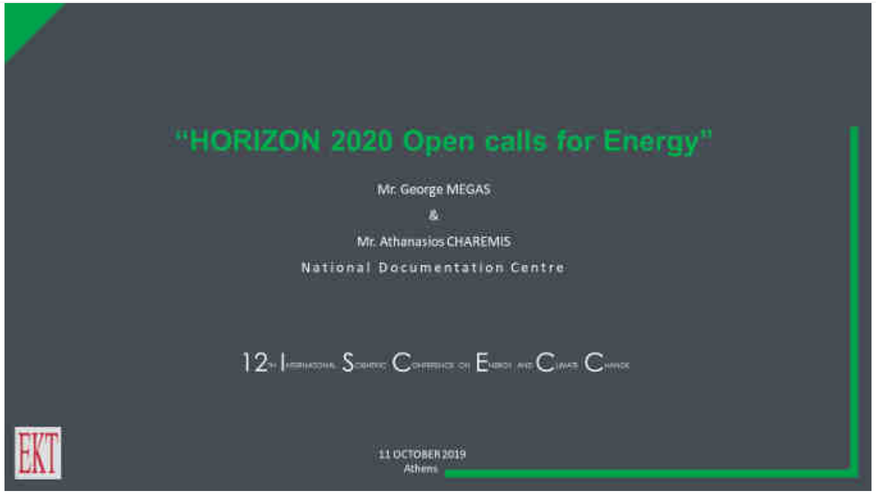
11 October 2019

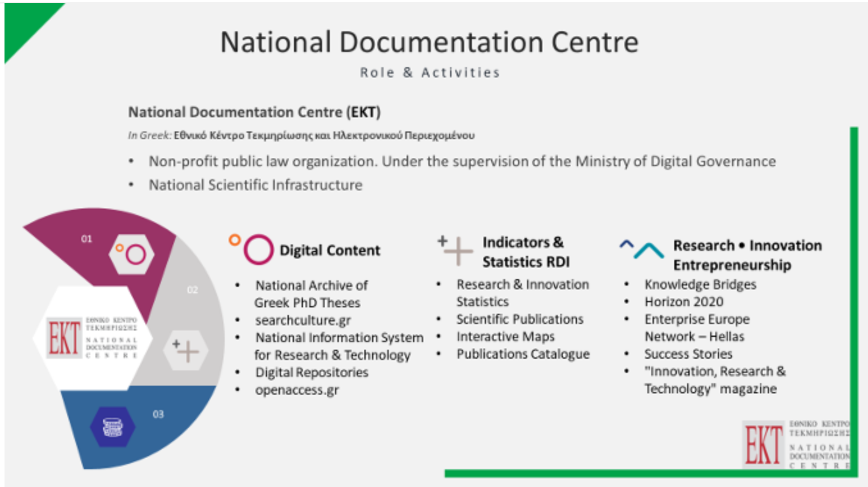

Information sources and support
• H2020 online manual:
http://ec.europa.eu/research/participants/docs/h2020-funding-guide/index_en.htm
• Check the Frequently Asked Questions:
http://ec.europa.eu/research/participants/portal/desktop/en/support/faq.html
• Contact the Horizon 2020 Research Enquiry Service
http://ec.europa.eu/research/index.cfm?lg=en&pg=enquiries
• National Contact Points (NCPs): https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/support/ncp
enterprise europe network
11 October 2019

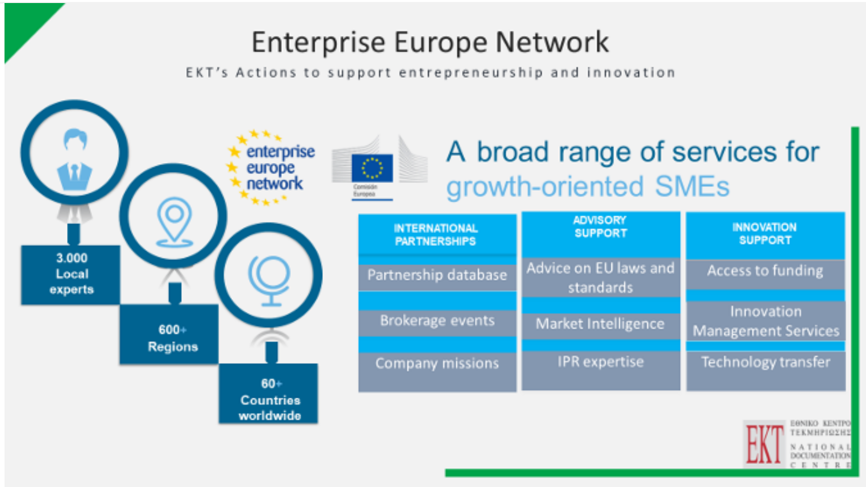

Thank you for your attention
Christiana Siambekou
NCP for H2020 – Climate Action, Environment and Raw materials
siambekou@praxinetwork.gr
Website: www.praxinetwork.gr
e-mail: praxi@praxinetwork.gr
praxinetwork

HORIZON 2020 Open calls for Energy

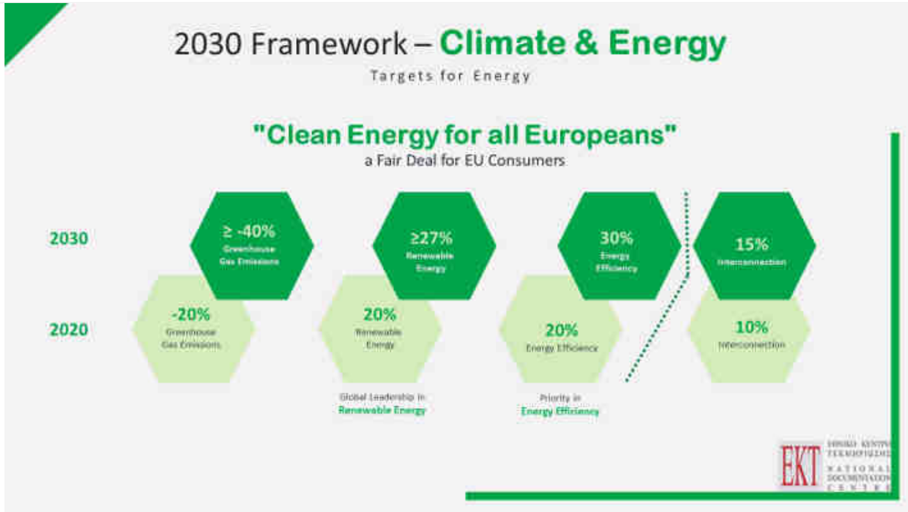
Mr. George MEGAS
National Documentation Centre (EKT/NHRF), Greece



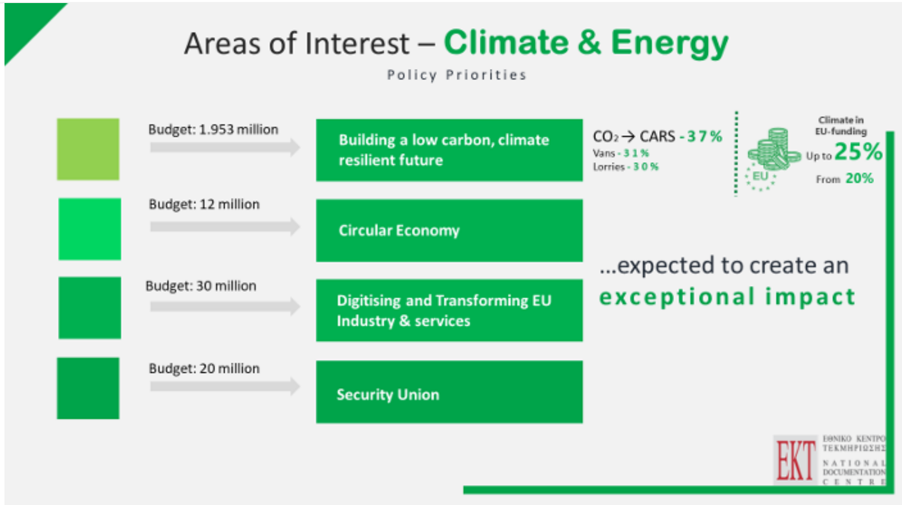





H2020 Work Program 2018-2020
H2020 Work Program 2018-2020
10. Secure, clean and efficient energy
European Commission Decision
C(2019)4575 of 2 July 2019)
Documentation in
Energy
EKT
NATIONAL DOCUMENTATION CENTRE


2030 Framework – Climate & Energy
Targets for Energy
"Clean Energy for all Europeans"
a Fair Deal for EU Consumers
2030
2020
≥ -40%
Greenhouse Gas Emissions
-20%
Greenhouse Gas Emissions
≥27%
Renewable Energy
20%
Renewable Energy
Global Leadership in Renewable Energy
30%
Energy Efficiency
20%
Energy Efficiency
Priority in Energy Efficiency
15%
Interconnection
10%
Interconnection
EKT
NATIONAL DOCUMENTATION CENTRE

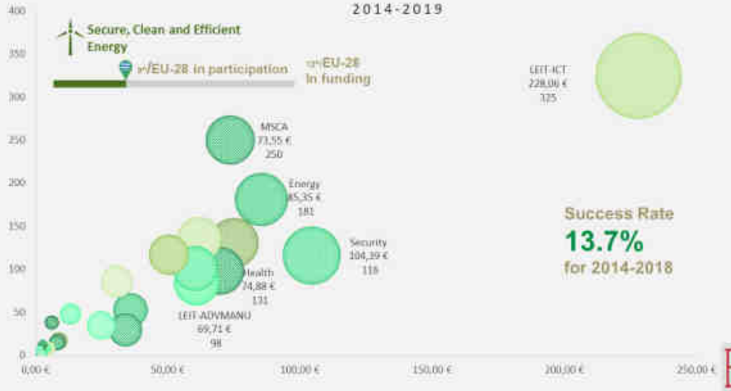

Priority Actions
Energy
Improving performance and reducing cost of renewable energy
Smart solutions for consumers
Smart Resilient and Secure Energy System
Energy Efficiency in Buildings
Energy Efficiency in Industry
Batteries and e-Mobility
Renewable Fuels and Bioenergy
Carbon Capture Utilization and Storage
Nuclear Safety
EKT
NATIONAL DOCUMENTATION CENTRE


Areas of Interest – Climate & Energy
Policy Priorities
Budget: 1.953 million
Building a low carbon, climate resilient future
Budget: 12 million
Circular Economy
Budget: 30 million
Digitising and Transforming EU Industry & services
Budget: 20 million
Security Union
CO2 → CARS - 37%
Vans - 31%
Lorries - 30%
Climate in EU-funding
Up to 25%
From 20%
EU
...expected to create an
exceptional impact
EKT
NATIONAL DOCUMENTATION CENTRE

Greece Performance in H2020

EU Funding & No grants by Priority

2014-2019



Success Rate

13.7%

for 2014-2018

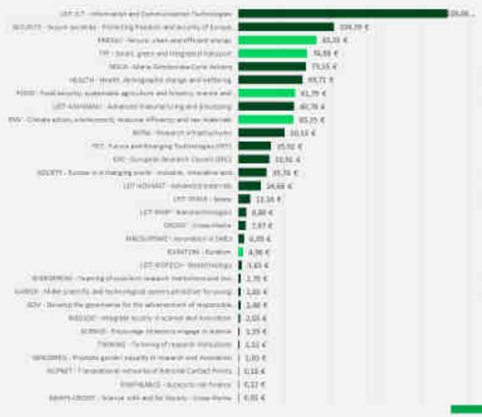
Greece Performance in H2020

SC3 – Energy major grants/ 2014-2019

	Topic	Topic Descr	H2020 Signed Grants	H2020 EU Contribution
1	LCE-02-2016	Demonstration of smart grid, storage and system integration technologies with increasing share of renewables: distribution system	3	€ 6.693.288
2	LCE-07-2016-2017	Developing the next generation technologies of renewable electricity and heating/cooling	7	€ 4.658.125
3	LC-SC3-ES-5-2018-2020	TSO – DSO – Consumer: Large-scale demonstrations of innovative grid services through demand response, storage and small-scale (RES) generation	2	€ 3.951.833
4	LCE-04-2017	Demonstration of system integration with smart transmission grid and storage technologies with increasing share of renewables	2	€ 3.876.156
5	LC-SC3-ES-1-2019	Flexibility and retail market options for the distribution grid	3	€ 3.865.791
6	LCE-08-2014	Local / small-scale storage	1	€ 3.544.742
7	LCE-01-2016-2017	Next generation innovative technologies enabling smart grids, storage and energy system integration with increasing share of renewables: distribution network	6	€ 3.404.625
8	LC-SC3-RES-4-2018	Renewable energy system integrated at the building scale	3	€ 3.348.150
9	LC-SC3-ES-3-2018-2020	Integrated local energy systems (Energy islands)	5	€ 3.286.816
10	LCE-07-2014	Distribution grid and retail market	2	€ 3.124.213
11	SMEInst-09-2016-2017	Stimulating the innovation potential of SMEs for a low carbon and efficient energy system	7	€ 2.954.181
12	EE-12-2017	Integration of Demand Response in Energy Management Systems while ensuring interoperability through Public Private Partnership (EeB PPP)	2	€ 1.896.156
13	EE-07-2016-2017	Behavioural change toward energy efficiency through ICT	4	€ 1.806.689
14	LC-SC3-ES-4-2018-2020	Decarbonising energy systems of geographical islands	3	€ 1.795.319
15	SCC-1-2016-2017	Smart Cities and Communities lighthouse projects	2	€ 1.770.231
16	EE-11-2015	New ICT-based solutions for energy efficiency	3	€ 1.703.207
17	LC-SC3-RES-6-2018	Demonstrate significant cost reduction for Building Integrated PV (BIPV) solutions	1	€ 1.654.580
18	LCE-14-2015	Market uptake of existing and emerging sustainable bioenergy	4	€ 1.608.281
19	FCH-02.1-2014	Research in electrolysis for cost effective hydrogen production	1	€ 1.248.350
20	LC-SC3-RES-21-2018	Development of next generation biofuels and alternative renewable fuel technologies for road transport	2	€ 1.187.613

Greece Performance in H2020

EU Funding & No grants by Priority / 2014-2019



Despite SC3 calls, for Energy keep an eye on other Horizon 2020 priorities

Bottom-up activities

- European Research Council (ERC)
- European Innovation Council (SME instrument, FTI pilot, FET)
- Marie Sklodowska Curie Actions

Industrial Leadership

- Materials
- PPPs on Energy efficient Buildings and SPIRE
- Information and Communication Technologies
- Space and aviation

Societal Challenges (SC)

- SC2: Bioeconomy, Blue Growth
- SC4: Electric vehicles, Batteries, Energy efficient transport
- SC5: Cities
- SC7: Cybersecurity, Critical energy infrastructure

Open calls for Energy

Keywords:	Industrial waste heat/cooling recovery, EPAC, Intergration, energy skills, smart services, Energy Union	Big Data, Smart Finance, heating/cooling for hot water, sustainability, public sector, optimization	REntech, CIEntech, storage, thin-film photovoltaic technologies, floating wind farms, photovoltaic plants, sustainable hydropower solutions, biofuels from aquatic biomass, CSP, next-generation Tech	Cooperation, informed decision-making, energy transition, energy poverty
	Energy efficiency 1.	Buildings in energy transition (B4E) 2.	Global leadership in renewables 3.	Smart and clean energy for consumer 4.

Open calls for Energy

5.	6.	7.	8.	9.
Smart citizen-centred energy system	2 calls for Smart Cities and Communities + 1 call Smart Airports	Enabling near-zero CO₂ emissions	Joint Actions	Cross-cutting issues
Integrated local energy systems (Energy islands), Smart Grids, Flexibility and Local Energy Networks, Digitalisation of Energy	–	Low carbon industrial production using CCUS, Geological Storage Pilots	EU-Africa co-operation	Cross-sector, Research, innovation and educational capacities for energy transition, coal transition,

Open calls for Energy

	Topic	Budget (EUR) - Year : 2020	Stages	Opening date	Deadline
1	LC-SC3-RES-10-2020 - PCP Pre-Commercial Procurement	15.000.000	single-stage	26 September 2019	26 March 2020
2	LC-SC3-JA-5-2020 - RIA Research and Innovation action	15.000.000	single-stage	26 September 2019	26 March 2020
3	LC-SC3-RES-26-2020 - RIA Research and Innovation action	8.000.000	single-stage	03 December 2019	21 April 2020
4	LC-SC3-RES-32-2020 - RIA Research and Innovation action	8.000.000	single-stage	03 December 2019	21 April 2020
5	LC-SC3-RES-31-2020 - RIA Research and Innovation action	8.000.000	single-stage	03 December 2019	21 April 2020
6	LC-SC3-RES-18-2020 - RIA-LS Research and Innovation action Lump Sum	8.000.000	single-stage	03 December 2019	21 April 2020
7	LC-SC3-RES-1-2019-2020 - RIA Research and Innovation action	45.000.000	single-stage	03 December 2019	21 April 2020
8	LC-SC3-RES-37-2020 - RIA Research and Innovation action	6.000.000	single-stage	03 December 2019	21 April 2020
9	LC-SC3-RES-19-2020 - IA Innovation action	25.000.000	single-stage	03 September 2019	11 December 2019
10	LC-SC3-RES-33-2020 - IA Innovation action	20.000.000	single-stage	03 September 2019	11 December 2019
11	LC-SC3-RES-9-2020 - IA Innovation action	20.000.000	single-stage	03 September 2019	11 December 2019
12	LC-SC3-RES-28-2018-2019-2020 - CSA Coordination and support action	25.000.000	single-stage	03 September 2019	11 December 2019
13	LC-SC3-RES-35-2020 - IA Innovation action	10.000.000	single-stage	03 September 2019	11 December 2019
14	LC-SC3-RES-27-2020 - IA Innovation action	10.000.000	single-stage	03 September 2019	11 December 2019
15	LC-SC3-B4E-12-2020 - CSA Coordination and support action	3.000.000	single-stage	05 March 2020	10 September 2020
16	LC-SC3-B4E-4-2020 - CSA Coordination and support action	6.000.000	single-stage	05 March 2020	10 September 2020
17	LC-SC3-B4E-13-2020 - CSA Coordination and support action LC-SC3-B4E-11-2020 - CSA Coordination and support action	16.000.000	single-stage	05 March 2020	10 September 2020
18	LC-SC3-B4E-3-2020 - IA Innovation action	8.000.000	single-stage	05 March 2020	10 September 2020
19	LC-SC3-EC-5-2020 - CSA Coordination and support action	9.000.000	single-stage	05 March 2020	10 September 2020
20	LC-SC3-EC-2-2018-2019-2020 - CSA Coordination and support action LC-SC3-EC-1-2018-2019-2020 - CSA Coordination and support action	12.000.000	single-stage	05 March 2020	10 September 2020
21	LC-SC3-B4E-14-2020 - CSA Coordination and support action	6.000.000	single-stage	05 March 2020	10 September 2020
22	LC-SC3-B4E-2-2020 - CSA Coordination and support action	4.000.000	single-stage	05 March 2020	10 September 2020
23	LC-SC3-B4E-12-2020 - CSA Coordination and support action	3.000.000	single-stage	16 July 2019	15 January 2020
24	LC-SC3-B4E-7-2020 - CSA Coordination and support action	4.000.000	single-stage	16 July 2019	15 January 2020
25	LC-SC3-B4E-5-2020 - IA Innovation action	3.000.000	single-stage	16 July 2019	15 January 2020

Open calls for Energy

	Topic	Budget (EUR) - Year : 2020	Stages	Opening date	Deadline
26	LC-SC3-B4E-1-2020 - CSA Coordination and support action	7.000.000	single-stage	16 July 2019	15 January 2020
27	LC-SC3-B4E-6-2020 - IA Innovation action	12.000.000	single-stage	16 July 2019	15 January 2020
28	LC-SC3-B4E-8-2020 - IA Innovation action	7.000.000	single-stage	16 July 2019	15 January 2020
29	LC-SC3-B4E-10-2020 - IA Innovation action	6.000.000	single-stage	16 July 2019	15 January 2020
30	LC-SC3-EC-4-2020 - RIA Research and Innovation action	10.000.000	single-stage	16 July 2019	15 January 2020
31	LC-SC3-B4E-9-2020 - CSA Coordination and support action	1.500.000	single-stage	16 July 2019	15 January 2020
32	LC-SC3-CC-1-2018-2019-2020 - RIA Research and Innovation action	10.000.000	single-stage	05 May 2020	01 September 2020
33	LC-SC3-RES-25-2020 - RIA Research and Innovation action	5.000.000	single-stage	05 May 2020	01 September 2020
34	LC-SC3-CC-7-2020 - RIA Research and Innovation action	5.000.000	single-stage	05 May 2020	01 September 2020
35	LC-SC3-SCC-2-2020 - ERA-NET-Cofund ERA-NET Cofund	5.000.000	single-stage	05 May 2020	01 September 2020
36	LC-SC3-RES-34-2020 - IA Innovation action	10.000.000	single-stage	05 May 2020	01 September 2020
37	LC-SC3-NZE-6-2020 - RIA Research and Innovation action	14.000.000	single-stage	05 May 2020	01 September 2020
38	LC-SC3-RES-20-2020 - IA Innovation action	10.000.000	single-stage	05 May 2020	01 September 2020
39	LC-SC3-RES-36-2020 - RIA Research and Innovation action	5.000.000	single-stage	05 May 2020	01 September 2020
40	LC-SC3-RES-3-2020 - RIA Research and Innovation action	10.000.000	single-stage	05 May 2020	01 September 2020
41	LC-SC3-EC-3-2020 - IA Innovation action	16.000.000	single-stage	03 September 2019	29 January 2020
42	LC-SC3-SCC-1-2018-2019-2020 - IA Innovation action	55.000.000	single-stage	03 September 2019	29 January 2020
43	LC-SC3-ES-12-2020 - IA Innovation action	9.000.000	single-stage	03 September 2019	29 January 2020
44	LC-SC3-ES-3-2018-2020 - IA Innovation action	15.000.000	single-stage	03 September 2019	29 January 2020
45	LC-SC3-ES-10-2020 - IA Innovation action	14.000.000	single-stage	03 September 2019	29 January 2020
46	LC-SC3-ES-4-2018-2020 - IA Innovation action	40.000.000	single-stage	03 September 2019	29 January 2020
47	LC-SC3-ES-11-2020 - IA Innovation action	4.000.000	single-stage	03 September 2019	29 January 2020
48	LC-SC3-SA-1-2020 - IA Innovation action	12.000.000	single-stage	03 September 2019	29 January 2020
49	LC-SC3-ES-5-2018-2020 - IA Innovation action	22.000.000	single-stage	03 September 2019	29 January 2020
		601.500.000			

NEXT-GENERATION BATTERIES

- NEXT-GENERATION BATTERIES
- Advanced Li-ion Tech (Gen3b)
- Next generation solid-state Li-ion technologies (Gen4)
- Technologies for stationary storage apps
  - smartphones, smart homes, smart wearables
- Research Pilot Line network

- Technology - Innovation
  - Sand battery gives three times more battery life (ex. lithium-ion battery uses silicon)
  - Capturing energy from Wi-Fi
  - Gold nanowire batteries (Hilander battery - recharged 200.000 times/3 months)
  - Solid state lithium-ion (Fast-charging batteries using sulfide superionic conductors - 7 mins)
  - Graphene batteries
  - Laser-made micro supercapacitors
  - paper-like battery
- Product Specific Characteristics
  - **Energy & Power Density**
  - **Life-Cycle, Life-Time**
  - **Charging rate**
  - **Temperature – stability**
  - **Safety**
  - **Cost efficiency methods**
  - **Manufacturing – market access**

Open calls for **Energy**

NEXT-GENERATION BATTERIES

- The Energy Challenge contributes to the call "Building a low-carbon, climate resilient future: Next-generation Batteries" (call identifier H2020-LC-BAT-2019-2020), in particular as regards the topics:
  - LC-BAT-2-2019: Strengthening EU materials technologies for non-automotive battery storage
  - LC-BAT-3-2019: Modelling and simulation for Redox Flow Battery development
  - LC-BAT-4-2019: Advanced Redox Flow Batteries for stationary energy storage
- For 2020, the following topics are indicated:
  - LC-BAT-8-2020: Next-generation batteries for stationary energy storage
  - LC-BAT-9-2020: Hybridisation of battery systems for stationary energy storage

Energy Poverty

vulnerable consumers in the energy sector across the EU

- Results from other projects:
  - *...on average, over 140€ and 300kg CO_2 savings per household.*
  - *Recommendations include publicly funded finance schemes and regulatory mechanisms targeted at improving the energy efficiency performance of the building envelope.*
  - *Energy consultations and energy efficiency interventions resulted in savings of around 35-228€ per households.*
  - *Identification of barriers impeding energy efficiency improvements in buildings; Key strategic areas to ensuring achieving EU 2020 energy efficiency in buildings targets (territorial and financial governance, competetiveness, economic activities and employment; market activation; smart energy management systems and services).*
  - *Promotion of adoption of local fuel poverty action plans.*
  - *Used a geographical analysis to estimate the level of fuel poverty in each of the cities based on the real estate prices, average income levels and estimated energy demand for space heating. All cities were assessed using the same criteria: low income, high energy prices, energy performance of buildings.*

