Romanian
Chairmanship

8th International Scientific Conference

Energy and Climate Change

Contributing to deep decarbonization

PROCEEDINGS

organized by

Energy Policy and Development Centre (KEPA)
National and Kapodistrian University of Athens

2015

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BSEC

Under the aegis of the Romanian Chairmanship

8th International Scientific Conference Energy and Climate Change

Contributing to deep decarbonization

Day 1 7 October 2015

Venue KEPA building
University of Athens, Panepistimiopolis 157 84, Ilissia
Lat. 37° 58΄ 6 ΄΄N, Lon. 23° 46΄ 30΄΄E

9:30 – 10:00	Registration
10:00 – 11:30	Session 1: Opening
	CHAIR
	Amb. Traian CHEBELEU Deputy Secretary General BSEC-PERMIS
	Prof. Dimitrios MAVRAKIS Director of KEPA, National and Kapodistrian University of Athens, Hellas
	ADDRESSES
	Prof. Nikolaos MILONAS Vice-Rector of the National and Kapodistrian University of Athens, Hellas
	Amb. Traian CHEBELEU Deputy Secretary General BSEC-PERMIS
	H.E. Mr. Lucian FATU Ambassador of the Romanian Embassy in the Hellenic Republic
	H.E. Mrs.Emilia KRALEVA Ambassador of the Bulgarian Embassy in the Hellenic Republic
	H.E. Mr. Margus RAVA Ambassador of the Estonian Embassy in the Hellenic Republic
	Dr. Miltiadis MAKRYGIANNIS Deputy Secretary General, Parliamentary Assembly of the BSEC-PABSEC

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	Mrs. Aliki SKLIRI General Director of Energy, Hellenic Ministry of Environment and Energy
	Mrs. Rebecca BATMANOGLOU Director of Climate Change, Hellenic Ministry of Environment and Energy
	Dr. Georgios AGERIDIS Director of Energy Efficiency, Center for Renewable Energy Sources and Saving, Hellas
	Mrs. Aliki PAPPA Director of Department for European Union issues, General Secretariat for Research and Technology, Hellas
	Prof. Dimitrios MAVRAKIS Director of KEPA, National and Kapodistrian University of Athens, Hellas
11:30 - 12:00	**Coffee break**
12:00 – 14:30	**Session 2: Policies**
	CHAIR
	Prof. Milton TYPAS National and Kapodistrian University of Athens, Hellas
	SPEAKERS
	"Strategies for a low carbon building stock in Germany" by Dr. Peter MARKEWITZ – Institute of Energy and Climate Research, Germany
	"Examining the Australian climate change regime: Carbon pricing scheme and direct action plan" by Dr. Evgeny GUGLYUVATYY, Southern Cross Univesity, Australia
	"Investigating urban sustainable energy policies in Europe: experiences from the Covenant of Mayors" by Dr. Benedetta LUCCHITTA, IEFE Bocconi University, Italy
	"Energy civilication through industrial modernity and beyond" by Prof. Thor Øivind JENSEN – University of Bergen, Norway
	"Sustainable hotels, ecocertification and the new tourism law in Greece" by Mr. Konstantinos GKARAKIS – TEI Athens, Hellas
	"Identification of knowledge needs on climate policy implications through a participatory process" by Ms. Phaedra DEDE – National Technical University of Athens, Hellas
	"Analyzing policy interactions for promoting energy efficiency in the Hellenic sectors of buildings and transport" by Dr. Popi KONIDARI - National and Kapodistrian University of Athens, Hellas
20:30	***Dinner for Conference participants***

End of Day 1

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Day 2 8 October 2015

Venue	KEPA building
09:00 – 09:30	**Registration**
09:30 – 11:00	**Session 3: Energy - Climate Change**
	CHAIR
	Prof. Krzysztof WARMUZINSKI Institute of Chemical Engineering, Polish Academy of Sciences, Poland
	Prof. Konstantinos KARAGIANNOPOULOS National Technical University of Athens, Hellas
	SPEAKERS
	"Regional Electricity Demand in Turkey: Dynamic Spatial Panel Data Analysis" by Dr. Gülsüm AKARSU – Ondokuz Mayis University, Turkey
	"A study of building thermal models for use in the analysis of energy sector coupling" by Mrs. Cherifa BEN AMMAR - Technische Universität München Germany
	"Problems encountered in Albanian power system by connection of new power generation units" by Dr. Astrit BARDHI – University Polytechnic of Tirana, Albania
	"Energy use optimization in cities: Innovative technological solutions for the local authorities" by Mr. Vangelis MARINAKIS - National Technical University of Athens, Hellas
	"Fuzzy Cognitive Maps and Zero Energy Building Technologies" by Prof. Peter P. GROUMPOS – University of Patras, Hellas
11:00 - 11:30	**Coffee break**
11:30 – 13:00	**Session 3: Energy - Climate Change**
	CHAIR
	Prof. Krzysztof WARMUZINSKI Institute of Chemical Engineering, Polish Academy of Sciences, Poland
	Prof. Konstantinos KARAGIANNOPOULOS National Technical University of Athens, Hellas
	SPEAKERS
	"New Advanced Technology Methods for Energy Efficiency of Buildings" by Prof. Peter P. GROUMPOS – University of Patras, Hellas

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	"Overview of behavioral, economic and institutional barriers to implementation of energy efficiency in the Hellenic building sector" by Mrs. Anna FLESSA – National and Kapodistrian University of Athens, Hellas
	"Mapping of the main behavioral, educational, economical and institutional energy efficiency barriers in the Hellenic transport sector" by Ms. Eleni-Danai MAVRAKI - National and Kapodistrian University of Athens, Hellas
13:00 - 14:30	**Lunch break**
14:30 – 16:00	**Session 4: Renewable Energy Sources**
	CHAIR
	Prof. Anton Ming-Zhi GAO National Tsing-Hua University, Taiwan
	Prof. Evangelos DIALYNAS National Technical University of Athens, Hellas
	SPEAKERS
	"Investigation of the Greek Wind Energy Market Time-evolution : 1987-2014" by Mr. Konstantinos GKARAKIS – TEI Athens, Hellas
	"Incentives, profitability and diffusion of Photovoltaic Grid-Connected Systems (PVGCS) in Spain between 2004-2014" by Mr. Javier López PROL – University of Graz., Austria
	"The step from the Feed-in Tariff to Net Metering Photovoltaic Sector in Greece" by Mr. Konstantinos GKARAKIS – TEI Athens, Hellas
	"A Decision Support Model for Economic Evaluation of Offshore Wind Farms" by Ms. Afrokomi-Afroula STEFANAKOU – University of Aegean, Hellas
	"Effects of European Transnational Cooperation on the promotion of Renewable Energy and Energy Efficiency in IPA countries: The experience of MED Programme" by Prof. Yorgos, J. STEPHANEDES - University of Patras, Hellas

End of Day 2

Day 3 9 October 2015

Venue **KEPA building**

Brokerage Event

9:30 – 10:00	**Registration**
10:00 – 11:30	**Session 5: Clean Coal Technologies**
	CHAIR
	Prof. Katherine M. PAPPAS National and Kapodistrian University of Athens, Hellas
	Mr. Adam TATARCZUK Institute for Chemical Processing of Coal, Poland
	SPEAKERS
	"Establishment of a Policy and Legal Framework for Carbon Capture Storage (CCS) Technology Development in Taiwan: A Critical Review" by Prof. Anton Ming-Zhi GAO - National Tsing-Hua University, Taiwan
	"Large-scale laboratory study on the CO_2 removal from flue gas in a hybrid adsorptive-membrane installation" by Prof. Krzysztof WARMUZINSKI - Institute of Chemical Engineering, Polish Academy of Sciences, Poland
	"Pilot study on the CO_2 removal from flue gas in an amine-based plant at Tauron's Power Plants" by Mr. Adam TATARCZUK – Institute for Chemical Processing of Coal, Poland
	Discussion - Proposals by Prof. Krzysztof WARMUZINSKI and Prof. Dimitrios MAVRAKIS
11:30 – 12:00	**Coffee break**
12:00 – 13:30	**Session 6: Projects and programs**
	CHAIR
	Prof. Katherine M. PAPPAS National and Kapodistrian University of Athens, Hellas
	Mr. Adam TATARCZUK Institute for Chemical Processing of Coal, Poland
	SPEAKERS
	"Policies for promoting research and innovation" by Mrs. Aliki PAPPA - General Secretariat for Research and Technology
	"Funding opportunities under Horizon 2020 - Secure, Clean and Efficient Energy" by Mrs. Christiana SIABEKOU - National Documentation Centre, Hellas

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	"HERON project – A forward-looking socio-economic research on Energy Efficiency in EU countries" by Ms. Aliki-Nefeli MAVRAKI – National and Kapodistrian University of Athens, Hellas
	"Infrared Thermography – Optimization of Power Plants Thermal Loss Management" by Mr. Nikolas KARPATHAKIS - National and Kapodistrian University of Athens, Hellas
	"DEPA/Smart future with natural gas" by DEPA, Public Company for Natural Gas, Hellas
	Closing remarks by Prof. Dimitrios MAVRAKIS, Director of KEPA, National and Kapodistrian University of Athens, Hellas

End of Conference

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PROMITHEAS Net

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8th International Scientific Conference on Energy and Climate Change
7 - 9 October 2015 in Athens

List of Participants

A/A	Title	First Name	Last Name	Organization
1	Dr.	Georgios	Ageridis	Center for Renewable Energy Sources and Saving (CRES), Hellas
2	Mr.	Lazaros	Agrafiotis	Welding & NDT Institute, Hellas, Hellas
3	Dr.	Gülsüm	Akarsu	Ondokuz Mayis University, Turkey
4	Mrs.	Cherifa Ben	Ammar	Technical University of Munich (TUM), Germany
5	Dr.	Kostas	Andriosopoulos	Public Gas Corporation S.A. - DEPA, Hellas
6	Dr.	Anastasios	Antonakos	NANODOMI S.A.,Hellas
7	Mrs.	Eftuchia	Bacopoulou	Hellenic Ministry of Foreign Affairs, Hellas
8	Dr.	Astrit	Bardhi	Polytechnic University of Tirana, Albania
9	Mrs.	Rebecca	Batmanoglou	Ministry of Environment and Energy, Hellas
10	Mrs.	Angeliki	Boura	Hellenic Ministry of Foreign Affairs, Hellas
11	Amb.	Traian	Chebeleu	Black Sea Economic Cooperation-PERMIS
12	Dr.	Athanassios	Dagoumas	University of Piraeus, Department of International and European Studies, Hellas
13	Ms.	Phaedra	Dede	National Technical University of Athens, Hellas
14	Prof.	Evangelos	Dialynas	National Technical University of Athens, Hellas
15	Amb.	Lucian	Fătu	Romanian Embassy in Hellenic Republic
16	Mrs.	Anna	Flessa	National and Kapodistrian University of Athens Energy Policy and Development Centre (KEPA)
17	Prof.	Anton Ming-Zhi	Gao	The Institute of Law for Science and Technology (ILST), National Tsing Hua University, Taiwan
18	Mr.	Petros	Giannopoulos	Eolfi Wind Hellas
19	Mr.	Konstantinos	Gkarakis	TEI Athens - Energy Technology Engineering Department

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20	Prof.	Petros	Groumpos	University of Patras, Hellas
21	Dr.	Evgeny	Guglyuvatyy	Southern Cross University, Australia
22	Ms.	Damla	Gümüşkaya	Turkish Embassy in Hellenic Republic
23	Mr.	Igor	Ivanchenko	Ukrainian Embassy in Hellenic Republic
24	Prof.	Thor Øivind	Jensen	University of Bergen, Norway
25	Prof.	Constantinos	Karagiannopoulos	National Technical University of Athens, Hellas
26	Dr.	Charikleia	Karakosta	University of Piraeus Research Centre, Hellas
27	Mr.	Nikolas	Karpathakis	National and Kapodistrian University of Athens Energy Policy and Development Centre (KEPA)
28	Mr.	Alexandros	Katsiaboulas	TITAN Cement Co S.A., Hellas
29	Dr.	Popi	Konidari	National and Kapodistrian University of Athens Energy Policy and Development Centre (KEPA)
30	Mr.	Antonios	Koumanakos	National Technical University of Athens, Hellas
31	Amb.	Emilia	Kraleva	Bulgarian Embassy in Hellenic Republic
32	Mr.	Ekaterine	Lortkipanidze	Georgian Embassy in Hellenic Republic
33	Mr.	Konstantinos	Loukidis	ENTEKA S.A., Hellas
34	Dr.	Benedetta	Lucchitta	IEFE - Bocconi University, Italy
35	Dr.	Miltiadis	Makrygiannis	Parliamentary Assembly of the Black Sea Economic Cooperation - PABSEC, Turkey
36	Mr.	Vangelis	Marinakis	National Technical University of Athens, Hellas
37	Dr.	Peter	Markewitz	Institute of Energy and Climate Research, Germany
38	Ms.	Aliki-Nefeli	Mavraki	National and Kapodistrian University of Athens Energy Policy and Development Centre (KEPA)
39	Ms.	Eleni-Danai	Mavraki	National and Kapodistrian University of Athens Energy Policy and Development Centre (KEPA)
40	Prof.	Dimitrios	Mavrakis	National and Kapodistrian University of Athens Energy Policy and Development Centre (KEPA)
41	Prof.	Nikolaos	Milonas	National and Kapodistrian University of Athens, Hellas

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42	Mrs.	Vassiliki	Mpelogianni	University of Patras, Hellas
43	Mrs.	Aliki	Pappa	General Secretariat for Research and Technology, Hellas
44	Prof.	Katherine	Pappas	National and Kapodistrian University of Athens, Department of Biology
45	Mrs.	Jenny	Passari	National and Kapodistrian University of Athens Energy Policy and Development Centre (KEPA)
46	Mr.	Michalis	Perakis	Welding & NDT Institute, Hellas, Hellas
47	Mr.	Javier López	Prol	University of Graz, Austria
48	Mr.	Kyriakos	Psychas	Ministry of Environment and Energy, Hellas
49	Amb.	Margus	Rava	Estonian Embassy in Hellenic Republic
50	Ms.	Zemfira	Rzayeva	Geotechnological Problems from Oil, Gas and Chemistry, Azerbaijan
51	Prof.	Tulparkhan	Salavatov	Geotechnological Problems from Oil, Gas and Chemistry, Azerbaijan
52	Mrs.	Christiana	Siabekou	National Documentation Centre, Hellas
53	Prof.	Tom	Skauge	University of Bergen, Norway
54	Ms.	Afrokomi-Afroula	Stefanakou	University of the Aegean, Hellas
55	Prof.	Yorgos	Stephanedes	University of Patras, Hellas
56	Mr.	Adam	Tatarczuk	Institute for Chemical Processing of Coal, Poland
57	Dr.	Fotis	Thomaidis	VIS Economic & Energy Consultants, Hellas
58	Prof.	Milton A.	Typas	National and Kapodistrian University of Athens, Department of Biology
59	Mr.	Ioannis	Varelis	Urban Rail Transport S.A., Hellas
60	Mr.	Spyros	Vassos	Public Power Corporation S.A., Hellas
61	Mrs.	Eleni	Vergini	University of Patras, Hellas
62	Mr.	Alfred	Wang	TAIPEI representative office in Greece
63	Prof.	Krzysztof	Warmuzinski	Institute of Chemical Engineerging, Poland

Opening Session

Opening speech by Prof. Nikolaos MYLONAS

Vice Rector of the National and Kapodistian University of Athens, Hellas

Excellencies, Ladies and Gentlemen and distinguished colleagues,

On behalf of the National and Kapodistrian University of Athens, the oldest and most prominent Greek university, I cordially welcome you to our university and the opening of the 8th International Scientific Conference on *"Energy and Climate Change"* that is organized by the Energy Policy and Development Centre of our University under the aegis of the Romanian Chairmanship in Office of the Black Sea Economic Cooperation Organization.

The conference aims to contribute to the common international effort to build scientific research that will allow our societies to confront the Climate Change challenge. As scholars and scientists, we have to work together through research and knowledge transfer to propose the best solutions and practices to our societies.

As far as our university is concerned, we are already in the process of completing natural gas installations for heating, reactivating our co-generation units, introducing LED lighting, smart energy saving applications and most important examining possible ways of transforming our buildings into near zero energy consuming ones. Besides helping our environment, we also help the university meet its needs under the reduced budget we are allocated.

Our university is interested and activated in issues of energy and climate change policy and particularly of promoting energy efficiency and renewable energy sources. The Horizon 2020 research project HERON about incorporating the preferences of end-users in energy modeling and whose coordinator is Energy Policy and Development Centre (KEPA) is one of these activities.

At this point, I would like to express my sincere gratitude to the Permanent Secretariat of the Black Sea Economic Cooperation Organization. As university, we support the efforts of PERMIS to mobilize the academic community in our region on the critical issues of Mitigation and Adaptation to Climate Change and on the associated issues of energy efficiency and Renewable Energy. We recognize the efforts of the Energy Policy and Development Centre (KEPA) of our university to develop the "BSEC Green Energy Network" under the auspices of the BSEC organization.

As Vice Rector of this university, I would like to thank the Deputy Secretary General ambassador **Traian Chebeleu** for his participation in this occasion and reassure him of our intention to increase and further extend our cooperation with them in additional fields of mutual interest by increasing the level of collaboration with the market forces and facilitating the necessary knowledge transfer and capacity building among the various market stakeholders on issues related to the green transformation of our economies.

I believe that through the established experience of KEPA and its PROMITHEAS network in the EU, BSEC and Asia and its participation in the United Nations Academic Impact Initiative, that the cooperation with the regions of the Black and Caspian Seas, the Central Asia, the Asia – Pacific and Africa without excluding any other area or country will widen.

I am looking forward to a fruitful conference and I cordially wish you success in all your activities.

Opening by Ambassador Mr. Traian CHEBELEU

Deputy Secretary General BSEC-PERMIS

Mr. Vice-Rector,

Dear Professor Mavrakis,

Distinguished Participants,

On behalf of the Secretary General of the Permanent International Secretariat of the Black Sea Economic Cooperation Organization (BSEC), Ambassador Michael Christides, I have the honour to convey warm greetings to the participants in this 8th International Scientific Conference on "Energy and Climate Change", and to the organizers of this great event, the prestigious Energy Policy and Development Centre (KEPA), directed with professionalism and impressive dedication by Professor Dimitrios Mavrakis.

We are proud that this yearly scientific event takes place under the auspices of BSEC, in the framework of which a small project has developed over the years into the *Promitheas* Network, managed by KEPA, connecting decision makers, prestigious academic and research institutions, and market stakeholders from all the 12 BSEC Member States and from other states in our neighbourhood. We have to emphasize, however, that the dimensions that this project has today were possible with funds offered by the European Union and with generous contributions of the Hellenic Government, for which we are all grateful and hopeful regarding their continued support in the future.

These scientific conferences and, in particular, the activities of the *Promitheas* Network have made significant contributions to the knowledge transfer and development on energy and climate change issues in the BSEC Region. The papers and discussions of the scientific conferences and the publications you prepared have been very valuable for us, providing food for thought as to where and what BSEC should focus on, so that it could bring added value and act really in support of the needs and interests of our Member States in these fields.

We are very glad and thankful to KEPA for agreeing to coordinate and manage the BSEC Green Energy Network, launched last year, linking administrative bodies and centres and organizations mandated to promote renewable energy sources and energy efficiency measures and policies in the BSEC Member States. This an important tool for exchanging information and for sharing know-how and good practices among our Member States, which had set for themselves, in the strategic document guiding the activities of the Organization - *BSEC Economic Agenda 2012* -, the task of taking gradual steps to materialize the vision of transforming the BSEC Region into a model for clean energy by the year 2050.

This year your Scientific Conference has a special importance in the perspective of the forthcoming COP21, which will take place in Paris in December 2015. COP21 will be a crucial conference, as it needs to achieve a new international agreement on the climate, enabling all countries to combat climate change effectively and boost the transition towards resilient, low-carbon societies and economies, whilst promoting fair and sustainable development.

To achieve this, the future agreement must focus equally on mitigation - namely, efforts to reduce greenhouse gas emissions - and societies' adaptation to existing climate changes. These efforts must take into account the needs and capacities of each country.

As each country is expected to make known before COP21its national contribution, presenting its efforts to the global effort against climate change that corresponds to its situation, I am confident that this Conference will be a significant complementary contribution to the national contributions of the BSEC Member States.

More generally, I would mention that a significant part of the efforts of BSEC are focused on the development of the regional cooperation in Green Energy. In these efforts, we will continue to count very much on the professional advices and contributions of Professor Mavrakis and his team.

In fact, the International Scientific Conferences on “Energy and Climate Change” have had significant contributions to bringing our Member States closer together and have provided valuable inputs to our activities within BSEC aimed at enhancing the regional cooperation in the fields of energy and environmental protection. The interaction with the academic sector and energy stakeholders always produces ideas and concrete recommendations that we can use afterwards in our discussions within the relevant BSEC Working Groups and materialize in concrete cooperation action.

I would like to conclude my remarks by expressing high appreciation and thanks for the excellent organization and for the warm hospitality offered by our hosts, and by wishing all of you fruitful exchanges during the Conference.

Opening by Mr. Lucian FATU, Ambassador of Romania in Athens

Dear Deputy Secretary-General
Dear Professor Mavrakis,
Distinguished participants,

As always, I am honoured to address the International Scientific Conference organized by the Athens University, and grateful for the invitation. This year, the more so as Romania currently holds her fifth Chairmanship in Office of the Black Sea Economic Cooperation Organization. Let me take this opportunity to renew my congratulations to Ambassador Emeritus Michael Christides, the new Secretary General of the BSEC Permanent International Secretariat, and, based on first- hand experience and official acknowledgement, recognize it as a significant contribution to the overall performance of the organization.

In addition to its explicit economic dimension, the BSEC has proven, during its 23 years existence, to be a reliable platform for consultations and networking, at various levels, aimed at fostering regional understanding and mutual confidence. Under the acronymic logo *Building Stability*, *Enhancing Connectivity* and in her capacity as EU member and BSEC co-founder – same as Greece and Bulgaria – Romania focused its Chairmanship priorities on enhancing dialogue and cooperation within the organization, as a pre-requisite to strengthening relations between all Member States.

Recently, on September 29, the BSEC Foreign Ministers and the EU Commissioner for Neighbourhood Policy and Enlargement met in New York, on the sidelines of the UN General Assembly, and addressed the pragmatic means of cooperation in promoting BSEC projects that can be eligible for EU financial support. Within the current complex regional context, a special emphasys was attached to the EU role in the continuation of reforms and economic stability in the Republic of Moldova.

Energy and climate change is an ongoing topical issue on the BSEC agenda, with the aim to harness the national Government and NGO actions around the Black Sea and add the value of regional cooperation and BSEC expertise. I am confident that this event will advance this recognized priority and build upon the excellent groundwork provided by our hosts.

I would like to wish us all stimulating exchanges and productive networking.

Thank you.

Opening by Mrs. Emilia KRALEVA, Ambassador of Bulgaria in Athens

Dear Professor Mavrakis, Ambassador Chebeleu,

Excellencies, distinguished guests,

I'm glad to have the opportunity to address the annual KEPA International Scientific Conference on Energy and Climate Change. It takes place right on time, on the eve of the world meeting COP-21 in Paris which is deemed crucial for reaching a legally binding and dynamic global agreement to keep global warming below 2°C.

It is true that in the recent months the world politics has been clearly dominated by other issues, not less important, like migration and unprecedented flow of refugees to Europe. This is an overwhelming problem sharply affecting Greece, SEE and the EU as a whole. However, we should strengthen even further our capacity and not diminish in anyway our long-standing efforts to prevent the climate change devastating consequences. It should stay as a strategic priority for the European Union and feature high on the agenda of different regional cooperation formats, among them the BSEC organisation.

The connection between decarbonisation and climate is evident – proceeding towards deep decarbonisation is indispensable condition for reaching the above goal.

As a member of the EU, Bulgaria is implementing legislation and undertakes particular actions which allow us to decrease carbon emissions whilst keeping the economy stable. Bulgaria is among the EU countries that contribute a lot to the common green targets being blessed with relatively rich green energy sources. We are among the few MS which have already over-fulfilled their renewable energy targets for 2020.

If you allow me to quote the French President Hollande, "nothing has been won for an agreement in Paris yet, nothing at all, but at the same time, everything is still possible". The EU has a solid negotiating position. Now we need to step up the pace of the negotiating process. In order to obtain an effective Agreement, not only the developed countries as a group but all Parties need to put forward their national contributions before Paris in a fair, transparent and quantifiable manner.

Research and kknowledge transfer have a key role in developing and implementing converging deep decarbonization pathways in all countries. The Energy Policy and Development Centre to the National and Kapodistrian University of Athens shall be praised for its devoted work to maintain and develop the PROMITHEAS Conference all over the years.

Let me conclude by wishing every success to this 8th conference and express my conviction, bearing in mind the prominence and expertise of the members of its International Scientific Committee that it will contribute to a large extent to the international efforts in the run-up to Paris so that the desired Agreement becomes a reality.

Thank you.

Opening by Mr. Margus RAVA, Ambassador of Estonia in Athens

Dear Prof. Mavrakis, dear collaegues, ladies and gentlemen,

It is a pleasure to be here again – as Professor Dimitris Mavrakis described, it has happened several times before that Estonian scientists appear and cooperate with his team.

Even if this event is organized under auspices of Black Sea Economic Cooperation BSEC initiative, of which Estonia is not a party, the topics of the conference are nevertheless important also for countries around the Baltic Sea.

If I think at a very broad level about these issues, two matters of example come to my mind from the Baltic Sea region.

First concerns shipping. Baltic Sea is fairly shallow and environmentally unfortunately not in the best shape yet. Baltic Sea has very active shipping traffic, in people, cargo and oil, in the East-West and North-South directions. One of the factors in the wellbeing of the sea is the fuel that the ships use. It has been agreed that LNG will be the right fuel for shipping on the Baltic Sea. At the same time - a lot of work and analysis has been done to ensure that the shipping industry remains competitive.

Second example is about energy. Estonia has and uses extensively oil shale. Even if it is a fossil fuel, a balance has to be found and indeed has been found between the necessities of energy security on one hand and environmental impact on the other. I see from the programme that matters of energy will be discussed also during this conference.

Even if Estonian scientists are not present this time, I have noticed people attending from other countries of the Baltic Sea region which shows that the challenges of energy and climate change between the two regions have some common points.

I wish this conference all the best in addressing those challenges!

Opening by Mr. Miltiades MAKRYGIANNIS

Deputy Secretary General, Parliamentary Assembly of the BSEC-PABSEC

Dear Ambassadors,

Dear Professors,

Dear participants,

Ladies and Gentlemen,

On behalf of the Parliamentary Assembly of the Black Sea Economic Cooperation and on behalf of PABSEC Secretary General Mr. Asaf Hajiyev, I would like to congratulate the Energy Policy and Development Center and Professor Dimitrios Mavrakis for his initiative to organize this Kick-off Meeting concerning HERON Project and to express our gratitude for his efforts to maintain active and strong the cooperation between the Parliamentary Assembly of the Black Sea Economic Cooperation and the Energy Policy and Development Center .

Although the Black Sea region is characterized by extreme regional disparities and a great number of problems and challenges, undoubtedly serves as a crucial oil & gas transportation corridor and at the same time consist a valuable natural asset of global importance.

Black Sea has not followed the urbanisation and industrialisation models of other parts of Europe, which led to fast environmental decline; however, the region faces severe environmental threats and future risks.

Energy production and consumption are the main contributors to the generation of greenhouse gas emissions and other air pollutants, oil and nuclear waste. The energy sector constitutes the backbone of economy for the countries of Black Sea, concerning either production or transportation, and therefore environmental impacts in the area are more evident than anywhere else.

It is already evident that climate is changing and the Black Sea area is particularly susceptible to this kind of changes.

Despite the plenitude of institutions and structures in the Black Sea area, it seems that there is a lack of political commitment, which influences negatively policy making procedures and national or regional cooperation.

In this framework, scientific and political debates agree on the need for a strengthened, more effective, and more coherent institutional and legislative framework for international and regional cooperation and environmental governance. To this end, the participation of the EU in certain organisations and conventions would act as a driving force in improving the legislative framework and enhancing cooperation among the Black Sea states.

In order to guarantee security, stability and prosperity in the Black Sea region, an ambitious and coherent policy in the field of Renewable Energy Sources is also a crucial requirement for the BSEC organization.

Such an energy policy should rely on a common political will and respond to security of energy supply, economic growth, sustainable development, climate change, employment and technological development. Renewable energy technologies in combination with energy efficiency have a positive effect on all these goals.

The Parliamentary Assembly of BSEC has always been placing emphasis to the issue of energy efficiency, green energy and environmental protection. Our Assembly has debated many times on energy and environmental challenges and has adopted several Reports and Recommendations. These documents outline the basic strategy of our Parliamentary Assembly on this issue.

The main point to all these documents is that national Parliaments have to pay more attention to policies and programmes that achieve a better balance between development and environmental concerns and explore more effective approaches on global climate change. National Parliaments should take leadership role in promoting deeper understanding of global climate change issue entailing serious social, economic, and even security implications and bring their contribution to facilitating more informed decision making regarding this all-encompassing threat.

Parliamentarians can reinforce climate change policy and legislation and they can enhance international cooperation on the basis of common but differentiated responsibilities under the international instruments in climate change area.

A successful low carbon transition requires a thorough understanding of the options, opportunities and challenges. It also needs long-term policy signals to encourage the investment decisions needed for a decarbonised economy. A global effort is a fundamental prerequisite to enable decarbonisation with prosperity.

The role of the parliaments is especially important in order to forge the laws, guidelines, frameworks and incentives that will allow efficient implementation of national and international engagement on the challenge of global climate change.

Parliaments' role is also important in order to improve legislation regulating the internal energy markets with a view to providing and creating a fully effective, competitive and stable common energy market in the region and to adopt necessary regulations or laws aiming at the measures on ensuring security of energy supply and consumption in the BSEC member states.

However, it was underlined that no effective action could be taken today without stronger international cooperation and solidarity. Cooperation at the trans-national, regional and local levels is of significant essence for efficient and effective address to the issue of climate change. BSEC states along with the international organisations and civil society must engage in a constructive dialogue which yields tangible results. The international community must demonstrate its capacity to provide people with secure livelihood and individuals, in their turn, must and do care for the environment.

Once again, on behalf of the International Secretariat of the Parliamentary Assembly of the Black Sea Economic Cooperation, I thank you for the invitation and I wish a fruitful discussion.

Opening by Mrs. Rebecca BATMANOGLOU

Director of Climate Change, Hellenic Ministry of Environment and Energy

MINISTRY OF ENVIRONMENT & ENERGY

8th International Scientific Conference

Energy and Climate Change

Contributing to deep decarbonization

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MINISTRY OF ENVIRONMENT & ENERGY

The de facto target for global climate policy:

Limiting warming to no more than 2 degrees.

Total greenhouse gas emissions:

- ☐ need to peak by 2020 at the latest
- ☐ be reduced by at least 50% by 2050 compared to 1990, and
- ☐ be near zero or below by 2100

2

MINISTRY OF ENVIRONMENT & ENERGY

The 21th UN Climate Conference (Paris, 30/11-11/12)

What Kind of an agreement?

-- An ambitious and durable legally-binding agreement that is applicable to all Parties and addressing in a balanced and cost-effective manner: mitigation, adaptation, finance, technology transfer and capacity building.

-- Strict monitoring, reporting, verification.

-- Penalties for those who don't comply.

3

MINISTRY OF ENVIRONMENT & ENERGY

What we are doing in the EU?

The EU has set itself targets for reducing its GHG emissions progressively up to 2050.

1st climate and energy policy package: reducing emissions to 20% below 1990 levels by 2020.

2st climate and energy policy package: reducing emissions to 40% below 1990 levels by 2030.

For 2050: reducing emissions by 80% compared to 1990 levels.

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MINISTRY OF ENVIRONMENT & ENERGY

How we are doing towards these targets?

During the two periods (2008-2020): greater emission reductions than required by the targets.

- ☐ **In 2012:** total EU emissions 21,7% below
- ☐ **In 2020:** 24,5% below (are projected)

GREECE: We have managed both Kioto-Protocol and EU targets

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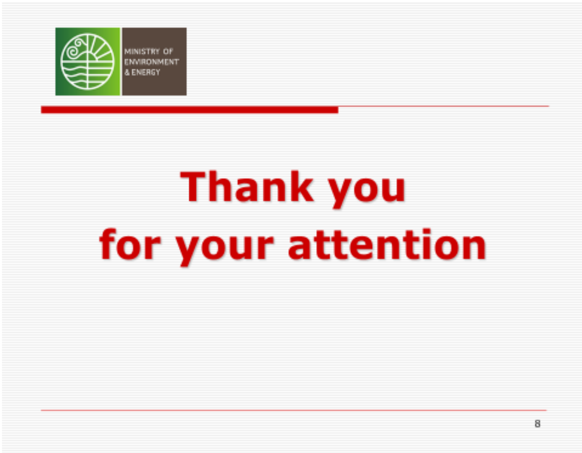
MINISTRY OF ENVIRONMENT & ENERGY

Comparing EU-28 with other major economies

- ☐ **1990-2012: the total annual GHG emissions per capita decreased by 24%**
- ☐ **Today's intensity is one of the lowest among major economies.**
- ☐ **The share of global GHG emissions from EU-28:** has dropped from 15% in 1990 to 12% in 2010. Today is about 10%.