Thank You

Open calls for **Energy**

Energy efficiency

- LC-SC3-EE-3-2019-2020: Stimulating demand for sustainable energy skills in the construction sector
- LC-SC3-EE-4-2019-2020: Upgrading smartness of existing buildings through innovations for legacy equipment
- LC-SC3-EE-17-2019: European City Facility - European cities as key innovation hubs to unlock finance for energy efficiency
- LC-SC3-EE-18-2019: Bioclimatic approaches for improving energy performance in buildings in Africa and Europe

Global leadership in renewables

- LC-SC3-RES-1-2019-2020: Developing the next generation of renewable energy technologies
- LC-SC3-RES-29-2019: Converting Sunlight to storable chemical energy
- LC-SC3-RES-7-2019: Solar Energy in Industrial Processes
- LC-SC3-RES-8-2019: Combining Renewable Technologies for a Renewable District Heating and/or Cooling System
- LC-SC3-RES-14-2019: Optimising manufacturing and system operation
- LC-SC3-RES-15-2019: Increase the competitiveness of the EU PV manufacturing industry
- LC-SC3-RES-16-2019: Development of solutions based on renewable sources that provide flexibility to the energy system
- LC-SC3-RES-17-2019: Demonstration of solutions based on renewable sources that provide flexibility to the energy system
- LC-SC3-RES-30-2019: Demonstration of plug and play solutions for renewable off-grid electricity
- LC-SC3-RES-23-2019: Development of next generation biofuel and alternative renewable fuel technologies for aviation and shipping
- LC-SC3-RES-24-2019: Boosting pre-commercial production of advanced aviation biofuels
- LC-SC3-RES-28-2018-2019-2020: Market Uptake support


Open calls for Energy
Energy efficiency
LC-SC3-EE-3-2019-2020: Stimulating demand for sustainable energy skills in the construction sector
LC-SC3-EE-4-2019-2020: Upgrading smartness of existing buildings through innovations for legacy equipment
LC-SC3-EE-17-2019: European City Facility - European cities as key innovation hubs to unlock finance for energy efficiency
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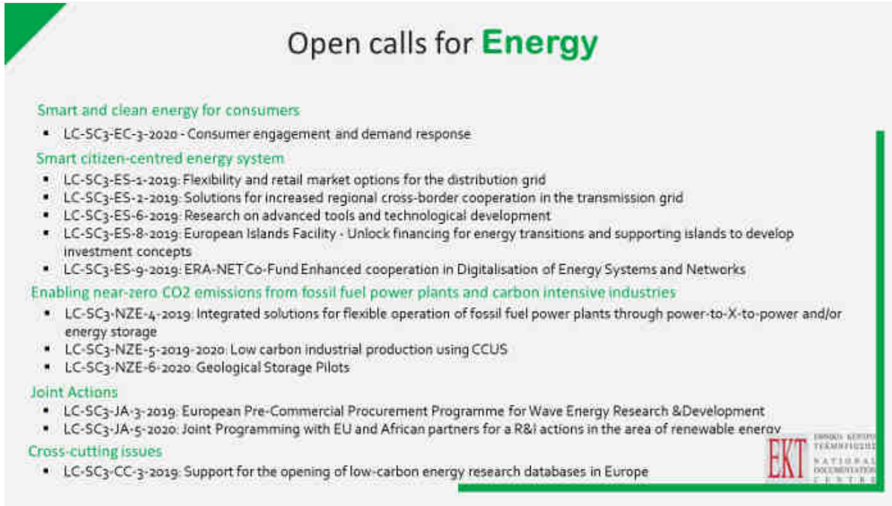
LC-SC3-RES-28-2018-2019-2020: Market Uptake support
EKT


Open calls for Energy
Smart and clean energy for consumers
LC-SC3-EC-3-2020 - Consumer engagement and demand response
Smart citizen-centred energy system
LC-SC3-ES-1-2019: Flexibility and retail market options for the distribution grid
LC-SC3-ES-2-2019: Solutions for increased regional cross-border cooperation in the transmission grid
LC-SC3-ES-6-2019: Research on advanced tools and technological development
LC-SC3-ES-8-2019: European Islands Facility - Unlock financing for energy transitions and supporting islands to develop investment concepts
LC-SC3-ES-9-2019: ERA-NET Co-Fund Enhanced cooperation in Digitalisation of Energy Systems and Networks
Enabling near-zero CO2 emissions from fossil fuel power plants and carbon intensive industries
LC-SC3-NZE-4-2019: Integrated solutions for flexible operation of fossil fuel power plants through power-to-X-to-power and/or energy storage
LC-SC3-NZE-5-2019-2020: Low carbon industrial production using CCUS
LC-SC3-NZE-6-2020: Geological Storage Pilots
Joint Actions
LC-SC3-JA-3-2019: European Pre-Commercial Procurement Programme for Wave Energy Research &Development
LC-SC3-JA-5-2020: Joint Programming with EU and African partners for a R&I actions in the area of renewable energy
Cross-cutting issues
LC-SC3-CC-3-2019: Support for the opening of low-carbon energy research databases in Europe
EKT

Youth Contest “Clean Energy in the combat for climate change

Mrs. Vivian KLEIDERI,
Association of Phycists, Greece

Brokerage Event

11 October 2019, Athens – Greece
"Kostis Palamas", Akadimias 48 and Sina street

12th International Scientific Conference on Energy and Climate Change

Youth Contest
‘Clean Energy in the Combat for Climate Change’

Vivian Kleideri – General Secretary of Association of Physicists in Greece

Introduction

- The Association of Greek Physicists (Hellenic Physical Society - E.E.F.) and the Energy Policy and Development Centre (KEPA) of the National and Kapodistrian University of Athens (NKUA) with the latter holding the dual status of the United Nations Academic Initiative (UNAI) Hub for the 7th Sustainable Development Goal (SDG7) and Coordinator of the Green Energy Network (GEN) of the Black Sea Economic Cooperation Organization (BSEC), agree on the need to seek and implement proposals for the promotion of actions and programs relevant with the SDG7 as this is defined by the United Nations (UN).

The Proposal

- One of these proposals that has already been launched in Greece is the Contest “Clean energy for the combat against Climate Change”. The purpose of the Contest is the creative and innovative mobilisation of young people, at national, regional and international level, in actions that promote the initiatives of the UNAI Hub for the SDG7, and lead to measurable reductions of Global Heating Gas (GHG) emissions. The ultimate aim is to increase the ambition of local communities to accelerate the "green" transformation of local economies (SDG7) as a prerequisite for economic development and support for climate change response efforts (SDG13).

The Contest

- The “Clean energy for the combat against Climate Change” Contest is a two-year International Youth Contest in Greece to develop and implement Clean Energy (SDG7) action plans in **educational building facilities** leading to measurable GHG reductions (SDG13).
- High school/university students aggregated in groups and motivated by their professors, in close cooperation with public authorities and market forces, will develop and implement action plans. Students will not only design it on paper, but will be called to put their thinking and plans on actual execution.

The Contest

- The first annual round of the contest awards the best national action plans. The second awards the highest achieved GHG emission reductions through these action plans. Additional awards are foreseen for the best impact in local societies. Annual summer schools are foreseen for motivators and delegates from the youth-groups.
- Further planning includes webinars for knowledge transfer for motivators and groups, a "group of excellence" from students and awards for innovative proposals.
- Outcomes will be disseminated to the countries of the Black Sea Economic Cooperation (BSEC) and worldwide (UNAI Hub for SDG7).

Target Groups

- Key activities concern all target groups. Students are expected to be multipliers for know-how in Electronic Evolution (EE) issues throughout their country, Europe & world.
- End-users: School-aged/universities students today, responsible energy-users tomorrow. Contest motivates them along with families/local societies in: behavioural change in energy use; climate change mitigation; adoption of EE technologies; dialogue within local communities for climate action.
- Local market forces: Planned actions support economic development & penetration of EE technologies/services from local market due to motivated youth.
- Municipal authorities: key activities facilitate them in achieving SEAPs (Sustainable Energy Action Plan); exchange knowledge, experience/best practices; develop local/regional EE concepts, test them in pilot projects; share successful approaches with other entities in EU.
- Central government: 3% of the total floor area of heated and/or cooled buildings owned/ occupied by central government ought to be renovated annually (EE Directive).

Impacts

- Contribution to national targets for GHG emissions: More environmentally sensitive citizens, more effective policies.
- Establishment of a long-term coordination mechanism that activates all target groups in the educational field, not only nationally, but regionally (BSEC), European and internationally (UNAI): KEPA is the UNAI Hub for SDG7 and is able step by step to promote internationally the contest.
- Support national, regional and international efforts in meeting the long-term energy/climate goals: The contest supports SDGs & Paris Agreement targets. It channels the youth climate change protests into actions.

Impacts

- Gradual inclusion of topics about Climate Change, EE/RES, SDGs and green economy in educational field: One of the main barriers for policy implementation is inadequate awareness and lack of knowledge on these issues. The contest creates the framework and the momentum to enrich the skills and capacities of youngsters and encourage them to think differently, while opening new horizons for future employment and professional development and fostering environmental awareness.

Conclusion

- Energy saving is a priority of the National Plan for Energy and Climate, which was submitted to the European Commission in January 2019.
- The country has an obligation as a Member State of the European Union to contribute to joint efforts for tackling climate change and achieving the objectives of the Paris Agreement.
- The competition is an opening to the interest and awareness expressed by young people across Europe concerning energy and environmental issues, seeking to secure the future of the planet in which we live.
- We only have one planet and we must take care of it!

Thank you very much!

https://youthcontestzeroenergyschools.wordpress.com

Energy School of Municipality Mouzaki

Mr. Evangelos KATSAROS,
Municipality of Mouzaki, Greece

A few words about the ZEMedS Program

✓The ZEMedS program is co-funded by the European Union under the Intelligent Energy Program (IEE), and promotes the renovation and construction of new Mediterranean schools in Nearly Zero Energy Conservation Buildings (nZEB).

✓The main goals of ZEMeds are to enhance nZEB know-how and support stakeholders, public organizations, building designers, builders and other professionals, with high quality tools focused on the technical and financial aspects of nZEB Middle School Renovation .

✓The program incorporates detailed information on the benefits, technical strategies, technologies available, public and private funding mechanisms and best practice studies for nZEB school upgrading. ZEMedS Strategic Upgrading Sets High Energy Goals by Ensuring Indoor Quality of School Buildings

nZEB in a nutshell: Energy

Reduction of Energy Requirements and Renewable Energy Needs Coverage

(a) Annual primary energy consumption to be covered by renewables: CPE - ProdRES ≤ 0

Where:

- CPE: Annual Primary Energy Consumption for All Uses (In Harmonization with National Primary Energy Indicators)
- ProdRES: Renewable energy produced

(b) Total energy consumption:

- CFE ≤ 25 kWh / m heat. Surface² year
- Heating, cooling, ventilation: CHVAC ≤ 20 kWh / m².year
- Lighting: Clighting ≤ 5 kWh / m².year

- BASIC STRATEGIES
- UFaçade: 0.20-0.40 W / m2K
- URoofs: 0.15-0.30 W / m2K
- UWindows: 1.40-1.80 W / M2k
- Solar protection is required
- Limited air leakage
- Basics for successful nZEB design:
- - Complete approach
- - Collaboration with users
- - Energy management
- - Monitoring, supervision

nZEB in short: Indoor Quality (IEQ)

- Ensure good indoor air quality and adequate thermal, optical and acoustic comfort
- The recommended value of carbon dioxide concentration within schools:
- CO_2 ≤ 1000 ppm
- In addition, the recommended concentrations for VOCs <0.05 ppm
- and particles
- PM10 <50 μg / m3 (24 hour average)

- BASIC STRATEGIES
- Ventilation rating: 5 -13 (l / s per person) Average amount: 8 l / s per person
- The ventilation strategy can vary depending on location and local climate, between natural ventilation and fully automated artificial heat recovery ventilation (taking into account many intermediate solutions)
- The use of non-toxic materials and the right choice of ventilation filters help improve air quality

nZEB in short: Thermal Comfort

Indoor Thermal Comfort Conditions:

- Minimum temperature in winter: 19-21°C
- Maximum summer temperature: 25-27°C
- Overheating (internal temperature greater than 28°C) should be limited to 40 hours per year

- T air above 28 ° C ≤ 40 hours / year

Motivations

✓Climate change is the dominant challenge and energy saving in the building sector is at the forefront of the fight to reduce carbon dioxide emissions

✓Schools represent a large proportion of public buildings. There are about 87,000 schools in the Mediterranean regions of Italy, Greece, Spain and France

✓In the area of energy saving in buildings, the interest in school buildings is extremely high: school design has specific energy requirements but must also guarantee high levels of indoor environment.

Study of the 2nd Elementary School of Mouzaki N. Karditsa Bioclimatic - Passive - Intelligent Building Almost Zero Energy Consumption Buildings nZEB
Evangelos D. Katsaros Civil Engineer AUTh.

nZEB definition in ZEMedS

✓Due to the lack of numerical indicators for achieving nZEB in the context of this and ZEMeds the targets are numerically set

✓School of zero energy consumption is one whose annual energy balance (in primary energy) is zero

✓In addition, the permissible maximum final energy consumption is 25 kWh / m2 / year

✓Finally, good internal conditions (IEQ) are guaranteed, at least in terms of air quality and thermal comfort

Study of the 2nd Elementary School of Mouzaki N. Karditsa Bioclimatic - Passive - Intelligent Building Almost Zero Energy Consumption Buildings nZEB
Evangelos D. Katsaros Civil Engineer AUTh.

nZEB definition in ZEMedS

✓Primary Energy from conventional sources covered by renewable energy sources

0 kWh / m².year (annual balance)

✓Final energy consumption (all uses except hot water and cooking)

CFE ≤ 25 kWh / m².year

✓Thermal conditions

40 hours above 28°C per year

✓Quality assurance of internal conditions

CO_2 ≤ 1000 ppm

Study of the 2nd Elementary School of Mouzaki N. Karditsa Bioclimatic - Passive - Intelligent Building Almost Zero Energy Consumption Buildings nZEB
Evangelos D. Katsaros Civil Engineer AUTh.

Basic criteria for nZEB in Mediterranean schools

nZEB schools: requirements

- **Required 1**
- A zero energy school is one whose annual energy balance for non-renewables is close to zero
- **Required 2**
- A zero-energy school has a maximum permissible final energy consumption of about 25 kWh / m2 .y
- **Required 3**
- A zero-energy school ensures a healthy environment and comfort for building users

Methodology

- **We carry out a "dynamic thermal simulation"**
  - To validate the projected final energy consumption
  - To validate the thermal comfort target
  - To help decision makers optimize proposed interventions
- **We calculate other energy consumption**
  - To estimate the consumption of hot water
  - To estimate the specific electrical consumption depending on the appliances
  - To determine the equipment with the highest energy consumption
- **We are doing a RES study**
  - To appreciate the local energy potential
  - To determine the techno-economic feasibility
  - To consider, if necessary, nearby or network RES

Methodology

- **Measurement of airtightness of the building**
  - After work, a measurement is performed to evaluate the implementation in accordance with the specific requirements of the program and to apply corrective measures.
- **Monitoring of the building**
  - To measure actual consumption per use
  - To measure indoor conditions in order to evaluate the comfort and quality of the environment
  - Adopting remedies or new actions to optimize the use of the building
  - To support a communication plan involving users

Remarks

- The NZEB objectives need to support an integrated approach, including dynamic simulations. Current regulatory processes in Italy, France, Spain and Greece do not allow the objectives of a ZEMedS approach to be achieved.
- NZEB goals are more difficult to achieve in a renovation / upgrade than in new buildings
- The NZEB goals are a long-term approach. Many measures may not prove effective if taken separately
- Why an absolute price? Because with the NZEB approach we are talking about the same energy result. If the energy target is a relevant criterion (eg -70% of thermal demand), energy consumption varies for each building due to different starting points
- In some cases, the NZEB approach is simply not feasible
- In addition to the work, it is necessary to organize the maintenance / use of the school to maintain the level of efficiency. The NZEB approach is not just for one year
- Users should be provided with documentation and instructions. The NZEB approach is related to the energy behavior of the user

Legislative and regulatory compliance

European Legal Framework

- **Three guidelines** promote the public effort to upgrade and energy efficient buildings:
- **- Energy Performance of Buildings Directive (EPBD):** The directive sets various requirements, including the need for public buildings to be almost zero energy consumption by 2019 and all new buildings by 2021. It also requires from Member States to set a minimum energy efficiency requirement for new and refurbished buildings in order to achieve an optimum cost level.
- **- Energy Efficiency Directive (EED):** The directive contains a series of mandatory measures aimed at achieving energy savings in all sectors and requires Member States to establish a long-term strategy to mobilize investment in housing renovation and commercial buildings
- **- Renewable Energy Directive (RED):** The directive is part of the legislation leading to the development of renewable energy solutions in buildings and their integration into local energy infrastructures.

European Legal Framework

- The nearest definition for a nZEB building at European level is referred to in the Energy Performance of Buildings Directive EPBD, Article 2, as' a building which has a very high energy efficiency. The almost zero or very low amount of energy required should be largely covered by renewables, including energy from renewables either in or near the same site. "
- The same directive states that "Member States should ensure that by 31 December 2020 all new buildings are virtually zero energy, and after 31 December 2020 all new buildings which will either be owned or used by public authorities. principles will be almost zero energy "
- Member States will also "develop national plans to increase the number of near-zero energy buildings and, following the public sector leadership, will develop policies and take appropriate measures such as setting targets to enhance the renovation of the buildings in question." to become almost zero-energy buildings

Greek National Framework

- **nZEB Definition: To date there is no national legislation incorporating Directive 2012/27 EED as regards the definition of nZEB, which includes both a numerical target and the percentage of renewable energy sources.**
- **Legislative Framework: Law N.3851 / 2010 on RES (FEK 85 / A / 4.6.2010); All public buildings from 2015 and all new buildings from 2020 should cover primary energy consumption from RES, combined heat and power generation, local heating or cooling, and energy efficient heat pumps. National targets by 2020: 20% contribution from RES to national gross final energy consumption (from 5% in 2007), 40% to gross electricity generation (from 4.6% in 2007), and 20% to final energy consumption for heating and cooling**
- Application: To date no application is recorded. It should be based on intermediate targets to improve the energy efficiency of new buildings by 2015, with more emphasis on enhancing energy efficiency in new buildings.

Economic benefits

- **Reducing energy demand**
- Implementing nZEB solutions will reduce fuel demand at public sector facilities. Long-term optimization of nZEB solutions will result in lower energy costs and a more sustainable approach
- **Secondary actions**
- The successful implementation of nZEB solutions in educational buildings will have a lasting impact on other public sector buildings and services and will ultimately have a significant impact on the overall public budget.
- **Innovation**
- The nZEB refurbishment and tools used will boost innovative materials in a new market by displacing older technologies
- **Maintaining economic activity**
- The implementation of nZEB solutions will help to enhance the professional activity

Energy and Environmental Benefits

- **Emission Reduction**
- The likelihood of significant emissions reductions in buildings is significant, as **80%** of the operating costs of new buildings can be saved through advanced design principles, often at no or minimal additional cost in the long run.
- **Participation of Public Agencies in a new energy standard**
- Analyzing the situation from a macro-economic point of view, it is important to involve the public sector in the development of specific activities aimed at shaping an energy model. This creates significant conflicts due to the heavy dependence of the Mediterranean regions on imported energy and makes them vulnerable to external and international energy crises

Health and Safety Benefits

- **Improving air quality**
- Air quality in nZEB schools is improved compared to buildings constructed in accordance with current practice. Improving air quality will result in a much safer and healthier environment for students and school staff.
- **Reduce the impact of allergies and respiratory problems**
- According to some studies buildings equipped with mechanical exhaust ventilation and heat exhaust systems show an association with health problems (allergies and respiratory problems) that will be reduced with nZEB solutions.
- **Reduce artificial lighting**
- Reducing the use of artificial lighting will have a positive impact on the well-being of students and their educational environment.
- **Reduce the risk of mold formation**
- Mold fungal cultures tend to grow in high humidity environments. Humidity usually increases in places occupied by a significant number of people, such as in the case of schools. Mold and fungi can be prevented by good thermal insulation.

Social benefits

- **Reducing fuel needs**
- One of the main benefits of implementing nZEB solutions stems from the need to reduce fuel demand. It is important to note that, as with the other benefits of nZEB solutions, depreciation will be fully achieved over time.
- **Development of a new model in the construction sector**
- In broad view, the development of a new model in public buildings management will have an impact on the economic and social conditions of the region
- **Strengthening a new economic model of the sector**
- The nZEB approach can help overcome current obsolete values and behaviors in a key area for economic and social development. A process by which public procurement needs to be accelerated
- **Regeneration of local working conditions**
- The implementation and development of new technical skills and
- competences in the field of construction and renovation will have a significant impact on the regeneration of a sector which is deeply affected by the financial stagnation of recent years.
- **Innovation for society**
- Supporting nZEB building development is a statement about the society we want for our children and the environmental and social values we want to give to younger generations

Educational benefits

- **Promoting education in ecological environments**
- Allowing the younger generations to grow up and be educated in ecological environments like nZEB schools will result in a profound awareness of our children. In turn this will create a cultural process that will have a major impact when these children become adults.
- **Promoting the "naturalness" of energy efficient solutions in children**
- Promoting the "naturalness" of energy-efficient solutions to young people's values and behaviors is one of the most valuable outcomes of nZEB targeted actions
- **Allowing students to better understand their energy consumption**
- In energy-efficient schools, students can monitor their school's energy consumption from energy databases and have the opportunity to learn about the benefits of smart energy management
- **Greater comfort will result in improved academic performance**
- Thermal comfort is an important factor for schools, since it guarantees student living

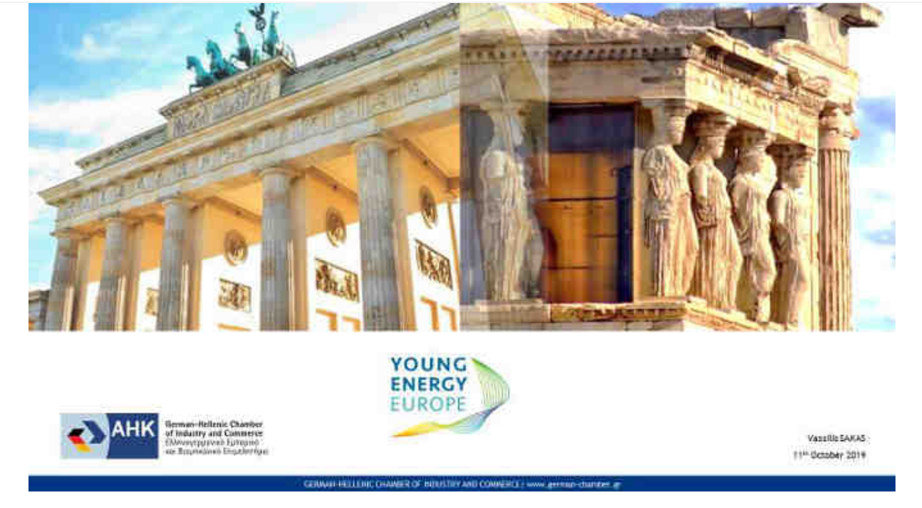
Aesthetic and Cultural Benefits

- **Preserving the Architectural and Cultural Heritage**
- The construction boom in the Mediterranean countries in recent decades has had an impact on the construction of school buildings from the beginning. Although these new buildings were constructed following the highest technical and energy standards, in the process the great architectural and cultural heritage of the area may have been forgotten. The nZEB outlook should be seen as a valuable mechanism to improve the situation.

Young Energy Europe

Mr. Vasileios SAKKAS,

Hellenic – German Commercial and Industrial Chamber, Greece

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Energy Efficiency
Efficiency of Ressources
Mobility
Measuring Instruments
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Εισαγωγή στη Εξοικονόμηση Ενέργειας
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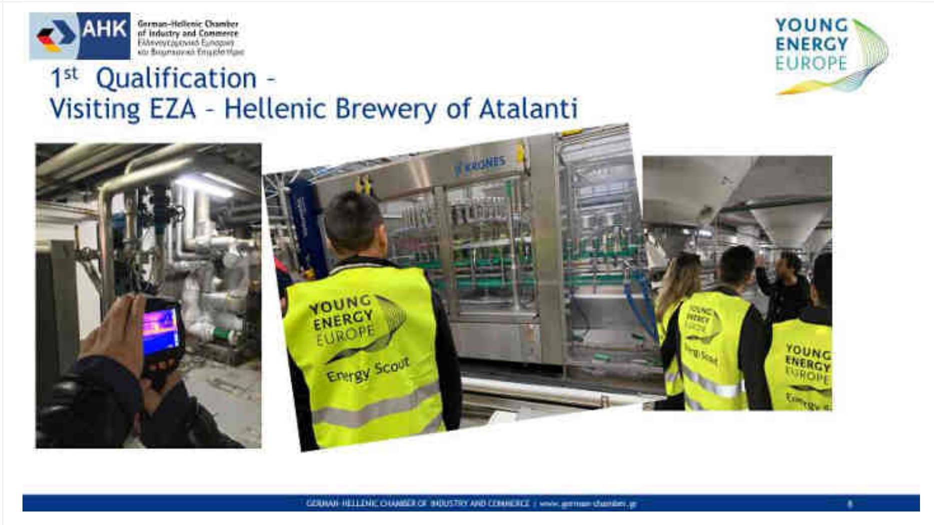
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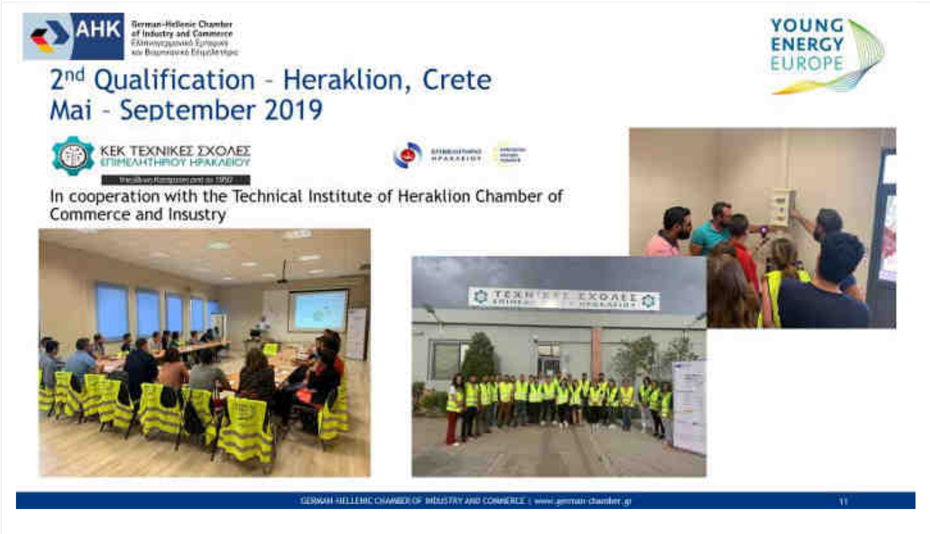
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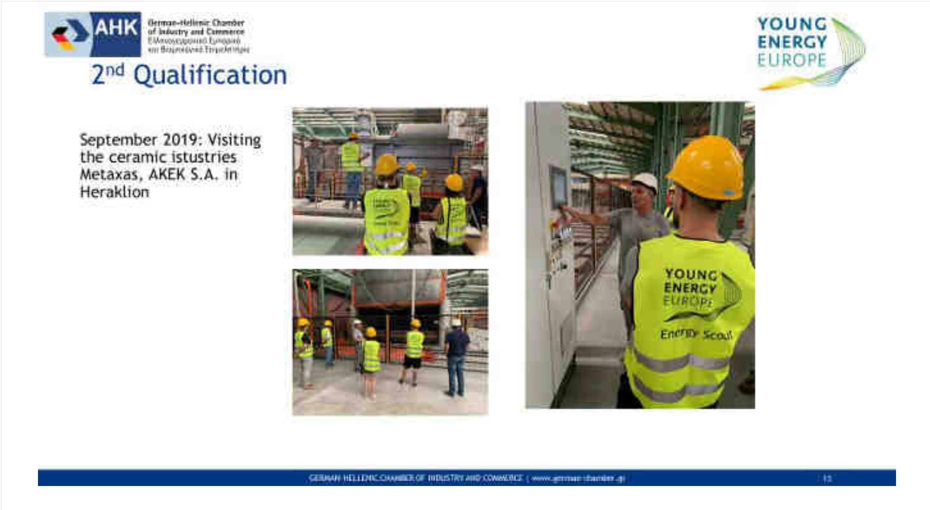
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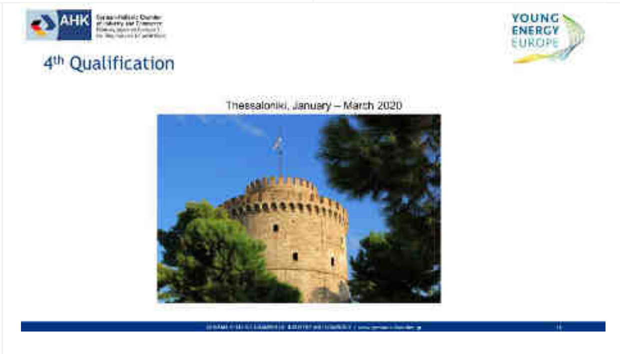
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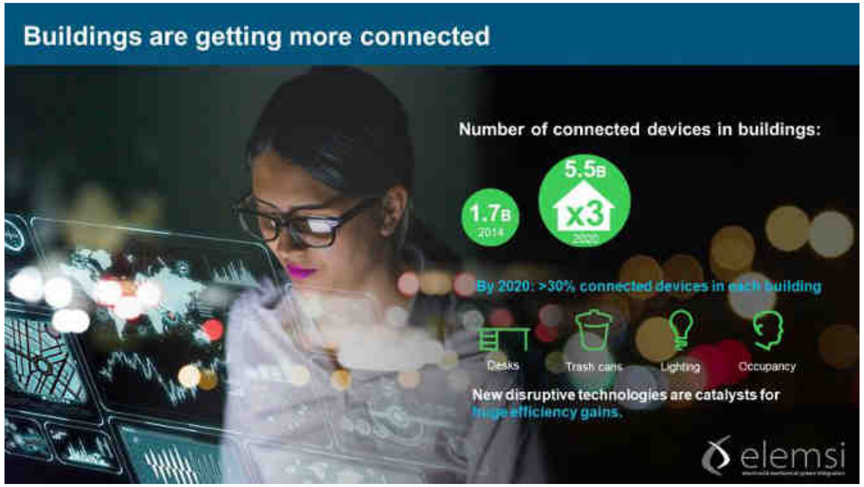
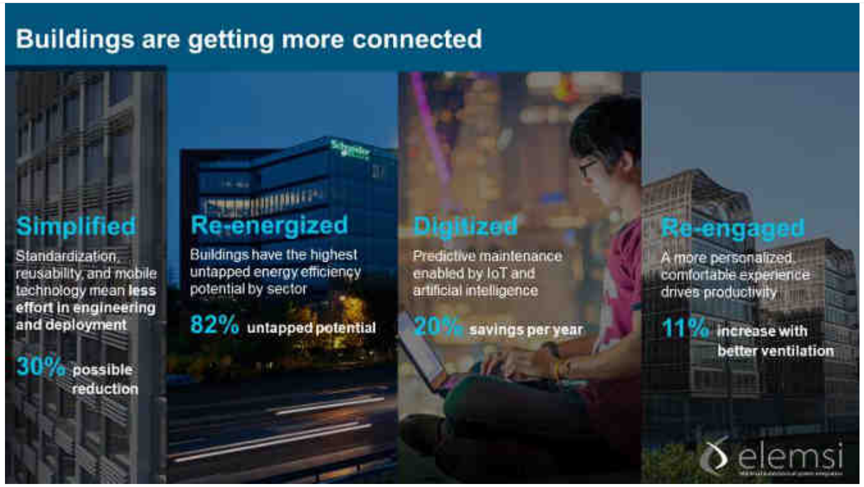
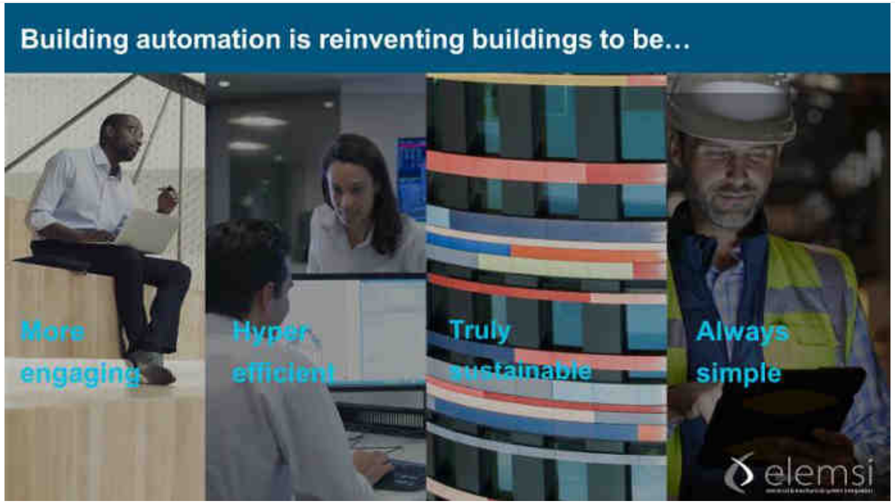
Building Energy Efficiency – Impact of Building Automation, Controls and Management

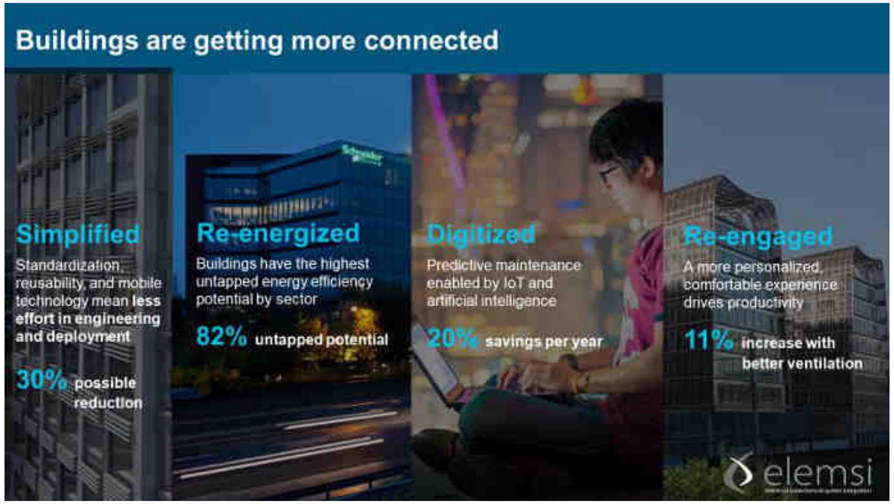
Mr. Michos KIRIAKOS

Elemsi, Greece






Building automation is reinventing buildings to be…
More engaging
Hyper efficient
Truly sustainable
Always simple
elemsi


Buildings are getting more connected
Simplified
Standardization, reusability, and mobile technology mean less effort in engineering and deployment
30% possible reduction
Re-energized
Buildings have the highest untapped energy efficiency potential by sector
82% untapped potential
Digitized
Predictive maintenance enabled by IoT and artificial intelligence
20% savings per year
Re-engaged
A more personalized, comfortable experience drives productivity
11% increase with better ventilation
elemsi


Building Management Systems
A building management system (BMS), otherwise known as a building automation system (BAS), is a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems e.t.c.
Maximize Efficiency of Buildings
Optimize Comfort & Productivity for Occupants
Increase Value of Buildings
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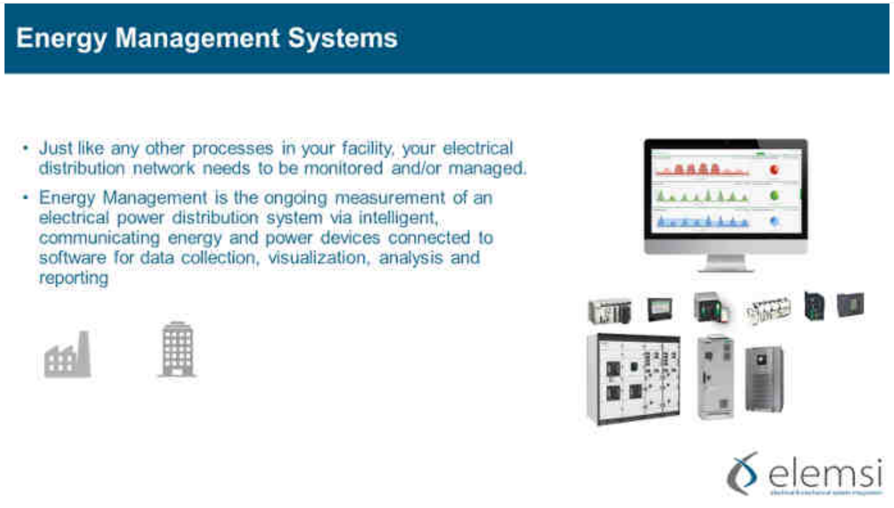
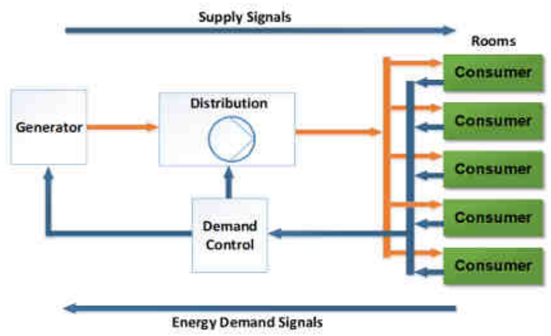

Energy Management Systems
• Just like any other processes in your facility, your electrical distribution network needs to be monitored and/or managed.
• Energy Management is the ongoing measurement of an electrical power distribution system via intelligent, communicating energy and power devices connected to software for data collection, visualization, analysis and reporting
elemsi

The European Standard EN 15232



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The European Standard EN 15232

Building Automation and Control (BAC) efficiency classes to EN 15232	Efficiency factor for thermal energy			Efficiency factor for electrical energy		
	Office	School	Hotel	Office	School	Hotel
A High Energy performance BACS and TBM	0.70	0.80	0.68	0.87	0.86	0.90
B Advanced BACS and TBM	0.8	0.88	0.85	0.93	0.93	0.95
C Standard BACS	1	1	1	1	1	1
D Non Energy efficient BACS	1.51	1.2	1.31	1.10	1.07	1.07

Difference in energy for three buildings types in the energy efficiency classes relative to the basis value in rating C

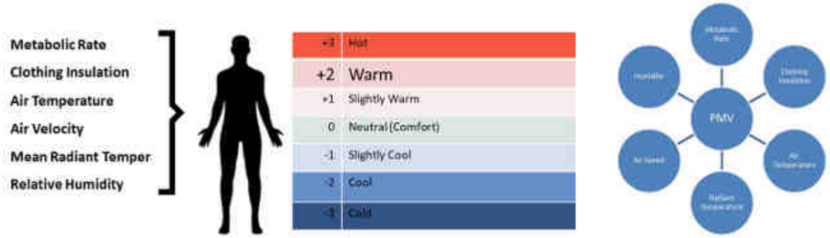
elemsi

The European Standard EN 15232

	Heating/Cooling control	Ventilation/Air condition Control	Lighting	Sun Protection
A	• Individual room control with communication between controllers • Indoor temperature control of distribution network water temperature • Total interlock between heating and cooling control	• Demand or presence dependent air flow control at room level • Variable set point with load dependent compensation of supply temperature control • Room or exhaust or supply air humidity control	• Automatic daylight control • Automatic occupancy detection manual on / auto off • Automatic occupancy detection manual on / dimmed • Automatic occupancy detection auto on / auto off • Automatic occupancy detection auto on / dimmed	• Combined light/blind/ HVAC control
B	• Individual room control with communication between controllers • Indoor temperature control of distribution network water temperature • Partial interlock between heating and cooling control(dependent on HVAC systems)	• Time dependent air flow control at room level • Variable set point with outdoor temperature compensation of supply temperature control • Room or exhaust or supply air humidity control	• Manual daylight control – • Automatic occupancy detection manual on / auto off • Automatic occupancy detection manual on / dimmed • Automatic occupancy detection auto on / auto off • Automatic occupancy detection auto on / dimmed	• Motorized operation with automatic blind control
C	• Individual room automatic control by thermostatic valves or electronic controller • Outside temperature compensated control of distribution network water temperature • Partial interlock between heating and cooling control (dependent on HVAC system)	• Time dependent air flow control at room level • Constant set point of supply temperature control • Supply air humidity limitation	• Manual daylight control • Manual on/off switch + additional sweeping extinction signal • Manual on/off switch	• Motorized operation with automatic blind control
D	• No automatic control • No control of distribution network water temperature • No interlock between heating and cooling control	• No air flow control at room level • No supply temperature control • No air humidity control	• Manual daylight control • Manual on/off switch + additional sweeping extinction signal • Manual on/off switch	• Manual operation for blinds

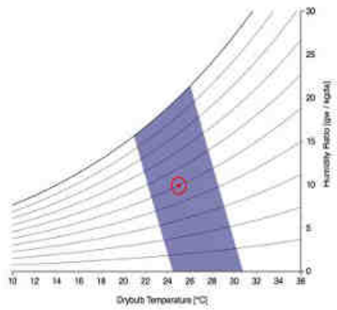
Thermal Comfort ASHRAE - 55

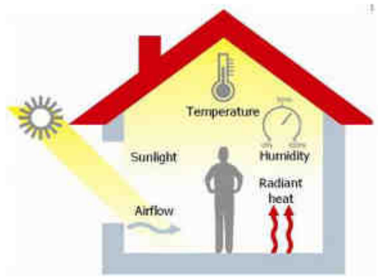
Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation



elemsi

Thermal Comfort ASHRAE - 55



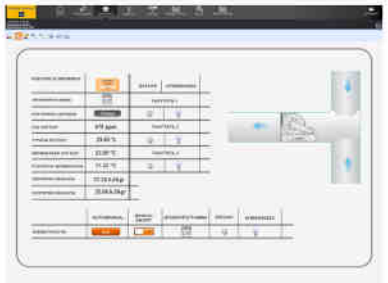


elemsi

Case Study - Bank Stores – A/C

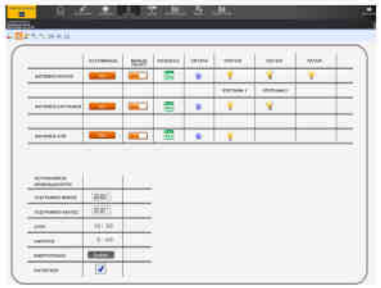
elemsi

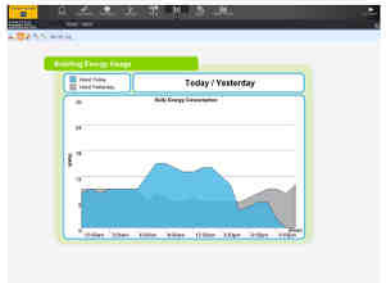
Case Study - Bank Stores - Ventilation



elemsi

Case Study - Bank Stores - Lighting





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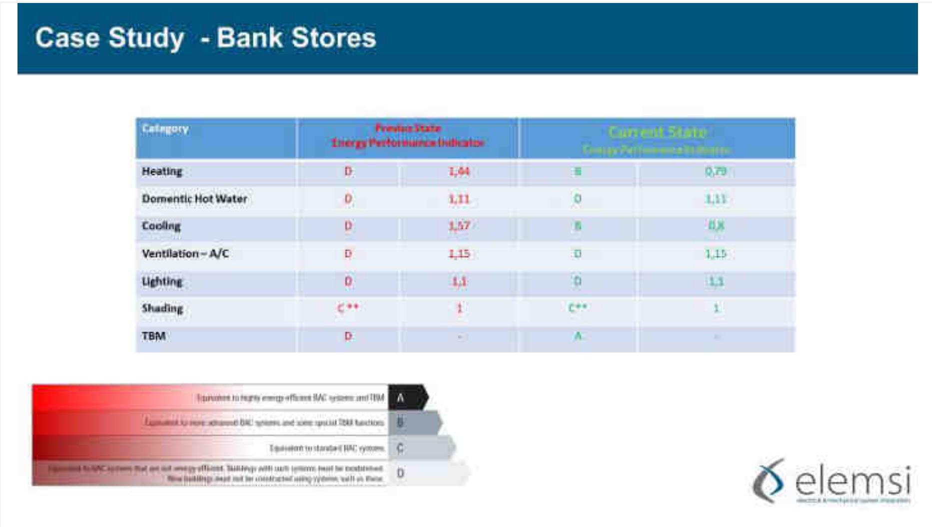

Case Study - Bank Stores

Category	Previous State Energy Performance Indicator		Current State Energy Performance Indicator	
Heating	D	1,44	B	0,79
Domentic Hot Water	D	1,11	D	1,11
Cooling	D	1,57	B	0,8
Ventilation – A/C	D	1,15	D	1,15
Lighting	D	1,1	D	1,1
Shading	C **	1	C**	1
TBM	D	-	A	-

Equivalent to highly energy-efficient BAC systems and TBM
A
Equivalent to more advanced BAC systems and some special TBM functions
B
Equivalent to standard BAC systems
C
D
elemsi


Our solutions are as
unique as you are
elemsi
electrical & mechanical system integration
Partner of Schneider Electric
PARTNER KNX
elemsi
Athinon 64, Kalamata 24134
T: 27210 24 379
F: 27211 10 353
www.elemsi.com
info@elemsi.com
Thank you!

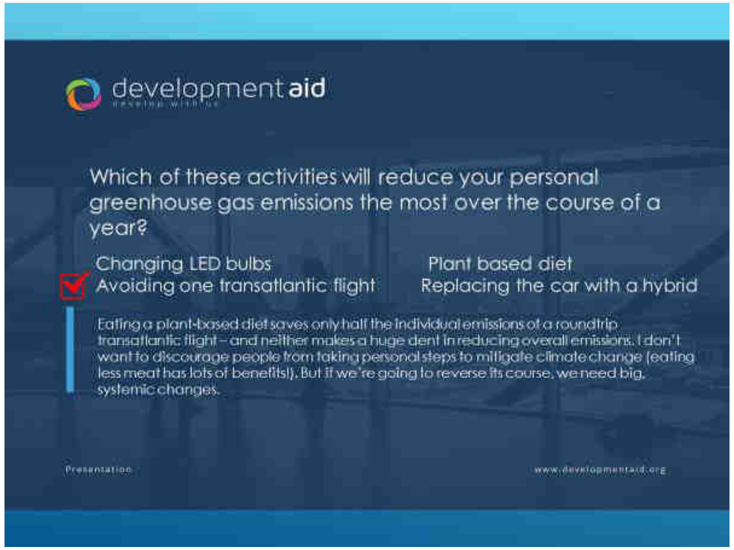
DevelopmentAid. Connecting you to the world of business opportunities

Mr. Sergiu CASU,
DevelopmentAid – International Organization


developmentaid
How many drivers would have to switch to electric cars to equal the annual emissions saved by replacing one coal power plant with a nuclear plant?
250
2,500
250,000
2,500,000
It's 2.5 million, assuming the electric vehicles get their electricity from the average mix of sources. But even if clean energy supplied all the power, over 1.5 million people would still have to switch.
To put that in perspective, there are currently only 3 million electric cars on the road in the entire world.
Presentation
www.developmentaid.org


developmentaid
How has the share of energy produced by fossil fuels changed in the last 20 years?
Cut by 25%
Cut by 50%
Doubled
The same
Despite our efforts to reduce emissions in recent years, the share of energy produced by fossil fuels is virtually the same today as it was two decades ago. That's why we urgently need clean, scalable sources of energy.
Presentation
www.developmentaid.org


developmentaid
Which sector of the global economy produces as many greenhouse gas emissions as Germany?
Automobile
Shipping goods
Running data centers
Foresty
Shipping (cargo planes, ships, etc.) currently equals both Germany and Britain in greenhouse gas output – and it's expected to grow in the future. One study projects global shipping emissions could rise by as much as 250 percent by 2050 and account for 17 percent of all emissions.
Presentation
www.developmentaid.org


developmentaid
Which of these activities will reduce your personal greenhouse gas emissions the most over the course of a year?
Changing LED bulbs
Plant based diet
Avoiding one transatlantic flight
Replacing the car with a hybrid
Eating a plant-based diet saves only half the individual emissions of a roundtrip transatlantic flight – and neither makes a huge dent in reducing overall emissions. I don't want to discourage people from taking personal steps to mitigate climate change (eating less meat has lots of benefits!). But if we're going to reverse its course, we need big, systemic changes.
Presentation
www.developmentaid.org


developmentaid
Total size of the internet was 2,7 Zettabytes until 2017.
Expected 44 Zettabytes by 2020*
*MarTech
Presentation
www.developmentaid.org


developmentaid
1000 bytes = 1 KB
1000 KB = 1 MB
1000 MB = 1 GB
1000 GB = 1 TB
1000 TB = PB
1000 PB = 1 EB
1000EB = 1 ZB = 1,000,000,000,000,000,000,000 bytes
Presentation
www.developmentaid.org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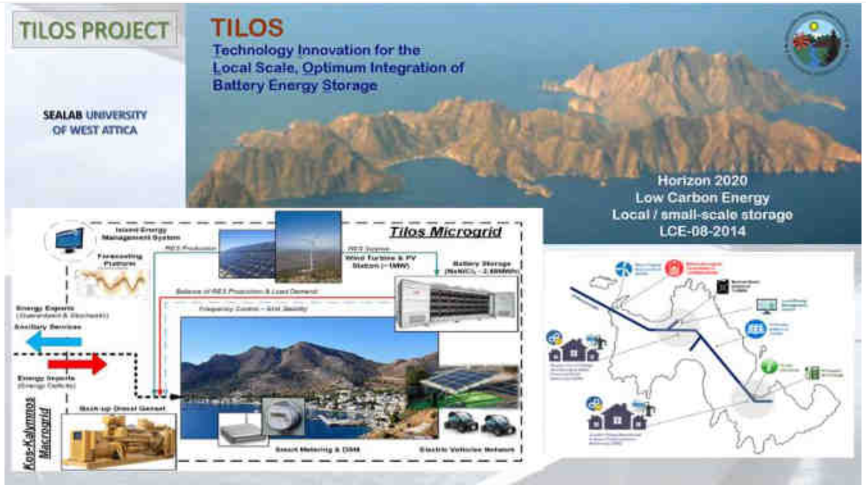
DevelopmentAid, Founded in 2007
Presentation
www.developmentaid.org