6


MINISTRY OF ENVIRONMENT & ENERGY
The 21th UN Climate conference
(Paris, 30/11-11/12)
We need to conclude and adopt an ambitious global agreement
7


MINISTRY OF ENVIRONMENT & ENERGY
Thank you
for your attention
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Opening by Dr. Georgios AGERIDIS

Director of Energy Efficiency, Center for Renewable Energy Sources and Saving

Ambassadors, Ladies and Gentlemen, good morning.

On behalf of the President of the Centre for Renewable Energy Sources and Savings, I want to thank the Organizing Committee and especially Prof. Mavrakis for the invitation to be here with you.

The reduction of greenhouse gases (GHG) that contribute to global warming and climate change is one of the greatest challenges of our time. According to the fifth report of the Intergovernmental Panel on Climate Change (IPCC), the continuation of the current patterns of development would generate a global warming, higher or equal to +4°C by the end of the century, the consequences of which would be unprecedented. Action to tackle climate change and reduce greenhouse gas emissions is therefore a priority for all of us. EU has committed to transform Europe into a highly energy-efficient and low carbon economy. It has also set itself the target of reducing greenhouse gas emissions by 80-95% by 2050 compared to 1990 levels. These emission reductions are to be achieved among others in the energy and transport sectors and EU should achieve its target largely through domestic measures, since, by mid-century, international credits to offset emissions will be less widely available, and any credits used would increase the overall emissions reduction beyond 80%.

In order to achieve an 80% European "domestic" reduction by 2050, cuts in the order of 40% and 60% below 1990 levels should be achieved by 2030 and 2040, respectively. Drastic changes are needed urgently. All sectors will need to contribute, and especially the energy sector, which is mainly responsible for GHG emissions. Therefore, the contribution of sustainable use technologies and Energy Saving (ES) as well as the "clean" energy technologies, such as renewable energy sources (RES), is of vital importance. We have to reduce energy dependency through improvements in energy efficiency and renewable energies. Investments in these fields are cost effective; they contribute to security of energy supply for long-term growth, acting as a source of innovation and providing opportunities for exports. Business ventures and investments in the energy sector should focus on the development, design and production of innovative products and services which contribute to:

- cost reduction
- improvement of RES technologies performance parameters
- optimal integration of RES in power grids
- development of new technologies and energy saving applications in buildings , industry and transport.

The aforementioned challenges are even higher now, especially in Greece, considering the implications of the continuous economic recession. Especially in present time, the Energy sector should become a pioneer for bring forward sustainable and innovative solutions, shifting investments towards low-carbon technologies that protect the environment and the consumers, and also support the transition to a low-carbon economic growth.

The Greek Centre for Renewable Energy Sources and Saving- CRES, under its dual role as the national energy centre for RES and ES as well as an energy research centre, will continue to promote the technology and policy evolution in the field of energy, aiming to deliver state of the art services by integrating all the appropriate developments, supporting a competitive energy market with affordable prices, ensuring the economic, social and environmental sustainability.

The EU, as well as the rest of the world, faces today critical energy issues that make our societies and economies vulnerable and collaborative action is needed to ensure the future of the planet. **The global nature of climate change means that** cooperation and action at international level **is crucial.** We need to ensure an environmentally friendly and economically sustainable development. Energy saving and renewable sources are important elements of a sound energy policy that can render the energy system more flexible and viable, offering improvements in security of supply and a series of important environmental, economic and social benefits. We all hope that the upcoming Paris 2015 UNFCCC conference will achieve its goal and succeed, for the first time in over 20 years of UN negotiations, a binding and universal agreement on climate, from all the nations of the world.

Thank you.

Opening by Mrs. Aliki PAPPA

Director of Department for European Union issues, General Secretariat for Research and Technology

Dear Ambassador/s

(Good morning), Distinguished guests, Ladies and Gentlemen

First of all, I would like to convey the apology from Thomas MALOUTAS, Secretary-General for research and Technology, Ministry of Education, Research and religious affairs, for not being able to come to this opening session.

We are delighted to welcome you all to the 8th International Conference on Energy and climate change and to Athens as well. You have a full and challenging agenda, with high level experts in the fields of energy and climate change, sectors crucially important for the sustainable development with new jobs. The technological development of these sectors is also expected to contribute to facing the major societal challenges all over the world such as to mitigate climate change and its implications and at the same time to ensure the humanity of the required energy resources and to provide access to them with affordable prices.

My organization, the GSRT, is responsible for the coordination of RTD policies in Greece and it is also the main competent body for policy planning and funding of RTDI programmes and research infrastructures. In parallel, GSRT represents Greece to the EU and other International organizations dealing with S&T matters. In this context, amongst others, GSRT is the body responsible for the RTD and Demonstration EU Frameworks Programmes.

Currently the E. Commission runs the 8th FP, known as the HORIZON 2020. This programme is designed in a way to contribute to the EU 2020 strategy and objectives. These objectives, which as you know, are linked to the increase of energy efficiency, the increase of the share of renewable energy resources in the final consumption and the reduction of CO2 emissions.

The content of Horizon 2020 and its funding opportunities as well as our efforts to support the Greek stakeholders to participate successfully in the Horizon 2020 calls will be presented in the session 6 by Mrs. SIABEKOY, our national contact point. What I would like to mention on this topic is the good participation of the Greek organizations (HES, research centers, private sector) in the Horizon 2020 calls, which is close to 2, 5 % of the total budget (11th out of 28 M-S). In the OP secure, clean and Efficient Energy-Horizon 2020, there are Greek participants in 19 projects (4 coordinators) out of 159 approved projects, with a total budget of 8.391.783 Euros (2,4%). However we think that our participation can be further improved. I would like to draw your attention to the quality of proposal (our success rate continues to be under the EU average), as well as to the better use of some H2020 instruments like the Instruments in support of SMEs, access to risk finance and others.

The lack of national resources for R&D limits the Greek participation to the ERA-related instruments like joint programmic initiatives (one is on climate change), articles 185 (AAL, clinical trials), ESFRI Research infrastructures, ERANETS-COFUND etc. To mitigate this effect, GSRT gives priority to actions that are in synergy and complementarity between HORIZON 2020 (programs and research infrastructures/ESFRI) and structural/investment funds.

At national level and in relation to the work of GSRT as a policy planning and funding organization it is worth mentioning that the National Research and Innovation Strategy for smart specialization 2014-2020 has been approved recently with a total budget close to 1 million Euros.

The sector of energy and the sector of environment-climate Change are amongst the 8 focus areas of our smart specialization strategy. In the area of Environment, GSRT intends to implement specific activities with a major impact on climate and environmental protection. In the energy sector the foreseen actions are expected to contribute to the improvement of the competitiveness of Greek economy (products and services). The energy saving/energy efficiency in industrial and agricultural sector as well as in buildings, the renewable energies and its storage, the Smart grids and the system for transferring and delivering electricity, and the reduction of implications from the use of conventional fuels are the main focus areas. Also actions aiming at the S&T support of other national policies and contributing to the attainment of national and EU policies and objectives are envisaged.

As far as synergies between Horizon 2020 and smart specialization concern, we can mention a) the funding of large scale research infrastructures linked to the ESFRI roadmaps, b)the funding by structural funds of Greek proposals that receive the “seal of excellence” in the context of horizon 2020 calls for proposals of ERC and the SMEs instruments. The “Seal of excellence” is attributed to proposal which is highly ranked by reviewers (above threshold), but does not receive funding by Horizon 2020 due to lack of resources.

International Cooperation and extroversion are important. Bilateral cooperation agreements with EU and non EU countries as well as action aiming at contributing to the implementation of ERA open to the world are the basic tools.

Ladies and gentlemen,

You have a full/loaded agenda over the next three days, and I do not propose to keep you from it any longer. I hope that the main message you will take from my words to you this morning is the importance given by Greek governments to energy and climate change sectors for sustainable development and jobs.

Finally, I would like to congratulate the University of Athens and KEPA for hosting this conference as well as the Romanian Chairmanship of the black Sea Economic Cooperation (BSEC), which supports this event. GSRT constantly supports this cooperation and will continue towards this direction.

Thank you.

Opening by Prof. Dimitrios MAVRAKIS

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

Excellences

Distinguished Guests and Honorable Colleagues

World leaders in a crucial meeting between the 30th of November and the 11th December 2015 in Paris will be challenged to make decisions that will enable to slow down climate change and adapt their societies to unavoidable climatic changes.

The 21st Conference of Parties under the UNFCCC is expected to conclude with a legally binding document allowing the restriction of the increase of the global atmospheric temperature to 2^0 C and if possible to further lower it to 1.5^0 C.

To this aim the secretariat of UNFCC will prepare by the 1st November a synthesis report on the aggregate effect of the Intended National Determined Commitments (INDCs) communicated by Parties until 1st October 2015.

As already noted by IPCC, scientists have determined that the increase of global temperature is proportional to the build-up of long lasting greenhouse gases in the atmosphere, especially carbon dioxide (CO_2). Achieving and keeping the 2^0 C limit is strictly related with the total amount of CO_2 that will be emitted over a time period between 2055 and 2070.

But confronting Climate Change is a complicated challenge since it is related to needs and expectations for economic development and well being of an exponentially booming human population whose economies depend on conventional fossil fuels. Switching fuels, promoting new technologies, developing new market mechanisms, restructuring the energy markets, creating and promoting the necessary international financing tools is not a simple process and when decided every step takes precious time before their implementation with the global clock ticking reminding the narrow period until the middle of this century.

Each country reserves the right to develop its path of economic development and the question is whether these paths are achievable, sustainable and converge to confront the interrelated global challenges of climate change, rational use of natural sources and environment.

Tackling the sensitive issue of convergence, KEPA has undertook the initiative to coordinate prominent scientists from EU, Japan, India, China, Taiwan and South Africa to develop a detailed proposal based on the perception that for the coming years it is necessary to provide concrete evidence base and procedures to their policy makers that will allow them to develop “triple win” 2^0C national pathways. Those pathways will be characterized by an optimum mixture of mitigation, adaptation and sustainable development policies and will be capable to converge with the relevant global efforts, in the context of the expected outcomes of COP21.

Our experience shows that regardless of scientific contributions and projects the most threatening challenge to confront Climate Change is the level of perception of the emerging threat among our leaders and societies. It takes time to ordinary people and their leaderships to understand its nature and magnitude. Even when they agree in principle it takes time even to start considering of developing and implementing alternative policies and measures, no matter how their lives or economies are affected.

For more than ten years, the Energy Policy and Development Centre, as academic institution, coordinator of the PROMITHEAS network and appointed coordinator of the “BSEC green energy network” promotes regional cooperation on Energy and Climate Change Policy issues in an effort to facilitate the development of the necessary knowledge base for policy makers and market stakeholders in the broad region of Central Asia and Black Sea.

For three years we have coordinated and trained personnel to develop mitigation pathways for twelve countries in the aforementioned region under the FP7 financed project of PROMITHEAS-4.

Our, so far developed, experience shows that the countries of the region should cooperate in developing common practices and infrastructures to decrease the emerging costs due to the increasing number of the extraordinary atmospheric phenomena such as the transboundary flood of rivers and of the forests’ fires or take the advantage of the relevant financing tools.

Our experience shows also that energy efficiency measures can easily contribute to reduce CO_2 emissions and decrease un-employment rates, given the existing enormous potential for improvement in the various sectors of our economies.

But regardless of the obvious benefits policy makers, market stakeholders and financing institutions remain reluctant. We would be happy to cooperate with the Black Sea Bank for Trade and Development in a regional effort to increase the energy efficiency awareness among the SMEs that cooperate with the BSEC Business Council but such a perspective necessitates change of the negative attitude of BSTDB to promote energy efficiency programs in our region.

We encourage the development of such policies and currently our research, together with seven European Institutions aims to incorporate non-economic and non-market elements, such as social, educational and cultural, into energy modeling for reflecting the end-users behavior towards energy efficiency policy mixtures.

We will be happy if we can share our findings with the policy makers and the governments of BSEC.

As it is already mentioned most of UNFCCC parties, including the BSEC countries have submitted their INDCs but their implementation necessitates certain amounts of knowledge, especially for countries with economies characterized as developing or under development. KEPA already participates in this type of missions in the area and examines the terms of sending experts for short missions in Central America.

Depending on the outcomes of COP 21 in Paris countries with economies under development will be invited to implement their National Appropriate Mitigation Actions (NAMA) in the context of the foreseen procedures and terms of financing. KEPA in cooperation with prominent European institutions is ready to support their development and implementation in the countries of BSEC and those of Central Asia.

For almost two years we attempt in vain to attract the interest of coal power companies in our region, including the Greek Power Corporation, on the need to participate in the efforts to develop carbon capture techniques, different that those aiming to store CO_2 in underground physical formations.

The idea is to use the produced ashes, through a chemical process, as capturing material of the emitted CO_2. We cooperate with the Polish Academy of Sciences and our aim is to develop a consortium consisted of academic institutions and coal fired power stations that will submit a proposal in the context of H2020. Our latest contacts with Turkish potential partners maybe proved successful.

Ladies and Gentlemen

I have already presented you the framework of our efforts, our main capacities and perspectives of cooperation.

The 8th international conference that has just opened is developed in three parts where the first aimed to communicate with all of you that honor us with your participation. The second will cover the scientific contribution of our foreign and Greek participants while during the third we will try to investigate common interests for joint projects especially in the context of H2020 and INTERREG calls for proposals.

Thank you for coming to this opening and you are kindly invited for a coffee at the reception hall.

Policies

Strategies for a low carbon building stock in Germany

by

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Abstract

14% of the total national CO_2 emissions are caused by heating systems in the residential sector. To meet the overall CO_2 reduction target (-40% in 2020, -80% in 2050), the German Federal Government has set a target in its "Energiewende" concept for Germany's building stock to be nearly climate-neutral by 2050 focusing mainly on thermal insulation measures. It is unclear, however, whether this preferred option is the most cost-efficient strategy.

We investigated different strategies for reducing energy demand and CO_2 emissions from residential building stock up to the year 2050. These strategies comprise the Federal Government's energy concept measures, on the one hand, and alternative paths and options using more renewable gases and innovative heating systems, on the other. The calculations are based on a dynamic simulation model that simulates the residential building stock in detail. The model simulates the effects of various energy-efficiency measures, such as thermal insulation and improvements to heating systems.

The results show that there are alternative strategies which can lead to a climate-neutral building stock. Alternative strategies focusing on an early replacement of heating systems, an increased use of renewable energy, and a forced use of innovative heating systems are more cost-efficient than strategies which mainly focus on thermal insulation measures. The sensitivity analyses we have performed underline the robustness of our results.

Keywords: Building stock, thermal insulation, dynamic simulation model, CO_2 reduction, heating system, energy efficiency, renewable energy

1. Introduction

In order to limit global warming to less than 2 °C, the EU has committed itself to reducing greenhouse gas emissions by 2020 by 20% compared to 1990 levels and as part of the plans for reducing emissions in industrialized countries to cutting them by 2050 by 80–95% compared to 1990 levels [EU-Rat, 2009]. Buildings are responsible for 40% of total energy consumption and 36% of CO_2 emissions in Europe [EU-COM, 2008]. Improving energy efficiency and an increased use of renewables are therefore decisive measures to ensure a decrease in the EU's dependence on energy imports, the use of fossil energy, and CO_2 emissions. Key parts of the European regulatory framework in this context are the Energy Performance of Buildings Directive (EPBD) [EPBD, 2002], and its recast [EPBD, 2010]. The recast EPBD established the obligation that all new buildings should be nearly zero-energy by the end of 2020.

These targets were confirmed in Germany by the German Federal Government's Energy Concept [Bundesregierung, 2010]. The German Federal Government aims to reduce emissions by 2020 by 40% and by 2050 by 80% compared to 1990 levels. The decision in favour of an accelerated nuclear power phase-out means that climate protection and energy efficiency in the buildings sector are becoming increasingly important [BMWi, 2011]. Private building stock is extremely important here, as it currently accounts for approx. 14% (124 million tonnes) of national CO_2 emissions and 23% (space heating and hot water) of final energy consumption in Germany [AGEB, 2013]. For the buildings sector, the aim is to achieve a climate-neutral building stock by 2050 by reducing the primary energy consumption of existing buildings by 80%. A key aspect here involves enhancing the energy efficiency of buildings by implementing additional thermal insulation measures. Such implementation will be promoted by regulatory measures (e.g. Energy Saving Ordinance) and diverse incentive programmes (e.g. KfW programme for energy-efficient construction and refurbishment). The new German Energy Saving Ordinance (EnEV 2014) came into force in 2014. Therefore, the standard for the construction of new buildings is being raised. From 2016, the maximum primary energy demand of a new building will be 25% lower than the level currently required under EnEV 2009. The amended EnEV 2014 provides for the introduction of a climate-neutral standard for new buildings by 2020 based on primary energy consumption rates [EnEV, 2013].

Many studies [EWI et al., 2014, EWI/gws/Prognos, 2010, Hansen et al., 2014, Hoier & H., 2013, Kirchner et al., 2009] that deal with reducing CO_2 in the buildings sector in Germany focus solely on the efficiency strategy favoured by the Federal Government. In [McKenna et al., 2013], a bottom-up model is used to analyse the importance of improving the energy efficiency of buildings to achieve the ambitious targets in Germany. Only through intensified policy measures that include the renovation of single-family houses will it be possible to meet the Federal Government's targets. A cost analysis is performed only in a few cases here [Pikas et al., 2015].

This paper investigates alternative strategies and scenarios that could help Germany to achieve its goal of climate-neutral residential building stock. The effects of forced thermal insulation versus the increased use of innovative heating systems and renewables are examined. The impacts are analysed using the dynamic bottom-up model JEMS-BTS, which details the German residential building stock and installed heating systems using a regionalized approach. It also allows an extrapolation by incorporating re-investment cycles. Scenarios are compared based on primary energy consumption and CO_2 emissions. Costs are compared using the actual cash value of each strategy.

The first chapter describes the modelling approach used. This is followed by a description of the scenarios with the most important assumptions. Finally, the model-based results are compared by outlining and discussing the potential for increasing efficiency and for decreasing CO_2 emissions as well as costs.

2. Methodology

In order to quantify the potential of efficiency to produce space heat and hot water, building stock models are used in most cases. For the scenario analysis, the model JEMS-BTS [Hansen et al., 2014] was used. It is a physical bottom-up approach to simulating energy consumption in residential buildings [Foucquier et al., 2013, Kavgic et al., 2010, Rysanek & Choudhary, 2013]. Building stock characteristics must be known in order to estimate the impact of energy-efficiency measures on the stock. To efficiently model the energy consumption of building stock, in a methodological approach similar to that in [Mata et al., 2014], a building stock simulation model was developed for Germany [Hansen, 2011, Hansen et al., 2014, Markewitz et al., 2012]. Using the bottom-up modelling approach in [Asadi et al., 2012], the dynamic simulation model JEMS-BTS extrapolated energy consumption based on the type of building, construction year, climate region, and energy carriers used to the regional and national levels and combined statistical calculation methods with technical and physical calculation methods. For the simulations, an extensive, regionalized building stock database was integrated into the model. It models the residential building stock in Germany based on typologized residential building types, sizes, and age classes including heating and hot water systems as well as corresponding energy conditions. Analyses in [Engvall et al., 2014, Gonçalves et al., 2013] show that energy consumption for heating depends significantly on the age of the building, type of building, and ventilation as well as on the age of the installed heating system. JEMS-BTS[1] can be used to simulate measures for single buildings in chronological sequence and to determine the impacts of these measures over a defined period of time. The modelling approach described in [Asadi et al., 2012, Ma et al., 2012] enables the simulation of all potential combinations of technical measures concerning the thermal insulation of the building envelope and improvements to heating systems. The development of buildings' energy requirements over time and the projection of technical options are simulated in the form of scenarios.

The potential for energy efficiency improvement is modelled for each building type using a probabilistic approach. This methodological approach allows the simulated ageing processes to be used to determine the renovation frequency for each building component [Hansen, 2011]. By setting a rate of energy efficiency improvement, the potential for saving energy and reducing CO_2 can be determined for each building type and projected onto the building stock. This approach is expanded to include the calculation of cost-related impacts and the determination of strategy costs [Krause et al., 2011, Markewitz et al., 2012].

3. Scenario definition

For the scenario analyses up to 2050, three scenarios were defined (see Table 1). In the "business as usual" (BaU) scenario, the impacts of measures and efficiency standards already in place are extrapolated. This applies to national regulatory instruments such as EnEV 2014 and the Renewable Energies Heat Act (EEWärmeG), as well as the provisions of the EU Energy Performance of Buildings Directive. This scenario also accounts for funding instruments within the KfW programmes for energy-efficient construction and refurbishment and the market incentive programme for renewable energy. Additionally in the BaU scenario, in accordance with the EU Buildings Directive, all new buildings must be nearly zero-energy buildings from 2021 onwards. The rate of energy efficiency improvement over the last few years remains at around 1%/year (BMVBS, 2013) until 2020 before gradually increasing moderately to 1.5 %/year in the subsequent period up to 2050. Old heating systems are replaced predominantly with conventional systems. In contrast to the BaU scenario, the "enhanced thermal insulation" (TI) scenario assumes that the measures for the buildings sector as defined in the Federal Government's Energy Concept are implemented in full. The focus here is on pushing building renovation. A renovation road map is introduced to progressively transfer the nearly zero-energy building standard for new buildings to existing buildings. Key elements are the doubling of the rate of energy efficiency improvement to 2%/year from 2020 onwards and a tightening of the EnEV efficiency standards for existing buildings. Furthermore, higher incentives are offered within the CO_2 Building Renovation Programme and energy contracting is expanded to enhance savings potentials in the rental accommodation sector. Old heating systems are replaced at the same rate as in the BaU scenario, namely 4%/year.

In addition to these scenarios, an alternative scenario was also defined. In the "modern heating systems" (MHS) scenario, the BaU scenario is taken one step further by assuming that measures and instruments applicable to buildings are supplemented by expanding the Renewable Energies Heat Act (EEWärmeG) to include existing building stock. This alternative MHS scenario assumes a rate of energy efficiency improvement in line with the BaU scenario and also concentrates on the intensified use of modern and innovative heating systems as well as an increased use of renewables. In addition, the use of local and district heat is taken into account mainly by stepping up network densification. In contrast to the BaU and TI scenarios, the MHS scenario assumes a shorter average renewal cycle of 20 years instead of 25 years for heating systems. Another important feature is that natural gas is more heavily substituted with CO_2-free gases, such as biogas and hydrogen produced from wind.

[1] JEMS-BTS = Jülich Energy Modeling Suite - Building Stock and Technology Simulation Model for Space Heating and Hot Water Supply

4. Scenario assumptions

The scenario calculations are based on the initial thermal state of buildings in 2012 and demographic development up to 2050 according to variant V1 of the Federal Statistical Office's 12th coordinated population projection for Germany [Destatis, 2010]. On this basis, the German Sample Survey of Income and Expenditure [Destatis, 2008] and household projections in Germany [DESTATIS, 2007] are used to derive the dynamics of household structure and the demand for living space. Accordingly, the demand for living space increases continuously despite a declining population. It is expected that living space as of 2012 totalling 3.62 billion m^2 will increase to a total of 3.87 billion m^2 by 2050 despite the decline in the residential population to 69.4 million in the same period (see Table 2). This is explained by the increasing number of single-person and two-person households as well as the higher amount of living space per person. This increasing consumption of living space appeared in the past across all age groups [IDW, 2009]. If we include living space in new buildings constructed in the period 2012–2050 amounting to 0.87 billion m^2, the inhabited living space increases by 7% to 3.67 billion m^2 in 2050. With respect to the development of the vacancy rate, it is assumed that it will rise slightly by 2050 from the current figure of 5.1% to 6.1%. The calculations also assume a constant annual demolition rate of 0.2% accross the entire period.

In addition to these input parameters, the energy carrier costs assumed in the scenarios are an important factor (see Table 3). Energy prices are assumed to develop in line with the same trend in the scenarios in [EWI/gws/Prognos, 2010, Krause et al., 2011], which are also used as the basis for the Federal Government's Energy Concept. Accordingly, a continuous increase is assumed in energy prices. For example, the annual rate of increase for light heating oil for private households is approx. 1.8%. With the exception of the price for gas mixtures, identical energy carrier prices are assumed for all scenarios. As the share of renewable gas varies in the scenarios, the prices of the gas mixtures also differ.

In order to extrapolate the heating system structure up to 2050, replacement rates for heating systems are defined. The replacement rate describes the technology-specific substitution rate for heating systems that must be replaced due to age.

Table 1: Definition of scenarios.

	BaU	TI	MHS
Policy instruments for building renovations	Updating of existing policy instruments	Implementing of energy concept	Measures (like BaU) and extension to the mandatory use of renewable energy in refurbished buildings
Energy efficiency standards	EnEV 2014 for existing buildings; EPBD 2010 requires all new buildings to be nearly zero-energy by the end of 2020	Tighter requirements for existing buildings (2020 and 2030: + 30%); EPBD 2010	EnEV 2014 EPBD 2010
Refurbishment rate of building envelope	1.0%/year and from 2020 moderate increase to 1.5%/year in 2050	Doubling the current rate up to 2%/year by 2020	1.0%/year and from 2020 moderate increase to 1.5%/year in 2050 (BaU)
Replacement rate of heating systems	4%/year	4%/year	5%/year, increased use of innovative heating systems

Table 2: Input data.

	2012	2020	2030	2040	2050
Population (millions)	80.5	79.9	77.4	73.8	69.4
Private households (millions)	40.7	40.9	40.6	39.3	37.7
1 Person	*16.5*	*16.8*	*17.0*	*17.1*	*17.1*
2 Persons	*14.0*	*14.6*	*14.9*	*15.0*	*15.2*
3 Persons	*5.1*	*4.8*	*4.4*	*3.6*	*2.7*
4 Persons	*3.7*	*3.5*	*3.2*	*2.8*	*2.2*
5 Persons and more	*1.3*	*1.2*	*1.1*	*0.8*	*0.5*
Persons per household	1.99	1.95	1.91	1.90	1.84
Living space (billion m^2)	3.62	3.68	3.83	3.88	3.87
New construction (billion m^2)	0.00	0.16	0.40	0.65	0.87
Inhabited living space (billion m^2)	3.43	3.34	3.24	3.01	2.80
Vacancies (%)	5.1	5.2	5.5	5.8	6.1
Living space per person (m^2)	44.7	46.1	49.5	52.6	55.8
Living space per household (m^2)	88.9	90.0	94.3	98.7	102.7

Table 3: End-user prices for private households (including VAT), [Krause et al., 2011].

	2012	2020	2030	2040	2050	Δ 2012–2050
	€ct/kWh					%/a
Gas (BaU)	6.6	7.0	7.6	8.1	8.7	0.7
Gas (TI)	6.6	7.0	7.6	8.3	9.5	1.0
Gas (MHS)	6.6	7.0	7.7	8.6	9.9	1.1
Oil	6.9	8.5	10.1	11.9	13.4	1.8
Briquettes	4.6	4.2	3.9	3.7	3.4	-0.8
District and local heat	7.7	8.4	9.0	9.6	10.2	0.7
Pellets	4.2	4.6	5.2	5.8	6.4	1.1
Electricity	25.1	26.9	28.8	30.8	32.5	0.7
Electricity for heat pumps	19.4	20.7	22.2	23.7	25.0	0.7

The combination of replacement rates and the age structure of relevant inventories is used to calculate the current stock of heating systems.

In the BaU and TI scenarios, it is assumed that most of the oil heating systems are replaced but that at least 20% of these oil systems will remain in 2050. Furthermore, it is assumed that these oil heating systems are increasingly replaced by a mixture of gas systems, biomass boilers, and electric heat pumps. In addition, it is assumed that micro-CHP units will begin to penetrate the market. It is assumed that heating systems run on natural gas are replaced from 2020 onwards by gas heating systems only. The highest replacement rates of 52.5% in 2050 apply to gas-fired condensing boilers with solar technology.

In the alternative MHS scenario, it is assumed that when heating systems are replaced that the oil and gas heating systems in need of renewal are exchanged from 2020 onwards for gas heating systems, electric heat pumps, biomass boilers, and local and district heating systems. It is also assumed that more heat pumps and micro-CHP units are installed as replacements for oil and gas heating systems. The substitution rate for gas heating systems in 2050 is based on the assumption that every third heating system is replaced with a micro-CHP unit.

5. German residential building stock

The residential building stock in 2012 comprises the results of the 2011 census [Zensus, 2013] and is made up of around 39.7 million dwellings, which are distributed across 18.5 million residential buildings. Almost 83% of residential buildings (15.3 million) are single-family and multifamily houses. Residential buildings with more than two dwelling units account for 17% and comprise 21.2 million dwellings [Destatis, 2013]. The total living space in residential buildings is currently 3.62 billion m^2. Figure 1 shows the existing stock broken down into building types and age classes which are divided into architectural building periods. It can be seen that more than two-thirds of today's stock was built before the first German Thermal Insulation Ordinance came into force in 1978. The greatest share of existing living space is made up of the building age classes 1958–1968 and 1969–1978 which account for 636 million m^2 and 579 million m^2, respectively. Since the introduction of EnEV in 2002, only 7% of living space had been newly built by 2012Almost 84% of the final energy demand of private households in 2012 is due to the production of space heating (69%) and hot water (15%). The temperature-adjusted final energy consumption of private households for space heating and hot water in the period from 1990 to 2013 decreased by approx. 14% compared to 1990 levels to 2,097 PJ [AGEB, 2013, AGEB, 2014]. The initial thermal state of residential building stock can be characterized according to building age classes and installed heating systems based on the final energy consumption determined from the thermal insulation of residential buildings. In accordance with the analyses of the data basis in [Diefenbach et al., 2010] and the level of modernization in [Walberg et al., 2011], the level of thermal insulation in residential buildings can be determined for 2012 according to building type and age class. Consequently, in 2012, more than 50% of the 18.5 million residential buildings had no or insufficient thermal insulation. A further 30% had at least a partially insulated building envelope and less than 20% of residential buildings were fully insulated. According to the distribution of existing living space, the age classes 1958–1968 and 1969–1978 have the largest quotas of residential buildings which simultaneously have the worst insulation.

In addition to how well insulated building envelopes are, the installed heating systems are also essential in characterizing final energy consumption for space heating and hot water.

According to statistical analyses and surveys, existing residential buildings were equipped with more than 23.2 million heating systems in 2012. At the end of 2012, installed heating systems in private households were dominated by 13.1 million gas heating systems.

In 2012, some 4.0 million gas condensing boilers were installed in residential buildings. At the same time, more than two-thirds of existing boilers in 2012 were inefficient and allowing for a mean replacement cycle of 25 years they can also be classified as antiquated and in need of renewal [BDH, 2013, DEPV, 2013, Shell & BDH, 2013, ZIV, 2013]. Therefore, replacing heating systems has huge potential for saving energy.

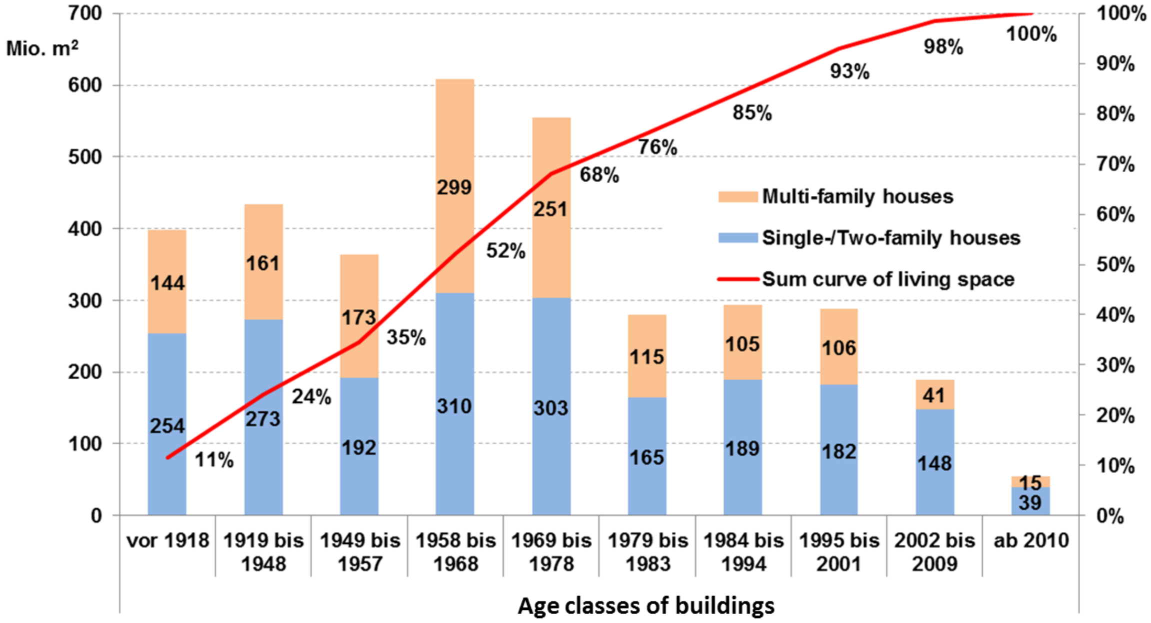

Figure 1: Residential building stock 2012.

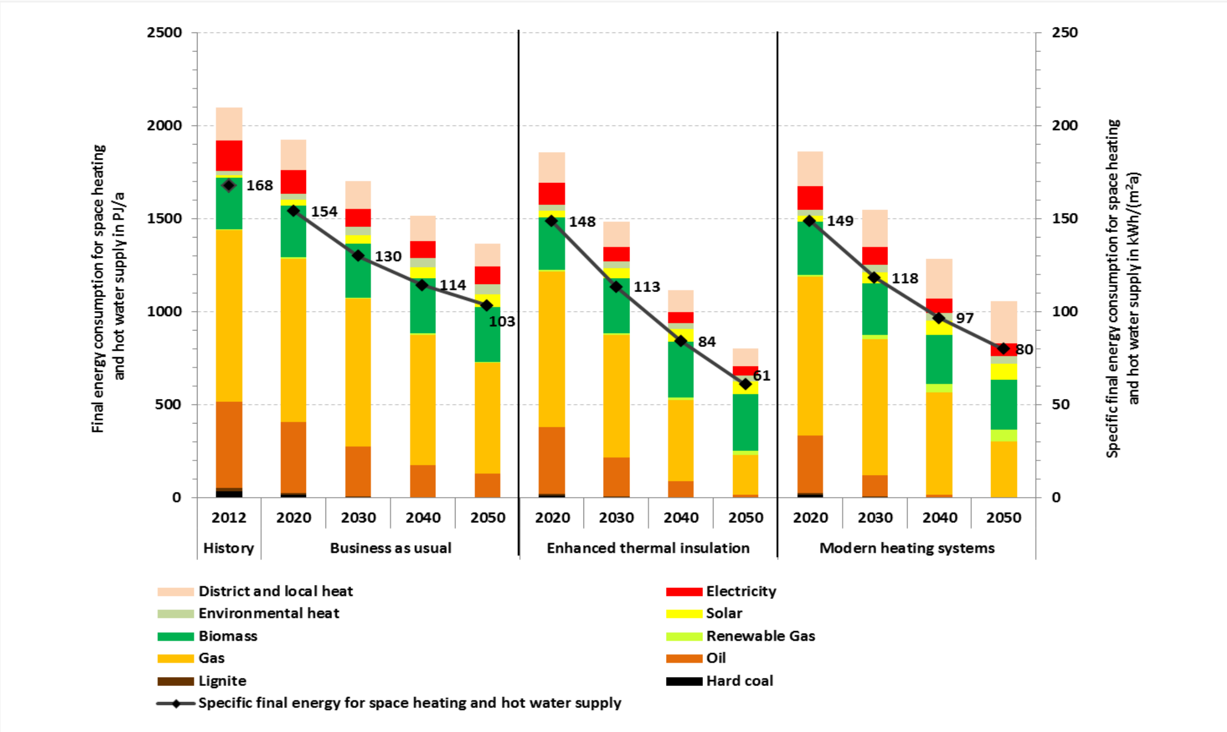

Figure 2: Final energy consumption for space heating and hot water supply.

6. Results

III.1 Final energy consumption

Final energy demand for space heating and hot water decreases considerably in the three scenarios for the period from 2013 to 2050 (see Fig. 2). The energy demand for heat and hot water supply in residential buildings drops by 35% by 2050 in the BaU scenario. This drop is due to the demolition of older buildings and the construction of new energy-efficient building as well as the energy-efficient renovation of old housing stock. Overall, the energy demand in the BaU scenario is reduced by 730 PJ by 2050. Accounting for almost 600 PJ, natural gas is the dominant energy carrier.

The calculations for the TI scenario show that doubling the rate of energy efficiency improvement to 2% per annum combined with a tightening of energy efficiency standards compared to the situation in the BaU scenario are the main factors that lead to a saving of more than 560 PJ by 2050. Overall, the heat demand up to 2050 in the TI scenario decreases by a further 27% compared to levels in 2012. The energy demand therefore drops to approx. 800 PJ by 2050. The largest decrease among the energy carriers by 2050 was ascertained for the use of natural gas, which drops by almost 710 PJ. Heating oil consumption drops by 450 PJ and in 2050 only a residual demand of 16 PJ for heat and hot water supply in private households needs to be covered by heating oil. Power consumption is reduced by almost 115 PJ and the use of district heating by a total of some 80 PJ by 2050. By adding biogas to conventional natural gas, this renewable gas mixture covers around 3% of the final energy demand in 2050 with 22 PJ. The share of renewables excluding renewable gases is successfully increased by more than 400 PJ by 2050.

The building renovation measures and measures for increasing the efficiency of heating systems in the MHS scenario enable the 2012 final energy demand of households for space heating and hot water to be reduced by almost 50% (1,040 PJ) by 2050. The demand for heat up to 2050 therefore decreases by almost 310 PJ more than in the BaU scenario. However, the savings are lower in the BaU scenario than in the TI scenario. The additional savings in the TI scenario compared to the BaU scenario can be explained by shorter replacement cycles for heating systems and predominantly by the growing use of innovative heating systems such as micro-CHP units. Heating oil is completely replaced by other energy carriers by 2050. The use of conventional natural gas is decreased by 620 PJ by 2050. In contrast, the use of renewable gases is increased to 64 PJ by 2050 through the admixtures of H_2 and biogas. The renewable gas mixture has a share of 6% in the total energy demand in 2050. The power demand decreases by more than 90 PJ in total by 2050 and the energy demand for local and district heat increases by 17 PJ. The share of renewables from biomass, solar energy, and environmental heat increases by 27%.

An indicator for energy savings is the area-specific energy consumption for the production of space heating and hot water. The values shown in Fig. 2 apply to the entire residential building stock. The area-specific consumption decreases for inhabited living space from 168 kWh/(m^2a) in 2012 to 103 kWh/(m^2a) in the BaU scenario by 2050. Due to the measures in the TI and MHS scenarios, an area-specific demand of 61 kWh/(m^2a) and 80 kWh/(m^2a), respectively, emerges.

III.2 Primary energy consumption and CO_2 emissions.

If the energy demand for space heating and hot water in the TI and MHS scenarios is calculated using the primary energy factors defined in EnEV [EnEV, 2013], then the primary energy consumption (PEC) can be determined. Fig. 3 shows that both scenarios achieve the 80% reduction envisaged in the Energy Concept by 2050 compared to levels in the base year 2008. Primary energy demand, therefore, drops by 80% in the MHS scenario (PEC-MHS) by 2050. In the TI scenario, primary energy demand is reduced by almost 84% in 2050. In addition, the emissions savings verify that CO_2 emissions produced by space heating and hot water supply of 28% in 2012 are decreased by 2050 in both scenarios by more than 80% compared to 1990 levels. The climate target of -80% compared to 1990 levels has therefore been exceeded in the MHS scenario (MHS-CO_2) where emissions are reduced by 88% and in the TI scenario (TI-CO_2) with a reduction of 91%.

In the BaU scenario, over the course of the scenario up until 2050, emissions are successively reduced. In 2050, the emissions reduction totals a good 120 million tCO_2 and emissions are thus 71% lower than levels in 1990. The measures for increasing efficiency and reducing CO_2 emissions that are already in place today and are extrapolated up to 2050 are responsible for this reduction. Climate protection targets set by the government, however, are not achieved in this scenario.

The measures in the TI scenario and the MHS scenario lead to greater CO_2 reductions than in the BaU scenario with figures of 35 million tCO_2 and 29 million tCO_2, respectively, by 2050. These figures also show that the Energy Concept measures have a greater impact on emissions than the measures in the MHS scenario. The main reason for this is higher building renovation rates compared to the MHS scenario. Up to 2020, the reduction in emissions in the TI and MHS scenarios is of a similar magnitude to that in the BaU scenario because the measures in the TI scenario only begin to take effect after the rate of energy efficiency improvement is doubled in 2020.

III.3 Costs

The simulation model calculates the investment costs and annual operating costs for the measures and on this basis assesses the annual costs of the scenarios from an end user's perspective. The annual costs of the scenarios were discounted with an interest rate of 4% in relation to 2013 and added up over all the years in the period under review. The total costs of the TI scenario are higher than those of the BaU scenario and at approx. € 75 billion are also higher than the equivalent figures in the MHS scenario at approx. € 26 billion (see Table 4). The main reason for this is the high investment costs for renovation measures, which due to the higher rate of energy efficiency improvement and the tightened energy efficiency standards are much higher than the investment costs in the MHS scenario. Doubling the rate of energy efficiency improvement, in particular, necessitates the implementation of measures beyond the usual renovation cycles, which in turn explains a considerable proportion of the higher additional investments. However, the energy savings in the TI scenario are considerably higher, which means that expenditure for energy is lower than in the MHS scenario. Overall, the reduced energy costs in the TI scenario cannot compensate the increased investments. The specific CO_2 avoidance costs in the TI scenario are approx. € 158/tCO_2 for cumulative CO_2 savings of 475 million tCO_2. In the MHS scenario, the specific avoidance costs in contrast are approx. € 58/tCO_2 for cumulative CO_2 savings of approximately the same magnitude at 445 million tCO_2.

7. Conclusions

The results clearly show that simply continuing the current measures put in place by the German Federal Government is not enough to achieve a climate-neutral building stock by 2050. Further measures will be necessary, similar to those proposed in the TI and MHS scenarios. The results also show that the currently favoured strategies in the residential building sector, which focus predominantly on energy-efficient measures for the building envelope, are not the only option for achieving a climate-neutral residential building stock by 2050 and that interesting alternatives exist which are simultaneously more cost-efficient. Implementing the package of measures in the two scenarios is ambitious. This applies in particular to the demanding renovation road map in the TI scenario but also to the measures in the MHS scenario, which envisage the early replacement of heating systems and a heightened use of innovative heating systems. Both scenarios involve several measures which are partially identical, but which often differ in how they are implemented and weighted. In all scenarios analysed, improving efficiency through thermal insulation measures represents a central and indispensable field of action. However, the analyses also indicate that by altering the priorities and focusing more on support measures, a climate-neutral building stock can be achieved at much lower costs. Today, incentives in the form of subsidies are already in place to encourage the implementation of existing political measures in the buildings sector (e.g. the KfW programmes). It can be assumed that incentives will also be necessary to stimulate measures in the TI and MHS scenarios – from the development of marketable technologies right up to educating the actors involved.

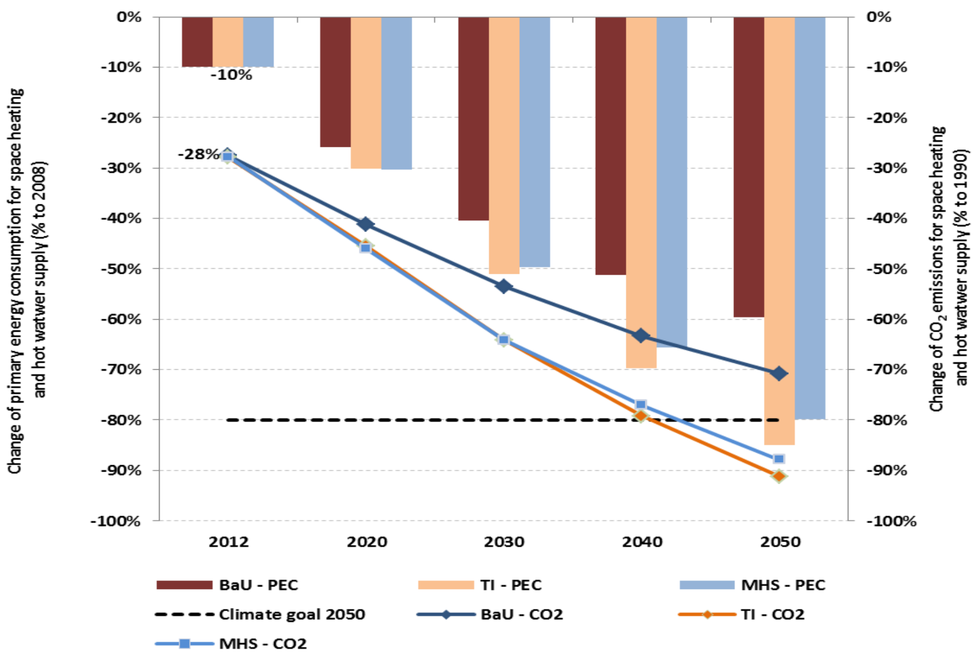

Figure 3: Primary energy demand and CO_2 emissions.

Table 4: Costs over strategy (present value 2013–2050).

		BaU	MHS	Δ to BaU	TI	Δ to BaU
Investment costs	billion €	443	515	72	617	174
heating systems (existing buildings)		*270*	*343*	*73*	*270*	*0*
heating systems (new buildings)		40	39	-1	39	-1
thermal insulation (existing buildings)		*87*	*87*	*0*	*262*	*175*
thermal insulation (new buildings)		*46*	*46*	*0*	*46*	*0*
Fuel costs	billion €	802	755	-47	703	-99
Net costs	billion €	1245	1270	26	1320	75
CO_2 emissions	million tCO_2	2364	1919	-445	1889	-475
Specific reduction costs	€/tCO_2			58		158

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Examining the Australian climate change regime: Carbon pricing scheme and direct action plan

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Abstract

A range of measures aimed to reduce Australia's greenhouse gas emissions have been on agenda at the Federal and State level for last decades. Successive Australian governments have been committed to the introduction of carbon tax or emissions trading scheme designed to mitigate climate change. This article examines the present Australian carbon pricing regime and the direct action plan proposed by the new Australian Government. Examination of the entire division of climate change regime, including all of the relevant policies, would be an enormous task. Thus, the article provides a comparative analysis of the major features of the carbon pricing scheme and the direct action plan.

Both policies are considered on the basis of the 11 principles specified by the Australian Government's Multi-Party Climate Change Committee (the Committee) that has designed the carbon pricing scheme. The Committee stated that these principles should direct the development of any carbon policy mechanisms. Therefore, it is logical to suggest that both policies – the current carbon price scheme and the proposed direct action plan – should be consistent with these principles. Accordingly, this paper analyses and compares the major characteristics of both schemes and their potential capacity to address the principles stated by the Committee. This analysis demonstrates that the carbon pricing regime and the direct action plan proposed by the new Australian government fail to address a number of the critical principles and contradict some of the principles which are often recognised as imperative climate change policy criteria.

1. Introduction

A range of measures aimed to reduce Australia's Greenhouse Gas (GHG) emissions have been on agenda at the Federal and State level for last decades. Successive Australian governments have been committed to the introduction of carbon tax or emissions trading scheme designed to mitigate climate change (Wilder M. and Fitz-Gerald L., 2009). In December 2006, the then-Prime Minister John Howard announced that Australia would move towards a domestic emissions trading system, to start no later than 2012.[2] The subsequent Rudd government proposed an Australian Carbon Pollution Reduction Scheme (ACPRS) in 2008 (CPRS, 2009). The ACPRS legislation was twice defeated in the Australian Parliament in 2009. As a result, at the beginning of 2010, the government put the ACPRS on hold. In 2010, the Gillard government announced its intention to propose a

[2] Ibid. Note, however, that in 2005, the Australian State and Territories issued a discussion paper concerning a national emissions trading scheme which would cover the power generation sector.

temporary carbon pricing scheme,[3] and also, set up the Multi-Party Climate Change Committee (the Committee)[4] consisting of members of the federal government and senators.[5]

The Committee's intention was to establish a climate change framework outlining the broad architecture for a carbon price. The Committee issued eleven policy principles designed to provide a consistent basis for the deliberations on a carbon price[6] The principles were as follows:

- Environmental effectiveness
- Economic efficiency
- Budget neutrality
- Competitiveness of Australian industries
- Energy security
- Investment certainty
- Fairness
- Flexibility
- Administrative simplicity
- Clear accountabilities, and
- To supports Australia's international objectives and obligations[7]

This article examines the Australian carbon pricing regime that was repealed in 2014 and the direct action plan recently introduced by the Australian Government. Examination of the entire division of climate change regime, including all of the relevant policies, would be an enormous task. The Multi-Party Climate Change Committee stated that the 11 principles will guide the design decisions of the pricing mechanism. The Committee also specified that these principles should direct the development of any carbon mechanisms.[8] Thus, the article provides a comparative analysis of the major features of the carbon pricing scheme and the direct action plan. Both policies are considered on the basis of the 11 principles specified by the Committee. Accordingly, this paper analyses and compares the major characteristics of both schemes and their potential capacity to address the principles stated by the Committee. This analysis demonstrates that the carbon pricing regime and the direct action plan proposed by the new Australian government fail to address a number of the critical principles and contradict some of the principles which are often recognised as imperative climate change policy criteria.

2. The carbon pricing scheme

The carbon price scheme (the scheme) operated from 1 July 2012 as a temporary measure designed to reduce greenhouse gases (GHG). The carbon price is $23 for the 2012–13 financial year and increases by 2.5 per cent in each of the following two years.[9] Under the scheme, liable entities buy and surrender carbon units equal to their direct emissions (based on historic levels) of carbon dioxide equivalents (CO_2). Failure to surrender necessary carbon units will result in a fine. After the transitional period, the carbon price mechanism converts to a cap-and-trade ETS supplying a flexible carbon price.[10] From 1 July 2015, the carbon units were supposed to be auctioned. Hence, even though the carbon pricing mechanism is sometimes labeled a

[3] A carbon pricing scheme is often called a 'tax' because during the fixed price period, the liable parties are obliged to purchase fixed price carbon units which is similar to paying tax. However, they cannot trade the units on the market, as under an emissions trading scheme.

[4] Multi-Party Climate Change Committee. Available at http://www.climatechange.gov.au/government/initiatives/mpccc.aspx

[5] The Committee includes: the Prime Minister, the Hon Julia Gillard MP, the Deputy Prime Minister, the Hon Wayne Swan MP and the Minister for Climate Change and Energy Efficiency, the Hon Greg Combet AM MP, joined by co-deputy chair of the Committee, Australian Greens Deputy Leader Senator Christine Milne, Australian Greens Leader Senator Bob Brown, Mr Tony Windsor MP, and Mr Rob Oakeshott MP. The Committee is assisted by the Parliamentary Secretary for Climate Change and Energy Efficiency, Mr Mark Dreyfus QC MP and Mr Adam Bandt MP, and by expert advisors Professor Ross Garnaut, Professor Will Steffen, and Mr Rod Sims.

[6] Multi-Party Climate Change Committee. Available at: http://www.climatechange.gov.au/~/media/Files/minister/combet/2011/media/february/mr20110224.pdf

[7] It is important to note that the principles are not stated in any order of priority. See Multi-Party Climate Change Committee, above note 4.

[8] Multi-Party Climate Change Committee, above note 4.

[9] Multi-Party Climate Change Committee, above note 4.

[10] Ibid.

'carbon tax', the Australian government was committed to emissions trading.

The carbon price scheme covers four of the six GHGs counted under the Kyoto Protocol, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and perfluorocarbon (PFC), [11] and has broad coverage of the following emissions sources:

- the stationary energy sector
- industrial processes sector
- fugitive emissions (other than from decommissioned coal mines), and
- emissions from non-legacy waste.[12]

The scheme covers around 500 entities which emit 25,000 tonnes of CO_2 per year or more and certain waste facilities emitting more than 10,000 tonnes per year, constituting about 50 per cent of Australia's GHG. [13] Agriculture and transport fuels are excluded from the scheme, although transport fuels used by off-road heavy vehicles (except for agriculture, fishing and forestry) are covered indirectly by a reduction in existing fuel tax concessions. During the fixed price transitional period under the scheme, liable parties cannot use international emissions reduction units for compliance. However, during the flexible price period, internationally recognised permits may be used to acquit up to 50 per cent of a party's' liability.[14]

There is no cap on emissions during the fixed price period and the number of carbon units is unlimited. However, starting from 2015–16, the Climate Change Authority (an independent statutory body) set a cap on emissions taking into consideration international and Australian emissions reduction targets. Currently, Australia is committed to reducing emissions by 5 per cent of 2000 emissions levels by 2020. [15] It was projected that the carbon price scheme raises $24.5 billion over its first four years. However, the budget deficit is expected to be around $4 billion.[16]

There are significant tax cuts and increases in allowances, payments and benefits. In particular, the tax free threshold has almost tripled from the previous $6,000 to $18,200 from 1 July 2012, and then increase to $19,400 from 1 July 1 2015. Thus, all taxpayers with an income below $80,000 will effectively receive tax cuts from 1 July 1 2012.[17] Further, an assistance package of $9.2 billion is to be allocated over the first three years to Australian industries to eliminate competitiveness issues associated with the carbon price scheme. [18] Most affected industries such as steel, aluminium, zinc, pulp and paper makers acquire free permits covering about 94.5 per cent of industry's average carbon costs. In addition, $300 million is to be assigned to the steel industry's

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[11] Hydrofluorocarbons and sulphur hexafluoride will face an equivalent carbon price, which will be applied through existing synthetic greenhouse gas legislation.

[12] Stationary energy includes emissions from fuel consumption for electricity generation, fuels consumed in the manufacturing, construction and commercial sectors, and other sources like domestic heating. Industrial processes emissions are side-effects of production from non-energy sources, for example, it includes emissions from cement production, metal production, chemical production, and consumption of HFCs and SF6 gases. The fugitive emissions relate to the energy sector and covers emissions that are linked with the production, processing, transport, storage, transmission and distribution of fossil fuels such as black coal, oil and natural gas. The waste emissions relate to waste dumped at landfills.

[13] Multi-Party Climate Change Committee, above note 4.

[14] The Commentary on the provisions also states that international linking with the European Union scheme and New Zealand Schemes are desirable and if agreed, EU Allowances and NZ units would be prescribed under the Clean Energy Bill. (Multi-Party Climate Change Committee, above note 7).

[15] The Australian Government has been criticised for these low GHG reduction targets. For example, Professor Garnaut (the federal government's climate change adviser) recommended a 25 per cent reduction, while many other commentators suggest that an even more ambitious GHG reduction target is needed. See for example: Garnaut, R. 2008. *Australia Counts Itself out*. Available: http://www.theage.com.au/national/australia-counts-itself-out-20081219-72ei.html?page=-1; Brook, B. 2009. *Carbon Tax or Cap-and-Trade? The Debate we never had*. Available: http://bravenewclimate.com/2009/02/14/carbon-tax-or-cap-and-trade-the-debate-we-never-had/

[16] Multi-Party Climate Change Committee, above note 7.

[17] However, the individual income tax rates for higher income earners are raised. For example: 19% for income over $18,200 (was 15%) and 32.5% for income over $37,001 (was 30%). Source: http://www.ato.gov.au/individuals/PrintFriendly.aspx?ms=individuals&doc=/content/00309813.htm

[18] Multi-Party Climate Change Committee, above note 4.

shift to clean energy. A coal sector jobs package at $1.3 billion is dedicated for mines that are most affected by the carbon price.[19] On top of that, the government is committed to closure of 2000 megawatts of the dirtiest power generators by 2020.

Overall, the broad architecture of the proposed carbon price scheme seems to resemble in some aspects the design of the previously introduced ACPRS.[20] However, the carbon price, in some respects, is a substantial improvement on the heavily compromised ACPRS. Generous compensation for affected industry is a temporary measure and based on historic emissions levels, thus the incentive to reduce emissions is not eroded. The assistance package for households is designed to compensate low and medium income earners rather than high income earners. Raising the income tax threshold allows taking about a million low income taxpayers out of the income tax system.[21] Finally, a range of supporting measures designed to encourage energy efficiency and green innovation is also a significant improvement.

3. An assessment of the carbon policy against core principles

This section is devoted to evaluation of the carbon pricing mechanism against each individual principal proposed by the Multi-Party Climate Change Committee. This evaluation will facilitate identification of the major shortcomings of the carbon policy.

Environmental effectiveness

The environmental effectiveness of climate change policy generally implies an effective reduction in GHG emissions. To evaluate the effectiveness of a policy option, it is necessary to determine whether the objectives are being achieved. However, ex-ante evaluation of the potential effectiveness of a policy is a key difficulty of much evaluation research (Munda G., Nijkamp P. & Rietveld P., 1994).

The environmental effectiveness principle is strongly interconnected with the other principles discussed below, but at this point it is taken as effective reduction of GHG emissions by the policy as defined by the Committee.[22] Generally, a carbon policy must achieve significant GHG reduction in order to be effective. There are certainly many other factors influencing the effectiveness of climate change policies, but a considerable GHG reduction target is undeniably a critical prerequisite of an effective policy. The present short/medium-term reduction target set by the Australian government is inadequate.

The coverage of the policy is another important aspect directly related to the effectiveness of the policy in an environmental context. The carbon price scheme covers just about 50 per cent of GHG sources, providing a clear price signal to covered polluters but leaving aside another 50 per cent of polluters. The coverage of the scheme might be expanded in the future but at this point it is unlikely that this policy would create broad-based incentives across polluting sectors and activities. If transport and agriculture sectors are included in the scope of the scheme, the price signal would be adequate. Thus, considering the low emissions reduction target and limited coverage of the policy, its effectiveness is likely to be rather low.

Economic efficiency

According to the Committee, a carbon price mechanism should achieve emissions reduction cost-effectively and minimise the costs of emissions reduction to the Australian economy. However, Pizer argues that it is preferable to let the levels of emissions remain uncertain, as under taxes, than to allow the marginal price of emissions reductions to linger uncertainly, as under an ETS.[23] In other

[19] For details see: Carbon Pollution Reduction Scheme and Carbon Pricing Mechanism: comparison of selected features. Available at: http://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/Browse_by_Topic/ClimateChange/cprs

[20] For details see: CPRS. 2009, above note 3.

[21] Clean Energy Future. Available at: http://www.cleanenergyfuture.gov.au/wp-content/uploads/2011/06/09-FS-Household-Assistance-Tax-Reform-110708-1234hrs.pdf

[22] All other discussed criteria are also considered according to the definition given by the Multi-Party Climate Change Committee.

[23] Pizer concludes that: ‘My own analysis of the two approaches [carbon taxes vs. emission trading] indicates that price-based greenhouse gas (GHG) controls are much more desirable than quantity targets, taking into

words, a fixed carbon price would by no means impose unreasonable costs on the reduction of GHG emissions, but a quantity target could.[24] A fixed carbon price is able to convey a certain price signal to industry and consumers whereas an ETS price signal entails less certainty. Experience indicates that a price signal under ETS policy may fluctuate due to changes in economic conditions,[25] and it will therefore be impossible to predict the carbon price even for big business.[26] Under an effective ETS, price volatility would significantly affect business investments.

Another precondition of economic efficiency is the equivalence of the price signal. It is well recognised that economic efficiency can be increased if all polluters face the same carbon price. As discussed above, the proposed policy covers a limited range of GHG sources, accordingly decreasing its cost-effectiveness. Taken as a whole, the design defects of the policy, such as its coverage and GHG reduction target, may significantly influence its efficiency. In addition, the price volatility associated with the future ETS will negatively affect its performance; specifically, reducing the economic efficiency of this policy.

Budget neutrality

It is preferable to develop a revenue-neutral carbon price mechanism where revenue is used to fund green innovations and to compensate both households and businesses.[27] As discussed previously, the revenue from the carbon price policy will be utilised to compensate low-income households and businesses. In addition, the revenue will be used for transition relief for displaced workers (such as miners), supporting energy research and development, and encouraging conservation activities.[28] However, industry assistance of $9.2 billion over the period 2014–15 is arguably too generous. Overall, the proposed legislation is not budget neutral because there will be $3.961 billion gap from 2011–12 to 2014–15 in funding needed from the budget for the programs proposed.[29] In addition, there will be an unknown cost to shut down the most polluting power stations. In this light it is reasonable to conclude that the proposed legislation in its present status is unlikely to be budget neutral.

Competitiveness of Australian industries

It is well established that the higher production costs caused by carbon policies affect the international and sectoral competitiveness of firms.[30] The concern for international competitiveness generates strong opposition to GHG reduction policy. In the case of Australia, the concerns for the competitiveness of export and energy-intensive industries represent a real political hurdle. Energy generators and energy-intensive industries, such as the steel and chemical industries, are the most disadvantaged by GHG reduction policies (Garnaut R., 2008). These industries exercise a political power that is sufficient to influence the implementation of carbon pricing in Australia. This is despite the fact that a

account both the potential long-term damages of climate change, and the costs of GHG control. This can be argued on the basis of both theory and numerical simulations.' (Pizer, W. 2002. Combining Price and Quantity Control to Mitigate Global Climate Change. *Journal of Public Economics,* 85, 409-434., p. 432).

[24] Literature seems to agree that it is more difficult to achieve cost-effectiveness under an ETS, especially in the early years, due to price uncertainty. See for example: Pizer 2002; Aldy, J. E., Ley, E. & Parry, I. 2008. A Tax-Based Approach to Slowing Global Climate Change. *Resources for the Future, Discussion Paper 08-26.* Washington DC.

[25] See: Aldy et al. 2009 above note 26; Brook 2009, above note 16.

[26] Green et al. suggest that an ETS is not able to offer certainty since emissions permits do not legally represent real property rights. The government may modify the ETS regulation, which could diminish the value of emissions permits owned by industry. (Green, K. P., Hayward, S. F. & Hassett, K. A. 2007. *Climate Change: Caps vs. Taxes*. Available: www.aei.org/publication26286/)

[27] The Committee suggests that the policy should be budget-neutral but this does not preclude other climate change measures being funded from the Budget.

[28] Multi-Party Climate Change Committee, above note 7.

[29] Ibid.

[30] See for example: OECD. 2003a. Environmental Taxes and Competitiveness: An Overview of Issues, Policy Options, and Research Needs. Available: www.olis.oecd.org/olis/2001doc.nsf/LinkTo/com-env-epoc-daffe-cfa(2001)90-final (Accessed 04/09/2009).OECD. 2008. Environmentally Related Taxes and Tradable Permit Systems in Practice. Centre for Tax Policy and Administration. Available: http://www.oecd.org/department/0,3355,en_2649_34295_1_1_1_1_1,00.html (Accessed 29/08/2009).

preliminary examination of the impact of the ACPRS on Australia's ASX100[31] companies indicated that for approximately 75 per cent of companies the impact would be less than 2 per cent of value, and in most cases, below 1 per cent of value if a carbon price is $20 tonne.[32]

Despite providing generous compensation for businesses, the carbon price mechanism and future ETS differ in some characteristics influencing the competitiveness of businesses. An ETS will be endowed with an international linkage mechanism[33] which provides an extra opportunity for businesses to meet their liability under the scheme.

The proposed legislation renders extensive assistance packages to affected industries, thus considerably reducing competitiveness concerns. Additionally, a generous international linkage mechanism provides extra opportunities for businesses to meet their obligations.

Energy security

Energy security is an increasingly important element of Australia's security policy agenda.[34] Australia is one of the world's largest exporters of coal and uranium, and therefore at present, Australia's position in the global energy market appears to be confident.[35] However, to increase energy security, Australia should diversify its energy sources. Future technological development can help to reduce the emissions intensity of the economy and to meet the challenge of energy security in the long term.

Reportedly, Australia trails behind other OECD countries in energy efficiency advancement, while there are many opportunities to upgrade energy efficiency.[36] Policies to improve energy efficiency need to be developed to address specific market failures. A number of analysts recommend targeting technology development directly, specifically by introducing measures aimed at stimulating research.[37] The Australian government proposed a number of critical complementary policies to support climate change mitigation efforts, including: energy efficiency information, the low income energy efficiency program, a household energy and financial sustainability scheme, the Remote Indigenous Energy Program, the Tax Breaks for Green Buildings Program, and the Energy Affordability Scheme, amongst other programs.[38] Undeniably, these initiatives and funding are needed for successful development of green technologies and therefore should supplement the GHG reduction policy. Overall, these measures may have dissimilar effects during the fixed price period and future emissions trading but such effects are difficult to forecast. For the purpose of this analysis, it is assumed that the

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[31] The ASX 100 index is Australia's premier large capitalisation equity index. It is comprised of 100 stocks selected by the Standard & Poor's Australian Index Committee.

[32] In particular, this report suggests that for the mining industry, a reduction in value would be 0.5–1.5 per cent; for paper, steel, cement, mineral sands and aluminium industries the impact would be 0.57 per cent. (Climate Institute 2008. Submissions to the Carbon Pollution Reduction Scheme Green Paper. *The Climate Institute*. Canberra., p. 15.) However, some industries such as LNG and a number of chemical companies could benefit from stronger demand generated by GHG reduction policy. For example, AGL profits might increase by almost $150 million (at $20 a tonne of carbon), and by in excess of $200 million if a carbon price would be $40 a tonne. (Parkinson, G. 2008. *Time for a Renewable Vision*. Available: http://www.businessspectator.com.au/bs.nsf/Article/Time-to-stop-backing-fossils-HR6CS?OpenDocument).