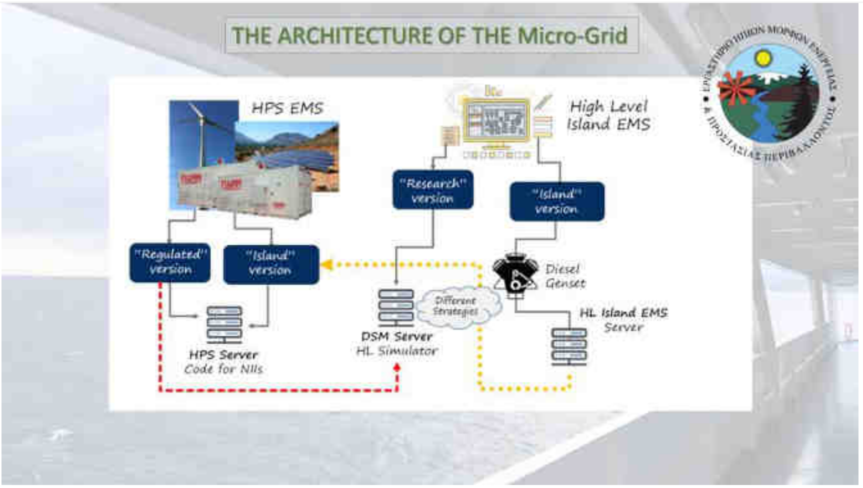

developmentaid
Mr. Sergiu Casu,
Business Development Director
s.casu@developmentaid.org
Presentation
www.developmentaid.org

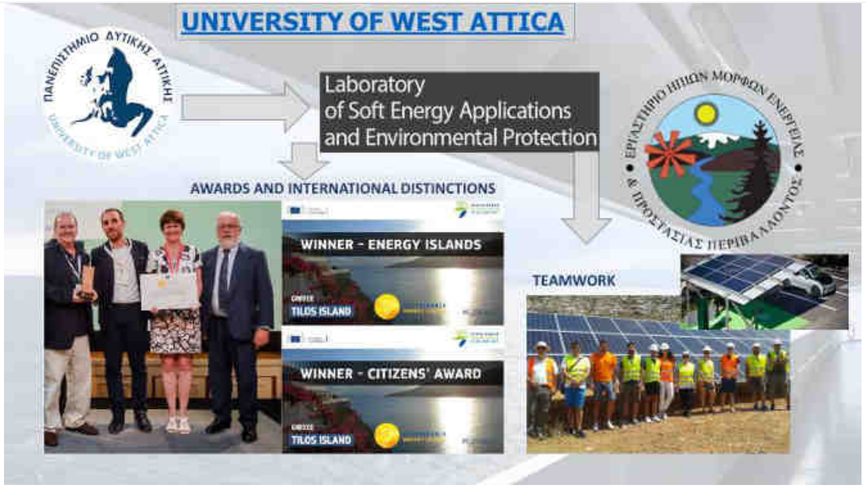
Session B: Projects

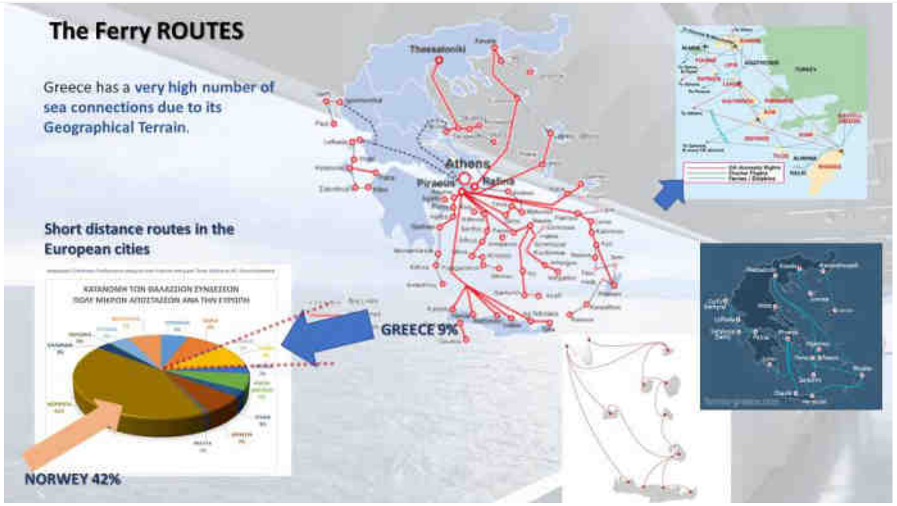
From the Renewable Energy islands – Tilos Project, to “Green” Ports and Ships

Mr. Panagiotis KTENIDIS, University of West Attica, Hellas

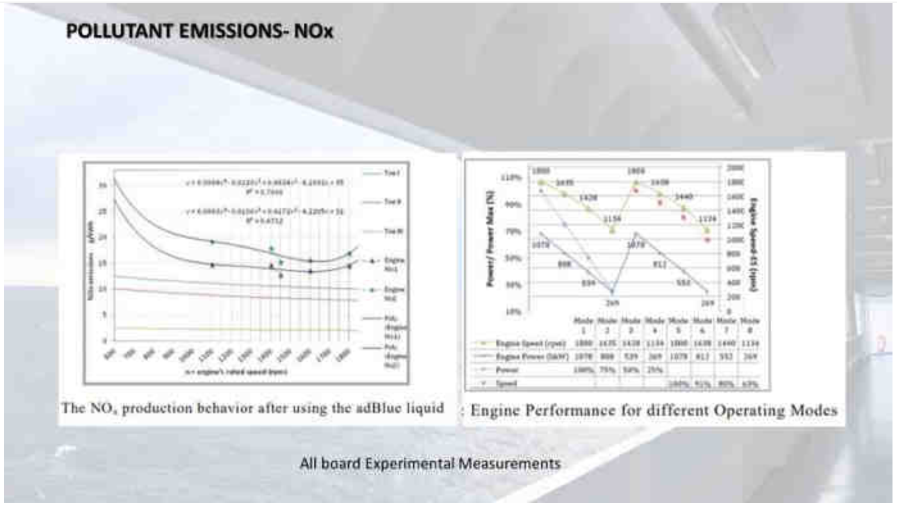


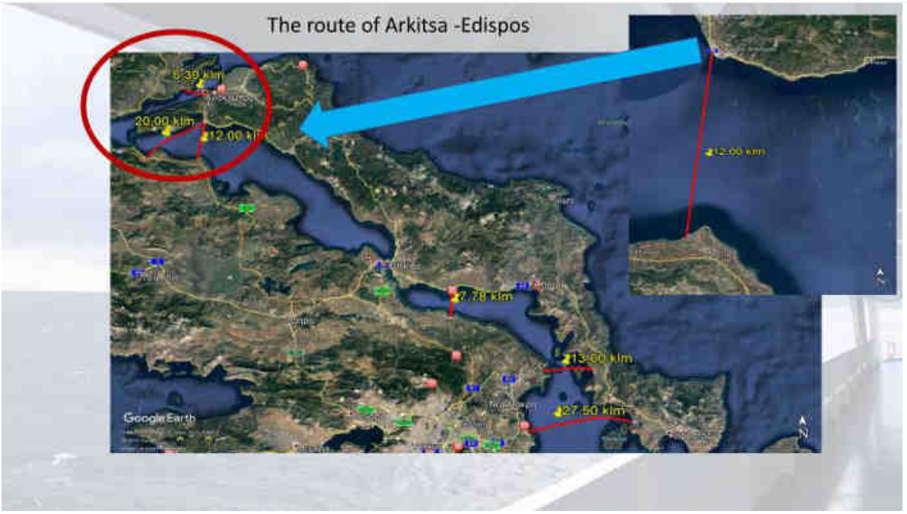






ΠΕΡΙΦΕΡΕΙΑ	ΓΡΑΜΜΗ		ΑΠΟΣΤΑΣΗ (ΝΜ)
ΑΝΑΤ. ΜΑΚΕΔΟΝΙΑΣ / ΘΡΑΚΗΣ	ΚΕΡΑΜΩΤΗ	ΘΑΣΟΣ	9,4
ΚΕΝΤΡΙΚΗΣ ΜΑΚΕΔΟΝΙΑΣ	ΤΡΥΠΗΤΗ	ΑΜΜΟΥΛΙΑΝΗ	4,9
ΣΤΕΡΕΑΣ ΕΛΛΑΔΟΣ	ΑΙΔΗΨΟΣ	ΑΡΚΙΤΣΑ	11,8
ΣΤΕΡΕΑΣ ΕΛΛΑΔΟΣ	ΓΛΥΦΑ	ΑΓΙΟΚΑΜΠΟΣ	6,8
ΣΤΕΡΕΑΣ ΕΛΛΑΔΟΣ	ΩΡΩΠΟΣ	ΕΡΕΤΡΙΑ	7,4
ΣΤΕΡΕΑΣ ΕΛΛΑΔΟΣ	ΑΓΙΑ ΜΑΡΙΝΑ	ΝΕΑ ΣΤΥΡΑ	12,0
ΠΕΛΟΠΟΝΝΗΣΟΥ	ΠΟΥΝΤΑ	ΕΛΑΦΟΝΗΣΟΣ	1,5
ΝΟΤΙΟΥ ΑΙΓΑΙΟΥ	ΠΟΥΝΤΑ ΠΑΡΟΥ	ΑΝΤΙΠΑΡΟΣ	1,4
ΝΟΤΙΟΥ ΑΙΓΑΙΟΥ	ΘΗΡΑ	ΘΗΡΑΣΙΑ	11,0
ΝΟΤΙΟΥ ΑΙΓΑΙΟΥ	ΨΑΘΗ ΚΙΜΩΛΟΥ	ΑΠΟΛΛΩΝΙΑ ΜΗΛΟΥ	6,8
ΝΟΤΙΟΥ ΑΙΓΑΙΟΥ	ΚΑΛΥΜΝΟΣ	ΜΑΣΤΙΧΑΡΙ ΚΩ	13,0
ΙΟΝΙΩΝ ΝΗΣΩΝ	ΣΑΜΗ ΚΕΦΑΛΛΗΝΙΑΣ	ΠΙΣΑΕΤΟΣ ΙΘΑΚΗΣ	10,6
ΙΟΝΙΩΝ ΝΗΣΩΝ	ΝΥΔΡΙ	ΜΕΓΑΝΗΣΙ	6,8
ΙΟΝΙΩΝ ΝΗΣΩΝ	ΛΕΥΚΙΜΜΗ	ΣΥΒΟΤΑ	12,6
ΙΟΝΙΩΝ ΝΗΣΩΝ	ΑΡΓΟΣΤΟΛΙ	ΛΗΞΟΥΡΙ	6,0
ΑΤΤΙΚΗΣ	ΠΕΡΑΜΑ	ΠΑΛΟΥΚΙΑ	2,6
ΑΤΤΙΚΗΣ	ΜΕΓΑΡΑ	ΦΑΝΕΡΩΜΕΝΗ	0,7
ΑΤΤΙΚΗΣ	ΠΟΡΟΣ	ΓΑΛΑΤΑΣ	0,5
ΑΤΤΙΚΗΣ	ΜΕΤΟΧΙ ΕΡΜΙΟΝΙΔΑΣ	ΥΔΡΑ	8,5
ΑΤΤΙΚΗΣ	ΚΟΣΤΑ	ΣΠΕΤΣΕΣ	3,0
ΔΥΤΙΚΗΣ ΕΛΛΑΔΟΣ	ΡΙΟ	ΑΝΤΙΡΡΙΟ	2,4

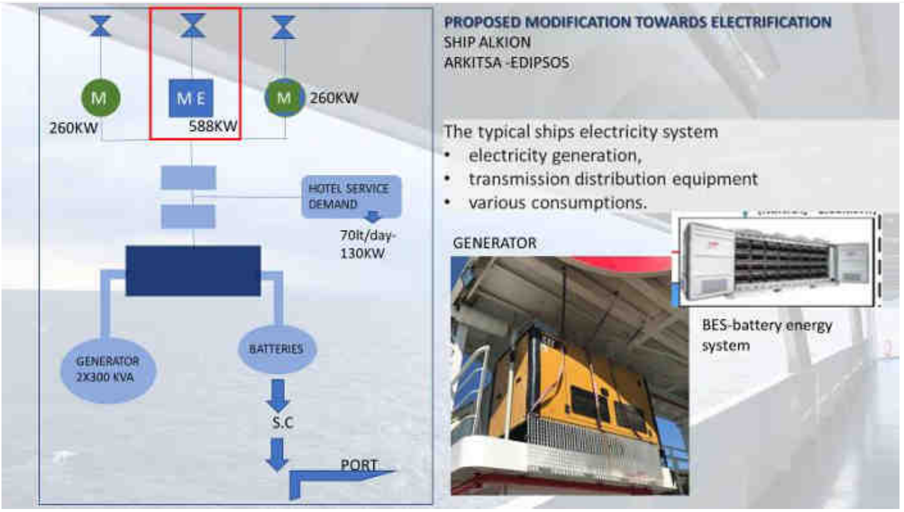



The route of Arkitsa -Edispos
6.30 klm
20.00 klm
12.00 klm
12.00 klm
2.78 klm
13.60 klm
27.50 klm
Google Earth

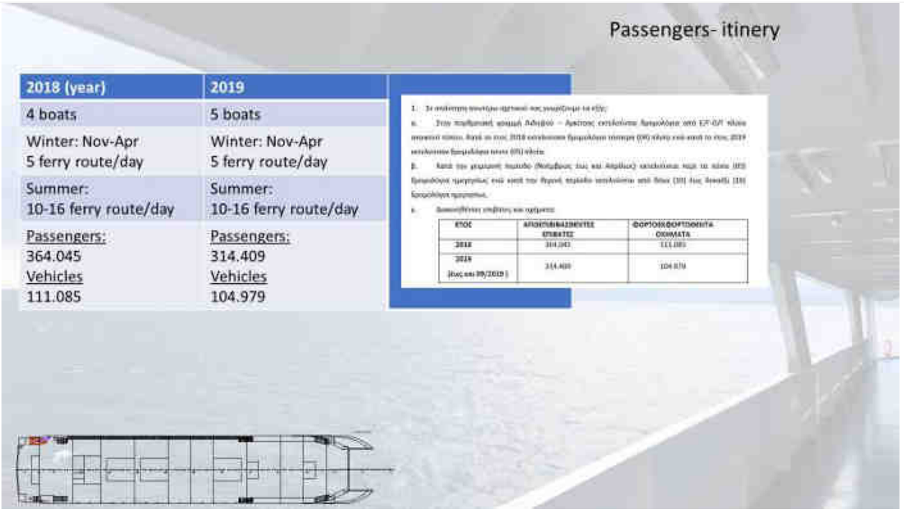

The Ferry boat – "ALKION"
CLIMATE
ACTION
NOW

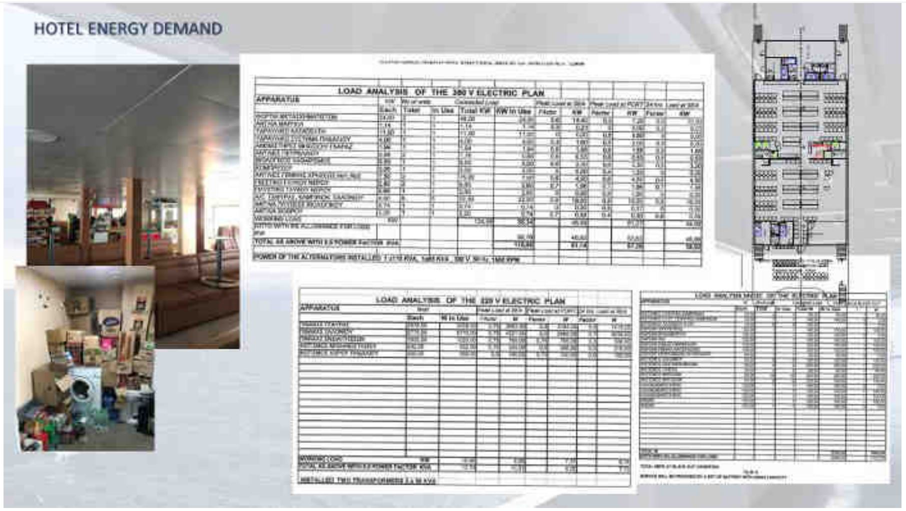

The Ferry boat sections – "ALKION"
main dimensions
Length overall 69.740 meters
Length water line 63.480 meters
Length B.P. 62.500 meters
Breadth maximum 13.200 meters
Depth moulded 2.300 meters
Design draft 1.420 meters
Frame spacing 0.550 meters
TECHNICAL OFFICE PETYCHAKI


EXISTING CONDITIONS- SHIP ALKION
ARKITSA -EDIPSOS
ΑΛΚΥΩΝ
GEN set 1
GEN set 2
220 V
380 V
MAIN ENG.
254KW
MAIN ENG.
588KW
MAIN ENG.
254KW


PROPOSED MODIFICATION TOWARDS ELECTRIFICATION
SHIP ALKION
ARKITSA -EDIPSOS
The typical ships electricity system
• electricity generation,
• transmission distribution equipment
• various consumptions.
GENERATOR
BES-battery energy system
M
260KW
M E
588KW
M
260KW
HOTEL SERVICE DEMAND
70lt/day-130KW
GENERATOR 2X300 KVA
BATTERIES
S.C
PORT


Route Sea Ports for BES land installation
THE PORTS...
EDIPSOS PORT
ARKITSA PORT


Passengers- itinery
2018 (year)
4 boats
Winter: Nov-Apr
5 ferry route/day
Summer:
10-16 ferry route/day
Passengers:
364.045
Vehicles
111.085
2019
5 boats
Winter: Nov-Apr
5 ferry route/day
Summer:
10-16 ferry route/day
Passengers:
314.409
Vehicles
104.979


HOTEL ENERGY DEMAND
LOAD ANALYSIS OF THE 380 V ELECTRIC PLAN
LOAD ANALYSIS OF THE 220 V ELECTRIC PLAN


Ferry Routes
Route: Arkitsa-Edipsos
Distance: 12 km
Speed: 10 Knots
MAX ENERGY DEMAND
PROPULSION: 2X300=600 kW
HOTEL ENERGY DEMAND = 130 kW
TOTAL ENERGY DEMAND/route = 730 kW
CO2 EMISSIONS
630.000 Kg CO2/year
566.140 Kg CO2/year use of Electricity
a. Autonomous RES Charging : 0 Kg CO2/year use of Electricity from Renewables
b. Distributed RES Feeding Installation : 450.000 Kg CO2/year use of Electricity from Renewables


ANOTHER FERRY BOAT AT THE SAME ROYTE


Οικόπεδο εγκατάστασης πάρκου PV 2MW στην Ιστιαία (Virtual Net Metering)


So switch on the Green Energy!
PETYCHAKI
ΓΑΙΑ
RES
THE END....
THANK YOU....


ENGINES, SHAFT, ANCHOR, GENSETS,

Operational Programme	Washi
Title: "Development of a combined rain harvesting and renewable energy-based system for covering domestic and agricultural water requirements in small dry Greek Islands" (MIS 5004775). **"WaSHI" Wa**ter **S**upply using **H**ybrid systems in small dry **I**slands. **Project Web Site:** https://washintua.wixsite.com/washi **Duration:** 17 months **Start Date:** 15/5/2018 **Key Words:** Desalination; Rain Water Harvesting; Climate Change; Energy Efficiency; Seawater Pumped Storage System; Greek Islands; Water Resources Management	**Funding mechanism**: Operational Programme Human Resources Development, Education and Lifelong Learning Co-financed by Greece and the European Union **Total Cost:** 50.050,00€ **EC Contribution:** Yes **Consortium:** New Researchers at NTUA **Project Coordinator:** National Technical University of Athens (NTUA)

The Challenge

The objective of the project entitled "*Development of a combined rain harvesting and renewable energy-based system for covering domestic and agricultural water requirements in small dry Greek Islands*" is the investigation of different scenarios for meeting water demand in small, dry islands in Greece. Particularly, different combinations of management practices and technical works are evaluated for eight islands, with the aim of finding the optimal one.

Scenarios included the operation of desalination units, as a part of a Hybrid Renewable Energy Sources (HRES) system and Rainwater Harvesting (RWH) Systems. The main purpose is the determination of a renewable Water Resources Management (WRM) scenario that minimizes the cost and maximizes the percentage of water autonomy, for a given reliability. The entire analysis takes into consideration any existing technical works for water storage and distribution.

Indicatively, a cost analysis is performed based on the Life Cycle Cost (LCC) Analysis method and the performance of each proposed scenario is investigated considering realistic population models and climate change scenarios.

Project Objectives

1. **Evaluation of five different WRM scenarios for meeting the increasing water demand in small remote islands of the Aegean Sea**: These scenarios included: (i) domestic RWH combined with water transportation; (ii) wind-powered seawater desalination; (iii) wind-powered seawater desalination and domestic RWH; (iv) wind-powered seawater desalination combined with seawater pumping and (v) wind-powered seawater desalination combined with seawater pumping and domestic RWH. Each alternative is examined for a 30-year time period, taking into account an increase in population and tourism, and evaluated in respect to cost, using the LCC methodology.
2. **Assessment of Climate Change impact on the system reliability:** As the performance of each alternative is directly related to the variability of meteorological conditions (e.g., wind speed for wind turbines operation and precipitation for rainwater harvesting), each solution is also assessed under six different climate change scenarios.

3. **Investigation of any particular spatial pattern regarding scenarios reliability:** While most of the above alternatives have either been proposed or implemented separately for water supply in various arid Greek islands, it is the first time that these different measures and combinations are assessed and compared on regional scale in seek of an optimal solution.

Methodology

The methodology that is implemented is consisted of separate steps that aim to develop the WRM and energy supply models per island that are different for each scenario; to evaluate different alternatives based on a LCC analysis; and to assess the Climate Change Impact on the system reliability for each island, in terms of energy supply, and for various climate change scenarios.

Results

There are three primary results based on the research conducted:

1. Coupling desalination processes with RES or employing more traditional techniques, such as RWH, can be proved to be an effective solution for water supply. The desalination plant capacity, the number of the wind turbines, the average daily coverage of the RWH tanks and the capacity of the seawater storage reservoirs for the combined scenarios range significantly per island. The energy reliability ranges from 80% to 83%, depending on the examined island.
2. Wind Powered Reverse Osmosis Desalination (WPROD) was found to be the most efficient solution, from an economic standpoint, for the majority of the islands.
3. Finally, each scenario is examined using the CORDEX climate change data for the period 2021-2050. Indicatively for the best WRM solution, a reduction in the system reliability was noticed that is linked to the RES-based energy supply. The percentage change between energy reliability achieved during the period of initial simulation and under climate change ranges considerably from island to island, while this reduction in the system reliability was systematic for all examined climate change scenarios.

Acknowledgments

We acknowledge support of this work by the project "Development of a combined rain harvesting and renewable energy-based system for covering domestic and agricultural water requirements in small dry Greek Islands" (MIS 5004775) which is implemented under the Action "Supporting Researchers with an Emphasis on Young Researchers", in the context of the call EDBM34, funded by the Operational Programme "Human Resource Development, Education and Lifelong Learning" (NSRF 2014-2020) and co-financed by Greece and the European Union (European Regional Development Fund).

Ευρωπαϊκή Ένωση
European Social Fund

Operational Programme
Human Resources Development, Education and Lifelong Learning
Co-financed by Greece and the European Union

ΕΣΠΑ 2014-2020

Project Team	
Evangelos Baltas, Professor, School of Civil Engineering, National Technical University of Athens; baltas@chi.civil.ntua.gr	Scientific Coordinator - Academic Advisor
Konstantinos Kotsifakis, Civil Engineer NTUA, MSc, PhD Candidate at NTUA; kkotsifakis@chi.civil.ntua.gr	Early-Career Researcher
Ioannis Kourtis, Rural and Surveying Engineer NTUA, MSc, PhD Candidate at NTUA; gkourtis@mail.ntua.gr	Early-Career Researcher
Elissavet Feloni, Geologist NKUA, MSc, PhD NTUA; feloni@chi.civil.ntua.gr	Early-Career Researcher

Climate Change Impact on Water Resources management in remote islands using Hybrid Renewable Energy Systems

Dr. Elissavet FELONI, National Technical University of Athens, Greece

12th International Conference on Energy and Climate Change

Climate change impact on Water Resources Management in remote islands using Hybrid Renewable Energy Systems

Elissavet Feloni, Konstantinos Kotsifakis, Ioannis Kourtis and Evangelos Baltas*

*Contact details:
Tel: +30 210 772 2883
e-mail: baltas@chi.civil.ntua.gr
Address: Department of Water Resources and Environmental Engineering, School of Civil Engineering, National Technical University of Athens, Heroon Polytechniou 9, Zografou, 15780 Athens, Greece

Introduction – Project summary

- **Water inadequacy in small dry islands** scattered in the Aegean Sea (Greece) is a major problem regarding Water Resources Management (WRM), especially during the summer period due to tourism.
- In the present work, **various WRM schemes are designed and presented.**
- The WRM schemes take into account current infrastructure and include **Rainwater Harvesting** tanks and Reverse Osmosis **Desalination Units.**
  - The energy requirements are covered mainly by **wind turbines** combined or not with a **seawater pumped storage system.**
  - **Sizing** is based on the available data for **population and tourism per island**, after taking into account a slight **increase** in the population (up to 1.5% per year), and it guarantees **at least 80% reliability for the energy** supply and **99.9% for potable water.**
- Scenarios' evaluation is performed from a financial perspective, after calculating the **Life Cycle Cost** (LCC) of each investment for a lifespan of **30 years.**
- Wind-powered desalination plant was found to be the most cost-effective practice, from an economic point of view.
- Finally, six different climate change (CC) scenarios were investigated, in order to estimate the CC impact. Overall, it is emphasized that CC needs to be incorporated in the design process for projects related to WRM.