[33] Generally, an international linkage mechanism offers companies covered by the ETS the opportunity of investing in emissions reduction projects in developing countries such as those in China, and bringing carbon credits back to use in the domestic ETS. Therefore, companies can use credits from the Kyoto Protocol mechanisms to fulfil their obligations under the ETS. Such international linkage undeniably provides an additional flexibility for the participants. For example, the EU ETS provides similar arrangement for the participants.

[34] National Energy Security Assessment December 2011. Commonwealth of Australia.

[35] Australia's Energy Production, Consumption and Exports. Available at: http://www.ga.gov.au/energy/basics.html

[36] IEA 2008. Worldwide Trends in Energy Use and Efficiency: Key Insights from IEA Indicator Analysis. International Energy Agency, Report to G8. Paris.

[37] Some analysts argue that it is necessary to address each market failure with separate policy instruments. See, for example; Daily, G. C. & Ellison, K. 2002. *The New Economy of Nature: The Quest to Make Conservation Profitable*, Washington DC, Island Press; Fischer, C. & Newell, R. G. 2007. Environmental and Technology Policies for Climate Mitigation. *Resources for the Future, Discussion Paper 04-05*. Washington DC.

[38] For details see: Multi-Party Climate Change Committee, above note 4.

supplementary measures proposed to be included in the carbon policy package are likely to increase Australian energy security.

Investment certainty

Investment confidence is critically important for the development and deployment of new, energy efficient and clean technologies in Australia and worldwide. In this context, the predictability or regulatory certainty of GHG reduction policy is a significant aspect influencing future investments. Considerable investment from the private sector is required to stimulate the progress and implementation of green technologies. Evidently, such investments depend on the predictability of GHG reduction policy.

Predictability and certainty of a climate change policy significantly depends on the certainty of a GHG reduction target. As discussed previously, the element of certainty in reduction targets is integrated into the considered carbon policy. However, it is worth noting that the government aims to establish the caps on emissions for the first five years of the ETS in 2014. [39] Investment decisions require full information on carbon caps well in advance but unfortunately, this is not the case under Australian carbon policy. The emissions price volatility associated with emissions trading would also significantly affect investment certainty.

Overall, the carbon price and the ETS might provide some investment certainty. Nevertheless, the uncertainty in price and emissions caps associated with the ETS decisively diminishes the credibility of this instrument. Thus, it is justifiable to suggest that the policy, particularly future ETS, proposed by the Australian government would not facilitate an adequate level of investment certainty.

Fairness

Generally, the literature indicates that distributional concerns are deemed to occur when a carbon tax or an ETS are introduced (Ekins P. & Dresner S., 2004). The negative distributional impact across households is a major issue for governments introducing climate change policies and the Australian government is no exception.

The impacts of carbon taxes and an ETS significantly depend on the revenue's utilisation. If the revenue is recycled in a proper way – in favour of low-income or disadvantaged groups – the adverse distributional effect can be neutralised substantially or completely, or even reversed, depending on the recycling scheme.[40] Another aspect of revenue recycling affecting households, especially in long term, is energy efficiency measures and research and development (R&D) funding. If part of the revenue is spent for these purposes, new green technologies and the energy efficiency measures available to households would facilitate a reduction in the distributional burden.[41]

It is compulsory to consider incorporating measures for compensating the unfavourable distributional effects when designing a new GHG reduction policy. As mentioned above, the Australian government is allocating part of the revenue from the carbon price scheme to increase the tax-free threshold and to expand welfare programs for low-income households.[42] Additionally, a significant part of carbon policy revenue is also dedicated to energy efficiency and R&D measures. Thus, it is reasonable to conclude that the proposed carbon policy is able to address this principle.

Flexibility

According to the Committee, a carbon price mechanism needs to be flexible to respond to changing international circumstances and new information on climate change. Indeed, the flexibility of the policy is especially vital in the context of climate change. In some areas of policy making, flexibility might not be a critical criterion for effective performance of policy. In the case of climate change – the consequences of which are decidedly

[39] If the parliament rejects the regulations presented in 2014, the mechanism will automatically allow for a pre-prescribed pollution cap to come into effect for the first flexible price year only.

[40] Ibid.

[41] Ibid.

[42] For example, according to the government, the average household will see cost increases of around $9.90 per week, while the average assistance provided will be around $10.10 per week.

uncertain and very difficult to predict – the degree of flexibility of the policy required to reflect new information must be reasonably high. Flexibility allows governments to respond to future uncertainties (Anda, J., Golub, A. & Strukova, E. 2009).

The actual legislative adjustment of a regime would depend on many factors, such as the design of a regime, bureaucracy, and parliamentary acceptance, amongst many others. The regime considered in this paper is theoretically flexible. The ETS emissions caps can be reassessed in the same way as the carbon price may be updated on a regular basis with regard to the latest scientific information. However, legislative adjustment of the regime – especially the enhancement of the reduction target – is unlikely to be easy.

Administrative simplicity

The Committee suggests that a carbon price mechanism should be designed to minimise compliance costs and implementation risks. Compliance costs are often analysed in conjunction with administrative costs that are borne by the government.[43] Generally, analysts are inclined to agree that carbon taxes are likely to be organisationally simpler than an ETS. There is also some literature investigating the compliance costs of an ETS. Pope and Owen estimated that the operating costs of the ACPRS will be around AU$200 million annually.[44] They also note that there will be additional start-up costs roughly estimated at about one year of operating costs (AU$200 million). Pope and Owen suggest that, since the ACPRS will cover about 1,000 emitters, aggregate compliance costs for the participants are likely to be moderate.[45] Indeed, compliance costs associated with the ACPRS may not seem to be drastic, but if we were to compare it with compliance costs under a carbon tax, the conclusion might be different.[46] Overall, compliance costs for businesses under an ETS may be comparably high.

Resembling the logic of compliance costs, the simplicity of the policy is significant for the minimisation of administrative costs. Pope and Owen, analysing the potential operating costs, suggested that the government should establish a new independent body to manage ACPRS. However, their estimation appears to be too optimistic.[47] The government has established a range of bodies to manage various climate policy related issues.[48] In this light, it seems that the administrative and compliance costs of the carbon pricing regime might be relatively high. Overall, this implies a number of new arrangements and complex rules which increase the administrative complexity of the policy.

Clear accountabilities

The Committee suggested that a carbon price mechanism should have transparent rules and clear accountabilities to promote business and community confidence. The transparency and accountability principle is often undermined by policy makers. The transparency of a policy is vital to support environmentally effective objectives, lower the overall costs of GHG reduction and to build a reliable foundation for decision-making. Transparency plays a key role in many aspects of climate change policy[49] and is often cited as the primary argument for a

[43] Some researchers have a tendency to unite administrative and compliance costs under the term ‘operating costs’ see for example: Pope, J. & Owen, A. D. 2009. Carbon Emission Taxes: Potential Revenue Effects, Compliance Costs and Overall Tax Policy Issues. *Australasian Tax Teachers Association Conference.* Christchurch.

[44] Ibid. Pope and Owen 2009, p. 16.

[45] Ibid.

[46] Tax is not as novel an instrument as an ETS and it does not require any new arrangements from the participants. Carbon tax involves little costs, over all stages of their life span, because a tax could be paid through the current tax infrastructure.

[47] For example, Humphreys, discussing the compliance costs associated with a potential Australian ETS, argues: “Many of these costs of trading are already apparent in other trading systems, such as the EU carbon trading system and the Australian taxi-licensing system. Taxi licences have been slow to adjust to changing conditions (resulting in a poor and prohibitively expensive service), have created a wasteful artificial market in licences that benefits licence traders but not the government or the economy, involves administrative and compliance costs, and has been notoriously difficult to reform.” (Humphreys, J. 2007. Exploring a Carbon Tax for Australia. *Centre for Independent Studies, Perspectives on Tax Reform 14.* St Leonards., p.4.)

[48] Clean Energy Agreement. Available at: http://www.climatechange.gov.au/government/initiatives/mpccc/resources/clean-energy-agreement.aspx

[49] For example, the EU ETS directive provides that the NAP must go through a mandatory public participation process to maximise transparency of the policy. GHG

carbon tax.[50] An ETS by definition is less transparent and a more multifaceted policy than a carbon tax. As noted above, an ETS requires complex and broad legislation that is not simple to comprehend for the public and businesses. Professor Mann vividly summarises this problem (Mann R., 2008):

> *The complexity of a cap-and-trade system makes it difficult for taxpayers and consumers to determine who will be paying the costs, and how much those costs will be. The complexity allows affected industries to jockey for advantage and exemptions without the general public understanding what is going on. From an end-user cost perspective, a carbon cap-and-trade system is opaque, not transparent. This may be viewed as a political advantage – if consumers don't understand that some industries are getting off without paying their fair share, it is unlikely that consumers will raise objections. Political compromises can then be made among the industries without fear of public uproar.*

The carbon price mechanism is able to provide a certain level of transparency and accountability, a future ETS would involve some uncertainty and complications – hence the overall ability of Australian carbon policy to address this principle is rather limited.

Supports Australia's international objectives and obligations

To support Australia's international objectives and obligations, a carbon pricing mechanism should have a capacity for international harmonisation. The Australian government tends to prioritise international harmonisation of climate change policies.[51]

Many analysts agree that an ETS is much easier to harmonise with other countries' carbon mitigation programs.[52] Indeed, an ETS generates a natural unit of exchange for harmonisation: permits denominated in units of GHG emissions. Since the costs associated with climate change (e.g. coastal flooding, crop loss, etc.) have no connection with the source of GHG emissions, the rationale for ETS global harmonisation is understandable. While the ETS is naturally equipped with such a unit, GHG reductions under the carbon tax are not easily transferable to a particular exchange unit. Furthermore, due to certainty in emissions targets, an ETS is more conducive to international environmental agreements, such as the Kyoto Protocol. Generally, emissions reduction targets can be settled more easily than, for example, tax rates.[53] Certain quantitative GHG reduction targets associated with the ETS can potentially be more naturally harmonised than such a sensitive issue as tax rates.

The present practical trend is that more and more governments are introducing and proposing emissions trading which adds further to its possible harmonisation.[54] Since major economies tend to propose and implement an ETS rather than carbon tax to reduce GHG emissions, many other countries are likely to follow suit.[55] Thus, the influence

reduction policy legislation and procedures must be maximally transparent, otherwise the stakeholder participation procedure will become obsolete and thus the public acceptability of the policy will be uncertain. (Matthes, F., Graichen, V. & Repenning, J. 2005. *The Environmental Effectiveness and Economic Efficiency of the European Union Emissions Trading Scheme: Structural Aspects of Allocation*. Available at: http://www.wwf.de/imperia/md/content/klima/2005_11_08_full_final__koinstitut.pdf).

[50] Broad literature suggests that a carbon tax is transparent and easy to understand for the public. See: Shapiro, R. 2007. Addressing the Risks of Climate Change: The Environmental Effectiveness and Economic Efficiency of Emissions Caps and Tradable Permits, Compared to Carbon Taxes. Available: http://www.sonecon.com/docs/studies/climate_021407.pdf; Freebairn, J. 2008. Taxes or Tradable Permits to Reduce Greenhouse Gas Emissions. *Musgrave Symposium, June 2008*. Sydney.

[51] See for example: Multi-Party Climate Change Committee, above note 7.

[52] See: Green et al., above note 28; Garnaut 2008, above note 33.

[53] Shapiro (2007, above note 55) suggests that despite a carbon tax having environmental and economic advantages over an ETS, an international harmonisation of carbon taxes would be rather difficult. See also, Garnaut 2008 above note 33.

[54] See: Status of Global Mitigation Action. Available at: http://www.climatechange.gov.au/en/government/initiatives/multi-party-committee/resources.aspx

[55] Garnaut (2008, above note 33, p. 311) states in this context: 'Australian mitigation policy needs to be considered in the international context of action and commitments. The world is now some way down the track towards an international system based on emissions reduction targets, starting with developed countries. Regulatory approaches, carbon taxes, hybrid schemes and baseline and credit schemes would not be

of international trends in climate change policy is another factor in favour of the ETS. Overall, a large amount of theoretical literature as well as the above discussion gives priority to the ETS in respect of international harmonisation. Therefore, the considered carbon policy, especially future ETS, implies a strong case to support efficiently Australia's international objectives and obligations.

4. Overall assessment

On the whole, the examination of the carbon pricing mechanism capability implies the following results:

Overall, the above analysis demonstrates that the carbon pricing mechanism may not address well a number of the critical principles outlined by the Multi-Party Climate Change Committee, particularly; environmental effectiveness, economic efficiency, investment certainty, administrative simplicity and clear accountabilities. The criteria that the carbon pricing sustains well are competitiveness of Australian industries, fairness and Australia's international objectives and obligations, which seems to be prioritised by politicians.

Table 1: Assessment of the Carbon pricing mechanism.

Principles (criteria)	Comments	Provisional Assessment
Environmental effectiveness	Under present settings it is unlikely that the proposed carbon policy would address this criterion.	Flawed
Economic efficiency	The design defects of the considered policy may significantly reduce its economic efficiency.	Flawed
Budget neutrality	In its present status, the introduced policy is unlikely to be budget neutral.	Flawed
Competitiveness of Australian industries	The carbon policy renders an extensive assistance package to affected industries and, in three years, will provide generous international linkage, thus considerably reducing competitiveness concerns.	Supported
Energy security	Supplementary measures included in the carbon policy package are likely to increase Australian energy security.	Supported
Investment certainty	The price uncertainty associated with the ETS as well as general legislative volatility significantly reduces investment certainty of the carbon policy.	Flawed
Fairness	Since a significant part of carbon policy revenue is dedicated to low-income households and energy efficiency as well as R&D measures, this principle is addressed.	Supported
Flexibility	The proposed policy provides certain degree of flexibility but the legislative adjustment of the policy may prove to be difficult.	Flawed
Administrative simplicity	The policy package has a number of measures which imply complicated rules and require the creation of new institutions thus eroding the administrative simplicity principle.	Flawed
Clear accountabilities	The considered policy is implicitly complex and non-transparent; hence it is unlikely to address this principle.	Flawed
Supports Australia's international objectives and obligations	The policy design is well suited to reflect this criterion.	Supported

readily integrated with existing and emerging international arrangements that could provide Australia with lower-cost mitigation opportunities.'

As a result, the introduced carbon policy contradicts some of the critical principles which were meant to be addressed in the first place. However, the policy may have been improved by increasing the GHG reduction target, expanding the coverage of the policy and reconsidering the international linkage mechanism.

5. Direct Action Plan

In September 2013, the Coalition won the federal elections leaded by Tony Abbot who's attitude to climate change was quite different from previous two prime ministers. The Gillard's Government carbon pricing legislation including carbon pricing has been repealed by the Abbott Government in July 2014. Instead of the carbon pricing mechanism the Abbott Government has introduced Direct Action Plan.[56]

The Direct Action Plan includes as a centerpiece the Emissions Reduction Fund (ERF) which is supposed to provide incentives for GHG reduction activities across the entire Australian economy. Under the ERF the Government will pay for projects that will reduce CO2 emissions at minimal cost. Funding from the ERF is allocated through auctions. A range of possible projects for CO2 reduction include: energy efficiency, cleaning up power stations, reafforestation and revegetation and/or improvement of soil carbon.[57]

There has been very little detailed public or economic analysis of the Emissions Reduction Fund and its proposed design.[58] However, there are numerous in-built design problems with the Emissions Reduction Fund. According to various comments the major design issues which will impact on the ERF's ability to reduce Australia's greenhouse gas emissions, include:

- additionality;
- difficulties in setting baselines;
- compliance mechanisms and penalties;
- overall limits on emissions;
- the need for longer timeframes, including funding and planning beyond 2020;
- future scalability of the ERF; and
- access to international permits.[59]

Manifestly, a policy to reduce Australia's GHG emissions requires a limit or 'cap' on overall emissions, and mechanisms preventing polluters from exceeding emissions limits.[60] However, at present there are no emissions caps or instruments that would insure that the polluters are limiting their GHG emissions. The Government issued a consultation paper on Safeguard Mechanism that will apply to facilities with direct emissions in excess of 100,000 tonnes of CO2-e per year.[61] According to the consultation Paper, the Safeguard Mechanism would cover around 140 businesses (emissions-intensive generators) which emit around 57 percent GHG from the electricity sector.[62] The Safeguard Mechanism obliges polluters to avoid the net emissions from their facility from exceeding the baseline emissions levels throughout a monitoring period (a financial year). Nevertheless, the Government indicated that the safeguard mechanism, which is absolutely critical to the scheme, will not be in place until July 2016 at the earliest.[63]

In 2015 there were contracts signed for 144 projects that supposed to reduce around 47 million tonnes of Australia's emissions.[64] These projects' cost is $660 million out of $2.55 billion allocated to the emissions reduction fund in the first 4 years. On average, the contracts signed by the government last for seven years that means a reduction of just 6-7 million tonnes of GHG a year. However,

[56] The Direct Action Plan. Available at: https://www.environment.gov.au/clean-air
[57] The Emissions Reduction Fund, available at: http://www.environment.gov.au/climate-change/emissions-reduction-fund/about
[58] The Australia Senate, Environment and Communications References Committee. 2014 'Direct Action: Paying polluters to halt global warming?
[59] Ibid.
[60] Ibid.
[61] The Emissions Reduction Fund: Safeguard mechanism - Consultation paper, available at: http://www.environment.gov.au/climate-change/emissions-reduction-fund/about/safeguard-mechanism
[62] Ibid.
[63] Ibid.
[64] The Emissions Reduction Fund http://www.cleanenergyregulator.gov.au/ERF/Pages/default.aspx

according to various estimates Australia will need to reduce more than 40 million tonnes of GHG each year to achieve the national target of a 5 per cent GHG reduction below 2000 levels by 2020.[65] In other words, the GHG reduction announced for the next decade needs to be delivered annually just to meet Australia's minimum target.

On the one hand, it is not easy to assess the Direct Action Plan since it has been introduced only recently. On the other hand, considering the voluntary nature of the Direct Action Plan it is likely that this policy would not be capable to address the majority of the principles set by the Committee.

Considering environmental effectiveness of the Direct Action Plan, numerous commentators argue that a voluntary carbon reduction policy does not provide incentive for businesses to participate and compete for participation in ERF.[66] The Australia Senate inquiry on the Direct Action Plan provides the following comment: ‘The committee is persuaded that the Government's Direct Action Plan and the proposed Emissions Reduction Fund are fundamentally flawed. They ignore the well-established principle of 'polluter pays', and instead propose that the Australian taxpayer should effectively subsidise big polluters.’[67] Therefore, the Direct Action Plan is unlikely to be environmentally effective instrument due to its voluntary nature.

The Abbott Government states that the Direct Action Plan is introduced to ‘efficiently and effectively source low cost emissions reductions that will contribute towards our 2020 target.’[68] This argument might be valid to certain extend considering that some low cost emissions reductions projects can be generated. However, the Direct Action Plan does not provide any price signal and it would cover only those companies which would choose to participate. Consequently, the policy fails to address economic efficiency principle.

Further, the Direct Action Plan is not budget neutral as discussed above. However, considering its voluntary nature there is no competitiveness issue for Australia industries. As for the energy security, there are no supplementary measures addressing Australian energy security in the Direct Action Plan. There was also significant criticism of the policy from industries. In particular, submissions from a broad spectrum of industry and expert questioned how sustainable the Direct Action Plan would be specifically in terms of achieving GHG reduction target.[69] In fact, the plan brings further investment uncertainty due to the unclear future prospects of the policy development in order to meet GHG reduction target. The current policy is not budget neutral which means that the Australian taxpayers are paying to polluters to cut GHG emissions and thus the policy is unfair to the taxpayers. It is not easy to assess how flexible this policy is but similarly to the carbon pricing legislative adjustment of the Direct Action Plan is unlikely to be easy considering Australian political environment.

Administrative simplicity and clear accountabilities of the Direct Action Plan can be questioned on the basis similar to the carbon pricing. In particular, a number of new arrangements and complex rules increase the administrative complexity of the policy but its voluntary nature and a limited number of participants may reduce administrative cost. It is also reasonable to suggest that the policy may facilitate a certain level of transparency and accountability taking in to consideration less complex rules related to Emissions Reduction Fund and relative transparency of auctions. Finally, it is quite obvious that the Direct Action Plan is not capable to support Australia’s international objectives and obligations.

Thus, the Abbott Government’s policy-making practice raises even more questions than its predecessors and as one may note the climate change regime in Australia is deteriorating rather than developing.

[65] Ibid.

[66] See for example, Australian Government Department of Environment, Emissions Reduction Fund, public submission of Professor David Karoly, Professor Ross Garnaut, WWF-Australia and others, available at: http://www.environment.gov.au/climate-change/emissions-reduction-fund/green-paper

[67] The Australian Senate, above note 64.

[68] The Emissions Reduction Fund, above note 63.

[69] The Age, Direct action's fitness for tougher emissions cuts questioned, April 27, 2015 http://www.theage.com.au/environment/direct-actions-fitness-for-tougher-emissions-cuts-questioned-20150427-1mufvt.html#ixzz3qfp8a9En

According to some commentators Tony Abbott 'reinstates industry influence over policy.'[70] Besides, the Australian Government neither disclosed what criteria has been used to develop the Direct Action Plan, if any, nor did it explained what criteria or principles were prioritised to establish the proposed legislation. Overall, the Direct Action Plan has been significantly criticised and it is labeled as a step backwards for Australian climate change policy.

6. Conclusion

This article has assessed the recently repealed Australian carbon pricing mechanism and current Direct Action Plan on the basis of the principles outlined by the Multi-Party Climate Change Committee. The policy was examined with particular reference to the relevant contemporary literature, existing practices and empirical studies. Generally, the carbon pricing mechanism with some limitations was capable of providing a carbon price signal. On the other hand, it is an obscure and complicated policy that is characteristic for an ETS.

Table 2: Assessment of the Direct Action Plan.

Principles (criteria)	**Comments**	**Provisional Assessment**
Environmental effectiveness	It is unlikely that the introduced policy would address this criterion.	Fundamentally flawed
Economic efficiency	The policy does not address this criterion.	Fundamentally flawed
Budget neutrality	The introduced policy is not budget neutral.	Fundamentally flawed
Competitiveness of Australian industries	The participation in Direct Action Plan is voluntary and polluters are paid to reduce emissions thus there are no competitiveness issues.	Supported
Energy security	The policy does not address Australian energy security.	Fundamentally flawed
Investment certainty	The repeal of the carbon pricing scheme and introduction of voluntary policy creates significant uncertainty for renewable energy investors.	Flawed
Fairness	Australian taxpayers are paying to polluting industries to reduce emissions under the policy therefore, this criterion is not addressed.	Fundamentally flawed
Flexibility	The proposed policy provides certain degree of flexibility but the legislative adjustment of the policy may prove to be difficult.	Flawed
Administrative simplicity	The policy is voluntary and does not require businesses to participate. Therefore, the administrative simplicity principle is supported.	Supported
Clear accountabilities	The considered policy and non-transparent; hence it is unlikely to address this principle.	Flawed
Supports Australia's international objectives and obligations	The policy design is not suited to reflect this criterion.	Fundamentally flawed

[70] Priest, M. Coalition Eyes $20bn Carbon Cuts, Australian Financial Review, 9-10 March 2013.

The policy nonetheless has some advantages – specifically, support for international action, which is being constantly delayed.

Heavily compromised Direct Action Plan is fundamentally flawed and cannot be considered as a real carbon policy aimed at GHG reduction and providing a price signal. The Direct Action Plan rather represents a policy that is introduced to protect industries from carbon price signal and to pretend that Australia have carbon reduction regime.

The conclusion of this analysis is that the previous carbon pricing regime was 'a curate's egg' or the policy which had a potential to address climate change and achieve Australia's GHG reduction target. However, the Direct Action Plan regime is a step backwards for Australia. Hence, Australian climate change policy must be substantially revised to implement polluters pay principle and intimately address the critical principles distinguished by the Multi-Party Climate Change Committee that would allow Australia to develop an effective and sustained carbon policy solution.

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Investigating Urban Sustainable Energy Policies in Europe: Experiences from the Covenant of Mayors

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Abstract

Local governments play a crucial role in reducing Greenhouse Gas (GHG) emissions. In order to endorse and support the efforts of local authorities, in 2008 the European Commission launched the Covenant of Mayors. Covenant signatories commit to reduce CO_2 by at least 20% in 2020, to prepare a Baseline Emission Inventory (BEI) and to submit a Sustainable Energy Action Plan (SEAP).

This paper analyses data from the BEIs and SEAPs of a sample of 124 cities. The aim is to assess the coherence between BEIs and SEAPs in the city sample. The paper is structured as follows: i) analysis of the emissions and emissions reductions commitments distribution for emissive sectorial sources; ii) cities sub-divisions into classes of analysis based on different variables; iii) analysis of the sectorial distribution of emissions and of emission reductions commitments related to the classes of analysis; iv) assessment of the most relevant categories of actions to reduce emissions and policy instruments in the achievement of reduction targets. Cities in the sample are committed to achieve an average reduction of 25% of emissions by 2020 with respect to baseline emissions. The distribution of intended emission reductions is coherent with the weight of emissions for different sectors. *Building* and *Transport* stand out as the most relevant sectors for emission reductions in SEAPs. Local electricity production is a very promising sector while the industrial sector (non-ETS) is expected to yield a minor contribution to the overall target, despite its relevance in the BEI. In order to study the variables that may influence the CO_2 emissions and emissions reductions commitments distribution, cities have been grouped into classes of analysis according to 6 variables. The variables that influence both emissions and emissions reduction are *population density* and *Gross Domestic Product* (*GDP)*. No other variable is significant for the emissions reduction, instead for inventory emissions both *Electricity Emission Factor* (*EEF)* and *geographical area* result to be significant. In general, the category of actions that have more potential for CO_2 reduction belong to the building and local electricity production sector (*integrated action on buildings, combined heat and power and wind power*). The policy levers with more CO_2 emission reduction potential are from building and transport sectors (*energy management and organization, management and organization, infrastructure and construction, transport / mobility planning regulation*).

The strength of results sometimes is constrained by the number of cities in the sample and the limited degree of details provided by some of them. Nonetheless, the uniform approach to emission accounting ensures the comparability of cities and the consistency of results with regard to available data.

1. Introduction

1.1 Role of cities in climate change mitigation

Cities are responsible for 67% (IEA, 2012) of the total global energy consumption and more than 70% of greenhouse gas emissions. Data from world cities suggest that climate, technology, density and wealth are important drivers of energy use and CO_2 emissions (Kennedy et al., 2009). However, the empirical relation between urbanization and GHG emission per capita is not conclusive (Lankao et al. 2008). Inventories show that levels of urban emissions per capita can differ considerably in the world, from 2 to 30 tCO_2eq (Dodman, 2009; Kennedy et al., 2009; Sovacool and Brown, 2009). Differences in emissions levels depend on specific local features: climate conditions, urban form, demographic features, economic activities in place, state of technology, mobility and housing infrastructures and prices, income and life style of city residents and users (UN-Habitat, 2011; Croci et al., 2011).

In the context of increasing energy import costs and risks, municipalities have the administrative power to decrease their energy dependence. They are increasingly recognised to have a high potential to drive sustainable energy and climate change mitigation thanks to their competences in several climate-related sectors. Thus, sub-national and local actors need to be involved by central governments to properly address energy and climate change issues (Bulkeley et al., 2013).

1.2 The Covenant of Mayors initiative

The Covenant of Mayors (CoM) was launched in 2008 by the European Commission to endorse and support the efforts of local authorities for GHG reduction and energy efficiency. By mid-May 2014 5.296 local authorities signed the CoM, for a total of ca. 160 million inhabitants in the EU-28, and ca. 186 million inhabitants in the whole initiative (JRC, 2015).

CoM signatories commit to a CO_2 reduction target (20% minimum) for year 2020, compute a Baseline Emission Inventory (BEI) and submit a Sustainable Energy Action Plan (SEAP). The BEI is a quantification of the amount of CO_2 emitted due to energy consumption in the territory of a Covenant signatory within a given period of time. It allows to identify the principal sources of CO_2 emissions and their respective reduction potentials (EU, 2010). The SEAP is the key document in which the Covenant signatory outlines how it intends to reach its CO_2 reduction target. It defines the activities and measures set up to achieve the targets, together with time frames and assigned responsibilities.

1.3 Objectives of the paper

This paper analyses data from the BEIs and SEAPs of a sample of 124 cities. The aim is to assess the coherence between BEIs and SEAPs in the city sample and to verify if there is any relation in the emission and emissions reductions distribution among sectors based on significant variables. The paper is structured as follows: i) analysis of the emissions and emission reductions commitments distribution for emissive sectorial sources; ii) cities sub-divisions into classes of analysis based on different variables; iii) analysis of the sectorial distribution of emissions and of emissions reductions commitments related to the classes of analysis; iv) assessment of the most relevant categories of actions to reduce emissions and policy instruments in the achievement of reduction targets.

2. Methodology

2.1 Definition of the sample

The analysis is based on data provided by a subset of cities participating in the EU Covenant of Mayors initiative. The cities included in the sample have been selected based on their size and on the SEAP acceptance status[71]. All European cities with more than 100.000 inhabitants and with an accepted SEAP by February 2014 are included in the study.

This yields a sample of 124 cities, with population ranging from about 108.000 to 7.67 million. Cities are spread across Europe:

[71] The acceptance of the SEAP assures that a quality check of the baseline emission inventory and the expected emission reduction, as performed by the Joint Research Centre of the European Commission, has been successfully passed.

42% are in Mediterranean Europe, 26% in Continental Europe, 14% in the UK and Ireland, 9% in Northern Europe and 9% in Eastern Europe. Moreover, most cities in the sample are also included in the "CoM Sample 2013", a selection of over 900 cities whose self-reported data has been further validated and harmonized by the European Commission, DG Joint Research Centre. This allowed to perform a direct correction of the inconsistences in the self-reported data of 69 cities. Other 49 cities were missing from the "CoM sample 2013" because their SEAP has been approved more recently, while only 6 cities were explicitly excluded from the "CoM sample 2013" because of inconsistencies detected in their self-reported data. Almost all of the inconsistencies have been corrected according to information reported in the approved SEAP document. This was not possible in a couple of cases only, which have been excluded from the analysis.

In order to describe emission and emission reduction sectorial distribution, cities have been grouped according to classes of 6 selected variables. These variables can affect both the distribution of emissions in the BEIs and the choice of policies to achieve the CO_2 emission reduction target (Peterson et al., 2009; UNPF, 2009).

The identified variables are Population size[72], Population density[73], Heating Degree Days (HDD)[74], GDP per capita[75] and Local Electricity Emission Factor (EEF)[76]. Furthermore, cities have been grouped according to their location: Geographical areas[77]. Table 1 summarizes the ranges of the different identified classes of variables.

In the "GDP" class of analysis, cities are mainly concentrated in the range from 20.000 to € 30.000 (55 cities). In the "population" and "HDD" classes, cities are equally distributed among the different ranges. In the last class of analysis, "geographical area", cities are concentrated in the Mediterranean area (53 cities), because the majority of cities that joined the CoM are from Italy and Spain.

2.2 Classification approach and analysis: sector, subsector, category of action and policy lever

The CoM set up the first harmonized framework for data compilation and city emissions reporting at the European level (European Commission, 2014). The reporting framework for baseline emissions and expected reductions is therefore common to all cities participating in the CoM. Both the BEI and the SEAP are organized according to a hierarchical approach of sectors and subsectors[78].

[72] Population size on the BEI year and on the signing year, as self-declared by cities, have been used to assess scale effects on baseline emission and expected emission reductions, respectively.

[73] Average population density has been computed as the ratio between population and city surface. Self-declared surface has been checked and corrected with data available on the official website of cities, when appropriate.

[74] Climatic conditions for the cities in the sample are proxied by HDD at NUTS 2 level, as provided by EUROSTAT. The closest available year to in the dataset has been associated to the relevant town according to the chosen BEI year.

[75] Average GDP per capita for the BEI year and for the year of adhesion to the CoM have been computed based on the Urban Audit data (EUROSTAT). This allowed to distinguish between the level of GDP for the relevant year of baseline emissions and GDP in the year of emission reduction estimation, respectively. GDP at current market prices by NUTS 3 region has been associated to cities for available years. When the BEI (or signing year) was not available in the Urban Audit dataset, the closest available year in the Urban Audit was considered multiplying it by the appropriate national GDP growth at market prices (for the period between the closest available year and the year of interest). GDP growth was extracted from the World Development Indicators.

[76] The local electricity emission factor is the self-declared amount of CO_2 emissions associated to a unit of electricity consumed in the city. This is a combination between national average emission factors for electricity consumed in the country and the emission factor associated to the share of electricity produced and consumed locally (see section 2.1.2).

[77] Cities from Hungary, Poland and Romania have been included the Eastern European group; cities from Greece, Italy, Portugal and Spain are included in the Mediterranean Europe; Denmark, Finland, Lithuania and Sweden have been included the Northern Europe; Belgium, France and Germany to Central Europe. The last group includes cities from the United Kingdom and Ireland.