The problem

Greece is a typical example of **challenging Water Resources Management** (WRM) for many reasons, especially due to the fact that **about 100 islands are inhabited,** most of which have insufficient water resources and need to be supplied via **water importation.**

Current practices to ensure water supply in small dry islands in Greece are **not fully sustainable and effective,** especially during summer months, as needs increase significantly due to tourism.

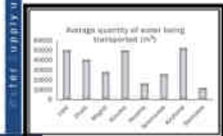
Various WRM practices are used for the islands' water supply, including mainly the **water transportation,** the intensive use of **groundwater,** the **Rainwater Harvesting** (RWH), and recently the seawater **Desalination** process.

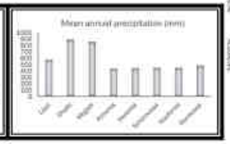
Island	Fresh Water Quantity imported per year (m^3/yr)				
Lipsi	55992	53934	69669	53707	16641
Chalki	54381	48555	47711	48560	2816
Megisti	37688	15444	24647	36347	23992
Kimolos	46488	46602	48107	52027	55340
Heraklia	16190	16839	17245	17298	14714
Schinoussa	28766	27054	17394	35309	19938
Koufonisi	49372	51614	53101	56461	51117
Donousa	15383	11781	8296	12602	10386

Study Area

Eight **small** (<1000 inhabitants) **dry islands** in the Aegean Sea that are **not autonomous,** according to the national legislation.

Lipsi	37.301	26.681	15.84	277	790
Chalki	36.222	27.602	26.99	593	478
Megisti	36.150	29.584	9.11	273	492
Kimolos	36.793	24.556	37.43	364	910
Heraklia	36.845	25.378	18.08	419	141
Schinoussa	36.871	25.506	8.14	133	227
Koufonisi	36.934	25.570	5.77	107	391
Donoussa	37.100	25.786	13.65	385	167





WRM Scenarios

0) **Zero Scenario:** Fresh water importation (mainly) & Local Resources (secondarily)

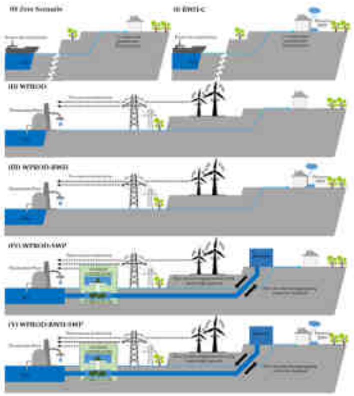
(I) **RWH-C:** domestic rainwater harvesting combined with water transportation;

(II) **WPROD:** wind-powered seawater desalination;

(III) **WPROD-RWH:** wind-powered seawater desalination and domestic rainwater harvesting;

(IV) **WPROD-SWP:** wind-powered seawater desalination combined with seawater pumping;

(V) **WPROD-RWH-SWP:** wind-powered seawater desalination combined with seawater pumping and domestic rainwater harvesting.



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Scenarios sizing per island

Zero		Fresh water importation (mainly) & Local Resources (secondarily)							
WPROD-RWH-SWP	Number of Wind Turbine(s)	1 (800kW)	2 (800kW)	2 (800kW)	2 (800kW)	1 (300kW)	1 (800kW)	2 (800kW)	1 (300kW)
	Reservoir Volume (m^3)	30,000	6,500	18,000	22,700	4,000	3,000	7,000	500
WPROD-RWH	Desalination capacity (m^3/d)	555	520	370	675	234	435	775	138
	Number of Wind Turbine(s)	2 (800kW)	3 (800kW)	4 (800kW)	3 (800kW)	2 (300kW)	2 (800kW)	2 (800kW)	2 (300kW)
WPROD-SWP	Number of Wind Turbine(s)	2 (800kW)	2 (800kW)	2 (800kW)	2 (800kW)	1 (300kW)	1 (800kW)	2 (800kW)	1 (300kW)
	Reservoir Volume (m^3)	15,000	12,500	25,000	27,500	7,000	8,000	12,750	500
WPROD	Desalination capacity (m^3/d)	560	530	380	680	235	440	780	140
	Number of Wind Turbine(s)	3 (800kW)	3 (800kW)	5 (800kW)	4 (800kW)	2 (300kW)	2 (800kW)	3 (800kW)	2 (300kW)
RWH-C	Optimal Tank Volume (m^3)	6-13	6-13	13-25	4-11	3-10	3-10	8-14	4-8
	Water saved per year (%/cap)	22.5	21.8	28.7	16.7	13.5	14.1	27.6	11.6

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Scenarios Evaluation – LCC Analysis (I)

Evaluation of each alternative **in respect to cost**, using the **Life Cycle Cost (LCC) methodology**.

- LCC is a type of investment calculus used to rank different investment alternatives and has been proved to be an effective tool for environmental decision making.
- Market prices for each parameter were used for cost estimation, along with all the details regarding cost assumptions, based on the global literature.
  - A range of unit cost values is also provided, when applicable, in order to highlight the uncertainty in cost estimates; values in parenthesis denote the ones adopted for the analysis.
  - For RWH, data was collected from various sources, including personal communication with local technicians along with values from the literature and correspond to the national market prices.
  - For the scenarios including desalination, costs were selected taking into account projects of similar scale in Greece.
- Finally, to quantify the difference in the cumulative cost of each scenario per island, the **unit LCC** (in €/yr) was introduced, calculated by dividing the cumulative LCC with the 30-year lifespan.

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Scenarios Evaluation – LCC Analysis (II)

Investment and operation costs

RWH	Tank (V=10-30 m^3)	1,320-4,050 (f(V))	€
	Pump	200	€
	Water distribution system	170	€
	Filters	160	€
	First Flushing Separator	100	€
	Backflow prevention device	120	€
	Operation and maintenance	0.05	€/m^3
	Additional Maintenance	20	€/yr
	Pump replacement	10	yrs
	Discount rate	6	%
RO Desalination plant	Investment	900-2,500 (2,500)	€/m^3/d
	O&M	4% of investment	€
	Discount rate	6	%
	Taxes	24	%
Wind Turbines	Investment	800-1,500 (800)	€/kW
	O&M	2% of investment	€
	Discount rate	6	%
	Taxes	24	%
SWP	Investment	500-2,000 (1,100)	€/kW
	O&M	2% of investment	€
	Discount rate	6	%
	Taxes	24	%

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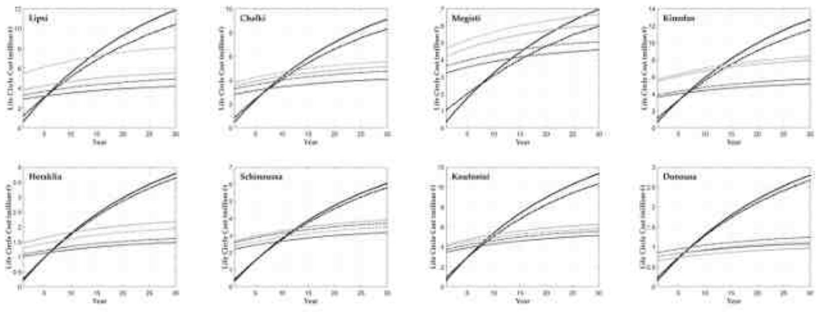
Scenarios Evaluation – LCC Analysis (III)



WPROD was found to be the most efficient solution, from an economic standpoint, for all the islands except for Donousa Island.

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Scenarios Evaluation – LCC Analysis (IV)

Unit LCC for all the scenarios (€/yr) and all the islands examined						
Scenarios/ Islands	WPROD	WPROD-RWH	WPROD-SWP	WPROD-RWH-SWP	RWH-C	Zero
Lipsi	139577	163810	185196	270449	346895	395649
Megisti	152889	169005	201708	221661	199232	232366
Chalki	136044	158900	171126	185443	276600	303945
Koufonisi	171210	186076	209143	194634	344923	378133
Kimolos	173041	191557	264975	279189	386687	424695
Heraklia	49359	53911	72399	64706	121244	126027
Schinoussa	105672	123733	129925	116819	193294	201489
Donousa	35980	41391	32294	37658	88909	93168

The lifespan LCC for the entire period of the project operation (€/yr) ranged from 32294 €/yr (WPROD-SWP, Donousa Island) to 424695 €/yr (Zero, Kimolos) considering all results.
Environmental, as well as, economic benefits from gas reduction produced by the examined approaches and the Zero scenario were not taken into account in the present work.

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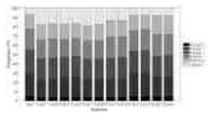
Calculation of RES energy supply for WRM under Climate Change: Datasets & Scenarios

After the WRM scenarios evaluation **under no climate change** conditions, an assessment regarding lifelong performance **under changing climate** was undertaken for the period 2021-2050, as the performance of each alternative is directly related to the variability of meteorological conditions (e.g., wind speed for wind turbines operation and precipitation for rainwater harvesting), each alternative is also assessed under six different climate change scenarios.

For this purpose, the freely available data of the Coordinated Regional Downscaling Experiment (**CORDEX**) research program wer



CLMcom-CCLM4-8-17	CNRM-CERFACS-CNRM-CM5	1.CC1	1.CC2
CLMcom-CCLM4-8-17	MOHC-HadGEM2-ES	2.CC1	2.CC2
CLMcom-CCLM4-8-17	MPI-M-MPI-ESM-LR	3.CC1	3.CC2
MPI-CSC-REMO2009	MPI-M-MPI-ESM-LR	4.CC1	4.CC2
SMHI-RCA4	CNRM-CERFACS-CNRM-CM5	5.CC1	5.CC2
SMHI-RCA4	MOHC-HadGEM2-ES	6.CC1	6.CC2

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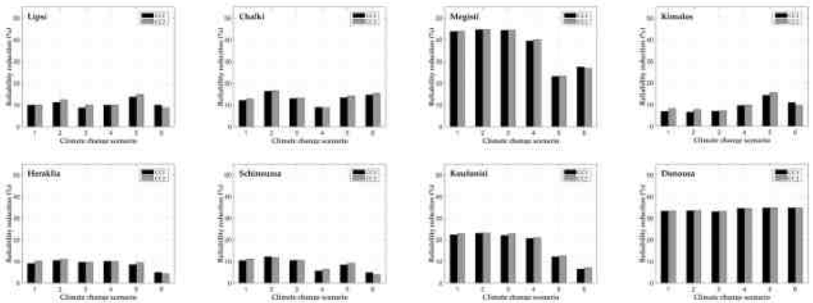
I. RES energy reliability under Climate Change for the best WRM scenario



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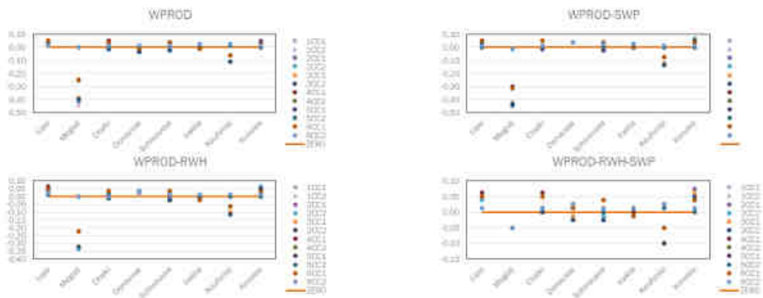
II. Overall results under Climate Change

Percentage change in RES energy mean annual reliability under all CC scenarios and for the four alternatives involving RES energy supply. Under CC, the scenarios performance decreases in most cases.



Discussion - Conclusions

the limited local water resources, current water management practices depend on water importation by ship, a solution that entails significant costs, as validated by the implementation of the Directive 2000/60/EC for the RBD No.14 of Greece.
In this frame, five different **alternatives for meeting water needs were examined** and compared for eight small islands located in the Aegean Sea based on their **economic performance** and their **feasibility under CC**.

Overall, **water desalination** can become a key in meeting the increasing water needs in water-stressed isolated areas with easy access to seawater, such as the small dry islands located in the Aegean Sea. Further, the gradual phasing-in of **renewable energy sources to power desalination plants**, such as the WPROD, WPROD-RWH, WPROD-SWP and WPROD-SWP-RWH scenarios examined, will help to **ensure the long-term sustainability** of such projects.

At the same time, against the current unsustainable practices, it reduces impact on the environment, as freshwater can be provided without significantly increasing greenhouse gas emissions. In terms of cost, despite the fact that a high initial investment is typically required, **funds expended are recouped in all cases examined**, with **payback periods** ranging from **five to fifteen years**, depending on the technological solution chosen and the characteristics of each island.

However, it should be addressed that **under CC the scenarios performance decreases** in most cases (in terms of RES energy supply reliability), a fact that should be taken into account in RES-based WRM projects.

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Project Information and Contact

Project Team:
Scientific Coordinator/Academic Advisor:
Evangelos Baltas, Professor, School of Civil Engineering, National Technical University of Athens; baltas@chi.civil.ntua.gr
Early Career Researchers involved in this project:
Konstantinos Kotsifakis, Civil Engineer NTUA, MSc, PhD Candidate; kkotsifakis@chi.civil.ntua.gr
Ioannis Kourtis, Rural and Surveying Engineer NTUA, MSc, PhD Candidate; gkourtis@mail.ntua.gr
Elissavet Feloni, Geologist NKUA, MSc, PhD NTUA; feloni@chi.civil.ntua.gr

Duration: May 2018 – October 2019
Budget: 50.050,00 €
Funding: co-financed by Greece

WEBSITE (coming soon)
EMAIL
TEL
HOURS

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Recent Publications

Kotsifakis, K., Kourtis, I., Feloni, E., Baltas, E., 2018. **Assessment of rain harvesting and RES desalination for meeting water needs in an island in Greece.** In *Frontiers in Water-Energy-Nexus—Nature-Based Solutions, Advanced Technologies and Best Practices for Environmental Sustainability*. Proceedings of the 2nd WaterEnergyNEXUS Conference, November 2018, Salerno, Italy, pp. 59-62, Springer, ISBN 978-3-030-13067-1. https://doi.org/10.1007/978-3-030-13068-8

Kourtis, I.M., Kotsifakis, K.G., Feloni, E.G. and Baltas, E.A., 2019. **Sustainable Water Resources Management in Small Greek Islands under Changing Climate.** *Water, 11(8)*, p.1694. https://doi.org/10.3390/w11081694

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Operational Programme
Human Resources Development, Education and Lifelong Learning
Co-financed by Greece and the European Union

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Renewable energy business models for realizing the competitive advantage of renewable energy

Neda MUZHO[1,] Ph.D. Candidate

Social Sciences & Solvay Business School, VUB & UNWE

[1] *Contact details of corresponding author*

Tel: +359 884 108 409

Fax: n/a

e-mail: neda.ilieva@gmail.com

Address: 1 Danail Detchev str, Lozenets, Sofia, Bulgaria

Abstract

Turning green into gold is the wake-up call du jour as the agenda for the new business models for sustainability is to move towards corporate sustainability (Lüdeke-Freund F. & Dembek K., 2017; Bocken N. et al., 2014; Benn S. et al., 2014), and going beyond the rationale of how an organization creates, delivers and captures value (Joyce A. & Paquin R., 2016).

The research objective of this paper is an assessment of the key success factors for effective use of the policy instruments that contribute to more efficient and sustainable production of Renewable Energy (RE) and RE equipment as well. However, RE Business Models (REBMs) need to be supported by the appropriate fiscal incentives.

We shall make a thorough analysis of the market regulation that has changed the business environment and made it favorable for the production of clean energy. The study incorporates qualitative research, using semi-structured in-depth interviews. A comparison analysis between different European countries' investments in REBMs will contribute in making the difference between the cooperatives and traditional business models.

The main findings of this study are related to the assumption that companies that specialize in high-tech production and implementation of photovoltaic and wind equipment may acquire additional competitive potential and make double dividend: pollution free production of electricity and sufficient profitability (Klein N., 2015).

We are implementing new facts and arguments supporting the conclusion that this highly dynamic energy sector may contribute to technological innovation and better market competitiveness.

References

Benn S., Edwards M. & Williams T., 2014. *Organizational change for corporate sustainability,* 3rd Edition, London, Routledge.

Bocken N., Short S., Rana P. & Evans S., 2014. *A literature and practice review to develop sustainable business models archetypes*, Journal of Cleaner production, Vol. 65, Pages 42-56.

Joyce A. & Paquin R., 2016. *The triple layered business model canvas: A tool do design more sustainable business models,* Journal of Cleaner production, Vol.135., Pp:1474-1486.

Klein N., 2015. *This changes everything, Capitalism vs. the Climate,* Simon & Schuster Inc. NY, 10020

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Renewable energy business models for realizing the competitive advantage of renewable energy

Neda Muzho, Joint PhD
Department of Economics, University of National and World Economy, Sofia
Department of Economics, Vrije Universiteit Brussel
Boulevard de la Plaine 2, 1050 Ixelles
Email: neda.ilieva@gmail.com

The XXIst Century Challenge- Sustainable Economic Development

- ***Companies that specialize in high-tech production and implementation of photovoltaic and wind equipment may acquire additional competitive potential and may realize double dividend: pollution free production of electricity and sufficient profitability.***
- Knowledge gap: Research gap remains in governance of BMs resulting from network participation for sustainability. In particular, resource dependency of energy companies involved in a sustainable development model. Resource dependency of energy companies involved in a sustainable development network affects innovation and management of BMs.
- The existing literature also argues that firms must redesign their BM based on networks and collaborative practices to attain sustainable development (Bocken et al., 2014; Roome and Louche 2016), there's little research into the role of individual level factors affecting the scaling process for impact [illegible]

Renewables: The cornerstone of Europe's decarbonized energy future

- Relevance: In contrast with the traditional fossil energy, Renewable energy (RE) comes from naturally replenished resources such as sunlight, wind, tides, rain, and geothermal heat. Though RE technology is improving fast, the general public has been slow to adopt it *(Van Der Horst, 2017)*.
- The age of SD recommends a holistic framework, in which society aims for environmentally sustainable and socially inclusive development, underpinned by good governance (Jeffrey Sachs, 2015)
- In order to reverse the process of global warming and to limit the process of environmental pollution the increasing production of renewable energy is viewed as one of the key instruments. However, the production of renewable energy is much more expensive than the production of energy based on non-renewables. Nevertheless, as stated by Lyytinen (2017), the establishment of favorable business model for sustainable development, supported by fiscal incentives, may overcome the problems with the cost increase.

The XXIst Century Challenge- Sustainable Economic Development

- Research objective:
  - To understand which are the key success factors for effective use of the policy instruments that contribute to more efficient and sustainable production of renewable energy equipment, respectively renewable energy electricity.
- Contribution statement:
  - On the verge of positive and negative arguments, there is an argument known for pushing forward economic development, namely that competition is the main advantage of the market economy. The contribution statement of this presentation is to offer an understanding on how the underlying mechanisms of achieving environmentally friendly production of RE equipment affect the positive externalities on nature and socio-economic effects.

RENEWABLE ENERGY BUSINESS MODELS

- Ownership Business Models, which focus on financing and risk mitigation concerns
  - Public-private partnership
  - Multiparty ownership
  - Lease or hire purchase model
  - Dealer Credit business model
- Service Business Models, which focus on providing specified services and highlight different methods of operation and maintenance
  - User Cooperative
  - Energy performance contracting

In practice, most real-world business models are hybrids, combining elements of various types and appro... For example, a utility or a private company may develop and own a minigrid system, operated and managed ... a community-based organization, while a private maintenance company provides the technical backup ... services (Rolland 2011).

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Market regulation - The role of government

- Governance can best be described in terms of the elements of a successful common pool resource management model (Nobel prize in economics to Elinor Ostrom)
- Given the central policy role of the state, the great diversity of capabilities and differences in resource endowment, a flexible, collaborative approach is necessary.
- The goal is to find polycentric modes of governance that fall between the market and the state where a community self- organizes to build institutions based on trust, legitimacy, and transparency.
- Governments have enough monetary, fiscal, and commercial means (foreign trade regulations; export incentives; technical, health and environmental standards; and administrative procedures for import and export) through which it can direct the whole investment process in the state's desired direction. Most of these tools are applied even now, but to insufficient extent, diversity, and interrelation.
- Some governments have introduced pricing programs to allow customers who wish to buy green power the opportunity to do so for a marginal fee. Various governments have also introduced regulatory programs - usually known as Renewable Portfolio Standard (RPS) - to force electricity supply companies to increase their production of electricity from RE sources.

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Multiple Criteria Analysis pour *"L'ènergie du jour"*
- An attempt for systematic approach
Presented at the World Renewable Energy Congress - Sweden, 8-13 May, 2011, Linkoping, Sweden

Multiple Criteria Decision Making_Renewable energy models parameters

Type of REM	Technology improvement	Maturity/reliability	Installation consistence and maintainance requirements	Climatic conditions	Continuity and predictability of perfomance	Value of energy output	Value of environmental benefit	Land requirement	Labor impact	Distribution cost	Compatibility with legal, administrative & political framework	Cost/Kwh As per 2017 Source: IRENA	Emissions /GWh
Solar Energy	1) Market availability of the technology for more than 10 years.	Mature technologies, close to reaching the theoretical limits of efficiency	1)great technical background for installation/maintenance	1)Depending on site specifics.	1)Predictable and continuous operation.	$VEO = E[XsmPsm + XcmPcm]$	The VEB can be calculated using two scenarios, the renewable energy certificate and the certified emission reductions scenario.	1) High land requirements and significant landscape alternation that has no affect on future growth of the area.	1)High employment during installation however low during the maintenance	1)High cost for connection to the grid lowering significantly the NPV	Renewables can be seen as a way to reduce carbon emissions, to promote industrial development, to decrease fossil fuel imports, and meet other policy goals.	1)0.10 USD / Kwh	1)low emissions/ 83 T CO2_GWH
Wind Power	1) Market availability of the technology for more than 10 years.	Mature technologies, close to reaching the theoretical limits of efficiency	1)great technical background for installation/maintenance	1)Depending on site specifics.	1)Predictable but not continuous operation.	$VEO = E[XsmPsm + XcmPcm]$	The registered CDM project obtains one CER for each 1 ton of CO_2	1) High land requirements and significant landscape alternation that has no affect on future growth of the area.	1)High employment during installation however low during the maintenance	1)High cost for connection to the grid lowering significantly the NPV		1) Offshore wind energy 0.14 USD/ kWh & Onshore wind energy 0.06 USD/ kWh.	1)low emissions/ 26 T CO2_GWH

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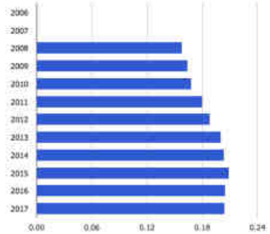
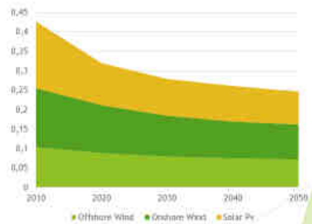
"L'ènergie du jour"- LCOE - Wind and Solar RE

- Levelized cost of electricity (LCOE), also known as Levelized Energy Cost (LEC), is the net present value of the unit-cost of electricity over the lifetime of a generating asset.
- Current energy prices EU-28/Eur-Kwh - LCOE Projections prices EU-28/Eur-Kwh





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Case study approach _ The Cooperatives "Overcoming the RE barriers"

- The research design used is adopted in order to discover how RE cooperatives are escaping the barriers to the uptake of RE.
- Originated from the Theory of Reasoned Action (Fishbein and Azjen, 1975), the Technology Acceptance Model (TAM) is used to identify the constructs of the barriers to RE adoption that the cooperatives are facing that.
- Our exploratory research will contribute on the fact that cooperatives effectively contribute to the uptake of RE with community-based social marketing initiatives that are creating the promotional factors required for a resilient energy sector.
- The findings would contribute to the literature about the governance for environmental sustainability.

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Renewable energy business models

- Qualitative research using semi-structured, in-depth interviews.
- data richness, depth and quality
  - Sufficient to create a theory on dealing with these confrontations (Eisenhardt, 1989).
  - compensate for the associated shortcomings of limited representativeness and generalization (Eisenhardt, 1989; Strauss and Corbin, 1994; Yin, 2003)
  - Using these case studies will unveil their basic logics and underlying dynamics (Eisenhardt, 1989; Yin, 2009).
- 15 Belgian PV & Wind producers and 15 Bulgarian firms
- 30 interviews /45min. average
- Founders, board members, management, key partners
- March until October 2019
- 10 open questions regarding Business Model, policy instruments, key success factors for increasing the competitiveness, technological innovation, subsidies and cooperation between public institutions
- Secondary data : articles, news reports, websites and internal reports

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Renewable energy business models

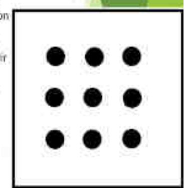
- Case selection criteria
  - Renewable energy (coming from Wind and Sun)
  - PV Firms and Wind producers located in Belgium & Bulgaria
  - Recognized as successful BMs by third parties (community, banks, municipalities...)
  - Cooperatives case studies in traditional model
  - National or international active

Findings

- Renewable energy building blocks: developers, financial parameters (equity provider and the loan provider), operation and maintenance of the installation and at last but not least, competitors in the energy market
- Important patterns: geographical location of the installations, access to resources, regulatory framework, grid access and mentality
- It is very important to consider as public policy instruments for technological innovation, as the key enabler is to accept the creation of "sandbox" (fintech innovations) on both regulatory and technical side
- Important policy instrument provided by the government which are used to enhance the competitiveness of renewable energy business models, is the secured and straightforward permitting system
- Building-up the "muscles" needed to pave the way towards sustainability and reshape the oligopolistic electrical market could be done through bold and stable subsidy framework, if any with market enabling possibilities (excluding the feed-in-tariff system due to regulatory and political risk)

Sustainable Energy Models: Connecting the dots

- The rationalist models of the early 1970s assumed that educating people about environmental issues would automatically result in more pro-environmental behavior (Burgess et al., 1998).
- Successful RE projects are typically managed by cooperative ventures rather than money making corporations (Sabbaran and Lloyd, 2011).
- We live in a time of transitions, in which we are searching together for new earning or transition models. But because everything we do and don do is based on a financially-driven transaction model, it is hard or sometimes even impossible to escape reality in such a way that brings other transaction models to the surface and - by using them - show their feasibility and value (Jan Jonker, 2012)
- Another way to think about RE is to conceptualize it as an innovation.



INTERREG	ZenH Balkan
Title: "Towards Zero Energy Hospitals in the Balkan Region (ZenH Balkan)" **Project Web Site:** https://www.zenhbalkan.edu.gr/ **Duration:** 24 months **Start Date:** December 2017 **Key Words:** nZEB, Zero Energy Hospitals, energy saving	**Funding mechanism**: The ZenH Project is supported by the INTERREG Balkan-Mediterranean Programme and it is funded by the European Regional Development Funds (ERDF) **Total Cost:** 816.096,92€ **EC Contribution:** 693.682,38€ **Consortium:** 5 partners from 5 countries **Project Coordinator:** DUTH (Hellas)

The Challenge

Hospital buildings are considered complex systems as they are hosting several energy intensive functions (HVAC under strict comfort conditions, high hot water demand, Kitchen facilities, etc). There is considerable work in EU on the definition of near Zero Energy residential buildings, offices and hotels but not for hospital buildings. The project ZenH aims to facilitate the implementation of the EPBD (Energy Performance of Buildings Directive) by defining the characteristics and Standards for Zero Energy Hospitals (ZenH) in the South Balkan region.

Project Objectives

The overall objective of the project is to contribute towards improving the energy efficiency of the building sector and specifically towards energy efficient hospital buildings. In addition, the project aims to facilitate the implementation of the EPBD by defining the characteristics and Standards for Nearly Zero Energy Hospitals. Project outputs can be appropriately transferred to other building types. To achieve the overall objective the consortium is introducing a set of specific objectives:

1. Benchmark nZenH Building under specific regional climate conditions;
2. Provide technical guidelines towards nZEnH buildings to hospital's management & technical staff;
3. Advance quality of hospital building data in existing building Hubs;
4. Support capacity building of technical staff towards ZEB in public & private sector;
5. Facilitate decision making on applicable technologies to hospitals at a regional level & assist in establishment of national renovation policies in existing building stock.

Methodology

- Energy data of hospitals will be collected.
- The energy audits will be performed to obtain actual data and determine the operational characteristics of the selected hospital.
- Identification of the most prominent Energy Efficient (EE) and Renewable Energy Sources (RES) technical solutions applicable to the energy consumption profiles of hospitals.
- Benchmarking of EE & RES technologies based on hospitals energy systems (e.g. heating, cooling, lighting) will be elaborated.

- Economic assessment on specific EE & RES technologies will be prepared.
- Training material that will assist hospitals' technical staff and designers to understand the basic concept of design methodologies and applicability of EE & RES technologies will be produced.

Results

- Produce benchmarks and design guidelines for ZenH;
- Improve the technical capacity of professional groups and government officials towards the ZE buildings notion;
- Prepare detail analysis and test the benchmark models for upgrading 7 hospital buildings into ZEB.

Project Team	
Democritus University of Thrace, Department of Environmental Engineering	GR (Greece)
ALBAFOREST	AL (Albania)
Association Sofia Energy Centre	BG (Bulgaria)
The Cyprus Institute	CY (Cyprus)
CeProSARD	MK (Republic of North Macedonia)

Zero Energy Hospitals – The prospects for energy upgrade of hospital buildings in the Balkan region

Prof. Argiro DIMOUDI, University of Thrace - Greece

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Zero Energy Hospitals - The prospects for energy upgrade of hospital buildings in the Balkan region

Argiro Dimoudi, Athina Kantzioura, Pavlos Toumpoulides, Stamatis Zoras
Despina Sergidou
Mehmet Metaj

Project co-funded by the European Union

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The building sector accounts for 40% of the total energy consumption and 36% of total CO2 emissions.

Thus, the sector has a very significant role to perform in implementing the EU energy efficiency objectives.

Non-residential buildings account on average for 25% energy consumption of the total European building stock, representing a heterogeneous sector compared with the residential.

Large buildings, such as hospitals, consume a lot of energy since the different services.
(continuous electricity, heating and cooling energy demand, thermal comfort, air quality levels, specialised services for the patients)

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As a result, hospitals present a great potential for energy and cost savings because the simultaneous demand of energy uses for the entire year allows several actions for energy efficiency improvement to be studied and planned.

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The ZenH Balkan Project

The project aims to facilitate the implementation of the EPBD by defining the characteristics and Standards for Zero Energy Hospitals (ZenH) in the South Balkan region.

The expected outputs

- Produce benchmarks and design guidelines for ZenH
- Improve the technical capacity of professional groups and government officials towards the ZE buildings notion
- Prepare detail analysis and test the benchmark models for upgrading 7 hospital buildings into ZEB.

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Methodology

- Energy data of hospitals will be collected.
- Energy audits will be performed to obtain actual data and determine the operational characteristics of the selected hospital.
- Identification of the most prominent Energy Efficient (EE) and Renewable Energy Sources (RES) technical solutions applicable to the energy consumption profiles of hospitals.

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The expected outputs

- Produce benchmarks and design guidelines for ZenH
- Improve the technical capacity of professional groups and government officials towards the Zen buildings notion
- Prepare detail analysis and test the benchmark models for upgrading 7 hospital buildings into ZEB.

The Partnership

The partnership covers all 5 eligible nations at the Balkan region

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Analysis of current Hospitals Energy Performance

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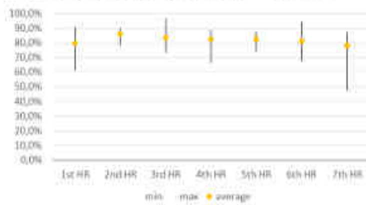
Greece

In all Greek hospitals buildings, the primary energy consumption per m2 declines from the European target for existing nZEB in tertiary sector, 90kWh/m2.

The deviation of the primary energy consumption per m2 of each hospital from the desired target value for nZEB Hospitals, is about 81.8%.

This marks the great challenge for interventions to improve the energy efficiency behaviour of buildings and their upgrading into nZEB-Hospitals.

DEVIATION FROM THE TARGET



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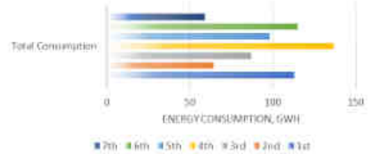
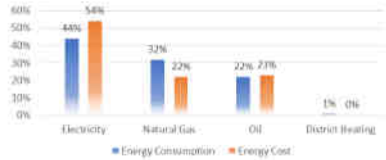
Greece

The energy demands in Greek hospitals are
- electricity 44%,
- natural gas 32%,
- oil 22% and
- district heating only 1%.



Regarding the energy cost, more than fifty percent is spent for electricity use



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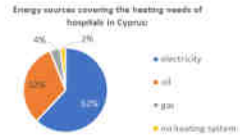
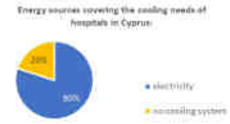
Cyprus

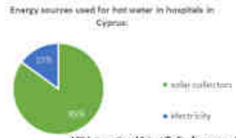
The total heating needs are covered
- 32% by oil,
- 4% by gas,
- 62% by electricity and
- 2% of the cases lack heating system.

The cooling needs are covered
- 80% by electricity
- 20% of the buildings don't have an installed cooling system.

For domestic hot water
- 85% of hospitals use solar collectors and
- 15% use electricity.







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Cyprus

The average national final energy consumption of healthcare institutions in Cyprus is 386.30 KWh/m2.
However, the average energy consumption of public hospitals rises to 509 KWh/m2.

PHOTOS FROM THE ENERGY AUDITING OF HOSPITALS

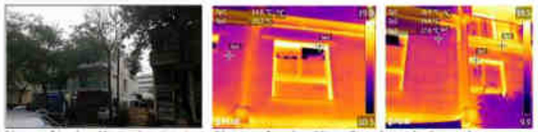

Photo of Ledra Clinic showing its physical context/surrounding environment

Photos of Ledra Clinic Façade with thermal camera

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Albania

- The main energy sources which are used in Albanian hospitals are electricity and oil, especially for heating (boiler) during the winter or Domestic Hot Water (DHW) production. Rarely are find gas boiler.
- In the last years pellet is another fuel that is used for heating or DHW production.
- Also, in cold zones wood stove are still in use in medical care buildings.
- The most energy intensive services in Albanian hospitals are heating, cooling, hot water, cooking, electrical equipment and illumination.

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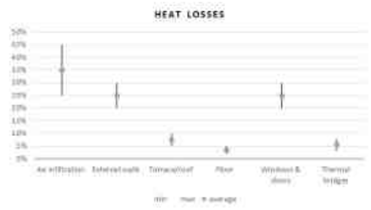
Albania

The data from hospitals auditing process indicates that the air infiltration is mainly responsible for the majority of heat losses (about 35%) and follows the heat losses from windows, doors and external walls (about 25%) due to insufficient insulation.



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Conclusions

There is a need for imperative interventions in hospitals, regarding the energy of appliances, the heating/cooling systems, the shelter of the buildings and the use of RES in order to reduce the energy needs, save/produce energy and upgrade them into nZEB Hospitals.

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Further research will be conducted to investigate important factors that affect energy consumption, saving and production, such as thermal insulation, heating and cooling systems, appliances, window frames, Renewable Energy Sources use for Hospitals' operation.

The energy efficiency of hospital buildings and their upgrading into nZEB Hospitals help to reduce costs, contributing to a better economic management of the hospital, to improve indoor thermal conditions and to a better care for the environment.

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Project co-funded by the European Union

HORIZON 2020	ZERO-PLUS
Title: Achieving near Zero and Positive Settlements in Europe using Advanced Energy Technology **Project Web Site:** http://www.zeroplus.org **Duration:** 60 months **Start Date:** 1/10/2015 **Key Words:** NZE settlements, Innovation technologies, Energy efficiency in buildings, sustainable energy technologies, Thermal-energy simulation, environmental and cost performance	**Funding mechanism**: Horizon 2020, Innovation Action **Total Cost:** 4165502,50€ **EC Contribution:** 3512024,38€ **Consortium:** 16 partners from 8 countries **Project Coordinator:** National and Kapodistrian University of Athens (NKUA)

The Challenge

ZERO-PLUS is a collaborative approach to the design and construction of settlements, involving technology providers, energy efficiency and renewable energy experts and developers who work together from the earliest stages of project conception.

The goal of this project is to provide the market with an innovative, yet readily implementable system for Net Zero Energy (NZE) settlements that will significantly reduce their costs. The benefits of the analysis at the settlement level arise from looking at the larger scale compared to single buildings, and at a system of houses with their interactions. This means, for instance, cost reduction through the deployment of renewable energy technologies at the settlement level instead of individually in each building. The concept can expand to aspects such as efficient water systems, electric mobility, etc.

ZERO-PLUS settlements exceed the state of the art by setting performance objectives requiring improvement relative to other energy efficient buildings:

- Operational energy usage in residential buildings in a ZERO-PLUS settlement is reduced to an average of 0-20 kWh/m^2 per year.
- The NZE settlement generates a minimum of 50 kWh/m^2 of renewable energy per year.
- The cost of the ZERO-PLUS building is reduced by at least 16%, compared to a regular NZE building.

Until the end of the project four ZERO-PLUS settlements will be realized. They will be located in different locations (Cyprus, France, Italy and the UK) and consist of different types of building (ranging from villas to apartment buildings for social housing) thus demonstrating the adaptability and wide applicability of the ZERO-PLUS concept.

Project Objectives

1. The first objective of the project is a reduction of the operational energy usage in residential buildings to an average **of 0-20 kWh/m^2 per year, compared with the current average of 70-230 kWh/m^2 energy per year**. The reduced energy consumption will be attained through the application of a number of technologies, including highly efficient insulation, heating and lighting, as well as automated Building Energy Management Systems (BEMS) in four selected case studies of 2600 m^2 of gross floor area of buildings.
2. In order to achieve the NZE goal, **at least 50kWh/m^2 renewable energy per year** will be generated, on average, in the NZE settlement. This objective will be attained through the

integration in the settlement of innovative energy production technologies such as advanced insulation components, solar energy concentration technology and advanced HVAC technologies.

3. Greater energy efficiency can only be achieved through **a transition from single NZE buildings to NZE settlements**, in which the energy loads and resources are optimally managed. This objective will be attained through the application of solutions for the distribution network, energy storage and micro grid control on a district level, as well as through an optimum climatic management of the open spaces in the settlement.
4. The cost of NZE settlements will be **reduced by at least 16%**, compared with current costs. This cost reduction will be achieved through strategies like the deployment of renewable energy and energy management technologies at the settlement level and the improvement of the microclimate.
5. To ensure that the results of this project will have an impact on the building industry, the final objective is a market uptake of the solutions developed in this project by the year 2018. This will be attained through the demonstration of the solutions **in four different real-life case studies across the EU under different climatic conditions**, and through the dissemination and exploitation of the results of these case studies, based on a comprehensive market analysis and business plan.
6. To support the shift towards resource-efficient, low-carbon and climate-resilient buildings and districts, by enhancing the role of Europe‘s construction industry in the reduction of the EU‘s carbon footprint by almost **77kgrCO_2/m^2 with a total 408 tonnes CO_2 offset for all ZERO-PLUS case studies.**

Methodology

In order to achieve the project's objectives, it will be carried out in a number of phases. Following the collection of all the required input data, different solutions will be developed and integrated into the system for NZE settlements. This system will then be optimized according to the specific requirements of each case study. Following the implementation, extensive monitoring will be carried out to verify the performance of the system. Finally, activities dedicated to the exploitation and dissemination of the results will be carried out to maximize the impact of these results. Accordingly, the project will be carried out in the following phases:

1. State of the Art on NZE and Positive Energy Settlements: Initial Preparation and Collection of Data in the Four Demonstration Sites;
2. Design of technologies and solutions;
3. Integrated Design and Optimisation of the Zero Energy Settlements;
4. Construction management, Cost Management and Implementation of the Innovative Technologies;
5. Monitoring and Evaluation of the Settlements Performance;
6. Market Analysis and Model for Business Growth;
7. Dissemination.

Results

- Increased energy and environmental performance.
- Improving innovation capacity and the integration of new knowledge:
    - Increased innovation capacity;
    - Delivery of innovations to the markets;
    - Integration of new knowledge;
    - Compliance of NZE Settlements with the EU Directive 2010/31/EU for buildings;
    - Contribution to standards.

Project Team	
National and Kapodistrian University of Athens	Greece (GR)
Technische Universität München	Germany (DE)
Ben-Gurion University	Israel (IL)
University of Perugia	Italy (IT)
Oxford Brookes University	United Kingdom (UK)
The Cyprus Institute	Cyprus (CY)
Technical University of Crete	Greece (GR)
ABB Italy	Italy (IT)
Anerdgy AG	Switzerland (CH)
FIBRAN S.A.	Greece (GR)
ConsorzioArca (ARCA)	Italy (IT)
Eco Ltd	United Kingdom (UK)
Office Public d’ Aménagementet de Construction de l’ Isére	France (FR)
CONTEDIL di Ricco M. & C.S.A.S.	Italy (IT)
George Vassiliou Ltd.	Cyprus (CY)
Joseph Rowtree Housing Trust	United Kingdom (UK)

Zero-Plus: Planning & Implementation of monitoring for the ZERO-PLUS Settlements – Lessons Learned

Prof. Margarita ASSIMAKOPOULOS, National and Kapodistrian University of Athens, Greece

Hellenic Republic National and Kapodistrian University of Athens

Horizon 2020 European Union Funding for Research & Innovation

Achieving near Zero and Positive Energy Settlements
in Europe using Advanced Energy Technology
H2020 - 678407

Planning & Implementation of monitoring for the ZERO-PLUS Settlements

Dr. M.N Assimakopoulos, Associate Professor
Group Building Environmental Studies, Physics Department, NKUA, Greece

PROMITHEASNET
12TH INTERNATIONAL SCIENTIFIC CONFERENCE ON ENERGY AND CLIMATE CHANGE
Projects and Funding Opportunities on Energy and Climate Change
11 OCTOBER 2019, Athens, Greece

The ZERO-PLUS project

Scope: ZERO-PLUS is a comprehensive, cost-effective system for the design, construction and monitoring of Net Zero Energy Settlements that is being tested and implemented in four pilot projects across Europe. Greater energy efficiency and economies of scale are achieved through a transition from single NZE buildings to NZE settlements in which the energy loads and resources are optimally managed.

- **Coordinator:** National and Kapodistrian University of Athens
- **Consortium:** 16 partners from the academia and the industry
- **Funding:** H2020
- **Total budget:** 4,165,502.50euros
- **Duration:** 60M i.e Oct. 2015- Sep. 2020
- **Website:** http://www.zeroplus.org/

M49

The ZERO-PLUS concept

TARGET

To develop a method and accompanying tools that will provide an overarching solution mitigating the barriers to successful AND COST-EFFECTIVE construction of new residential Net Zero Energy Settlements (NZES).

ZERO-PLUS building

- ✓ Net Regulated energy of **0-20 kWh/m2 per year**
- ✓ RES energy production of **50kWh/m2** energy per year
- ✓ **16% reduction of initial costs**

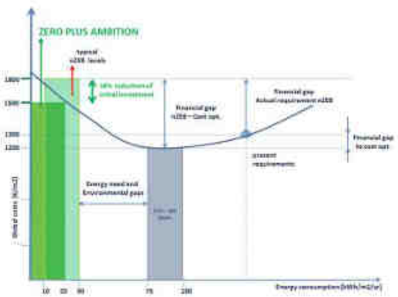
STRATEGIES

Increasing the efficiency of the components directly providing the energy conservation and energy generation in the NZE settlement.

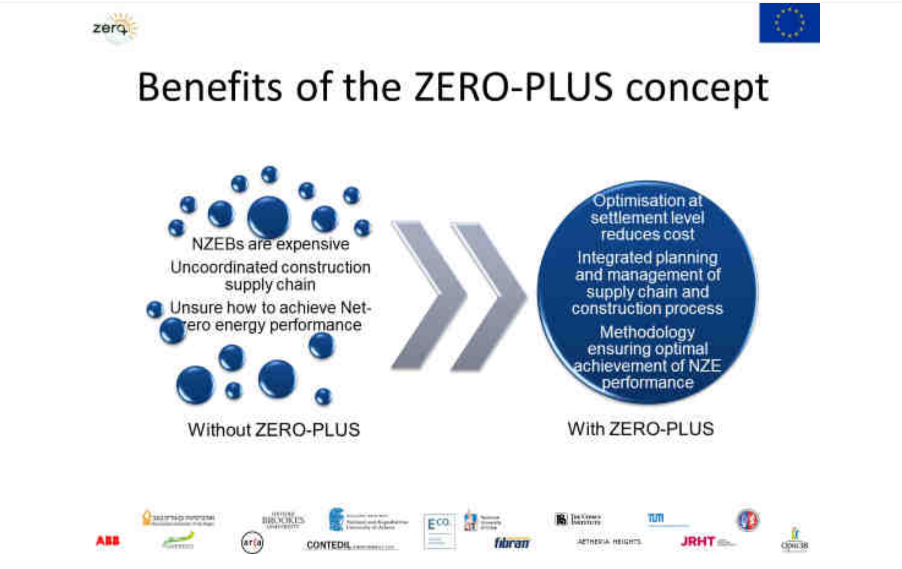
Reducing the costs through efficient production and installation processes.

Reducing operational costs through better management of the loads and resources on a district scale rather than on the scale of a single building.

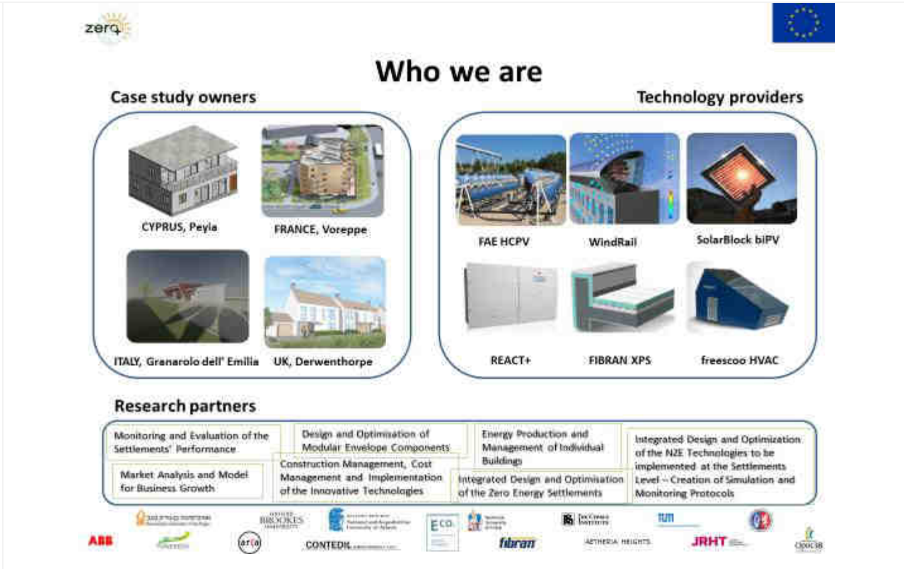
The ZERO-PLUS concept



Financial, energy and environmental gaps between cost optimal levels and NZEB levels in Europe, and the ambition of ZERO-PLUS



Benefits of the ZERO-PLUS concept
NZEBs are expensive
Uncoordinated construction supply chain
Unsure how to achieve Net-zero energy performance
Optimisation at settlement level reduces cost
Integrated planning and management of supply chain and construction process
Methodology ensuring optimal achievement of NZE performance
Without ZERO-PLUS
With ZERO-PLUS



Who we are
Case study owners
CYPRUS, Peyia
FRANCE, Voreppe
ITALY, Granarolo dell' Emilia
UK, Derwenthorpe
Technology providers
FAE HCPV
WindRail
SolarBlock biPV
REACT+
FIBRAN XPS
freescoo HVAC
Research partners
Monitoring and Evaluation of the Settlements' Performance
Market Analysis and Model for Business Growth
Design and Optimisation of Modular Envelope Components
Construction Management, Cost Management and Implementation of the Innovative Technologies
Energy Production and Management of Individual Buildings
Integrated Design and Optimisation of the Zero Energy Settlements
Integrated Design and Optimization of the NZE Technologies to be implemented at the Settlements Level – Creation of Simulation and Monitoring Protocols

Four years in the project...
From
FRANCE, Voreppe
ITALY, Granarolo dell' Emilia
UK, Derwenthorpe
To
FRANCE, Voreppe
ITALY, Granarolo dell' Emilia
UK, Derwenthorpe

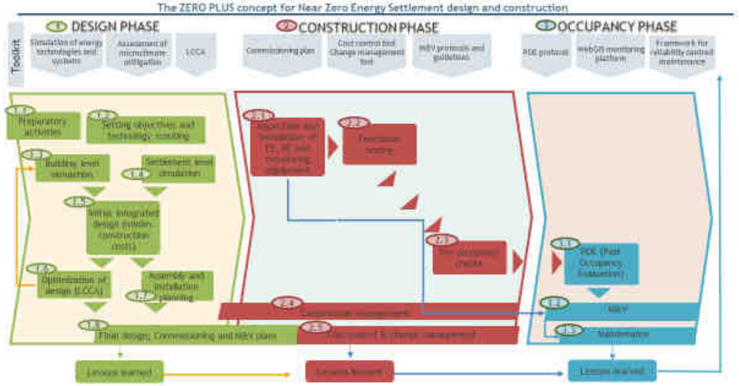
Four years in the project...
From
WindRail® C30
To
Multifunctional Roof Edge MRE
But how did we get there?