[78] Cities can choose the sectors to tackle within their BEI and SEAP, subject to some constraints. Mayors are strongly recommended to compute emissions and design a strategy for emission reduction that includes both the transport and building sectors. They are key sectors for the CoM because they are relevant contributors to total emissions and the local administration has some regulatory control on them (exclusively or together with the regional/central administration, depending on the national legal framework). Signatories are generally required to include in the BEI at least three sectors

All BEI sectors and subsectors have a correspondent one in the SEAP, however additional sectors are included in the SEAP. This may hinder the association of emission reductions to baseline emissions.

A key difference between the methodology to compute emissions in the BEI and to estimate emission reduction in the SEAP is related to the local production of electricity and heat/cold. In the BEI, all emissions from electricity and heat/cold production are associated with the sectors of final consumption. Instead in the SEAP two new sectors were added to account the emissions reductions from local production of electricity and heat/cold, these sectors are: "*local electricity production*" and "*local heat/cold production*".

In order to ensure consistency and homogeneity in the analysis of baseline emission sources in the BEIs, expected emission reductions and planned actions in the SEAPs, a re-classification of sectors and subsectors has been performed, based on their description. The sectors and sub-sectors have been defined as shown in Table 2.

The "*Building*" sector is further divided into 4 subsectors: residential buildings and facilities; tertiary building and facilities; municipal buildings and facilities and mixed actions (additional subsector for holistic actions). The "*Transport*" sector includes: private and commercial transport; public transport; municipal fleet and mixed actions (additional subsector for holistic actions). Compared to the CoM classification methodology, we consider the public lighting subsector and the industrial subsector as independent sectors.

As in the SEAP, additional sectors for the classification of emission reductions are "*Local electricity production*"; "*Local heat/cold production*"; "*Land use planning*"; "*Working with citizens and stakeholders*". The reclassification of the sectors consists also in the addition of a sector: "*Waste and water*". We do not consider any subsector for the latter. Any other sector is classified as "*Other*".

The lowest level of disaggregation for BEIs is the subsector. Conversely, SEAPs provide specific information on planned actions for emission reduction. In order to identify the most important types of actions, they have been classified based on their official description. The classification of actions required two steps: (i) a re-allocation of actions from the SEAP specific sectors to the Building and Transport sectors, in order to associate emission reductions to the sector of final consumption, when possible; (ii) a classification of each action into a "category of action" (describing the area of intervention targeted by an action) and into a "policy lever" (describing the instrument used by the local authority to implement the action).

In total 117 categories of actions and 28 policy levers were defined. Categories of action are associated to a specific sector and subsector. Policy levers can be common to different sectors (e.g. awareness raising) or specific to a sector (e.g. building standards). For example, if the action is on "Thermal insulation of residential buildings", the category of action is the "Building envelope" and the policy instrument could be setting new "Building standards". Graph 1 synthesizes the analysis classification used in the paper and gives an example of classification for the building sector:

Residual sectors for non-disaggregated emissions and emission reductions were created. These sectors are: i) "*emissions not disaggregated into specific actions",* grouping emissions and expected reductions that have not been disaggregated between subsectors by municipalities (this causes a discrepancy between total declared emissions/ emission reductions and the sum of emissions by subsector/ expected reductions by action); ii) "*Not possible to assign",* reporting the level of emissions associated to actions with unclear

between (i) the residential buildings; (ii) the commercial building; (iii) the municipal buildings; (iv) the transport sector. In addition, mayors can report emissions (and emission reduction targets) for other sectors that fall under their jurisdiction (e.g. solid waste, wastewater treatment). In order to limit the administrative burden for the participation in the CoM, signatories can (and some did) limit the BEI reporting to total emissions and expected reductions by sector, without disaggregating them among subsectors. The SEAP should contain actions targeting at least three of the above-mentioned four CoM key sectors. Disaggregated reporting of emission reductions is compulsory up to the sector level only. Moreover, cities are allowed to report only the most significant actions.

descriptions and thus impossible to classify in a category. Based on the share of emissions by sector and subsector in the sample obtained using the described classification approach, an analysis of the emission and emission reduction patterns has been developed. In addition, the categories of actions and policy levers have been identified in terms of frequency and share of expected emission reductions in the total sample.

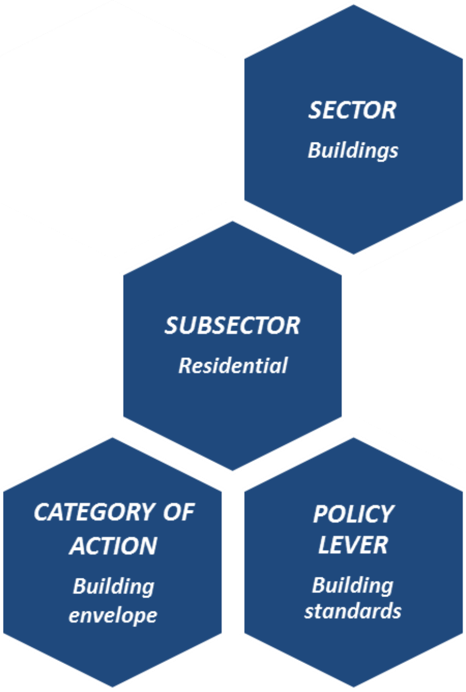
Table 1: Ranges of the different identified classes of variables.

Population size	Population density	HDD	GDP	EEF	GEO
< 150.000 inh.	< 1.000 inh./km^2	< 1.500	< 10.000 €/year	< 0,25	North Europe
from 150.001 to 250.000	from 1.001 to 2.500	from 1.501 to 2.500	from 10.001 to 20.000	from 0,25 to 0,5	East Europe
from 250.001 to 500.000	from 2.501 to 7.500	from 2.501 to 3.000	from 20.001 to 30.000	from 0,5 to 0,75	Mediterranean Europe
from 500.001 to 1.000.000	> 7.500	> 3.000	from 30.001 to 50.000	> 0,75	Continental Europe
> 1.000.000			> 50.000		Great Britain and the Islands

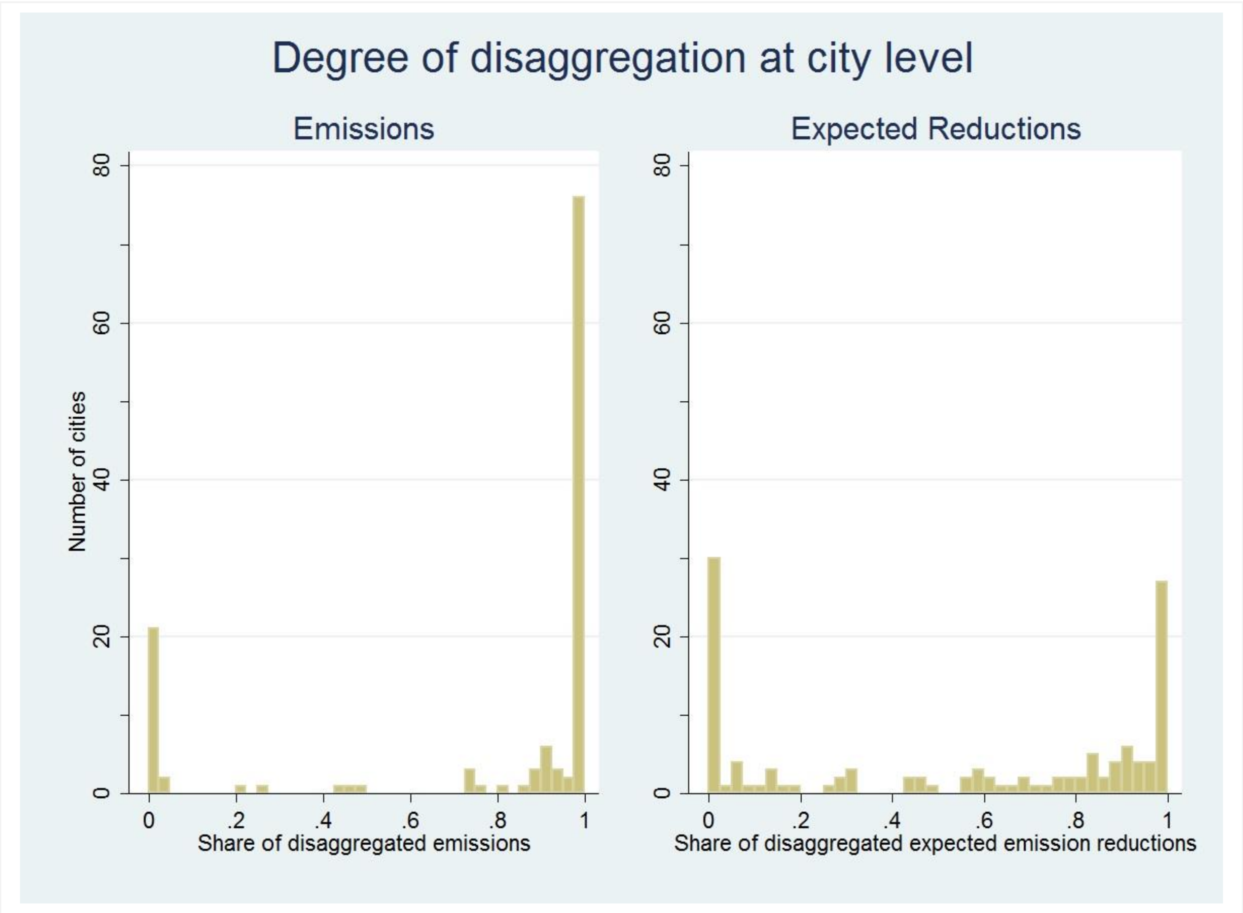
Table 2: Sectors and sub-sectors in SEAPs.

SECTOR and subsectors	BEI	SEAP
BUILDINGS	**x**	**x**
Residential	*x*	*x*
Tertiary	*x*	*x*
Municipal	*x*	*x*
Mixed action	**not present**	*x*
TRANSPORT	**x**	**x**
Private and commercial	*x*	*x*
Public	*x*	*x*
Municipal fleet	*x*	*x*
Mixed actions	**not present**	*x*
INDUSTRY	**x**	**x**
PUBLIC LIGHTING	**x**	**x**
LOCAL ELECTRICITY PRODUCTION	*****	**x**
LOCAL HEAT/COLD PRODUCTION	*****	**x**
LAND USE PLANNING	**not present**	**x**
WASTE AND WATER	**x**	**x**
WORKING WITH THE CITIZENS AND STAKEHOLDERS	**not present**	**x**
OTHER	**x**	**x**

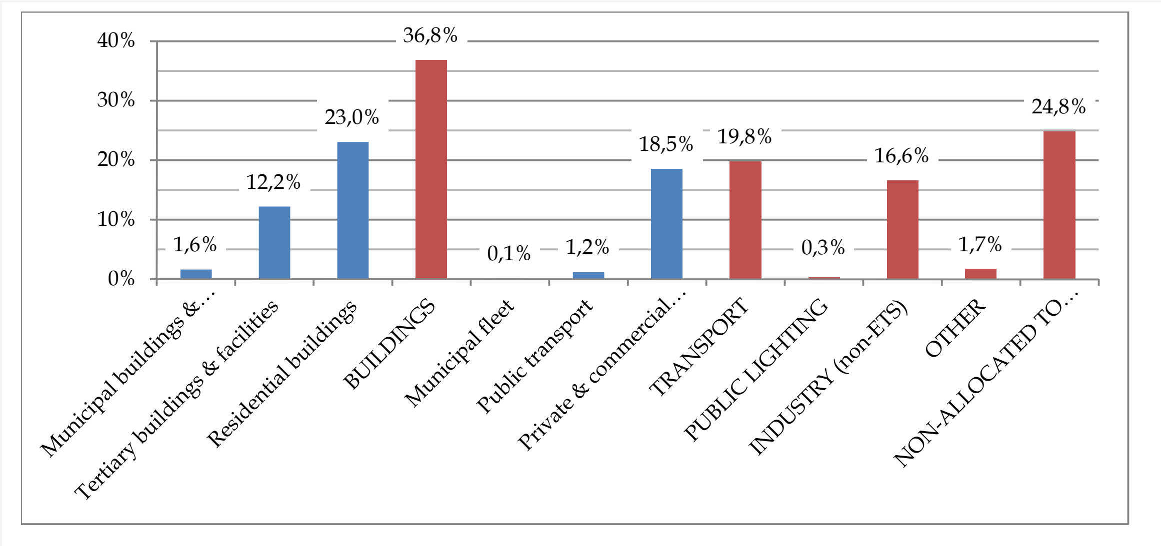
* Emissions from electricity and heat/cold production are allocated to the sector of final consumption in the BEI. The local authority can decide whether to compute a local emission factor based on the energy sources used to produce electricity and heat/cold within the city boundaries and following CoM guidelines (EU, 2010).



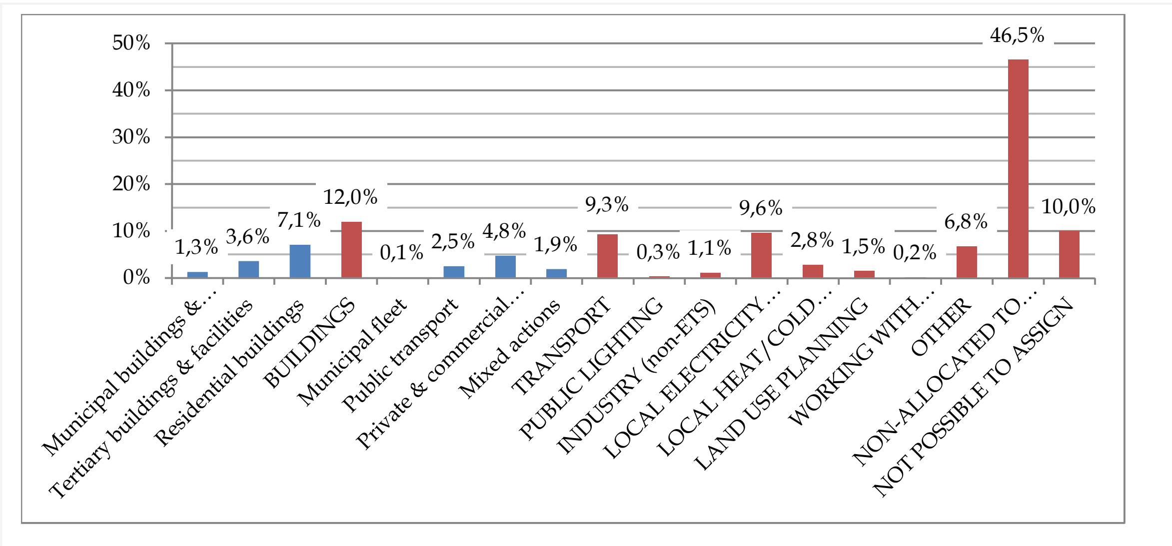
Graph 1: Classification for the building sector.



Graph 2: Distribution of cities by share of disaggregated emissions and expected emission reductions.



Graph 3: Distribution of total declared emissions by subsector and sector (with respect to total BEI).



Graph 4: Expected emission reduction by subsector and sector (with respect to total SEAP).

3. Results

3.1 Descriptive statistics of baseline emissions and planned emission reductions (BEI and SEAP)

3.1.1 Total emissions and planned emission reductions

Cities in the sample account for a total of 370 Mton of greenhouse gas emissions for selected baseline years and 94 Mton of planned reductions of yearly emissions, to be reached by 2020. This mainly corresponds to direct CO_2 emissions in sectors covered by the Covenant of Mayors[79].

Total emissions in the sample correspond to 10% of total CO_2 emissions from the European Union in 2013, in all sectors (Jos et al., 2014). The total level of emission reduction planned by cities corresponds to 25% of baseline emissions in the sample, beyond the minimum target of 20% required by the CoM.

[79] Indeed, most cities in the sample computed direct emissions based on IPCC emission factors, while only 12% followed a LCA approach. On the contrary, almost half of the cities (45%) included emissions of other greenhouse gases in the inventory, converted into CO_2 equivalents according to their global warming potential, but their importance in CoM sectors is minor.

	0-150k	150k-250k	250k-500k	500k-1M	1M-8M
Non disaggregated emissions	-37,4%	-12,4%	-32,6%	-26,7%	-22,6%
Other	0,3%	1,8%	0,6%	0,2%	4,3%
Private & commercial transport	27,0%	26,9%	21,4%	22,1%	26,2%
Public transport	1,1%	0,8%	1,3%	2,2%	1,7%
Municipal fleet	0,3%	0,1%	0,1%	0,4%	0,0%
Industry (non-ETS)	15,7%	21,8%	16,8%	21,2%	25,4%
Public lighting	0,7%	0,5%	0,5%	0,5%	0,1%
Residential buildings	34,9%	30,1%	33,8%	30,0%	29,4%
Tertiary buildings & facilities	18,2%	16,1%	22,6%	21,7%	10,6%
Municipal buildings & facilities	1,7%	1,7%	2,9%	1,7%	2,2%

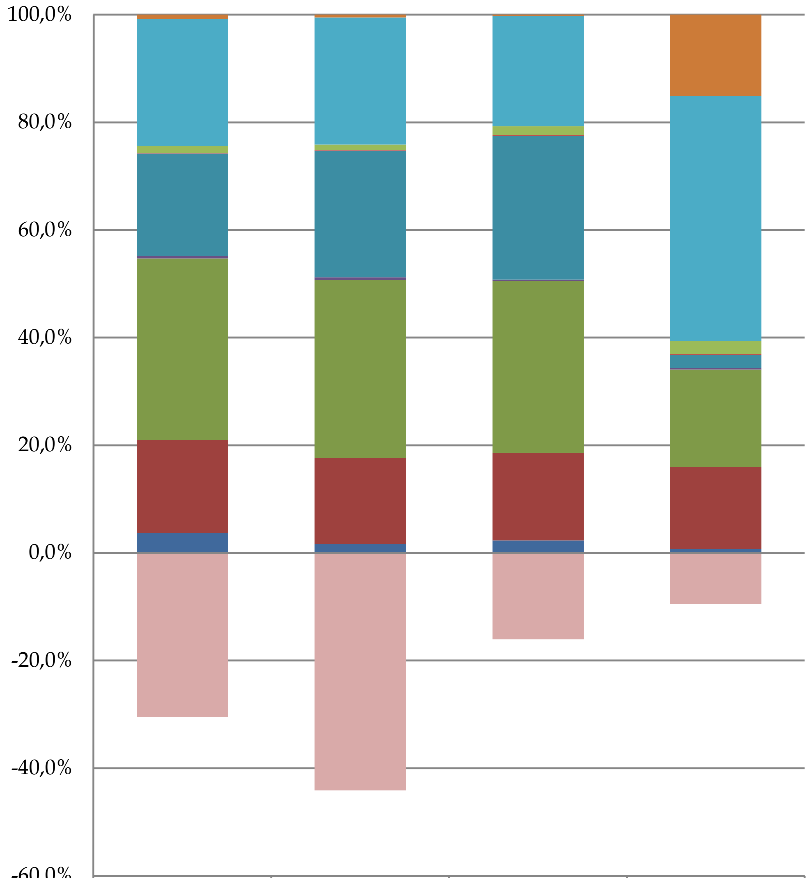
Graph 5: Distribution of emission between sectors (with respect to total emissions disaggregated by subsectors) by Population.

3.1.2 Breakdown of emissions end expected emission reduction

The analysis of self-reported data in BEIs and SEAPs confirms that cities face increasing difficulties in computing emissions and emission reductions at the increase of the degree of detail (disaggregation) to be provided (sector; subsector; energy source; SEAP actions; etc.). In order to encourage cities to join the CoM, only reporting at sector level is mandatory, thus the detail of analysis is sometimes limited by data availability.

More than 75% of total emissions reported in baseline inventories can be disaggregated between the main sectors of analysis (*Buildings; Transport; Public Lighting; Industry; Other*). The distribution of emissions between sectors and subsectors, as a percentage of total declared emissions for all the cities in the sample, is reported in Graph 3, with blue bars referring to emissions in the subsectors and red bars referring to aggregated emissions by sector (as a sum of blue bars on the left).

Non-disaggregated emissions derive mainly by a limited number of cities that do not perform any disaggregation between sectors (graph 2, left side). Very few cities provide a partial disaggregation.



	0-1000	1000-2500	2500-7500	7500-25000
Non disaggregated emissions	-30,5%	-44,1%	-16,0%	-9,5%
Other	0,8%	0,5%	0,3%	15,1%
Private & commercial transport	23,6%	23,6%	20,5%	45,6%
Public transport	1,3%	1,0%	1,7%	2,4%
Municipal fleet	0,1%	0,1%	0,2%	0,2%
Industry (non-ETS)	19,0%	23,5%	26,7%	2,5%
Public lighting	0,5%	0,5%	0,3%	0,3%
Residential buildings	33,7%	33,2%	31,9%	18,0%
Tertiary buildings & facilities	17,3%	15,9%	16,3%	15,3%
Municipal buildings & facilities	3,7%	1,7%	2,3%	0,8%

Graph 6: Distribution of emissions between sectors (with respect to total of emissions disaggregated by subsectors) by density.

Cities face even higher difficulties in estimating emission reductions from planned actions. In particular, emission reductions to be associated with soft measures, such as awareness raising campaigns, are difficult to forecast and thus no figure is generally provided. Moreover, some cities decided to focus on planning actions to be implemented in the short term, while remaining actions to reach the committed level of emission reduction, by 2020, are left to be designed subsequently. Indeed, Graph 2 (right) shows that cities most frequently perform either a complete disaggregation or no disaggregation. However, differently from the case of emissions, there is a relevant share of cities providing only a partial disaggregation of total expected emission reductions.

Overall, almost half (46,5%) of emission reductions are not assigned to sectors, subsectors and specific actions by municipalities.

Table 3: Comparison between the relative importance of sectors and subsectors in the BEI and SEAP (excluding non-disaggregated emissions) and corresponding expected reduction of baseline emissions.

SECTOR and subsectors	BEI	SEAP	% reduction of baseline emissions
BUILDINGS	49,0%	30,2%	8%
Residential	*30,6%*	*15,8%*	*8%*
Tertiary	*16,2%*	*8%*	*8%*
Municipal	*2,2%*	*2,8%*	*20%*
Mixed actions	-	*3,6%*	-
TRANSPORT	26,3%	20,6%	12%
Private and commercial	*24,6%*	*10,6%*	*7%*
Public	*1,6%*	*5,6%*	*54%*
Municipal fleet	*0,1%*	*0,3%*	*33%*
Mixed actions	-	*4,1%*	-
INDUSTRY	22,1%	2,5%	2%
PUBLIC LIGHTING	0,3%	0,7%	29%
LOCAL ELECTRICITY PRODUCTION	*	21,3%	-
LOCAL HEAT/COLD PRODUCTION	*	6,5%	-
LAND USE PLANNING	not present	3,4%	-
WASTE AND WATER	-	4,9%	-
WORKING WITH THE CITIZENS AND STAKEHOLDERS	not present	0,4%	-
OTHER	2,2%	15,5%	**
TOTAL	100%	100%	15% ***

* Emissions from electricity and heat/cold production are allocated to the sector of final consumption in the BEI. The local authority can decide whether to compute a local emission factor based on the energy sources used to produce electricity and heat/cold within the city boundaries and following CoM guidelines (EU, 2010).

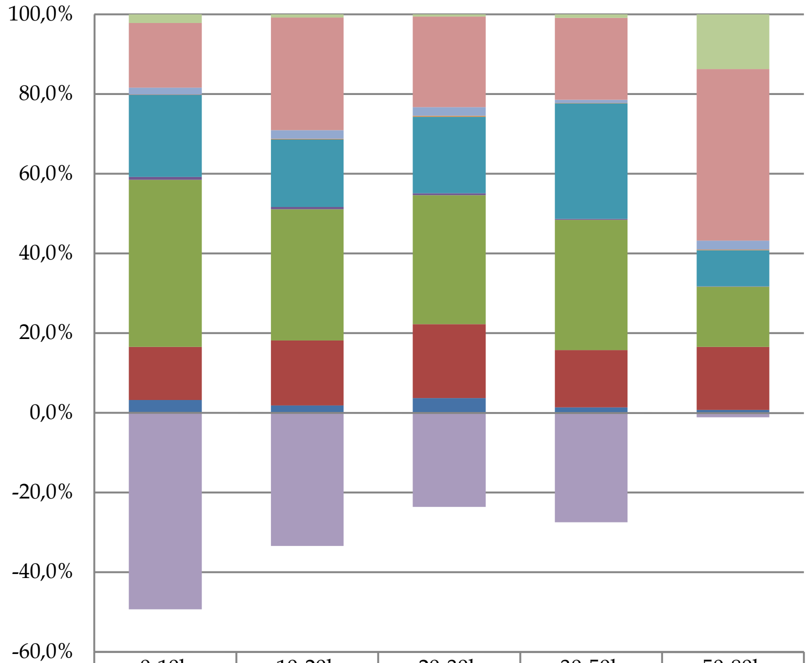
** The "Other" sector in the BEI and in the SEAP might not match: the percentage reduction of emissions is not relevant here.

*** The aggregated reduction of BEI, is 25%. This is the emission reductions target computed as the ratio between planned actions disaggregated by subsector and baseline emissions disaggregated by subsector.

Moreover, an additional 10% of emissions were associated to actions with unclear descriptions and thus they were impossible to classify. Graph 4 shows the breakdown of emission reductions between sectors and subsectors.

3.1.3 Baseline emissions and expected reductions by sector and subsector

In order to analyse and compare the relative importance of baseline emissions and expected emission reductions in the most relevant CoM sectors, we re-compute the share of emissions by sector and subsector with respect to the total of *disaggregated* emissions only. Table 3 summarizes the comparison between sectors and subsectors in the BEI and SEAP, excluding baseline emissions and expected emission reductions that were not possible to disaggregate. The last column of Table 3 reports the share of expected emission reductions by sector and subsector, considering disaggregated emissions only. Graph 8 and 9 show the relative weight of sectors (in terms of emissions and expected reductions respectively) across classes of selected variables.



	0-10k	10-20k	20-30k	30-50k	50-80k
Non disaggregated emissions	-49,4%	-33,5%	-23,7%	-27,5%	-1,1%
Other	2,1%	0,8%	0,5%	0,9%	13,7%
Private & commercial transport	16,2%	28,3%	22,8%	20,5%	43,1%
Public transport	1,8%	2,2%	2,1%	0,8%	2,2%
Municipal fleet	0,0%	0,1%	0,3%	0,1%	0,1%
Industry (non-ETS)	20,6%	16,9%	19,2%	29,0%	9,1%
Public lighting	0,7%	0,6%	0,5%	0,2%	0,1%
Residential buildings	42,0%	33,0%	32,4%	32,7%	15,0%
Tertiary buildings & facilities	13,3%	16,3%	18,6%	14,4%	15,9%
Municipal buildings & facilities	3,2%	1,9%	3,7%	1,3%	0,7%

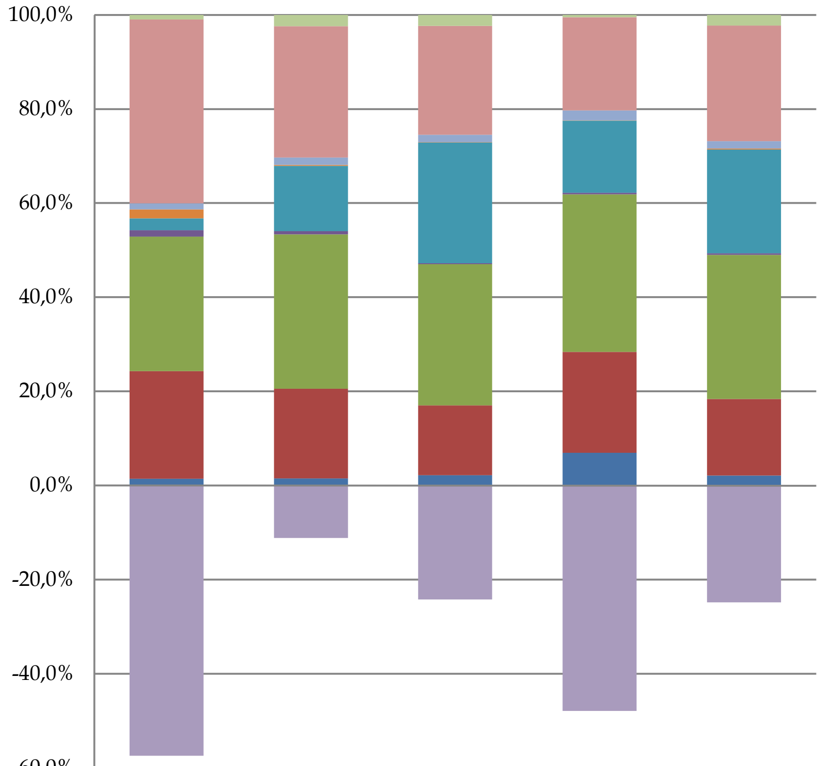
Graph 7: Distribution of emissions between sectors (with respect to total of emissions disaggregated by subsectors) by GDP.

The *Building* sector is the most relevant source of emissions. It accounts for 49% of total disaggregated emission in the sample, with residential emissions being the most relevant component (almost 2/3 of emissions from the building sector). The transport sector accounts for 26,3% of emissions, with private and commercial transport being essentially the only responsible of it (over 90% of emissions in the sector). Almost all the rest of emissions (22,1%) come from the Industrial (non-ETS) sector. Public lighting accounts for 0,3% of emissions only. Finally, the residual category "Other" (2,2% of total emissions) is optional for cities and may include additional areas of intervention that the city wants to tackle, such as waste and wastewater treatment.

The most emitting sector (buildings) is also the main focus of city action for emission reduction (27,6% of total expected CO_2 emission reductions).

The distribution of expected emission reductions broadly replicates the relative importance of subsectors in terms of baseline emissions: actions in the residential building sector are expected to yield 15,8% of reductions, while tertiary buildings should account for 8% and municipal buildings for 2,8%.

The *Transport* sector follows in importance the building sector, both for baseline emissions and planned emission reductions (20,6%).

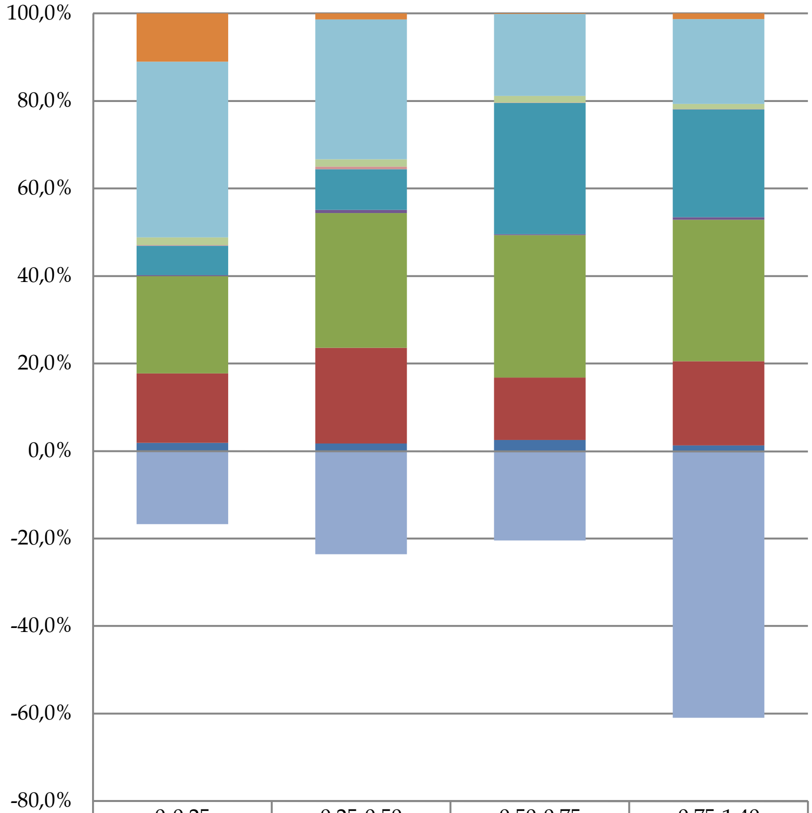


	0-1500	1500-2500	2500-3000	3000-7000	Total
Non disaggregated emissions	-57,4%	-11,1%	-24,2%	-47,9%	-24,8%
Other	1,0%	2,4%	2,3%	0,5%	2,2%
Private & commercial transport	39,0%	27,9%	23,2%	19,8%	24,6%
Public transport	1,3%	1,6%	1,6%	2,1%	1,6%
Municipal fleet	1,9%	0,2%	0,1%	0,1%	0,1%
Industry (non-ETS)	2,5%	13,9%	25,7%	15,3%	22,1%
Public lighting	1,4%	0,6%	0,2%	0,3%	0,3%
Residential buildings	28,6%	32,8%	30,0%	33,5%	30,7%
Tertiary buildings & facilities	22,8%	19,1%	14,9%	21,4%	16,2%
Municipal buildings & facilities	1,5%	1,5%	2,2%	7,0%	2,1%

Graph 8: Distribution of emissions between sectors (with respect to total of emissions disaggregated by subsectors) by HDD.

The ranking of subsectors within the transport sector is the same as for baseline emissions; however, their relative weight is different. Cities expect to be able to reduce emissions from public transport proportionally more than from private and commercial transports. Indeed, private and commercial transport accounts for 24,6% of baseline emissions, while it is expected to contribute to only 10,6% of reductions. Conversely, emissions from public transports represent 1,6% of transport emissions, but it is expected to contribute to 5,6% of CO_2 reductions. Additional areas of interventions are municipal fleet (1,6%) and mixed actions (20,1%).

Local electricity production is also a very promising sector, contributing to 21,3%. This cannot be compared to a BEI sector because baseline emissions are associated to the sector of final consumption. Expected emission reductions in this sector benefit all BEI sectors according to their share of electricity consumption, as it will decrease the level of emissions embedded in the electricity used within the city. Similarly, *Local heat/cold production*, *Land use planning* and *Working with citizens and stakeholders* are sectors that do not have a correspondence in the BEI.



	0-0.25	0.25-0.50	0.50-0.75	0.75-1.40
Non disaggregated emissions	-16,7%	-23,6%	-20,5%	-61,0%
Other	11,0%	1,4%	0,1%	1,3%
Private & commercial transport	40,2%	31,9%	18,7%	19,4%
Public transport	1,7%	1,7%	1,6%	1,2%
Municipal fleet	0,2%	0,6%	0,0%	0,1%
Industry (non-ETS)	6,8%	9,3%	30,0%	24,7%
Public lighting	0,2%	0,8%	0,2%	0,5%
Residential buildings	22,2%	30,8%	32,5%	32,3%
Tertiary buildings & facilities	15,9%	21,9%	14,3%	19,3%
Municipal buildings & facilities	1,9%	1,7%	2,5%	1,3%

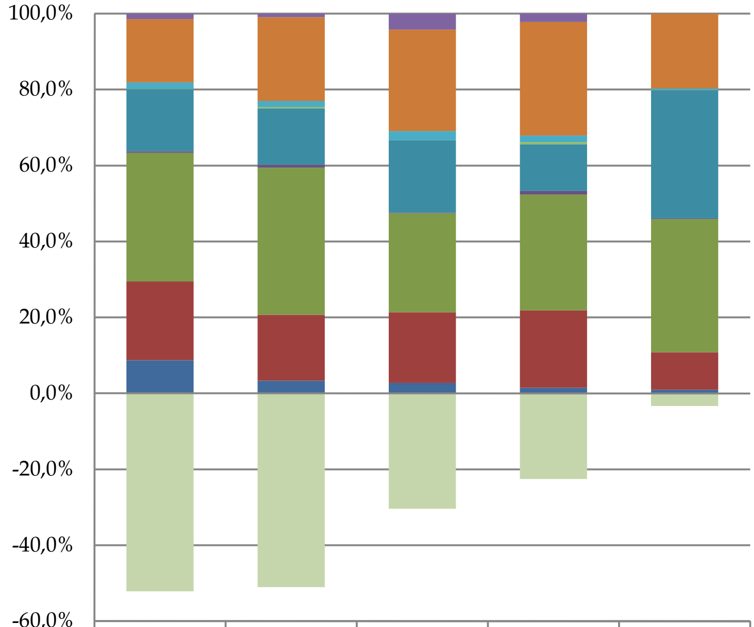
Graph 9: Distribution of emissions between sectors (with respect to total of emissions disaggregated by subsectors) by EEF.

The introduction of these sectors has generated a higher level of detail in the emissions reduction distribution, because the number of the sectors in the SEAPs is higher than the baseline. Thus this different level of disaggregation increased the differences in the allocation of emissions among sectors compared to baseline emissions. Nonetheless, these sectors are minor contributors to total expected reductions[80].

Finally, most cities decided to tackle the *Industrial* sector (optional in the CoM). Despite its relevance in the BEI (22,1% of disaggregated emissions are from local non-ETS industries), planned actions for emission reduction are expected to yield a minor contribution to the overall target (2,5% of expected emission reduction in the SEAP).

Overall, cities prove to be better able to plan actions, and compute related emission reductions, in the public sector (see table 3.1). Based on disaggregated data only, baseline emissions from public transports, municipal fleet, municipal buildings and public lighting show the strongest expected decreases (54%, 33% and 20%, respectively).

[80] 6,5%, 3,4% and 0,4%, respectively



	Nord	Est	Continental	Mediterranean	GB and IE
Non disaggregated emissions	-52,2%	-51,1%	-30,4%	-22,5%	-3,3%
Other	1,5%	0,9%	4,2%	2,2%	0,0%
Private & commercial transport	16,6%	22,1%	26,8%	29,9%	19,7%
Public transport	1,7%	1,6%	2,4%	1,8%	0,4%
Municipal fleet	0,1%	0,3%	0,0%	0,5%	0,1%
Industry (non-ETS)	16,4%	14,8%	19,0%	12,3%	33,8%
Public lighting	0,4%	0,8%	0,2%	0,9%	0,1%
Residential buildings	33,9%	38,8%	26,1%	30,5%	35,1%
Tertiary buildings & facilities	20,8%	17,4%	18,6%	20,4%	9,8%
Municipal buildings & facilities	8,7%	3,3%	2,7%	1,4%	0,9%

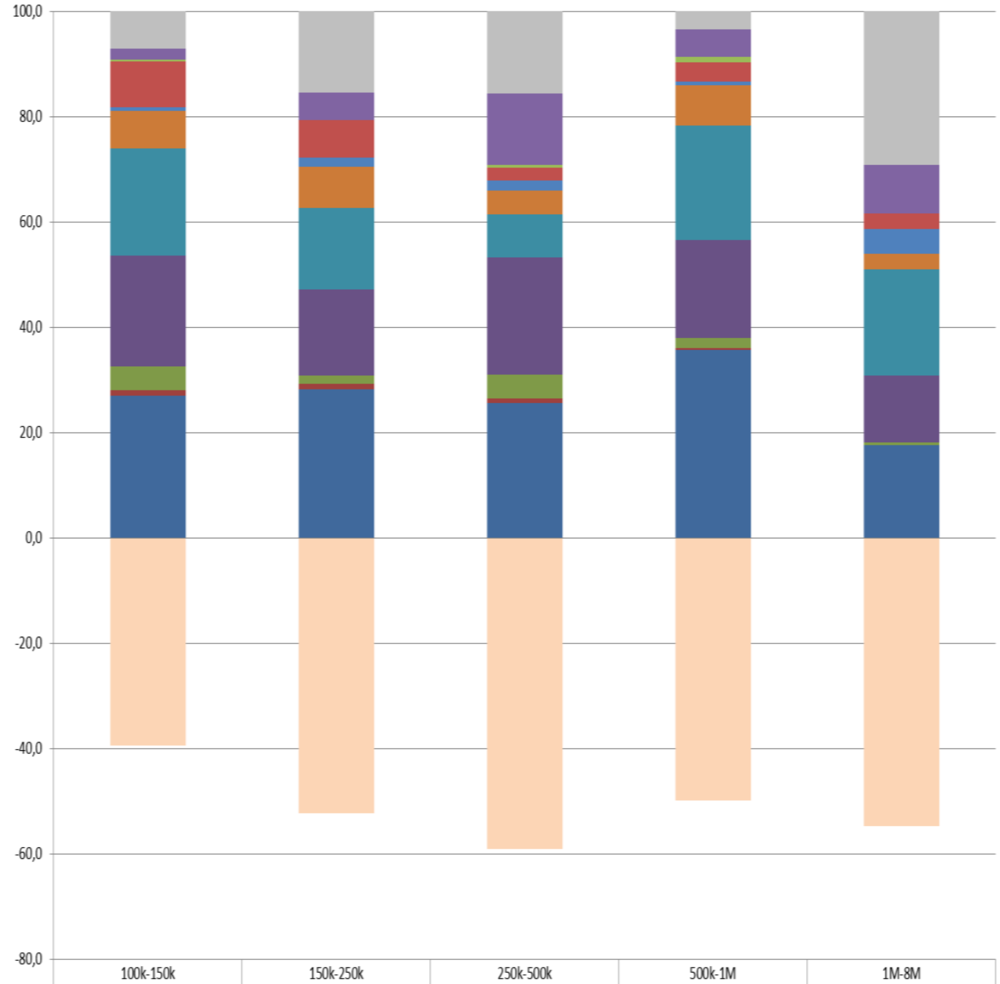
Graph 10: Distribution of emissions between sectors (with respect to total of emissions disaggregated by subsectors) by GEO.

Planned reductions in all other BEI subsectors correspond to less than 10% of their baseline emissions. In total, baseline emissions are expected to decrease by 15% only, based on planned actions and disaggregated data.

3.1.4 Comparison between the relative importance of sectors and subsectors across selected variables

As anticipated, in order to study the possible variables of influence of the CO_2 emission sources and of the choices of the SEAPs strategy, cities have been grouped into one-dimensional classes according to 6 variables. The quota of emissions that are not disaggregated between subsectors varies a lot between classes, possibly biasing the results. The population size of the city does not seem to have any impact on the overall distribution of emissions between sectors (Graph 5)[81]. Neither the distribution of emission reductions among sectors seems to be affected by the population variable (Graph 11). On the contrary, population density variation seems to influence the distribution of emissions and emissions reduction between sectors (Graph 6 and 12).

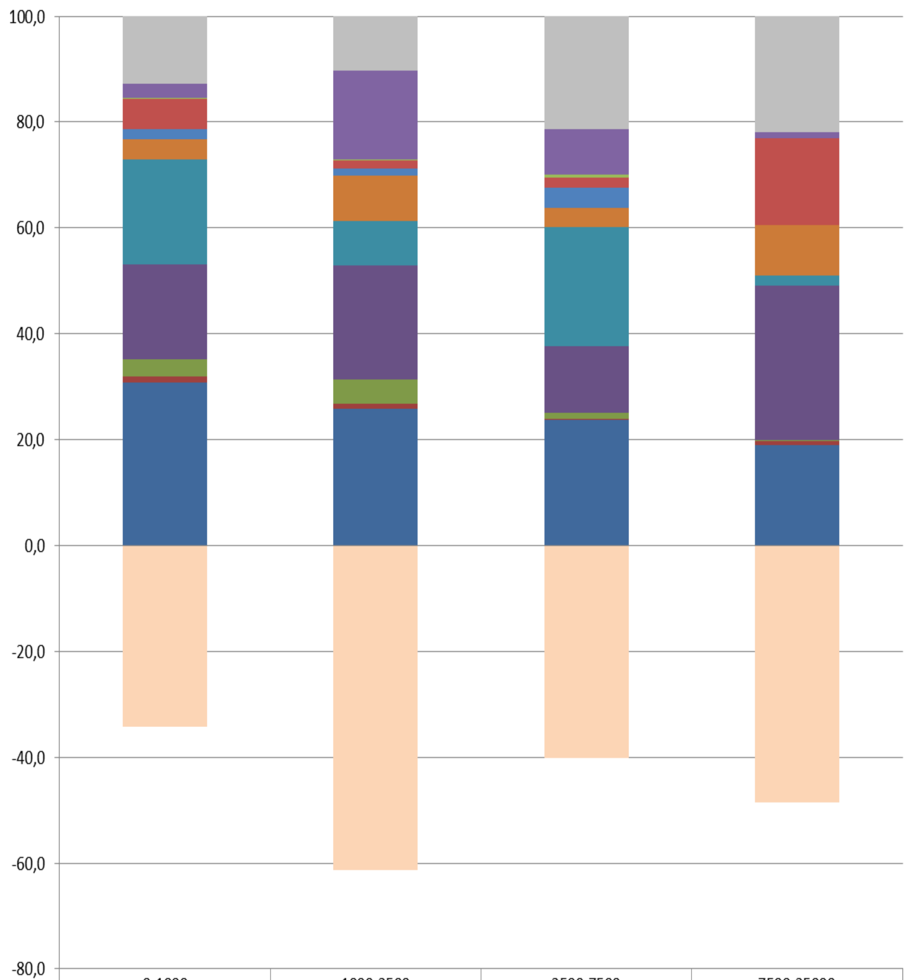
[81] Please note that all the graphics describe the percentage value of expected emissions reduction for different classes of selected variable and the percentage value of the non-disaggregated expected emissions reductions (negative column). It's important to underline that the share of non-disaggregated expected emission reductions for different classes of selected variables are calculated with respect to total expected reductions; instead the distribution of expected emission reductions between is calculated with respect to total expected emission reductions disaggregated by subsectors.



	100k-150k	150k-250k	250k-500k	500k-1M	1M-8M
not disaggregated emissions	-39,5	-52,3	-59,2	-49,9	-54,8
not possible to assign to a specific category	7,1	15,5	15,6	3,5	29,2
OTHER	2,1	5,1	13,6	5,3	9,2
WORKING WITH CITIZENS AND STKH	0,3	0,1	0,5	1,0	0,0
WASTE AND WATER	8,7	7,1	2,4	3,5	3,1
LAND USE	0,7	1,7	1,9	0,8	4,7
HEAT AND COLD PRODUCTION	7,2	7,8	4,6	7,7	2,9
LOCAL ELECTRICITY PRODUCTION	20,4	15,6	8,2	21,7	20,1
TRANSPORTS	21,0	16,2	22,3	18,5	12,8
INDUSTRY	4,4	1,7	4,5	1,9	0,4
PUBLIC LIGHTING	1,1	0,9	1,0	0,5	0,1
BUILDINGS	26,9	28,2	25,5	35,6	17,6

Graph 11: Distribution of emissions emission reduction between sectors (with respect to total of emissions disaggregated by subsectors) by population.

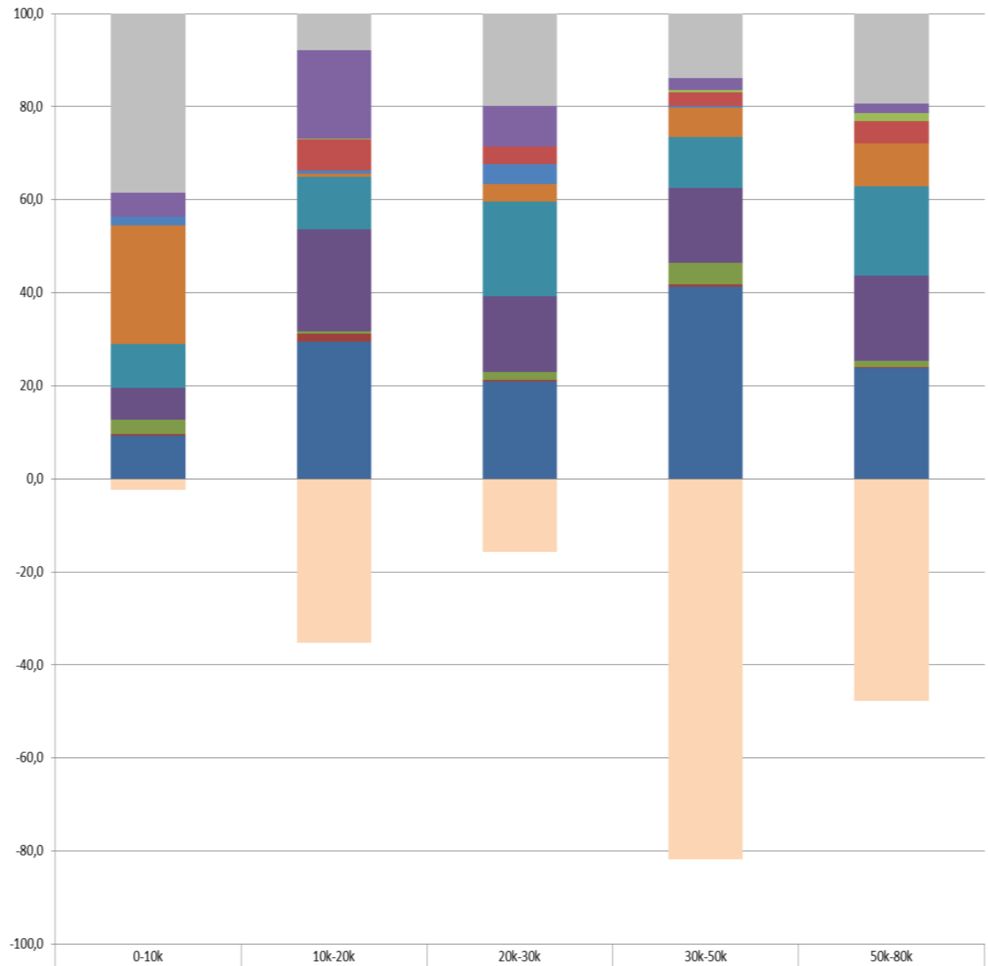
In the emission inventories the distribution of emissions between sectors is quite stable, while the share of emissions from private, commercial and public transport increases significantly for population density between 7.500 and 25.000 inh/km^2. The opposite happens to the share of emissions from industry, residential and municipal buildings. Also in the SEAPs the sectors influenced by population density are the same: building and transport. The *building* sector seems to play a more relevant role in terms of expected CO_2 reductions in cities with lower population densities. The weight of the building sector on total emission reductions decreases as density increases, ranging from 30% in the lowest density range to 19% in the highest density range. The *transport* sector has a more relevant role in terms of expected CO_2 reductions in cities with the highest population density.



	0-1000	1000-2500	2500-7500	7500-25000
not disaggregated actions	-34	-61	-40	-49
not possible to assign to a specific category	12,8	10,3	21,4	21,9
OTHER	2,7	16,9	8,5	1,2
WORKING WITH CITIZENS AND STKH	0,1	0,2	0,5	0,0
WASTE AND WATER	5,7	1,4	2,0	16,3
LAND USE	2,0	1,4	3,8	0,0
HEAT AND COLD PRODUCTION	3,8	8,6	3,6	9,5
LOCAL ELECTRICITY PRODUCTION	19,8	8,3	22,5	1,9
TRANSPORTS	18,0	21,6	12,7	29,2
INDUSTRY	3,2	4,6	1,1	0,3
PUBLIC LIGHTING	1,2	0,8	0,2	0,7
BUILDINGS	30,7	25,9	23,7	19,0

Graph 12: Distribution of emissions emission reduction between sectors (with respect to total of emissions disaggregated by subsectors) by density.

The weight of the *transport* sector on total emission reductions ranges from 18% in the lowest density range to 29% in the highest density range. GDP seems to influence both emission and emission reductions but in different sectors (Graph 7 and 13). In the emission inventories the share of emissions from *transport* sectors follows an inverse U shaped curve. Poorer and richer cities seem both to be associated to lower shares of emissions from transport. This is compensated by the combined effect of a decreasing share of emissions from public lighting and residential buildings; and an increasing share of emissions form the tertiary sector.

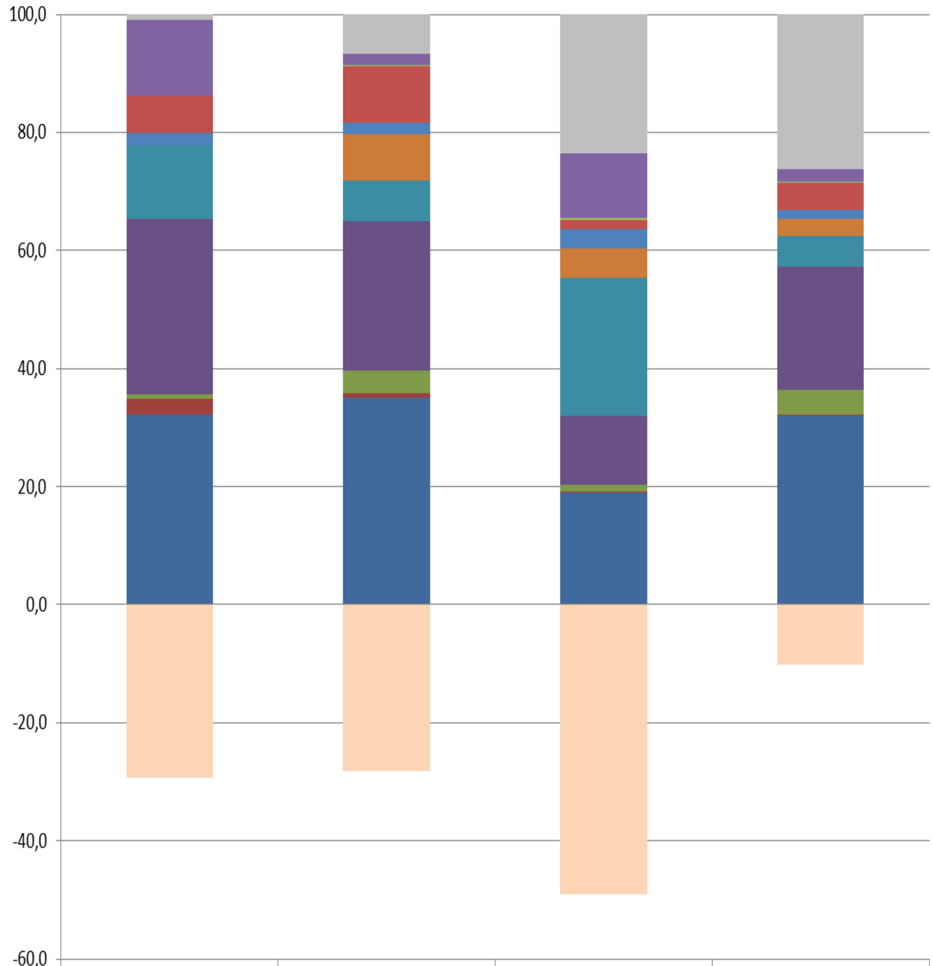


	0-10k	10k-20k	20k-30k	30k-50k	50k-80k
not disaggregated actions	-2,342396489	-35,2523995	-15,74679745	-81,84386687	-47,79659433
not possible to assign to a specific category	38,5	7,8	19,9	13,9	19,3
OTHER	5,1	19,1	8,7	2,5	2,2
WORKING WITH CITIZENS AND STKH	0,0	0,2	0,1	0,5	1,6
WASTE AND WATER	0,0	6,7	3,7	2,8	4,8
LAND USE	1,8	0,6	4,3	0,4	0,0
HEAT AND COLD PRODUCTION	25,6	0,6	3,6	6,4	9,3
LOCAL ELECTRICITY PRODUCTION	9,5	11,4	20,4	10,9	19,2
TRANSPORTS	6,7	21,9	16,3	16,0	18,2
INDUSTRY	3,1	0,4	1,7	4,7	1,4
PUBLIC LIGHTING	0,5	1,7	0,3	0,6	0,1
BUILDINGS	9,2	29,6	20,9	41,2	23,9

Graph 13: Distribution of emission reduction between sectors (with respect to total of emissions disaggregated by subsectors) by GDP.

This confirms that richer cities are associated to more activity in the tertiary sector and, to some extent, in the industrial sector. In the SEAPs GDP is significant just for the building and heat and cold production sector.

The *building* sector seems to play a relevant role in terms of expected CO_2 reductions in cities with a high GDP (it varies significantly from 9% to 41% depending on the GDP range). This could be due to the different financial means for the investments. The *Heat and cold production* sector plays a relevant role in terms of CO_2 expected reduction for cities in the lowest GDP range (it represents 25% of total expected reductions from these cities). Anyway it should be pointed out that in the first range the share of not-assigned emissions is significantly high and might bias results. The electricity emission factor (EEF) and the geographical area are significant variables for the inventory emissions.

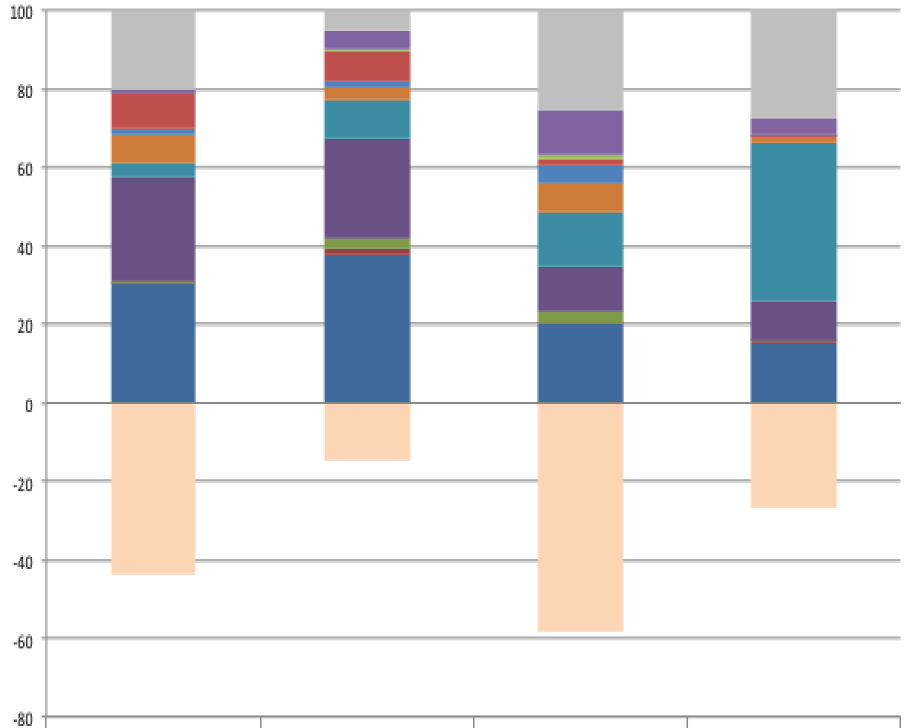


	0-1500	1500-2500	2500-3000	3000-7000
not disaggregated emissions	-29,3	-28,1	-49,0	-10,1
not possible to assign to a specific category	1,0	6,7	23,6	26,2
OTHER	12,8	2,0	10,8	2,1
WORKING WITH CITIZENS AND STKH	0,0	0,2	0,4	0,2
WASTE AND WATER	6,2	9,6	1,5	4,6
LAND USE	2,1	1,8	3,3	1,6
HEAT AND COLD PRODUCTION	0,1	7,8	5,0	2,9
LOCAL ELECTRICITY PRODUCTION	12,5	7,0	23,4	5,1
TRANSPORTS	29,6	25,1	11,7	20,9
INDUSTRY	0,9	3,9	1,1	4,2
PUBLIC LIGHTING	2,6	0,8	0,2	0,2
BUILDINGS	32,2	35,0	19,0	32,0

Graph 14*:* Distribution of emissions emission reduction between sectors (with respect to total of emissions disaggregated by subsectors) by HDD.

In fact, overall higher local emission factors for the electricity consumed in the city are associated to higher emissions in the industry and residential buildings (Graph 9).

This decreases mainly the weight of private and commercial transport in the inventory. The tertiary sector and municipal buildings seem to be able to compensate higher emission factors with proportionally lower energy consumption, as the share of emission in these sectors is stable across clusters.The weight of reported emissions changes also between geographical areas (Graph 10).



	0 - 0,25	0,25 - 0,5	0,5 - 0,75	0,75 - 3
not disaggregated actions	-44	-15	-58	-27
not possible to assign to a specific category	20	5	26	28
OTHER	1	5	11	4
WORKING WITH CITIZENS AND STKH	0	0	1	0
WASTE AND WATER	9	8	2	0
LAND USE	2	1	5	0
HEAT AND COLD PRODUCTION	7	3	7	1
LOCAL ELECTRICITY PRODUCTION	3	10	14	40
TRANSPORTS	26	25	11	10
INDUSTRY	1	3	3	0
PUBLIC LIGHTING	0	1	0	0
BUILDINGS	30	38	20	15

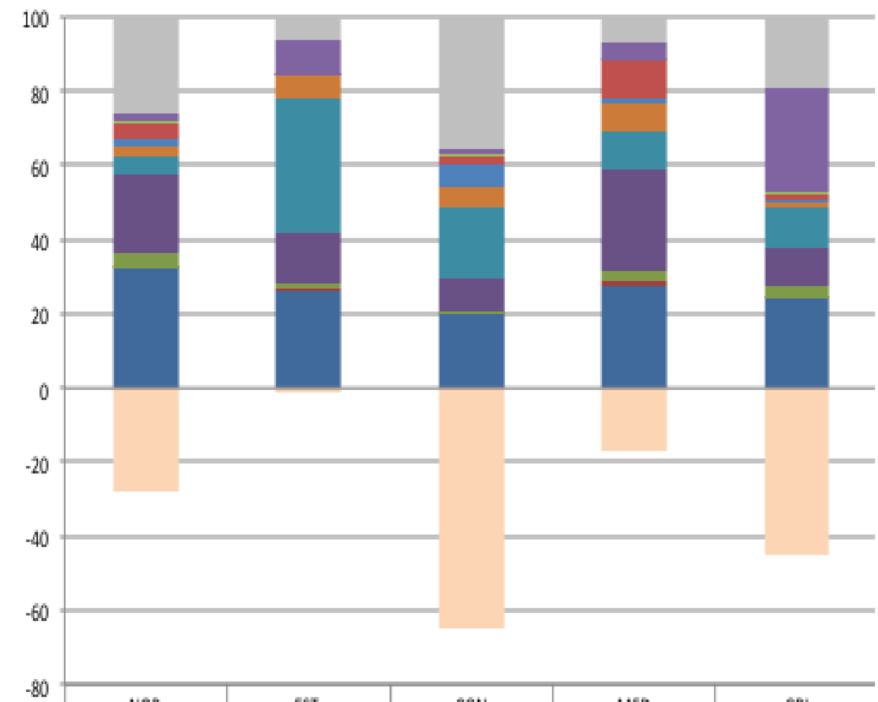
Graph 15: Distribution of emissions emission reduction between sectors (with respect to total of emissions disaggregated by subsectors) by EEF.

Continental Europe reports more emission from the industrial sector (non-ETS), while private and commercial transport, as well as the residential buildings sectors are more important in northern, eastern and Mediterranean countries. Finally, cities in the UK and Ireland display higher emissions from the industry and residential sectors. On the contrary, these two variables (EEF, geographical area) and no other variable seem to influence the distribution of expected reduction among sectors (Graphs 14, 15, 16).

3.2 SEAPs category of action and policy lever results

Only the full results of the classification concerning the sectors that have the greatest weight in the strategies adopted by cities in the sample, both in terms of expected CO_2 reductions as well as numbers of actions planned, are reported. These sectors are: *Building*, *Transports* and *Local electricity production*[82].

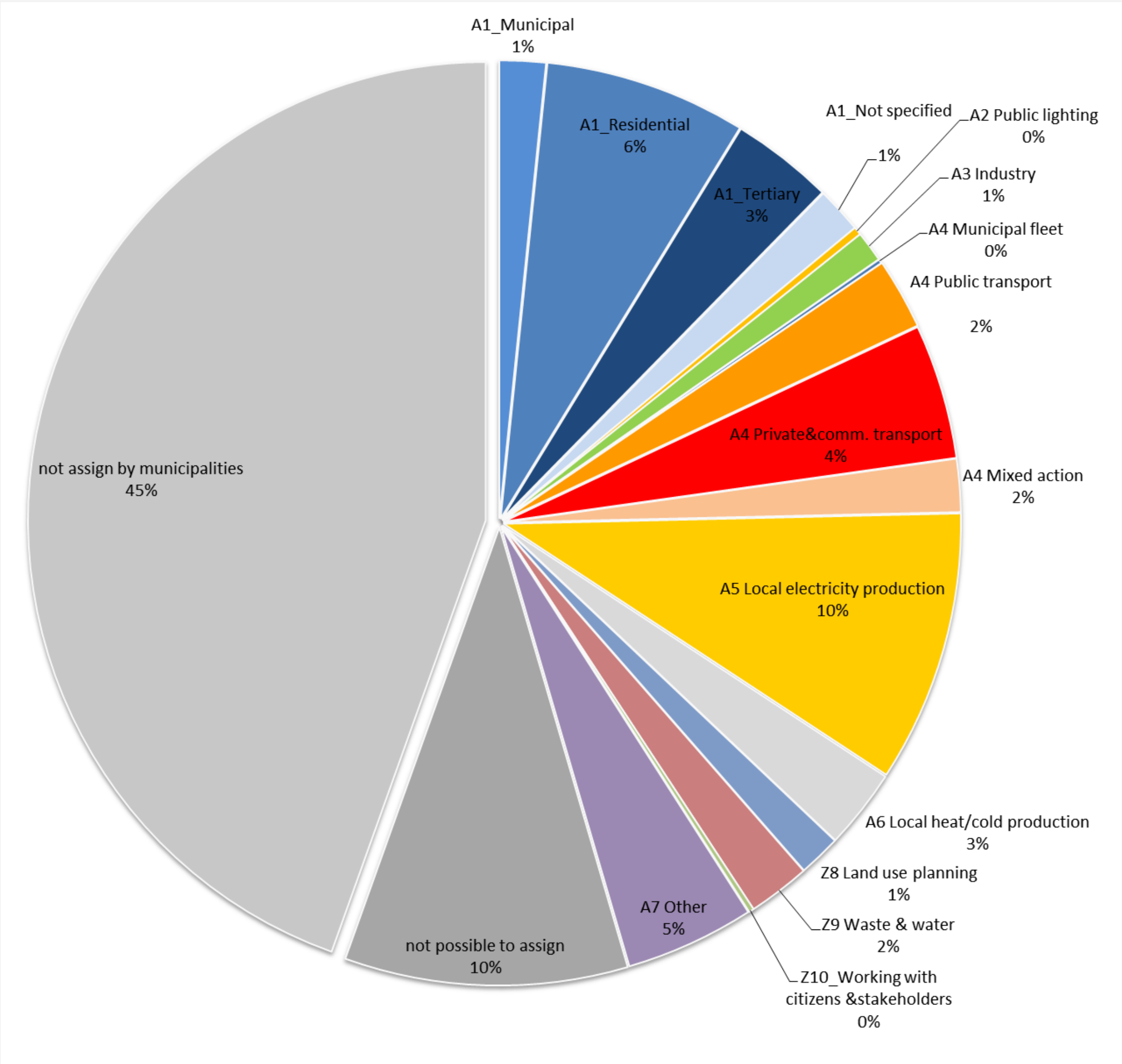
[82] The expected CO_2 reductions for the other sectors are: A1 Buildings 13,60%; A2 Public lighting 0,29 %; A3 Industry 1,09%; A4 Transports 9,28%; A5 Local electricity production 9,59%; A6 Local heat/cold production 2,82%; Z8 Land use planning 1,49%; Z9 Waste & water 2,19%; Z10_Working with the citizens and stakeholders 0,18%; A7 Other 4,56%; not possible to assign 9,99%; not disaggregated actions 44,92%.