Four years in the project...

From | To

But how did we get there?

The ZERO-PLUS concept



LESSONS LEARNED

Purpose:
To <u>capture the lessons learned from the planning, construction and monitoring for Zero Plus</u> and as a result <u>generate **best practices**</u> as well as <u>**recommendations**</u> **for similar future projects**

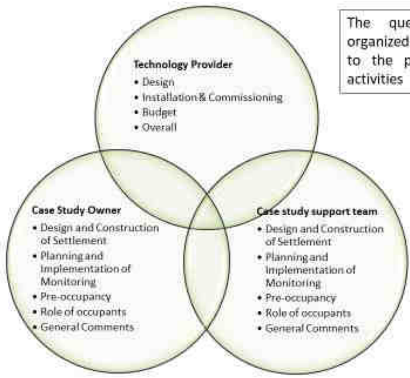
Through questionnaires answered by three main groups of project:
-Case study owners
-Case study support teams
-Technology providers

Opportunity to:

1.identify success stories, pitfalls and/or **unintended outcomes** (positive or negative).

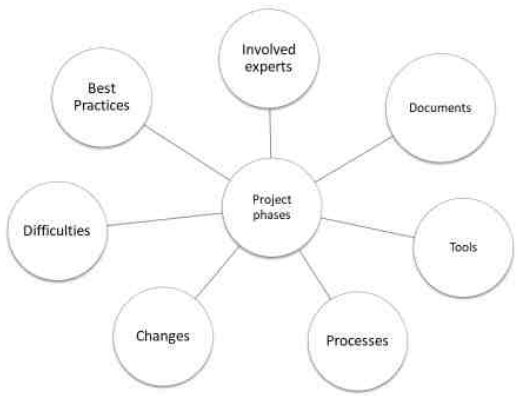
2.recognize things that went well, things that might have been done differently, the **causes** of pitfalls and **suggestions** for facing or avoiding those.

ZERO PLUS – LESSONS LEARNED



The questionnaires were organized in sections related to the project topics and activities

ZERO PLUS – LESSONS LEARNED



ZERO PLUS – LESSONS LEARNED

Best Practices
Broad team of experts
Local microclimate assessment, LCA, Environmental considerations in the design, Energy simulations
Tools: Change Management, Risk registry, Cost Management, Construction Milestones, Commissioning Plan, M&V Plan
Pre-occupancy monitoring
Post-occupancy evaluation, Continuous monitoring of the building and settlement performance
Comprehensive monitoring schema
Welcome Package for occupants

Pitfalls
Restrictions of Local Regulations
Inexperience of contractors with certain processes/technologies

These occurred because the concept was implemented for the first time. Therefore they are not limitations, but opportunity to develop relevant guidance for future projects that will implement this concept

ZERO PLUS – LESSONS LEARNED

Lessons
Identify and bring together a team of partners early on (pre-design)
Establish early collaborations and shared vision among all involved partners/experts
Study of technology applicability at an early stage (regulatory requirements, site constrains) Selection of applicable technologies that can contribute to delivering project targets Feasibility analysis in relation to local context
Continuous management of the design development Work-plan: assign responsibilities, define collaborations necessary at each stage, allocate appropriate timeframe for each phase/action, set milestones
Use of tools that can provide support, highlight risks, and suggest solutions (Commissioning Plan, Risk Registry, Change Management, Cost Management, Construction Milestones, M&V Plan)

Horizon 2020
European Union Funding
for Research & Innovation

THANK YOU

http://www.zeroplus.org/

- ***A. Mayrigiannaki,*** *Research Associate, TUC,* amavrigiannaki@isc.tuc.gr
- *Dr. K. Gobakis,Research Associate, TUC*
- *Dr. D. Kolokotsa, Associate Professor, TUC*
- *M. Saliari, Research Associate, UOA*
- *M. Laskari, Research Associate, UOA*
- ***Dr. M. N. Assimakopoulos****, Associate Professor, UOA,* masim@phys.uoa.gr
- *Dr. S. Isaac, Senior Lecturer, BGU*
- *M. Isaac, Senior Consultant, E Co.*

National funding	GEOPAR
Title: Development of a measurement network, modelling, data base and web mapping service for photosynthetically active radiation (GEOPAR) **Duration:** 36 months **Start Date:** 1/01/2017 **Project Web Site:** http://projects.ciemat.es/web/geopar **Key Words:** Photosynthetically active radiation, PAR, modelling, measurement network, web map service	**Funding mechanism**: Coordination and support actions from Spanish Ministry of Science, Innovation and Universities. **Total Cost:** 57700€ **EC Contribution:** - **Consortium:** - **Project Coordinator:** CIEMAT (Spain)

The Challenge

Photosynthetically Active Radiation (PAR) is the portion of solar irradiance corresponding to the visible spectrum (400-700 nm). It is the portion of solar irradiance which the plants convert into energy through photosynthesis. PAR is of interest in many fields of study and industries such as biomass production, assessment of energy balance in ecosystems, cultivation of vegetables and algae, etc. Unfortunately, only a few radiometric stations can provide ground PAR measurements. In order to fill this gap, a network of PAR stations over mainland Spain is planned in GEOPAR project. This project consists of *the Development of a network of measurements, modelling, database and web service of photosynthetically active radiation maps*.

Project Objectives

1. ***Establishment of a network of PAR stations***: A measurement station of PAR radiation will be implemented in each of the areas obtained from a regionalization process carried out. Thus, it will be possible to have a long, continuous and high-quality series that collect the temporal variability of the variable in each of the defined areas.
2. **Generation and validation of models that allow estimating this type of radiation at the regional level:** These models will allow in each of the areas obtained during the regionalization process to correct the initial estimate provided by the numerical model so that at any point a more accurate estimate is available when supported by the measures obtained.
3. **Elaboration of PAR maps for the peninsular area of Spain:** From the available models in the previous phase, a new value for the PAR can be estimated at each of the points in the study area. The values will be represented graphically.
4. **Generation of the database that collects and makes available to the public the values supplied by the measuring stations:** The data collected in the measuring stations will be monitored and included in a database that can be consulted by interested users.

Methodology

With that purpose, the optimum locations for the stations have been calculated. In consequence, it was decided to start-up the network with 9 stations distributed over mainland Spain. In order to place the stations, several factors were taken into account, such as the optimum distribution over the territory, or the feasibility of the facilities to install the stations. Once the network is set-up and running it will provide not only PAR data but also global horizontal irradiance (GHI), temperature and relative humidity data.

Results

The results of the project will represent an added value since it will allow the network of PAR measures to be available for the Spanish territory. The open publication of the results of the project, and in particular of the new databases generated, would help the biomass producing industry in the planning and promotion of new sites. Also, the benefits will be expanded to areas of basic research, such as the study of plant physiology, and applied research for the production of microalgae.

National funding	ALGATEC-CM
Title: Development of advanced technologies of microalgae for a circular economy (ALGATEC-CM) **Duration:** 48 months **Start Date:** 1/01/2019 **Project Web** Site: http:// www.algatec.es. **Key Words:** microalgae, sustainability, circular economy	**Funding mechanism:** Coordination and support actions Comunidad de Madrid, co-financed by the European Social Fund and the European Regional Development Fund. **Total Cost:** 880340€ **EC Contribution:** - **Consortium:** 6 partners from Spain **Project Coordinator:** URJC (Spain)

The Challenge

ALGATEC-CM project address the *Development of advanced technologies of microalgae for a circular economy*. Nowadays microalgae are a promising field of study of the so-called third-generation biofuels since they are renewable, sustainable and non-polluting raw material that contributes to reduce greenhouse gas emissions. ALGATEC-CM project focuses on addressing the technical and economic difficulties that hinder the full industrial implementation of microalgae.

Project Objectives

1. ***Implementation of CRISPR-Cas technology in cyanobacteria to obtain improved strains for industrial use***: The CRISPR-Cas system allows to develop gene mutations in organisms difficult to manipulate from another way. However, it is necessary to optimize it and tune it up for each organism.
2. **Study of consortia of microalgae and bacteria for industrial uses:** The intention is to study the viability of consortia of eukaryotic or prokaryotic microalgae with bacteria. It is intended not only to study the stability of these consortia but also to develop some practical applications especially in the field of bioremediation and wastewater treatment.
3. **Optimal location of domestic wastewater treatment plants with microalgae in the Community of Madrid:** To maximize the efficiency of microalgae growth, it is necessary to analyze how atmospheric conditions affect, in terms of photosynthetically active radiation (PAR) and temperature the growth of a species of microalgae, simulating the conditions of natural lighting and outdoor temperature in a pilot plant. In this way, we can determine the ideal places within the Community of Madrid to carry out wastewater purification processes through the use of these microalgae.
4. **Extraction with green and advanced techniques of valuable biomass compounds from selected microalgae and cyanobacteria:** It is intended to study the feasibility and optimize the extraction of polar carotenoids (xanthophylls), lipids with EPA or DHA and other valuable bioactive compounds such as phycobiliproteins, beta-carotene, etc.
5. **Energy recovery of the residual biomass of microalgae after the extraction of compounds with high added value:** Bioenergy is key to meeting the energy objectives set in Europe and in Spain. These objectives aim to achieve an increase in the diversification of energy sources and a decrease in the high external energy dependence, as well as in greenhouse gas emissions, thus contributing to alleviating the climate change that the planet is suffering.
6. **Design and study of the viability of the processes:** The simulation model will be constructed from theoretical data and subsequently, said simulation scheme will be adapted to the

experimental data obtained. Once the processes are simulated, they will be optimized from an energy integration perspective. Likewise, its environmental and energy viability will be evaluated through Life Cycle Analysis (LCA).

Methodology

One of the objectives of this project is the assessment of the PAR resource in Madrid Community (CM) and modelling the best conditions of PAR irradiance and temperature for the growth of microalgae. A new set of PAR stations is planned to be installed over the territory of CM. These stations will be included in the GEOPAR network. Therefore, a sound study to select the best areas in the CM to place microalgae biorefineries will be carried out. This study will be validated at pilot scale simulating the optimal environmental conditions obtained.

Results

The results of ALGATEC-CM will have a significant social and economic impact as companies may make products and processes available to the public at competitive prices. This product may also be used for animal feed and in particular for aquaculture companies. The products and processes derived from the project will also be of high social value as long as they have health benefits. Finally and related to the previous impacts, it is necessary to mention the environmental impact that ALGATEC provides to the extent that the cultivation of microalgae is a CO_2 sink and can be used to reduce the greenhouse effect. At the same time that it can reduce pollution, it can also reduce the consumption of fossil fuels if, at the time, it was used to produce biofuels.

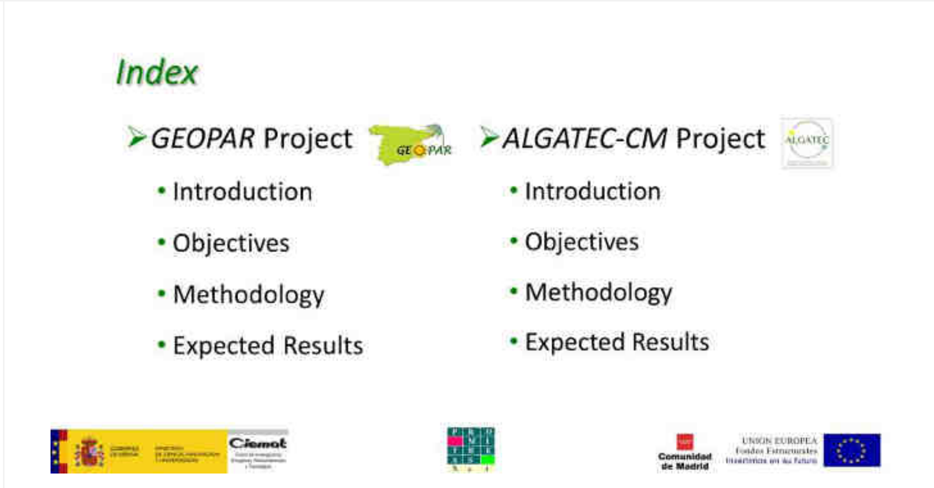
Acknowledgment

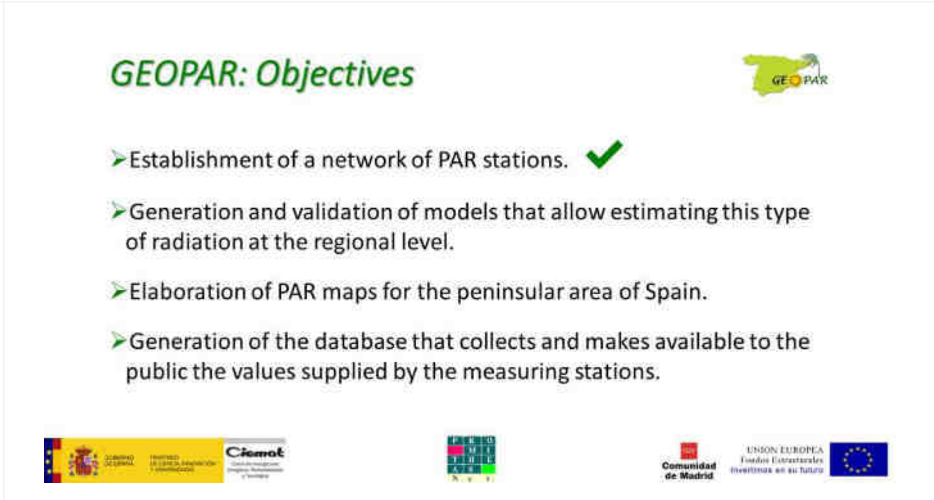
The authors gratefully acknowledge the financial support from the Spanish Ministry of Science, Innovation and Universities, Project CGL2016-79284-P AEI/FEDER/UE and from Comunidad de Madrid provided through project ALGATEC-CM (P2018/BAA-4532), co-financed by the European Social Fund and the European Regional Development Fund.

Project Team	
Universidad Rey Juan Carlos / Escuela Superior de Ciencias Experimentales y Tecnología (URJC)	Spain (ES)
Agencia Estatal Consejo Superior de Investigaciones Científicas / Centro de Investigaciones Biológicas (CIB-CSIC)	Spain (ES)
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT)	Spain (ES)
Universidad Complutense de Madrid / Facultad de Ciencias Biológicas (UCM)	Spain (ES)
Universidad Autónoma de Madrid / Facultad de Ciencias (UAM)	Spain (ES)
Fundación IMDEA Energía (IMDEA)	Spain (ES)

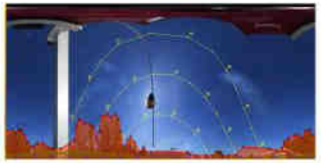
Start – up of a network od PAR stations over mainland Spain and its applications

Mr. Francisco FERRERA – COBOS, CIEMAT - Spain

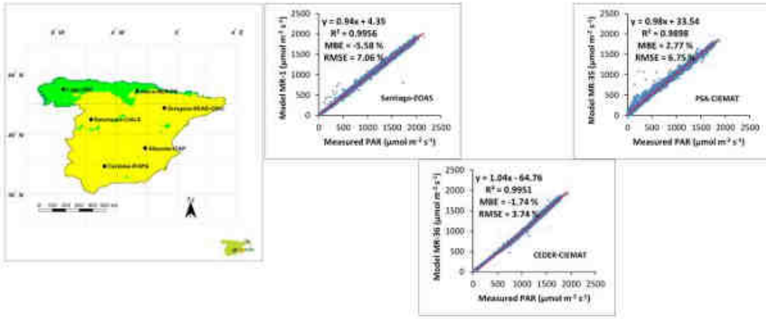




GEOPAR: Methodology



GEOPAR: Methodology



GEOPAR: Methodology

From the measures taken and once the PAR model(s) is validated, a map of PAR radiation in Spain will be developed

ADRASE (www.adrase.es)

GEOPAR: Methodology

The data collected in the measurement network will be monitored and can be consulted in real time.

GEOPAR:Expected Results

- The results of the project will represent an added value since it will allow the network of PAR measures to be available for the Spanish territory.
- The open publication of the results of the project, and in particular of the new databases generated, would help the biomass producing industry in the planning and promotion of new sites.
- Benefits will be expanded to areas of basic research, such as the study of plant physiology, and applied research for the production of microalgae.

ALGATEC-CM: Introduction

At a Glance

Title: Development of advanced technologies of microalgae for a circular economy (ALGATEC-CM)

Funding mechanism: Coordination and support actions Comunidad de Madrid, co-financed by the European Social Fund and the European Regional Development Fund.

Total Cost: 880.340,00 €

Duration: 48 months

Start Date: 01/01/2019

Consortium: 6 partners from Spain

Project Coordinator: URJC (Spain)

Project Web Site: http://www.algatec.es.

Key Words: microalgae, sustainability, circular economy

ALGATEC-CM: Introduction

Project Partners	
Universidad Rey Juan Carlos / Escuela Superior de Ciencias Experimentales y Tecnología (URJC)	ES (Spain)
Agencia Estatal Consejo Superior de Investigaciones Científicas / Centro de Investigaciones Biológicas (CIB-CSIC)	ES (Spain)
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT)	ES (Spain)
Universidad Complutense de Madrid / Facultad de Ciencias Biológicas (UCM)	ES (Spain)
Universidad Autónoma de Madrid / Facultad de Ciencias (UAM)	ES (Spain)
Fundación IMDEA Energía (IMDEA)	ES (Spain)

ALGATEC-CM: Objectives

- Implementation of CRISPR-Cas technology in cyanobacteria to obtain improved strains for industrial use.
- Study of consortia of microalgae and bacteria for industrial uses.
- Optimal location of domestic wastewater treatment plants with microalgae in the Community of Madrid.
- Extraction with green and advanced techniques of valuable biomass compounds from selected microalgae and cyanobacteria.
- Energy recovery of the residual biomass of microalgae after the extraction of compounds with high added value.
- Design and study of the viability of the processes.

ALGATEC-CM: Methodology

- Cluster analysis of the PAR.
- Installation of PAR stations.
- Obtaining representative type days.
- Testing in pilot plant.
- Determination of the most suitable treatment plants.

ALGATEC-CM: Expected Results

- The products and processes derived from the project as cultivation of microalgae is a CO_2 sink and can be used to reduce the greenhouse effect and pollution.
- The results of ALGATEC-CM will have a significant social and economic impact as companies may make products and processes available to the public at competitive prices.
- This product may also be used for animal feed and in particular for aquaculture companies.

Acknowledgements

The authors gratefully acknowledge the financial support from the Spanish Ministry of Science, Innovation and Universities, Project CGL2016-79284-P AEI/FEDER/UE and from Comunidad de Madrid provided through project ALGATEC-CM (P2018/BAA-4532), co-financed by the European Social Fund and the European Regional Development Fund.

THANK YOU

Energy efficiency on Greek islands buildings: the cases of HAPPEN and STEPPING

Mr. Stavros APOSTOLOU, Aegean Energy and Environment Agency, Hellas

aegean energy & environment agency
THE SUPPORTING ORGANISATION FOR GREEK ISLANDS

Aegean Energy & Environment Agency

ΕΠΕΓΑ AEGEA

The Agency was established in 2008 as a non profit organisation to support islands and local authorities on sustainable development.

The Agency's strategic target is to increase the islands' capacity on renewable energy, energy efficiency, wastes & water management, rational use of local resources, preservation of cultural heritage and landscape.
Furthermore, AEGEA is acting as the technical and political advisor of islands in their participation in European projects and networks (Pact of Islands, Smart Islands Initiative etc.)
AEGEA is also an active member of the European organization FEDARENE.

ΕΠΕΓΑ AEGEA

Scientific and Technical Consultant

- Establishment of Ios-Aegean Energy Agency, NPO, founded in 2008
- 2016: Change of name "Aegean Energy and Environment Agency"

Activities

- **Cooperation**: brings together interested parties, i.e. island authorities, private sector, financial institutions, civil society
- **Project maturation**: focus on making innovative projects that are of interest to local authorities bankable
- **Local energy planning**: has delivered over 20 SEAPs for local island authorities (Covenant of Mayors, Pact of Islands)
- **Advocacy**: FEDARENE Vice-Presidency for Smart and Sustainable Islands

ΕΠΕΓΑ AEGEA

Main fields of activity

- Traditionally energy – still backbone of smart infrastructure management
- 2016: change in name → Aegean Energy and Environment Agency to underscore the need for an integrated approach to islands' development

HAPPEN
MedZEB certified

Holistic APproach and Platform for the deep renovation of the Med residential built ENvironment

Overcoming market barriers and promote deep renovation of buildings

HAPPEN is a project funded by the European Union's Horizon 2020 research and innovation programme. HAPPEN is run by a consortium of 13 partners from 7 countries: Spain, France, Italy, Croatia, Slovenia, Greece and Cyprus.

Call: EE-11-2016-2017 "Overcoming market barriers and promoting deep renovation of buildings" – Project main outputs: HAPPEN ICT Platform; MedZEB Protocol; Voluntary Certification Scheme; MedZEB Coordination Group;

Duration: 2018-2020 | **Overall budget**: 2.1m EUR | **AEGEA budget**: 140k EUR | **Partners**: 13

AEGEA role: support the preparation of two thematic pilots (Lefkes, Paros island; Polyvotis, Nysiros island) for the deep retrofitting of buildings using the HAPPEN methodology.

It aims to stimulate the **deep retrofitting market** and to contribute to reducing the energy consumption of buildings in the Mediterranean area.

This area is characterised by **specific types** of climate and buildings, as well as **peculiar socioeconomic conditions**, which makes it necessary to adopt a tailored approach for the deep renovation of buildings.

In light of this, HAPPEN intends to adapt the European-wide concept of **nZEB (nearly Zero Energy Building)** to the Mediterranean context, proposing the MedZEB approach.

The ambitious challenge of HAPPEN is to **boost the high potential market of buildings retrofitting**, while raising the awareness of stakeholders about the issue of energy efficiency.
On this purpose, the project will:

- bring together and **engage with inhabitants, owners** building professionals and policy makers in 10 pilot sites;
- **develop optimal packages of solutions** for the deep retrofit of buildings (including financial solutions) and test them in the pilot sites;
- produce an **ICT platform** aimed to facilitate the match between demand and offer of renovation actions, as well as to **share knowledge and training materials** produced within the project.

OUTCOMES

WE'LL MAKE IT HAPPEN! – EXPECTED OUTCOMES

- Developing a **virtual platform** matching demand and offer in the Med area;
- **Empowering and integrating key actors** of the retrofitting value chain;
- Proposing **standardized cost-optimal packages of solutions**;
- Developing and testing **new financial solutions**;
- Suggesting **new regulatory approaches** for the Med area;
- **Raising trust** in the retrofitting market through a shared guarantee protocol.

HAPPEN

1st Pilot - Lefkes Paros - Hostel

HAPPEN

1st Pilot - Lefkes Paros - Hostel

- Orientation: SE
- Constr. Year: Mids 70
- Surface: 995 sqm.
- Rooms: 15
- Envelope: Non insulated
- Heating: Oil boiler
- Function: Mainly during the summer

HAPPEN

2nd Pilot – Polyvotis Nysiros- Hostel

HAPPEN

2nd Pilot – Polyvotis Nysiros- Hostel

- Orientation: North
- Constr. Year: Two stages 70 - 80
- Surface: 1050 sqm.
- Rooms: 120
- Envelope: Non insulated
- Heating: Oil boiler
- Function: All year long



Interreg Mediterranean STEPPING

STEPPING Project

Supporting The EPC Public Procurement IN Going-beyond

Interreg Mediterranean STEPPING

STEPPING

Supporting The EPC Public Procurement IN Going-beyond

Main objective: to adapt the application of EPC investment schemes for public building in Mediterranean Area:

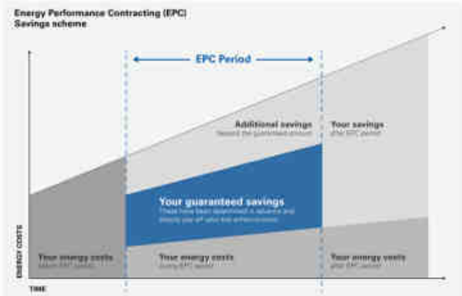
- Prepare 8 investment plans in MED AREA
- Launch 4 investment plans in 4 countries
- Deliver MED guidelines for EPC in public buildings for wider dissemination

Call: Priority Axis 2: Fostering low-carbon strategies and energy efficiency in specific MED territories: cities, islands and remote
Areas | 2.1 : To raise capacity for better management of energy in public buildings at transnational level

Duration: 2016-2019 | **Overall budget**: 1,95 m EUR | **AEGEA budget**: 258k EUR | **Partners**: 9

AEGEA role: select 10 municipalities, conduct energy audits in identified buildings, specify interventions, conduct energy audits, prepare the ESCO market, develop investment plans, issue tender documents.