	NOR	EST	CON	MED	GBI
not disaggregated actions	-28	-1	-65	-17	-45
not possible to assign to a specific category	26,2	6,4	35,5	7,3	19,1
OTHER	2	9	2	4	28
WORKING WITH CITIZENS AND STKH	0	0	1	0	0
WASTE AND WATER	5	0	2	10	2
LAND USE	2	0	6	2	0
HEAT AND COLD PRODUCTION	3	6	5	7	2
LOCAL ELECTRICITY PRODUCTION	5	37	19	10	10
TRANSPORTS	21	14	9	27	10
INDUSTRY	4	1	1	2	3
PUBLIC LIGHTING	0	0	0	1	0
BUILDINGS	32	26	20	27	24

Graph 16: Distribution of emissions emission reduction between sectors (with respect to total of emissions disaggregated by subsectors) by GEO.

Looking at the number of planned actions, 68% of cities in the sample have planned activities in the *Building* sector, 66% in the *Transport* sector and 49% in the *Local electricity production* sector. The *Building* sector represents 13,6% of total expected CO_2 emission reductions corresponding to 12.826.742 tons of CO_2 per year. These are spread out over four subsectors: *Residential Building* (52%), followed by the *Tertiary Building* (27%) and *Municipal Building* (9%). The remaining 12% is categorized under the "*Mixed actions*". The categories of action most frequently used in the building sector are: "*integrated actions"* and the "*energy efficiency in space heating and hot water"* (they appear respectively 435 and 171 times). These categories of action represent respectively 4,5% and 1,1% of the total expected CO_2 reductions. The "*purchase of green energy production*" category of action has a very low frequency (5) but has a relatively high potential of CO_2 emission reduction (2,3%) (Graph 18).



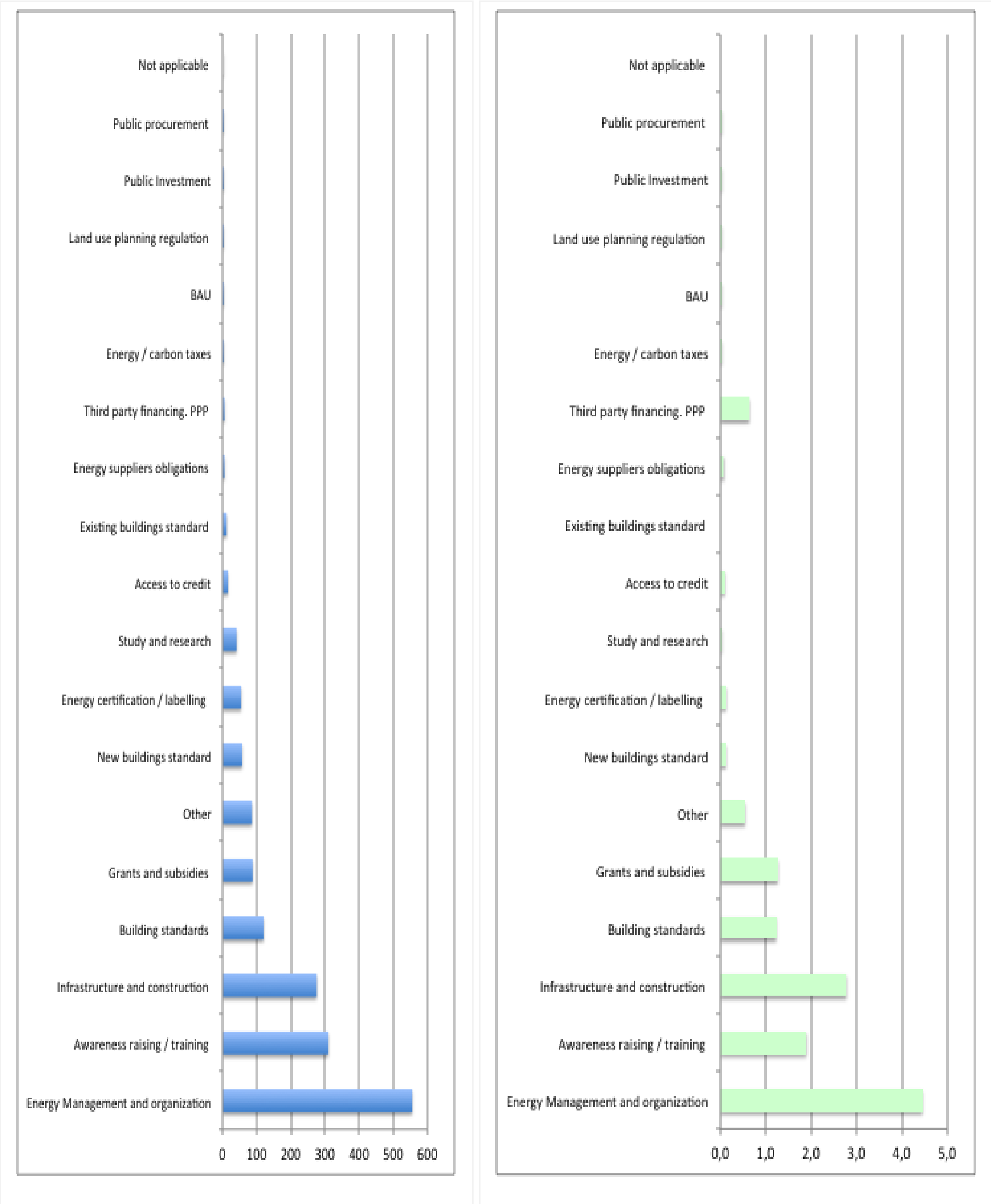
Graph 17: Percentage expected reduction from each sector on total SEAPs expected reduction in the city sample (%).

The most used policy levers include the "*energy management*", "*awareness raising*" and "*construction of infrastructure*" (respectively 555, 310 and 276 times). In this case there is full correspondence between the lever frequency and the expected CO_2 reduction that has been attributed to them (energy management 4,4%, infrastructure and construction 2,8% and awareness raising 1,9%) (Graph 19).

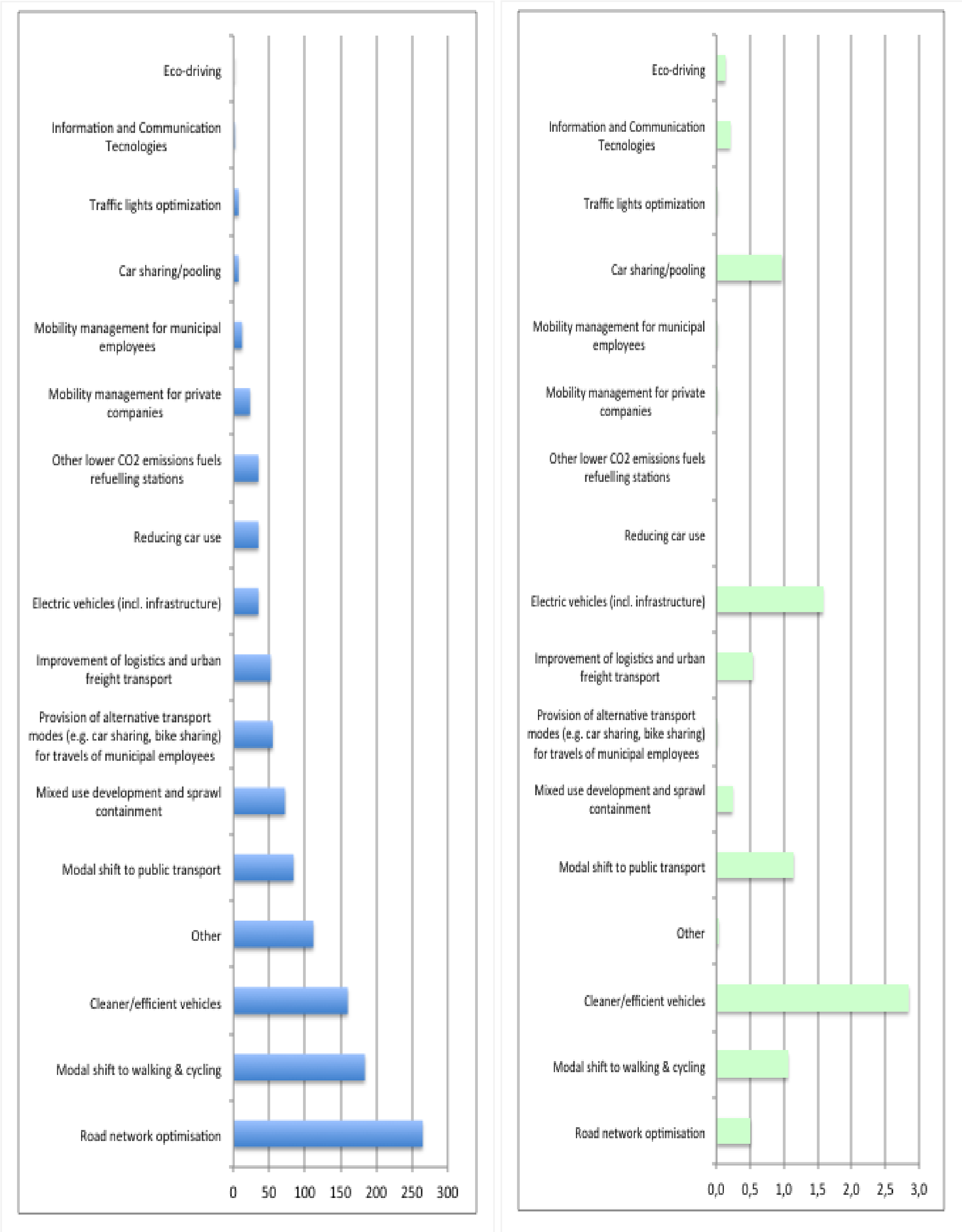
The *Transport* sector has 9,3% of CO_2 expected emission reduction, for a total of 8.749.578 tons of CO_2 per year. It is further divided into four subsectors, of which the two most relevant ones in terms of CO_2 emission reductions are "*Private and commercial*" subsector (51% of the CO_2 expected reduction) and "*Public transport*" (27%)[83].

[83] The other areas of interventions are: municipal fleet 2% and mixed actions 20%.

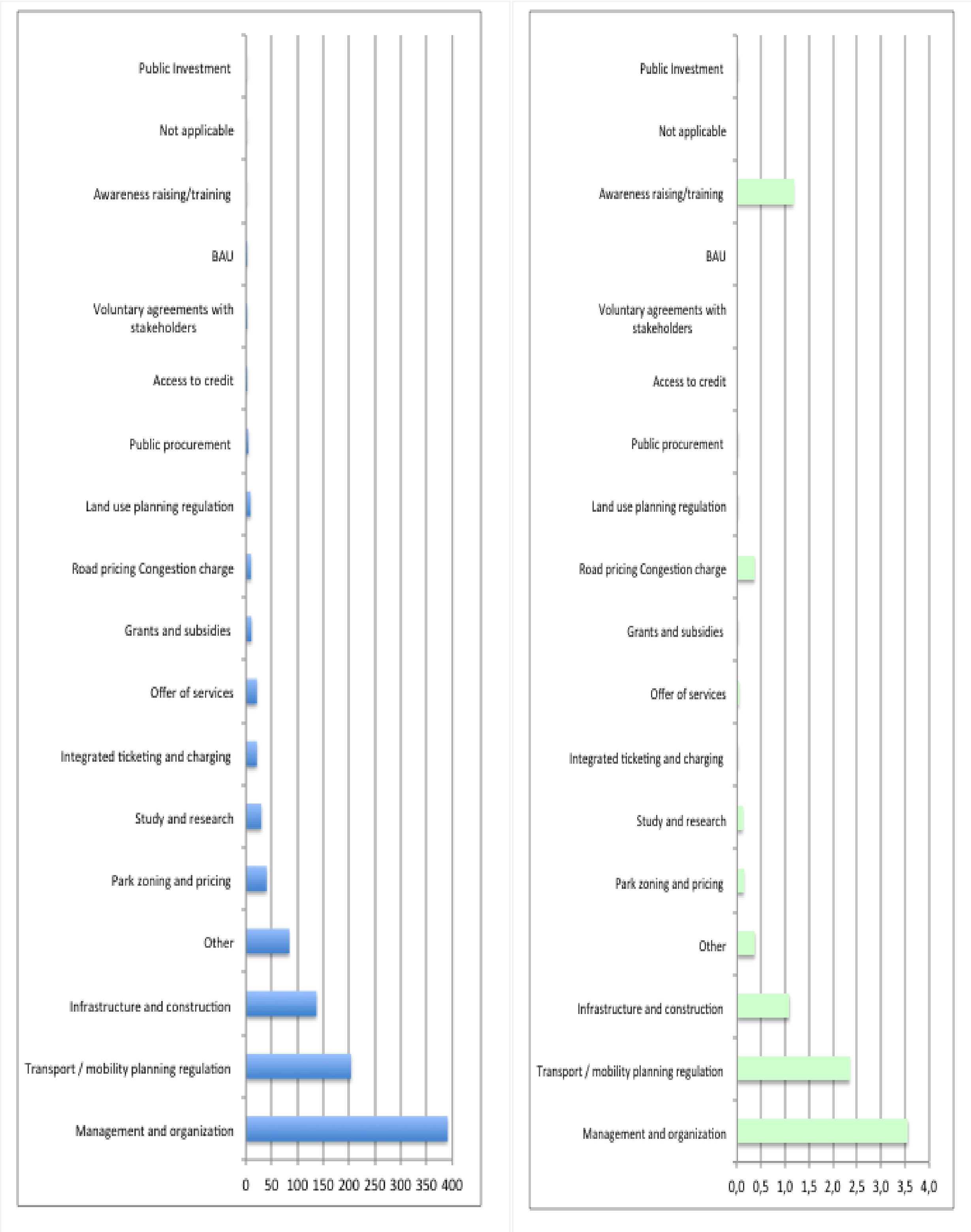
Graph 18: Frequency and expected emission reduction for each category of action for the BUILDING SECTOR on the total of the sample, SEAP.



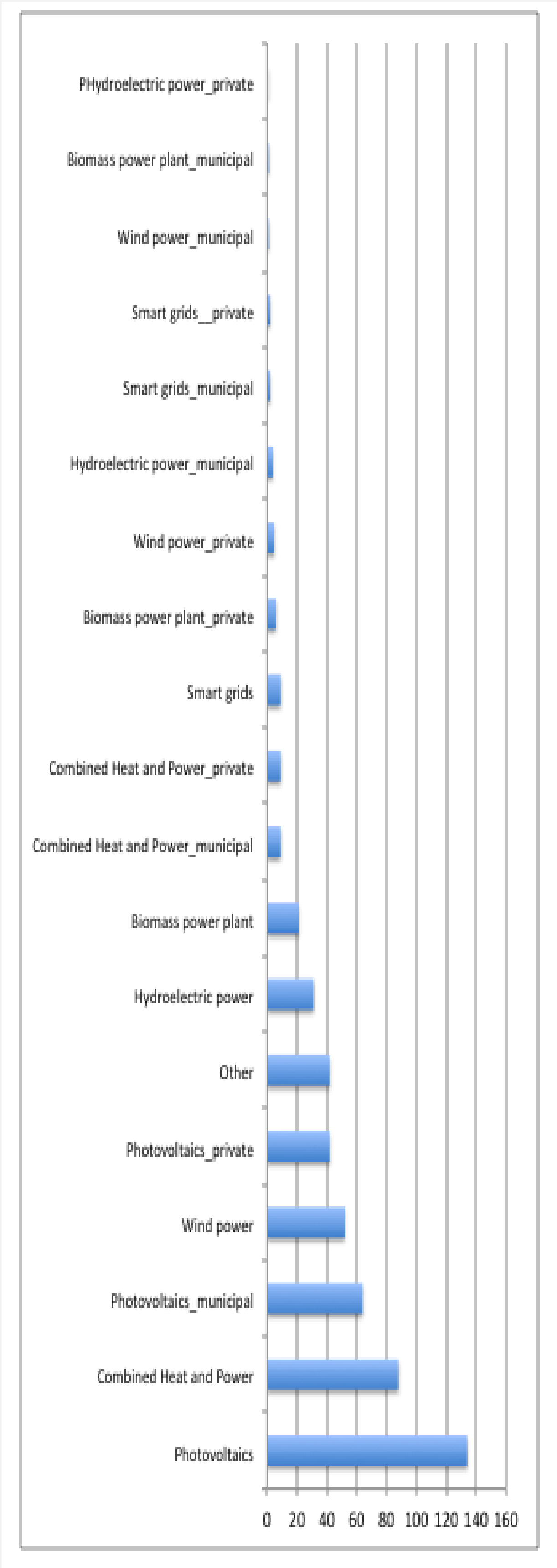
Graph 19: Frequency and expected emission reduction for each policy lever for the BUILDING SECTOR on the total of the sample, SEAP.

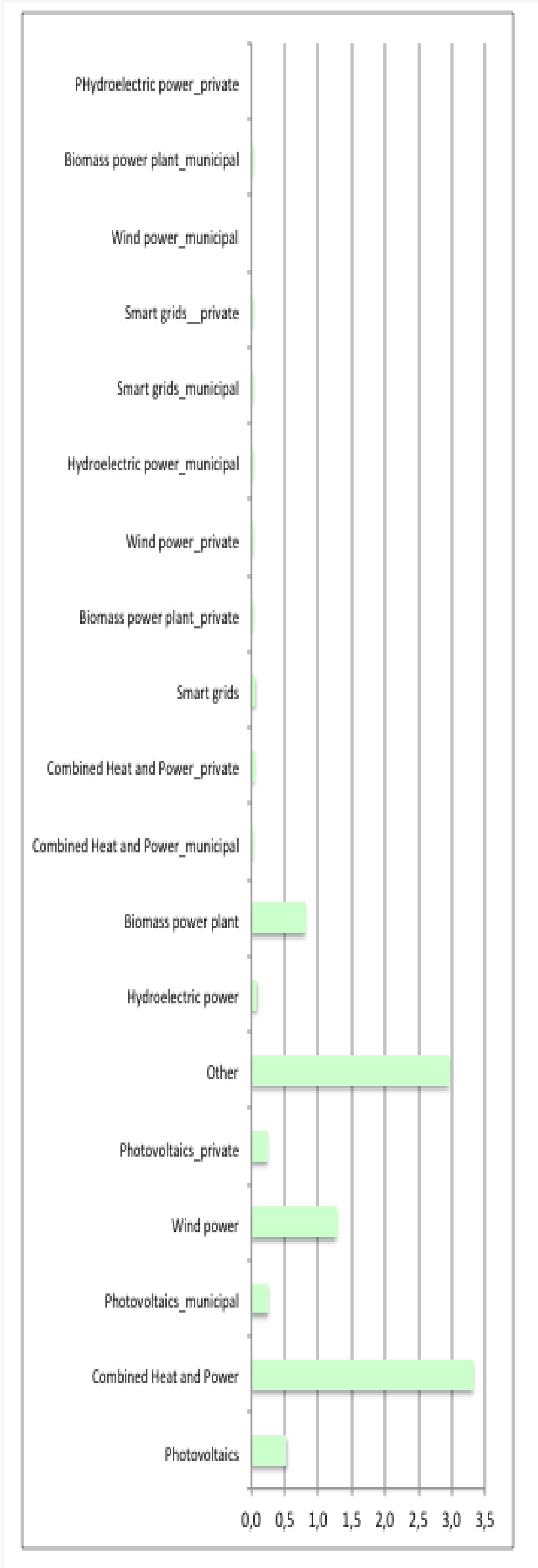


Graph 20: Frequency and expected emission reduction for each category of action for the TRANSPORT sector on the total of the sample, SEAP.

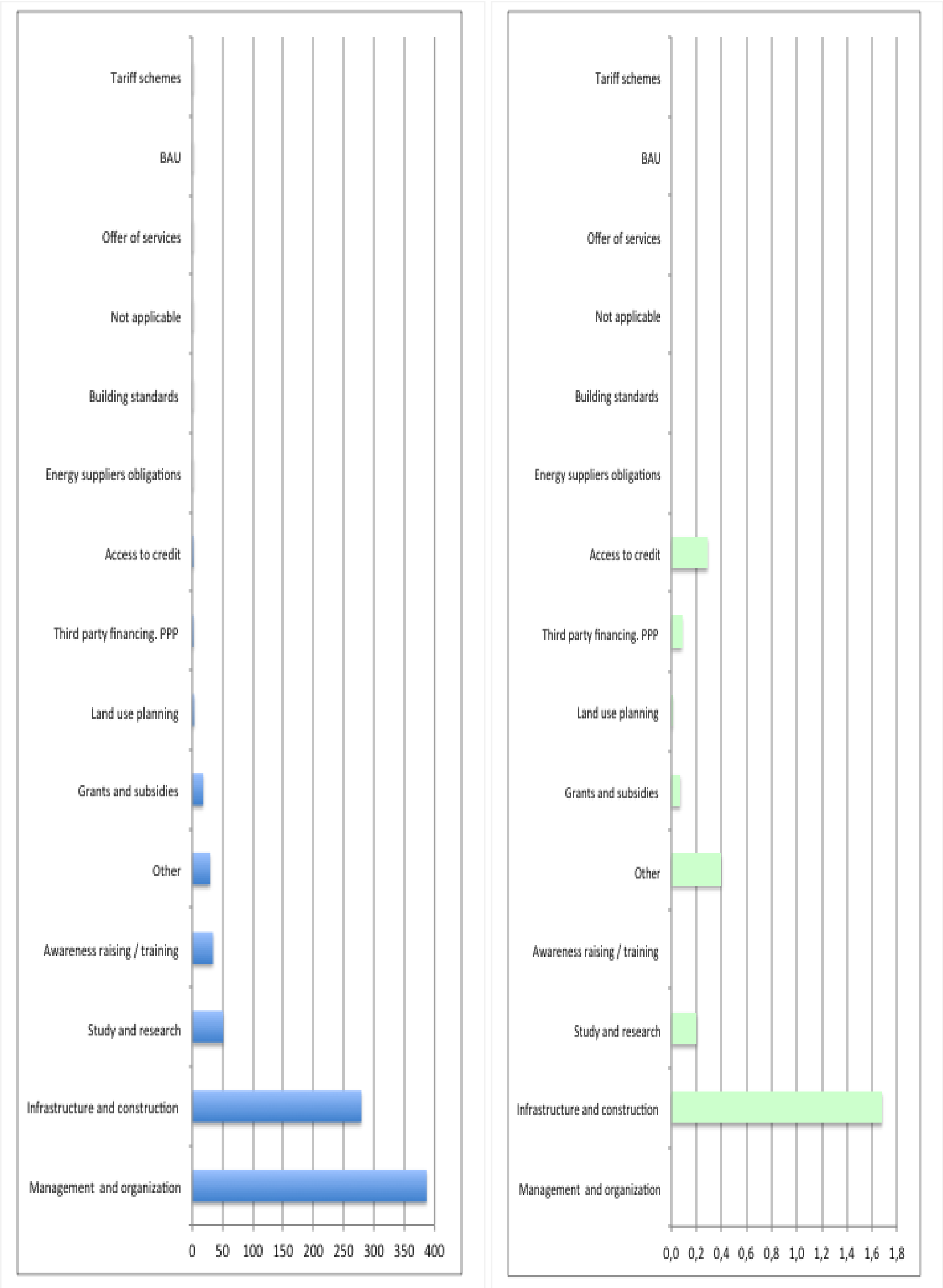


Graph 21: Frequency and expected emission reduction for each policy lever for the TRANSPORT sector on the total of the sample, SEAP.





Graph 22: Frequency and expected emission reduction for each category of action for the LOCAL AND ELECTRICITY PRODUCTION sector on the total of the sample, SEAP.



Graph 23: Frequency and expected emission reduction for each policy lever for the LOCAL AND ELECTRICITY PRODUCTION sector on the total of the sample, SEAP.

The categories of actions most frequently used in the *transport* sector are related to the "*road network optimization*" (cycle paths, restricted traffic zones, etc.) and the "*modal shift to walking & cycling*" (they appear respectively 265 and 184 times). In this case their frequency does not always coincide with a high reduction of CO_2 (respectively 0,51% and 1%). Instead the categories that foster the use of cleaner vehicles (2,84%) and electric vehicles (1,58%) are the ones which have the greatest amount of expected emissions reduction (Graph 20).

The most used policy levers in the transport sector are related with "*management and organization*", "*transport and mobility planning*" and "*awareness raising*". In this case the expected CO_2 emission reduction from each lever is coherent with the frequency (respectively 391, 204 and 137 times): "*Management and organization*" 3,56%, "*Transport and mobility planning*" 2,34%, "*Awareness raising*" 1,17% (Graph 21).

The third most important sector in terms of expected CO_2 emission reductions is the *Local electricity production* sector, with 10% of total expected CO_2 emission reductions that correspond to 9.048.108 t of CO_2. No subsectors were identified for this sector. The results show that there is no match between the expected emission reduction and the frequency for the categories of action.

For example, the category of action that has the greatest frequency is "*photovoltaics"* (134) with a total expected reduction of 0,53%. Instead, the category of action "*combined heat and power"* recurs 88 times and has an expected CO_2 emission reduction of 3,32%. The same happens for the "*wind power"* and *"biomass power plant"* categories of action (recurrences: 55 and 21; expected CO_2 emission reduction: 2,95% and 1,17%). The aggregation of the data shows that the categories with the highest expectation of CO_2 emission reduction are: "*combined heat and power"* (3,32%), "*wind power"* (2,95%), "*biomass power plant"* (1,17%) (Graph 22).

Instead the relationship between the policy levers frequency and the policy levers expected CO_2 emission reduction is coherent except in two cases: "*access to credit*" and "*management and organization*". In the first case there is a low frequency (2) which corresponds to a high expected emission reduction value (0,3%). Instead there is no correspondence between CO_2 reduction emission and frequency for the "*management and organization*" lever (recurrences: 387; expected emission reduction: 0,1%). The policy levers that have the highest amount of CO_2 expected emission reductions are: "*infrastructures and construction*" (1,68 %), "*access to credit*" (0,29%) and "*study and Research*" (0,2%) (Graph 23).

In general the category of actions that have more potential in the CO_2 reduction are the one that belong to the building and local electricity production sector (*integrated action on buildings, combined heat and power and wind power*). The policy levers with more CO_2 emission reduction potential are from building and transport sectors (*energy management and organization, management and organization, infrastructure and construction, transport / mobility planning regulation*). It could be noticed that the policy levers adopted by cities are related to the organization and to the raising awareness of the population, instead of the adoption of economics instruments for the actions implementation. This may arise from different abatement costs or from the social acceptability.

4. Conclusion

In the city sample that has been analysed, the distribution of intended emission reductions is coherent with the weight of emissions for different sectors and subsectors. Building and transport sectors stand out as the most relevant for emissions in the BEIs and for emission reductions in the SEAPs. Local electricity production is a very promising sector in terms of emission reductions, while the industrial sector (non-ETS) is expected to yield a minor contribution to the overall target, despite its relevance in the BEI. In general, intended emission reductions are higher in public activities in relation to emissions in base year, even if the weight of public activities is relatively low compared to private activities. On average, cities in the sample are committed to achieve a reduction of 25% of baseline emissions by 2020.

The variables that influence both emissions and emissions reduction are *population density* and *GDP*. No other variable is significant for the emissions reduction, instead for inventory emissions both *EEF* and *geographical area* result to be significant. In general, the category of actions that have more potential in the CO_2 reduction are the one that belong to the building and local electricity production sector (*integrated action on buildings, combined heat and power and wind power*). The policy levers with more CO_2 emission reduction potential are from building and transport sectors (*energy management and organization, management and organization, infrastructure and construction, transport / mobility planning regulation*).

The strength of results is often constrained by the bounded number of cities available in the sample and the limited degree of details provided by some of them, with regard to the source of emissions and expected emission reduction. Nonetheless, the uniform approach to emission accounting ensures the comparability of cities and the consistency of results with regard to available data.

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Energy civilizations: industrial modernity and beyond *)

by

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Abstract

Three of the authors (Jensen, Shearing, Skauge) are in the core group of the SANCOOP project Transition to Sustainable Energy Systems in Emerging Economies. A South African Focused Comparative Project. Financed by the Norwegian and South African Research councils 2014-2016. Countries included are Brazil, China, India and South Africa.

This paper will present the theoretical framings that have shaped the project along with some preliminary analyses. The paper recognises that energy systems are attracting increasing attention as scholars, politicians and practitioners address the necessity, especially in "developing" countries, of responding to increasing demands across the public, the private and community sectors to increase the supply of electricity while protecting vulnerable and threatened ecosystem services. This paper canvases some very preliminary conclusions of our project regarding actors and mechanisms that relates to response to this wicked conundrum and how different socio-bio-physical contexts are shaping these responses.

1. Introduction

Energy systems have become central actors (or in Latour's (2005) terms "actants") shaping earth systems. The Intergovernmental Panel on Climate Change (IPCC), in its 2014 report, identified the generation of electrical energy (especially coal-fired production) as a principal driver of the earth system changes that are defining what is been termed "the Anthropocene" (Crutzen and Stoermer 2000) – an age within which humans, via their institutions, have become "geological agents" (Chakrabarty 2009), agents who may change the earth systems and push the civilizations close to or beyond long established "planetary boundaries" and the "safe operating space" they have enabled (Rockstrom, et a.l 2009).

2. Our Research

The Transition to Sustainable Energy Systems in Emerging Economies project, upon which this paper is based, is examining the ways in which the BASIC countries (Brazil, China, India and South Africa) are responding to the challenges of ramping up supplies of electrical energy while better protecting "ecosystem services" (Costanza 1997). In this article China and South Africa is most touched upon as the are most analyses, so far. A foundational assumption that grounds, and shapes, this research is that today's civilizations (and the economies that sustain them) require a constant and expanding supply of electricity -- today civilizations are electrical civilisations. At the same time, as awareness grows about the impacts of established generation practices on ecological systems these civilisations need more sustainable ways of producing and distributing electrical energy. It is reconciling these two incentives constitutes a difficult conundrum as vested interests contest developments to shift energy production. Our research is focused on how countries with different histories and different contemporary contexts are responding to the challenge posed by these, often competing, demands.

This forms part of a programme of work concerned with the way in which institutions are recognizing and responding to the new harm and risk landscapes that the Anthropocene has brought with it (Shearing 2015). In our context Anthropocene has three meanings, 1) the fact that human civilizations are shaping and maybe destroying their habitat and 2) knowledge of this are widespread together with 3) the available technology and means for shaping our environment for better or worse . Together this creates a strong role as actors. This programme of work, with its governance focus that has been exploring the shaping of the flow of events within the Anthropocene, has drawn upon a "nodal governance" (Johnston and Shearing 2003) framing that recognizes governance as a |"whole-of-society" (Ayling 2013) activity. One of theoretical outcomes of this larger programme of work has been an exploration of an AMP framework for understanding change – Awareness, Motivation and Pathways (Honig et al 2015). This project utilizes and develops this emerging framework.

3. Humans and Energy

Harari (2011) argues that humans should be referred to as Sapiens as we belong to species Homo Sapiens which forms part of the more inclusive genus Homo. Apart from other bio-physical entries that inhabit the planet earth, it has been our capacity to successfully generate, collect and store far more energy than our bodies produce. At the heart of this capacity has been our ability to capture and use the energy of others – both biophysical others (e.g. slaves and animals) and physical others (e.g. fossil deposits, weather systems, sun, nuclear forces). This is a necessity to build and develop civilizations. Failure in this area has also ruined civilizations (Diamond 2005).