Interreg Mediterranean STEPPING



The Energy Performance Contract (EPC) is a contractual arrangement between the beneficiary and the provider of an energy efficiency improvement measures, verified and monitored during the whole contract, eher investments in that measure are paid for in relation to a contractually agreed level of energy efficiency improvement or other agreed energy performance criterion, such as financial savings.

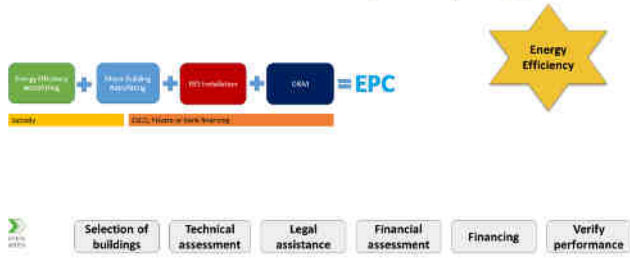
Interreg Mediterranean STEPPING

The EPC: key features

1. We are speaking about PERFORMANCE and not construction works, The latter are the way we achieve the goal of the contract and not the way around
2. The SAVINGS repays in total or partially the investments
3. There is the need to VERIFY and MONITOR the performance
4. EPC has a long term DURATION

Interreg Mediterranean STEPPING

"One-stop-shop" approach



Interreg Mediterranean STEPPING

"One-stop-shop" approach

Interreg Mediterranean STEPPING

About

- About 90 Municipalities involved
- More than 100 buildings analized
- Common Training format designed
- Common investment plan and tools developed
- Tender procedure guide developed

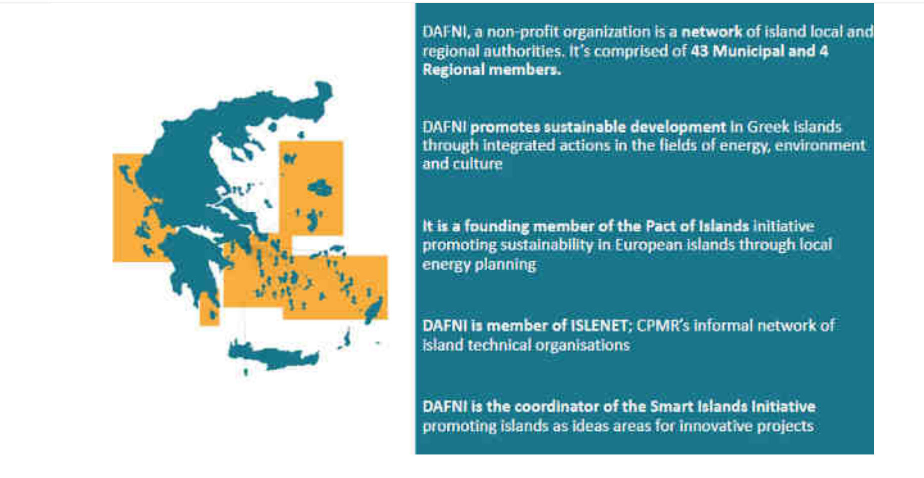
Interreg Mediterranean STEPPING

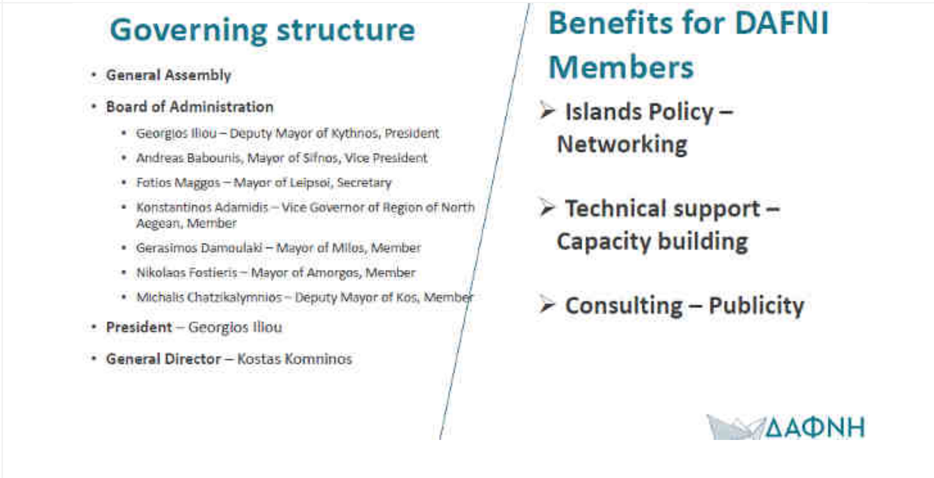
aegean energy & environment agency

Thank you!

Towards clean, affordable and reliable energy in insulated areas: the cases of SMILE and INSULAE projects on Greek islands

Mr. Petros MARKOPOULOS, Network of Sustainable Greek Islands (DAFNI), Hellas





Examples of projects under development

- **Energy retrofitting of public buildings:** Audits, technical studies, financing.
- **Energy efficiency in street lighting:** LED lighting and smart control applications.
- **EV infrastructure :** Installation of EV charging stations and promotion of EV market
- **Biogas plant, Naxos:** Feasibility study for the exploitation of the local farming residuals.
- **Desalination with RES:** Promotion of systems combining desalination plants with installation of RES plants.
- **Energy Communities:** Technical assistance to local authorities.
- **Municipal wind park, Lesvos:** Repowering and extension of a licenced wind park with parallel operation of an environmental and RES park.
- **Geothermal district heating, Lesvos:** Reoperation and extension of a geothermal pilot district heating network to heat private houses, a poultry farm and several greenhouses.
- **Sustainable tourism project in multiple islands:** Hiking trails, Biking trails, Trails of cultural heritage, Digital applications
- **UNESCO Geopark of Cyclades**

ENERGY TRANSPORT WATER ECONOMY WASTE ICT

ΔΑΦΝΗ

EU projects in a nutshell

Past projects

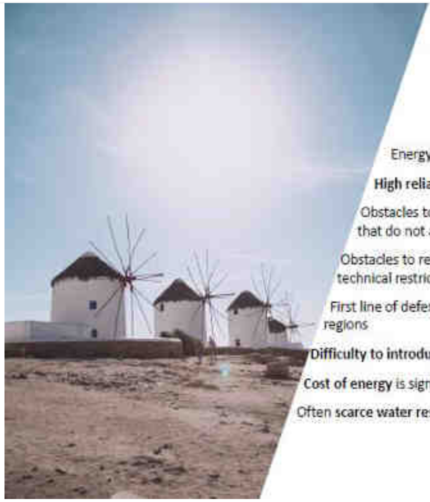
- Establishment of "Ios-Aegean Energy Agency", IEE (2008-2010)
- ISLEPACT, IEE (2009-2011)
- PROMISE, IEE (2012-2014)
- Smart Grids in 5 Greek Islands, ELENA Fund, EIB (2011-2014)
- SMILEGOV, IEE (2013-2015)

On - going projects

- **Kythnos - Smart Island**

yenesis SMILE insulae

ΔΑΦΝΗ



What is special about Islands

Structural handicaps related to energy

- Energy planning based on **seasonality**
- **High reliance on hydrocarbons,** high potential for emissions reduction
- Obstacles to reduce emissions for interconnected islands due to **low capacity cables** that do not allow high RES penetration
- Obstacles to reduce emissions for non-interconnected (NI) islands due to technical restrictions in the **grid that does not allow high RES penetration**
- First line of defence and **most severe impact from climate change** compared to continental regions
- **Difficulty to introduce natural gas** in the islands' energy market
- **Cost of energy** is significantly higher due to transportation costs
- Often **scarce water resources** – Energy intensive desalination plants

ΔΑΦΝΗ

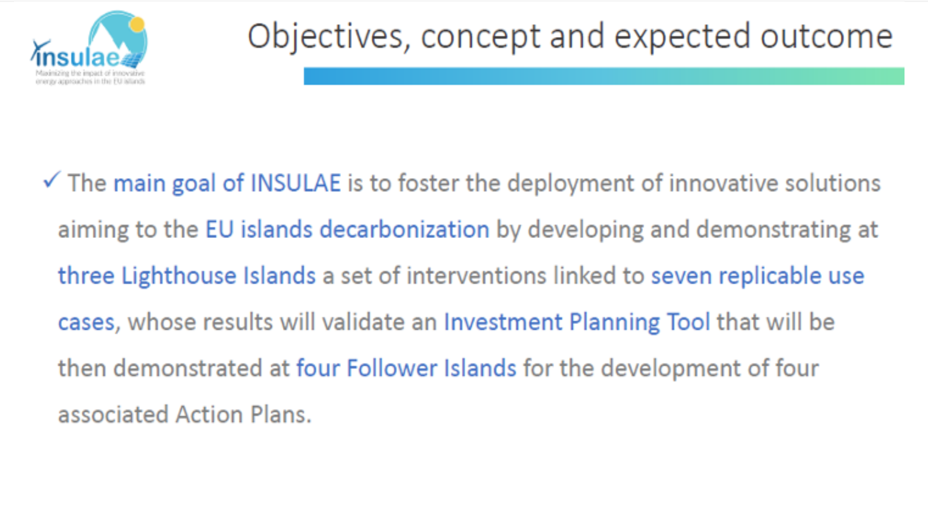
Opportunities for Islands

ΔΑΦΝΗ

- Local CO2 Emmisions Production
- Local Utility Infrastructures
- Innovation In Islands Matters
- Islands As Test-Beds
- Replicability Potential


insulae
Maximizing the impact of innovative energy approaches in the EU islands
INSULAE Project


insulae
Project info
✓H2020-LC-SC3-2018-ES-SCC Call
✓ Innovation Action
✓ EU Funding 12.160.234,50 €
✓ Duration 48M
✓ Coordinator CIRCE
✓ 27 partners
circe
RINA
Artelys
Suite5
DNV·GL
FSB
REA
DTU
ERICSSON
FREMSYN
efacec
albufera
ACIF
Renewables


insulae
Objectives, concept and expected outcome
✓ The main goal of INSULAE is to foster the deployment of innovative solutions aiming to the EU islands decarbonization by developing and demonstrating at three Lighthouse Islands a set of interventions linked to seven replicable use cases, whose results will validate an Investment Planning Tool that will be then demonstrated at four Follower Islands for the development of four associated Action Plans.


insulae
Objectives, concept and expected outcome
Specific goals
✓ To create an Investment Planning Tool
✓To carry out a complete demonstration program in three Lighthouse Islands
✓ To ensure a large project replication of the seven uses cases
✓To engage islands inhabitants as an active player in the energy system
✓To protect the islands ecosystems preserving its biodiversity and cultural heritage
✓To exchange knowledge within the BRIDGE Initiative
✓To create a critical mass of professionals ready to replicate INSULAE

Lighthouse Islands

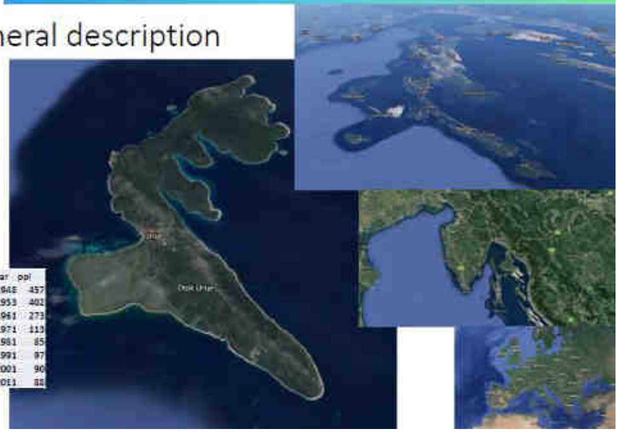
UNIJE Island

Location and general description

The Island of Unije

- Surface: 16.83 km²
- Coastline: 38.012 km
- the island peak: 138 m.a.s.l
- Unije, only settlement
- 85 people
- 47 households
- 292 objects
- No cars on the island
- Small sea port and airport

year	Ppl.	year	ppl
1869	520	1948	457
1880	650	1953	402
1890	678	1961	273
1900	696	1971	113
1910	758	1981	85
1921	783	1991	97
1931	717	2001	90
1945	638	2011	88



UNIJE Island

USE CASES

- #1 - Joint management of hybridized RES and storage
- #2 - Smart integration and control of water and energy systems
- #3 - Empowerment of islands' energy communities through 5G and IoT technologies for flexibility services

BORNHOLM Island

Location and general description

- 40000 inhabitants; 588.3 km2
- Approx. 1% of Denmark (size and population wise)
- Touristic/historical attraction; presence of industry
- Self-sufficient community
- Target to be 100% carbon neutral by 2025
- Pioneer in smart grid projects

BORNHOLM Island

USE CASES

#4 - Transition to DC grids

#5 - Local bio-based economies supporting the electrical, thermal and transport systems integrated management

Madeira Island

Location and general description

- 262.000 inhabitants; 801 km2
- 1000 km away from Lisbon
- Economy is mainly based on tourism and agriculture Self-sufficient community
- Counts with a **Sustainable Energy Action Plan**

Madeira Island

USE CASES

#6 - Electrification of the islands' transport looking to grid frequency and voltage regulation

#7 - Storage and power electronics for the stabilization of weak grids and microgrids

Follower Islands

NORDENEY

MENORCA

PSARA

CREATE ACTION PLANS FOR DECARBONIZE THE ISLAND USING THE IPT

Role of DAFNI

- Our member, Municipality of Psara is one of the 4 Follower islands and DAFNI will support it during the application of IPT
- As coordinator of Smart Islands Initiative, DAFNI will spread the knowledge produced to all EU islands that support the Initiative
- DAFNI is responsible for the stakeholders and citizens engagement processes in the Lighthouse islands
- DAFNI provides the relevant KPIs, from its long-term experience in islands, for the island typologies definition and parameterization
- DAFNI is the leader of WP10: Communication and dissemination activities

Role of DAFNI

WP10. Specific objectives:

- To disseminate the project results to external stakeholders.
- To prepare the visual identity and promotion materials.
- To carry out engagement and interaction activities with key external stakeholders.
- To enable a showcase at each demo-site for dissemination and training purposes.
- To contribute to common information and dissemination activities to increase the visibility and synergies between H2020 supported actions

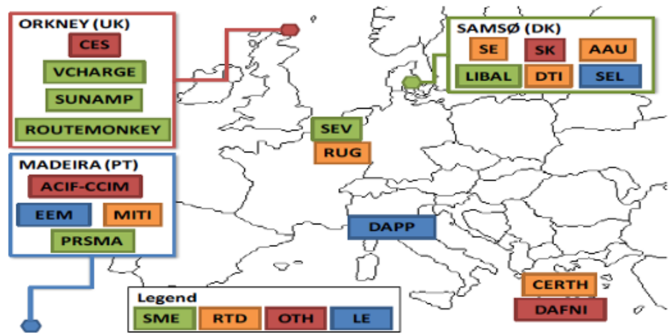
SMILE

SMART ISLAND ENERGY SYSTEMS

Overview of the project and objectives

Geographic distribution

- 19 partners from 6 different European Countries



SMILE overall objective

- The SMILE project aiming to demonstrate, system-wide in real-life operational conditions, a set of both **technological and non-technological solutions** adapted to local circumstances targeting the **distribution grid** to enable:
  - **Demand response**
  - **smart grid functionalities**
  - **storage and energy system integration**
- **3 large-scale pilot** projects in **3 regions** with **similar topographic characteristics** but different **policies, regulations and energy markets**

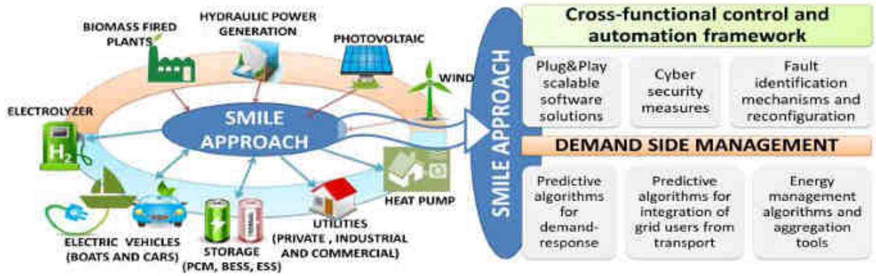
SMILE scope and main goals

- Demonstrate 9 innovative technological solutions in large-scale smart grid demonstration projects in 3 islands:

- Pumped hydro
- EVs / Electricity stored on vessels
- Aggregator approach to DSM

- Integration of battery technology
- Power to heat
- Power to fuel

Overall Concept



Why island locations?

- Island communities can be more easily engaged in the real-life testing of solutions with measurable impact
- The 3 selected case studies:
  - characterised by high shares of RES
  - intend to demonstrate stable grid operation in the context of the adoption of energy storage solutions and/or the connection between the electricity network and other energy networks
  - intend to demonstrate smart integration of grid users from transport and mobility.

Why island locations?

- Each pilot brings:
  - Specific set of challenges
  - Technology options
  - Energy market conditions
- The sites are therefore **effectively representative of the majority of the EU energy** markets and offer excellent demonstration settings which will deliver **maximum impact in terms of replicability**.

Replication

- Each case study is **representative of an important energy challenge common to several** locations in Europe, on islands as well on mainland.
- **Orkney Islands and Samsø are electrically connected to the mainland network** and can therefore be representative of **smart grids located on the mainland as well**
- **Madeira is the only case of a total energy island**, not connected to the mainland network.
- Mutual learning approaches
- Replication (DAFNI/Greek islands)

The role of DAFNI in SMILE

- **Communication and dissemination**
  - EU Sustainable Energy Week 2018 & 2019 in Brussels
  - Local workshops in Greek islands
  - B2B sessions

The role of DAFNI in SMILE

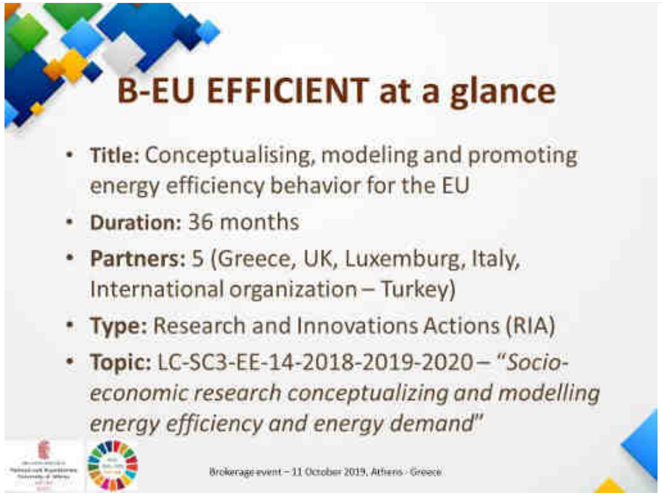
- Replication
  - DAFNI will develop replication roadmaps for the transferring of tested technologies and business models to three identified islands in Greece that share similar characteristics with the SMILE pilots
- Policy & Regulation
  - Building on the Smart Islands Initiative (supported by +200 islands and networks of islands), DAFNI provides SMILE with insights regarding barriers and opportunities associated with the energy transition of islands across Europe, i.e. regulatory, market, technological, financing

Thank you!

ΔΑΦΝΗ

The B-EU Efficient Proposal

Dr. Popi KONIDARI, National and Kapodistrian University of Athens – Energy Policy and Development Centre - Hellas



Problem

Under the complexity of EU economy & energy policy, different impacts of Energy Efficiency (EE) policies need to be explored using data & behavioural variables of the demand side.

Brokerage event – 11 October 2019, Athens - Greece

Concept

Develop novel "soft-link" between Computable General Equilibrium Model, Agent – Based Model, HERON – DST and AMS.

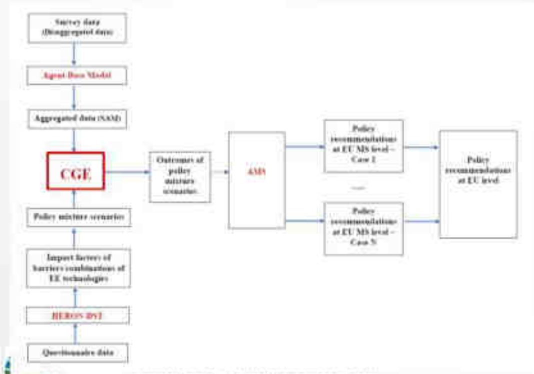
Brokerage event – 11 October 2019, Athens - Greece

Ambition

- Introduction of "bottom up" information from consumer surveys so as to disaggregate household energy use in a CGE model.
- Use of HERON-DST to develop scenarios for the CGE analysis.
- Deliver a methodology by combining the strong points of all used models/tools.

Brokerage event – 11 October 2019, Athens - Greece

Methodology



Brokerage event – 11 October 2019, Athens - Greece

National cases -1

- Greece
  - In contrast to EU – very little decoupling between energy consumption and economic activity
  - Economic recovery is an opportunity for supporting EE, increase share of natural gas and RES in energy mix

Brokerage event – 11 October 2019, Athens - Greece

National cases - 2

- Italy
  - Strong economy
  - Recovery from a fierce recession
  - Energy intensity lower by 18% than EU 28 in average

Brokerage event – 11 October 2019, Athens - Greece

Work Packages

- WP1: Conceptualizing behavioural patterns of energy consumption and barriers (SWIDE – Italy)
- WP2: Modelling energy services in CGE (STRATH-CEP – UK)
- WP3: Promoting Energy Efficiency Behaviour in EU (NKUA-KEPA – Greece)
- WP4: Dissemination – Exploitation (BSEC-GEN)
- WP5: Management (NKUA-KEPA – Greece)
- WP6: Ethics – Data and Research Management (SWIDE – Italy)

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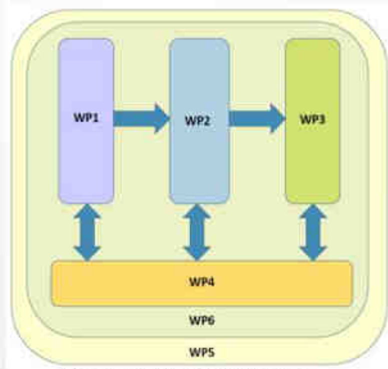
Links among WPs



Brokerage event – 11 October 2019, Athens - Greece


Target groups
Other projects
Media
Research Community
Energy Industry
TG9
TG1
TG2
TG3
TG4
TG5
TG6
TG7
TG8
B-EU EFFICIENT
Decision/policy makers
Households/General public
Building sector professionals
Financial institutes
Brokerage event – 11 October 2019, Athens - Greece


Expected impacts
• More accurate and holistic mapping and modelling of the demand side
• Better assessment of
– energy consumption trends for different categories of economic agents
– demand-side policy trends at European level
Brokerage event – 11 October 2019, Athens - Greece


Evaluation outcomes
Brokerage event – 11 October 2019, Athens - Greece


Thank you
Brokerage event – 11 October 2019, Athens - Greece

Networking for H2020

Dr. Popi KONIDARI, National and Kapodistrian University of Athens – Energy Policy and Development Centre - Hellas

12TH INTERNATIONAL SCIENTIFIC CONFERENCE ON ENERGY AND CLIMATE CHANGE
Brokerage event
11 October 2019, Athens-Greece

PERSPECTIVES OF COOPERATION

Dr. Popi KONIDARI
Scientific Secretariat, NKUA – KEPA

Outline

- Institutes
- Open calls
- Discussion

Institutes (1)

- EUC Research Center - Cyprus
- Energy & Environmental Design of Buildings Research Laboratory, University of Cyprus - Cyprus
- Aegean Energy and Environment Agency – Greece
- DAFNI – Network of Sustainable Greek Islands - Greece
- Energy Policy and Development Centre – National and Kapodistrian University of Athens - Greece

Institutes (2)

- School of Science and Technology, Hellenic Open University - Greece
- Centre for Hydrology and Informatics, National Technical University of Athens – Greece
- Solar & Other Energy Systems Laboratory, NCSR "Demokritos - Greece
- Department of Environmental Engineering, Democritus University of Thrace – Greece
- ModlEcon S.à.r.l.-S - Luxemburg

Institutes (3)

- IIE – SRF and RheinMain University of Applied Sciences - Germany
- Group Building Environmental Studies, Section of Environmental Physics and Meteorology, Physics Department – National and Kapodistrian University of Athens – Greece
- Polytechnic University of Milan, Department of Architecture and Urban Studies, Public Law Chair - Italy

Institutes (4)

- Research Center for Energy Resources and Consumption (CIRCE) – Spain
- CIEMAT - Spain

Common expression of interest

	EUC Cyprus	DAFNI Greece	NKUA-KEPA Greece	DWREE	DEE	CIRCE	CIEMAT	PUM	DAFNI	GBES Greece
LC-CLA-10-2020			x							
LC-CLA-14-2020				x						
LC-CLA-15-2020				x						
CE-SC5-25-2020					x					
SC5-27-2020				x						
LC-SC3-B4E-9-2020					x					
LC-SC3-B4E-11-2020			x							
LC-SC3-EC-2-2018-2019-2020	x		x							
LC-SC3-EC-2-2018-2019-2020	x		x		x					x
LC-SC3-EC-4-2020	x		x							
LC-SC3-EC-5-2020	x		x							

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Thank you

Dr. Popi KONIDARI
Tel.: 0030 210 72 75 830
e-mail: pkonidar@kepa.uoa.gr

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