As we have alluded, a crucial barrier to the sustainability challenge is less damaging methods of generating electrical energy. Physically, energy is in itself not a finite or scarce resource from a human need perspective. At the most principal physical and cosmological level all things are highly concentrated energy, as illustrated by the emerging (but still impractical) fusion technology (Grossman 2015) "Scarcity" is depending of the technology for extracting, storing and distributing. Some technologies use finite or slow-circulating resources (wood, coal, oil, gas), others are restricted by building costs and balance against other values (sun, wind, hydro, nuclear).

I older times energy handling was in a large degree linked to the household; heating and cooking, as well as energy usage in farming and manufacturing were linked to personal skills. Chopping wood, making fire, keeping the oven hot, caring for the horses, looking after wind or water-driven mills where integrated in daily life. Humans were closely and personally linked to energy production. The modern electricity system changed this, and electricity is now one of the most commodified and standardized services in the household.

Under industrial modernity electricity became a main energy transporter, and the electricity grids and their forces of change are our focus. One author puts it this way: *Fairly, we could argue that much of what we call modernity is fundamentally electrical in nature or at least dependent in a fundamental way on the electrical grid.* (Schewe 2007, loc 308). Driven both by technology and modernity cultural pattern, electrical energy systems under modernity developed mainly into huge centralized production and distribution systems linked to heavy material structures, economic interest and political-social systems of knowledge. When change becomes necessary these will show as institutional path dependences (see March and Olsen 1998), with a lot of lock-in mechanisms associated with existing forms of generation. Geels, and his collaborators, use the term "regimes" (e.g. Elzen, Geels and Green's 2004) for these and add the useful term "niches" for technological and economic functioning systems on a smaller scale. How regimes hampers niches from transferring into full scale development and how the niches may be helped into regime status are major topics for the project as many of the sustainable energy extraction technologies are already established in the niches (solar, wind, wave, small hydro) The way from niches to regime status is critical to understand. At the technological side there are series of theoretically and small-scale sustainable alternatives that is not yet developed into a fully functioning niche (wave, tidal, Solar CSP, IV phase nuclear), but more important, there are many sustainable technologies that are well established, manufactured and realistic, also economically (wind, solar PV, small-scale hydro). At the grid and total system side it is easy to see a more decentralised, multi-sourced system with two-way and more complicated grids, and also here are technologically realistic solutions well established (smart grids, co-production solutions). The problems are not the energy in itself, not lack of technology or economic possible solutions, but the institutional frames and arrangements that will help or hamper.

Understanding how humans are able to shift their electrical energy enrolment strategies is the project's central focus.

4. Awareness

We must understand how it is that we humans, acting in and through institutions, have engaged earth systems in ways that have so significantly, and rapidly, undermined the safe operating space that earth systems have provided us. We have, like others (e.g. White 1967 and Latour in his ever expanding oeuvre), focused our attention, in part, on the "mentalities" (Johnston and Shearing 2003), or "ways of seeing" (Smith 1987) that have enabled our energy enrolments to appear sensible. These appearances of "sensible" use of nature are now gradually replaced by the Anthropocene actor-awareness of respect for nature and/or awareness that we <u>are</u> nature.

Well established ideas of Nature and the Social, as two a separate sui generis domains that do not impinge on each other (e.g Durkheim 1982), have long guided human engagements with earth systems. This history has roots that lie deep within religion and myth (White 1967). These established framings have had a deep, and pervasive, influence in governing human engagements with earth system. For example, Western civilisations have an enormously influential framing in the Platonic idea of "pure reason" that must abandon the "nature" in humans (passions, production) as the basis for understanding and subsequently engaging nature. Within this framing humans are, as with Durkheim, conceived as located "outside" of, and "above", Nature. During the centuries when Christians, and particularly the Catholic, framings became increasingly dominant in Western thinking, this classical view of Nature was both embraced and reshaped. Nature was understood as a bio-physical realm, created by God, that humans, as God's children, should utilize and exercise dominion over. With the Renaissance, these conceptions of Nature as a realm that humans occupied was again embraced and reshaped. This acceptance and reform , and a new system of governance thinking is nicely shown in Abraham Bosse's celebrated frontispiece for Hobbes' Leviathan (1651). In his frontispiece Bosse pictures a benign source of governance, drawn as a mosaic of humans that towers over both nature and the social, as the source. By the 18th and 19th Century the dominate framing, again with strong resonances to earlier framings, conceive of nature as an autonomous realm that not only can be objectively studied through but as in Heidegger's critique of the industrial era an endless "standing reserve" for human production (Heidegger 1977, Verbeek 2005). This (lack of) awareness for natures' balances and humans as part of nature got much stronger, both as a state of mind and as practical action through industrialism and its two major ways of system building, called capitalism and socialism.

The (short-time) progress made by technology and this framing was easy to see through the 19th and 20th century (UK, European and US growth, Soviet Union, Nazi Germany). This was an age of optimism and growth on behalf of science, industry and central governance that still form parts of our thinking and values It was also the forming period of the dominant energy regimes of today: the technology, the structure, the popular raw materials to use, the calculative skills, the mentalities as well as the grid distribution system and all its social fabric. (Hughes 1988) With electricity as an energy carrier; electrical grid-based energy systems became crucial to industrial growth, they became centralized and one of the core public utilities.

An old power station is a symbol of pride. It's polished brass, copper and marble and the building itself is designed as a temple of progress and prosperity. It was man's victory over nature. This industrial-romantic and progress-oriented perspective is also today important (and reasonable) as symbol and value in poor countries. To be connected to electricity is the sign of progress in welfare, hygiene, education and family safety.

One specific aspect of "nature's value" is the tendency to see it as money. With the modernity perspective of which Heidegger accuses industrialism, nature have no value per se, the only value is the one linked to the extraction and usage for production purposes. Even if early works of Karl Marx had a (for the time) good understanding of the metabolism of nature (Foster/Clark/York 2010), his theory of value is linked only to the work that goes into the extraction and production. His analytical system (and his legacy) still remains a production-side value-system.

Our project is exploring how established awareness of nature and the social, has been embedded in institutions, and how new ways of seeing and new organisations challenge and reshape energy regimes.

What we have found across all the BASICs is very clear across a wide swath of literatures. Although the insights of earth scientists captured in the term the Anthropocene is very recent (this term was only coined in 2000) there is widespread awareness, and increasingly vocal across all sectors of the crucial links between ecosystem services what is being termed "livelihood security" (Ziervogel 2008). While popular media provide considerable space to "climate sceptics" as part of their balanced reporting strategies we have found very little questioning of the ideas that underlie the Anthropocene or the need for all sectors to reshape their engagements with earth systems. Political documents, expert sources (our interviews) and popular polls are firmly pointing away from the simple picture of nature "as stockpile" and "dumping ground". There is a new awareness that may be linked to the Anthropocene actor argument. We know we are part of nature, we know we may be damaging our habitat and that we should change. But the means and priorities and actions of this is not clear and the institutional patterns are forged in the old (lack of) awareness, A recognition of both the vital importance of "energy security" and "environmental or ecological security" and the need for both of these securities to be realised simultaneously constituted a deep and underlying consensus across sectors and across the BASICs. We found very few persons in interviews who did not accept that new levels of responsibility were required to realise energy security (often framed as the "right to security" where socio-economic rights were recognized, e.g. in South Africa) in a sustainable manner. This framing of the need for environmental responsibility is being recognized in both popular and academic literatures through terms such as "consumer citizenship" (Jensen 2005) and linked to a myriad of labelling and certification of market goods and services, indicating a response from suppliers. A pervasive finding has been the legitimacy and significance of the reports of the IPCC despite often acrimonious global debates that the global media has often focused on in its reporting.

At the more practical level we observed that many of our interviews had a dual character, the awareness of the necessity to change and the support of a new framing of the human-nature question was more prominent when they spoke "as persons" than when they spoke as "institutional representatives". That changing values may start outside institutional framework and roles and not being expressed by their organizations, is a classic finding in organizational theory on change and learning (Olsen 1978). However, there are also awareness changes at the institutional and organizational level. At the market, many companies engage in Corporate Social Responsibility (CSR), and in South Africa it is quite popular to show responsibility by more sustainable energy usage and production (like rooftop PVs). At the political level, the top level energy plans in South Africa has declared a significant contribution to Co2 reduction (but implementation is unclear). In China the top level planning and legislation have clear signs of Anthropocene awareness. The passing of a law "Circular economy promotion law" in 2009 fits within this picture, this concept pointing to the full circle of nature-production-humans and the necessity of a healthy nature for human production. The president and party leader Xi Jinping writes (2014) about ecological civilization and ecological progress as keywords for change. In 2015 a new law with significant stricter possibilities for sanctioning environmental crime was implemented, and have already been used in individual cases. Both our general discussion and our preliminary findings support the impression that there is a fundamental awareness of the Anthropocene challenge, that this is rooted in a new framing of the human/nature interface and that change in energy production is necessary. The consensus is however linked to a character as a "weak value", given that the institutional setup is mostly infused with values from the production (owners and workers) side and formed as such through the process of governance and industrialism, and hence these values are not prominent at the level of string institutions.

5. Motivation

Awareness is not the same as action, it is not even the same as practical behavior and drive for change. The complicated links between values/awareness on one side and practical motivation/action on the other are the object of huge amounts of research, both in consumer behavior, the research on consumer citizenship and general research on organizational change. For the area of organizational change to sustainability this is discussed and summed up in Peterson, Shearing and Neal 2015, using the Awareness-Motivation-Pathway (AMP) concepts.

This quite extraordinarily level of consensus we found was not reflected in widespread action – although much action was taking place in all the BASICs. At the core of this gap between awareness, most interviewees agreed, was what organisational theorists (such as March and Ohlin 1998) have referred to as "path dependencies" and "lock ins". Central to these institutional barriers to institutional change are vested interests that shape incentives, such as the interests associated with significant investments, by economic elites in established energy generation technologies that depend on fossil fuels – again especially coal (see, e.g., Mitchell 2009 for a discussion of how a resource such as coal shapes institutions, and for South Africa Baker 2012). These vested interests exercised considerable influence over government policy that was reinforced by a history of good investment returns within stock markets, and these institutional forces makes the role-manuscripts for organizational members.

What our findings and preliminary analyses show is that motivation is a contested terrain. While regime stability is supported by set of often mutually supporting vested interests, changes in socio-biophysical landscapes – as multilevel transition theorists have argued (Geels et al 2004) -- produce "shocks" that may up open spaces for innovation that support other economic interests. Crucial here in all the BASICs have been the extent to which new technologies (see section on Pathways below) are available that enable new players to compete within energy.

Both our findings and other research (Petersen, Shearing and Nel 2015) have observed how the transition from awareness to motivation towards sustainability is often a process of linking different values and interests into the same motivational direction. The simplest combination is the one where sustainability goes together with a exploiting a profitable niche or is thought of as a marketing advantage. More specific to our cases and study of energy regime transformations in BASIC countries there seem to be several combinations at work that create a relevant motivation. In China the serious local pollution problem was mentioned in most of our interviews as a joining awareness that made the motivation to shift away from coal and change coal to cleaner technologies. Also the national interests involved in being a positive participant in international Co2 negotiation were mentioned. Finally the evolving economic interests linked to the manufacturing of solar and wind power equipment was mentioned and is also described in the literature (Mathews 2014). In China the Anthropocene awareness is linked with local pollution crisis, with some manufacturing interests and interests form the international scene, all merging to a motivation for changing energy mix in a more sustainable direction. In South Africa the mix is different: The serious supply and grid crisis that makes rolling blackouts a part of daily life and the rising electricity costs, together with the organizational crisis with the main stat supplier ESKOM makes a supply-crisis. The governmental promises at the international level plays a role and the private market and the middle class purchasing power have several initiatives for sustainable energy change that motivate for new sources of electricity, and finally many poor areas can realistically be supplied with off-grid sustainable energy. The very high level of unemployment in South Africa is also opening up for energy projects with employment openings. In South Africa the supply crisis is merging with Anthropocene awareness, citizens and business demand and some political efforts into a motivation for sustainable energy shift. On the other hand, the established interests, the governmental traditional values of central rule and huge power plants may also motivate in the direction of more big power plants (coal and nuclear) as a kind of business-as-usual decisional pattern.

What has been recognized, but insufficiently explored, by the multilevel transition theorists is the role of regulation in shaping responses to socio-biophysical landscape changes that shifts in awareness recognize. This lacuna constitutes a major focus of attention of our project. The comparative data that the project is providing across countries is proving to be an important source of insight in understanding how regulatory environments impact on motivation and hence on the possibilities of shifting awareness to bring about significant changes in energy regimes. What we have found is that regulatory environments can, contrary to much scepticism about policy impacts, can prove to be game changers. The special regulatory setup for bringing private medium-size energy providers (IPPs) into the South African grid has been a huge success, especially the REIPPP program under a special semi-independent regulatory unit. We have also found that the effectiveness of regulatory environments in bringing about changes in energy regimes is closely tied to the availability of venture capital both from the private and the public sectors and the extent to which regulation provides guarantees of returns on investment within limited time frames – the South African REIPP case has been particularly instructive in this regard.

A further factor that our research has highlighted is consumer action. Consumers care about the crucial importance of developing sustainable forms of energy generation. Their concerns create new market niches that entrepreneurs and investors take into account. But both market actors and consumers often depend on regulation systems like certifications, and inspections as well as formal regulation openings for implementing local energy solutions. In sunny South Africa with electrical supply crisis and high prices there is naturally a significant motivation for rooftop solar water heaters and rooftop PVs, at least for middle class houses and small/medium business buildings. But not much is happening (with some exceptions). This is where we leave motivation to the discussion of the last threshold for change: Pathways

6. Pathways

A crucial feature linking both awareness and motivation to action is pathways. No matter how aware and motivated individual and institutional actors are the absence of viable pathways will mean that existing regimes are likely to remain stable. Within the energy field governments and the private sector have been actively engaged in exploring and supporting efforts to promote discover and then promote viable pathways for more sustainable forms of energy generation. These initiatives range from the huge investments that are being made to explore nuclear fusion to the development and use of solar water heaters. Motivation are not enough if products are not on the market, maintenance and service not available or grid regulations or other factors makes installation illegal or very difficult. On the other hand, a functioning manufacturing line and regulations that invites and protects will join the awareness and motivation onto a transformation to sustainability. The history of electrical energy systems is consistent in its involvement of state authority, both due the character of public utility (energy security, safety, distribution of supply) and the special production properties of high initial investments and low running cost (threat of market failure). Even if new technology often are smaller and more standardized, it is difficult to see it becoming a regime without political support. In Brazil, the relative success of wind-power and its low operices was dependent upon governmental action that opened up lock-ins, technology, entrepreneurs and a good product were not enough (Persson 2015). Regulation systems are complex and have developed together with the established supply structure and without special changes they are likely to be quite hostile or sceptical to new production technology, new structure or decentralised solutions. This is our impression so far, for South Africa, together with some success examples when special an new disconnected regulatory bodies as put up (the REIPPP process). There are also examples of lock-ins that seem very strong. The best examples are probably the problems of the local revenue systems in South Africa that relies on selling of electricity that is mainly delivered by the centralized coal-based system. On-roof local solar panels, solar water heaters and business coproduction or own production then will look like a kind of tax evasion, threatening local municipal economy and the whole system of municipal income. So far this is a strong force that easily locks local production into small niches (nice, but not threatening), and it is a combination of a regulatory setup and an income system built in the era of single state monopoly coal-based production. Also in China there was some structural lock-ins linked to distribution of sustainable energy, but our impression was that external central pressure was used on regional and sector-based units to gradually solve the problems and bottlenecks.

7. Preliminary summing up the path to sustainable energy for BASIC countries

A major factor that affects the extent to which shifts in awareness will lead to major shifts in motivation is the extent to which combinations of factors will create motivation for change that again is linked to pathways not blocked by institutional lock-ins, but rather helped by regulatory door-openers. Our discussion so far is built on general literature on sustainability, change and electrical energy systems, document analysis and around 1oo interviews in our four case countries, with China and South Africa being the most analysed. This must not be seen as final empirical results, but as opening up a discussion. Our impression is that there are few problems on the awareness stage, people are worried and have a new framing of the human/society/nature interface, and this is also coming onto the formal scene of institutions. The motivation for change seems to be dependent on specific configurations, with crisis as a major moving force (pollution in China, supply in South Africa). The social configurations that make up the motivation are composed in different ways according to local conditions. We cannot contribute with our findings to the ideological market vs state debate. Central state and political level plays very different roles in China compared to South Africa. One observation was that the Chinese consumers/citizens were not mobilized in a significant way and the actions that they even have taken (Solar Water Heaters and 200 million electrical vehicles) did not seem to be merged with political plans and actions. While both China and South Africa has market activities as important parts of the change, China seems to be top-down with planned changes (with popular support) while South Africa seems to be more bottom-up with problematic institutions at the top. At the pathways level there was difficult to find significant problems linked to technological or strictly economic factors, but market regulations setups and links to other institutional structures (like municipal taxing and financing possibilities) and manufacturing maturity seemed important. If there is one long sharp sentence that sums up our impression so far : Transition to regimes of sustainable energy for BASIC countries are possible, well backed in awareness at several levels, plays together with many other factors to create real-life motivations for change, helped forward by crisis definitions, and is dependent on pathways that must be opened and protected , including removing lock-ins, and such market and regulatory changes will, eventually create the new sustainable regimes with a new mix of interests and institutions.

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Sustainable hotels, ecocertification and the new tourism law in Greece

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Abstract

In the European Union (EU) buildings are responsible for 40% of energy consumption and 36% of CO_2 emissions. Hotel buildings, due to their specific characteristics of operation, generally have the largest ecological impact. However, only during the last years, the hotel industry acknowledged the significance of its environmental influence. Until recently, industry self-regulation developed eco-certification and labelling schemes, which although have positive impacts, were voluntary and have been mainly used, in a wrong way, just as a marketing tool for the rising market of eco-tourists. At the beginning of 2015, two new national tourism legislations were published, which at first sight define the procedure of categorizing the Greek hotels and furnished apartments for rent on different stars/keys categories. However, after careful reading and deeper understanding an important benefit arises; the transition from the voluntary "Sun and Sea" model, to a qualitative, beneficial and Sustainable tourism. This work enlightens the expected benefit on the Greek Tourism industry and the positive environmental impact emerged by the sub-criteria on these legislations. We present the minimum principles and guiding lines concerning the environment introduced in the new laws. Finally, since eco-certification is introduced for first time by a national regulation as an optional but highly rewarded criterion, we discuss the benefits of the eco-certificate adoption not only in order to comply with the other mandatory criteria of the two laws, but also to the improvement of the tourism product and the environmental influence of Greek hotel industry.

Keywords: Sustainable hotels, ecocertification, tourism law, Greece, Sustainable tourism, green key

1. Introduction

During recent decades, the European Union (EU) has set targets in order to reduce the greenhouse gas emissions (GHG) [1]. Buildings are responsible for 40% of total energy consumption and 36% of CO2 emissions [2]. Hotel buildings, due to their specific characteristics of operation, generally have the largest ecological impact, comparing with other commercial buildings.

Additionally, the tourism industry is ranked as the third in the world and as the most dynamically developing industry. In 2013, according to the annual report of The World Travel & Tourism Council (WTTC) the total contribution of the tourism industry to the global economy rose to 9.5% of global GDP (US $7 trillion) [3]. In total, nearly 266 million jobs were supported by Tourism industry, i.e. one out of every 11 jobs in the world.

While, tourism industry benefits the local economies and it is an important tool of development and employment, its continue growth simultaneously rises the need to control its' environmental impact and its sustainability. However, only during the last years, the hotel industry acknowledged the significance of its environmental influence. Firstly, industry self-regulation developed numerous certification and labelling schemes, which were voluntary and have been mainly used, in a wrong way, just as a marketing tool for the rising market of eco-tourists.

Recently, the policy in international level is aiming not only at the improvement of the tourism product in terms of infrastructure, lengthening of the operating period, encouragement of alternative tourism (eco-tourism, health-tourism, etc.) but also, on putting emphasis on environmental matters [4]. The EU Communication from the Commission (19 October 2007) was the official launching and endorsement of an Agenda for sustainable and competitive tourism [5].

At the beginning of 2015, in national level, two new tourism laws were published in the Greek Government Gazette, which at first sight define the procedure of categorizing the Greek hotels and furnished apartments for rent on different stars/keys categories. [6, 7].

This paper presents in detail the sub-criteria on these legislations which have direct positive environmental impact and benefit the Greek Tourism industry to transit from the "Sun and Sea" model, to a qualitative, beneficial and Sustainable tourism industry. Finally, since eco-certification is introduced for first time by a national regulation, this paper reviews the current status of eco-certification in the Greek tourism industry and discusses the benefits of the eco-certificate adoption.

2. The importance of Greek tourism in the Greek economy, its global share and its weakness

In the Greece of crisis, Tourism remains one of the key pillars of growth, recovery and competitiveness of our country. The data in Table 1, which summarizes the contribution of Tourism in the Greek economy, confirm the common saying that it is the country's "heavy industry" [8,9]. The significance of tourism for the Greek economy is unquestionable. Unhappily, its weakness also; the Greek tourism industry offers mainly the "Sea and Sun" product so appears big seasonality where approximately 60% of arrivals and income occur in the 3rd quarter and only 6% of arrivals and 3% of revenues in the 1st quarter [8]. This seasonality is presented in the figure 1, reproduced from the SETE 2013 report [8].

Figure 2 is reproduced by the EL.STAT. (Hellenic Statistical Authority) recently published report of 2nd quarter of 2015 for the sector of accommodation and catering services [10]. From this figure two major conclusions can be exacted:

a) The Greek tourism industry seasonality
b) The continuously increasing revenue after 2012. It appears that tourism industry is very strong against the crisis and recovers after two years of recession.

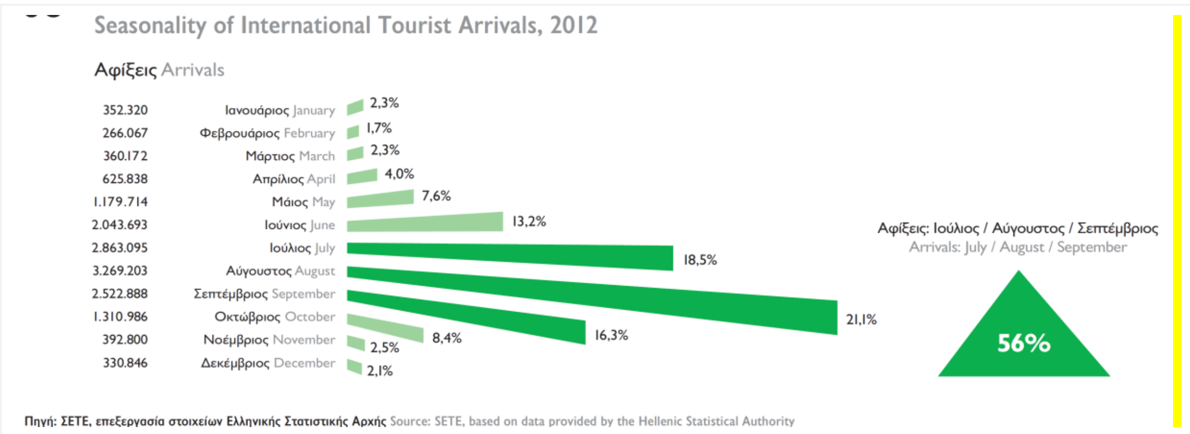

Figure 1: Seasonality of greek tourism [8].

Table 1: The contribution of Tourism in the Greek Economy (SETE Intelligence) [8,9].

Direct Contribution to GDP	9,3% (~17 billion €)
Direct & indirect Contribution to GDP	20-25%
Contribution to Employment	30% of private sector
Industry Growth	11%
2014 International Tourism Receipts	~13,2 billion €
2014 International Tourism arrivals	22 million (23% increase)
European Market Share *(Ranking)*	3,3% *(9th)*
World Market Share *(Ranking)*	1,4% *(19th)*
3 island Regions (Crete, South Aegean, Ionian) GDP contribution	50%
Each 1 € of Tourism income	2.2-2.65 € of GDP
Travel receipts from abroad covered 76% of the trade deficit.	
These receipts are nearly equal to receipts from the exports of all other products exported by the country, excluding receipts from the export of ships and oil.	

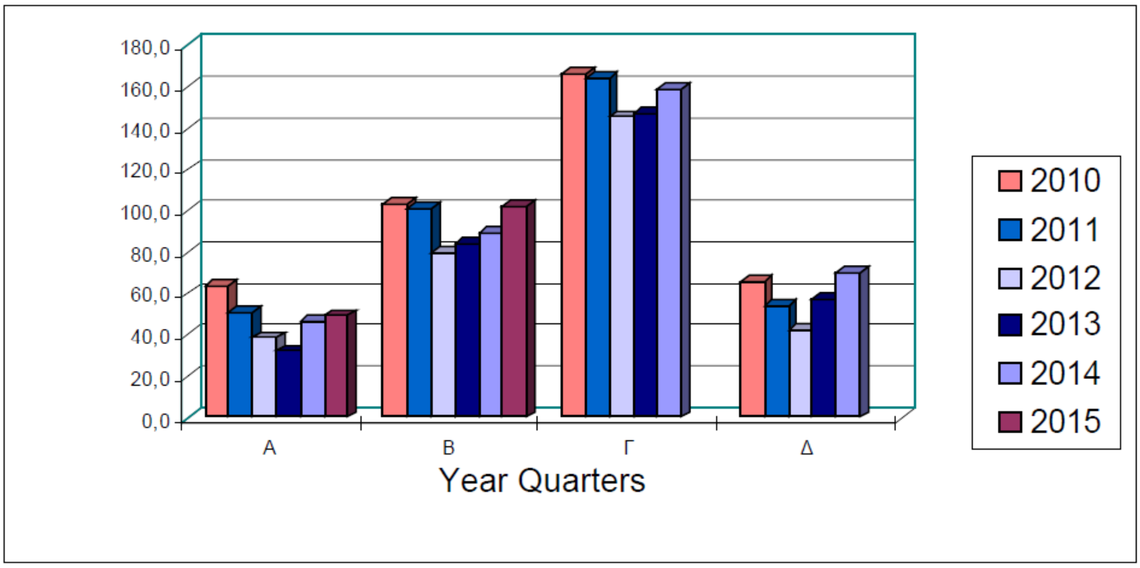

Figure 2: Revenue matrix for the sector of accommodation and catering services 2nd quarter 2015 [10].

3. The New Greek legislations

At the beginning of 2015, two new national tourism legislations were published [8,9], which at first sight define the procedure of categorizing the Greek hotels and furnished apartments for rent on different stars/keys categories. However, after careful reading and deeper understanding important principles and guiding lines concerning the environment are legislated.

In this work, we will focus on the mandatory specifications and optional criteria which have impact on the environmental footprint of hotels/furnished apartments and to their sustainability. However, it worth mentioning that most of the rest criteria not discussed here also strengthen the competiveness and the quality of the Greek industry product.

Table 2: The categorization of a hotel on a star category by the minimum required points collected on the optional criteria.

Star Category	5 *****	4 ****		3 ***	2 **	1 *
Minimum required points	5500	4000		3200	2200	1500

3.1 Greek Government Gazette (FEK) B10 - 09.01.2015, p. 31-50 [9]

In this legislation, the mandatory technical and operational specifications along with optional criteria which are awarded by a point system are introduced defining the procedure of categorizing the Greek hotels on different stars categories.

The categorization of a hotel on a star category is based on the minimum collected points according to table 2.

<u>Mandatory Criteria</u>

Building Criteria:

Criteria 1.8/1.9: Heating or Cooling in all spaces of the whole year/seasonal working hotels for the whole year (Bioclimatic buildings are excluded)

These criteria fight again seasonality of the hotels and therefore contribute to a quality, diversified tourism offering. Additionally, indirectly reinforce the bioclimatic hotels.

Criterion 1.10: Heating insulation windows with double glazing (According to “Regulation of Energy Performance of Buildings” (KENAK) [11])

This criterion has direct impact to the energy efficiency of the hotel building and the seasonality as well. In Greek tourism industry, mainly due to its seasonality many windows are with singles glasses. The mandatory replacement-upgrade to double glass will result to even 200% better insulation performance, which in turn means less energy consumption for heating/cooling and expansion of the tourist season. The importance of interaction between this legislation and KENAK law is also underlined.

Criterion 1.11: Natural lightening and ventilation at all rooms.

Within this technical criterion significant energy savings are achieved and the sustainability of the hotel buildings is fortified.

Common specifications for rooms and apartments Criteria:

Criterion 4.5/4.6: Television at least 24’’/29’’ of latest technology

Many hotels, even today, are equipped with old technology televisions which in turn mean more consumption. Latest technology televisions are usually of LED technology and surely more energy efficient than the old ones.

Other Criteria:

Criterion 13.3: Promotion of the environmental information and education of the staff – distribution of brochures

Education, Public awareness, Dispersion of environmental and social responsibility, respect on local environment and culture are among the promoted actions and values which are important for a more sustainable tourism model.

<u>Optional Criteria (point awarded)</u>

Building Criteria:

Criterion 1.5: Electric Car Station

Points: 100

Although this criterion has not direct environmental impact, it has indirect since socializes the electric cars, which are the “green” solution of mobility for a sustainable future without fossil fuels.

Common Areas Criteria:
Points: 100

Criterion 2.19: Natural lightening of the multiple purpose room (conference, etc)

As in Criterion 1.11, energy saving and sustainability are promoted.

Common specifications for rooms and apartments

Criteria:

Criterion 4.6: Television at least 29’’ of latest technology

Points: 100

This mandatory criterion for >3*** hotels gives extra points on the 1 and 2 ** hotels.

Criterion 4.24: Automatic setting of temperature at the rooms (in the case of central heating).
Points: 100

Many of the costumers use to overheat or overcool their room, which leads to an increased consumption of energy. By adopting this criterion energy saving is achieved.

Special Certifications Criteria:

The significant in this category is that every available standard – certification is multiplied by the relative point subcategory. So, if a hotel has more than one certification gets multiple points.

Criterion 10.1: Development of environmental services – standards.

10.1.a: ECOLABEL, EMAS, ISO14001.

Points: 200

Adopting environmental policies is introduced for first time by a national regulation as an optional but highly rewarded criterion (200 points).

10.1.b: GREEN GLOBE, GREEN KEY, TRAVEL LIFE or other special public or private certificates

Points: 150

More points are rewarded to the hotels, if they be certified on more eco-labels. Any of them, due to their requirements will also improve the energy footprint of the hotels.

10.1.c: biological agricultural or use of biological products

Points: 150

One more criterion for the environmental influence and the sustainability of the services.

Criterion 10.4: Certification of the social corporate responsibility by ISO26000 or relevant standard.
Points: 100

Part of the social corporate responsibility is the Sustainability of the product and the environmental impact minimization.

Criterion 10.5/10.6: Accession in the “Greek breakfast” program [12]/special quality signal of Greek cuisine or certification of regional cuisine
Points: 150

This criterion focuses on giving back to local society.

3.2 Greek Government Gazette (FEK) B2840 - 22.10.2014, p. 34499 – 34506 [8]

Similarly to FEK B10, the mandatory technical and operational specifications along with optional criteria which are awarded by a point system are introduced defining the procedure of categorizing the furnished apartments for rent on different keys categories. The categorization on a key category is based on the minimum collected points according to table 3.

Mandatory Criteria

Building Criteria:

Criterion 19: Heating / Cooling or/and air condition or/and roof fans.

Again the season is expanded by adding heating and the apartments can operate 365 days per year. Additionally, roof fans assist on the energy saving, while according to the new EU standards air conditioners and other heating/cooling devices, such as heat pumps, should have ERP labels, be energy efficient and use ecofriendly coolants.

Other Criteria:

Criterion 81: Information for visitors concerning policies relevant to environment protection, which they can utilize during their staying.

This mandatory criterion shows the government policy for the transition from the “sun and sea” model to a more qualitative and Sustainable tourism product.

Optional Criteria (point awarded)

Building Criteria:

Criterion 18: Heating insulation windows with double glazing (According to KEKAK [11])

Points: 100

Table 3: The categorization of a furnished apartment on a key category by the minimum required points collected on the optional criteria.

Key Category	3 keys	4 keys
Minimum required points	3500	5500

As mentioned for the hotels this criterion has direct impact to the energy efficiency of the hotel building and the seasonality. It is a chance for furnished apartments to upgrade their windows and achieve better service, energy savings and longer seasons.

Specifications for room equipment:

Criterion 31: Flat Television at least 22''

Points: 100

Many of the apartments for rent even today use old type televisions, which are more energy consuming than the new ones (up to 200%). Following this criterion, the replacement with new technology TVs gives 100 points, but also assists in the energy saving of the apartments for rent.

Other Criteria:

Criterion 82: Use of ecofriendly cleaning products

Points: 50

National and international policies become more sensitive on environmental issues.

3.3. The opportunity from FEK B10-2015 and FEK2840-2014

In the previous two paragraphs (3.1 and 3.2) we presented in detail the specific criteria from the two new legislations that have direct impact on the energy footprint of hotels/apartments for rent. Each criterion, as described, has a certain effect with bigger or smaller energy saving result. The important thing however is the spotlight of a strategic plan towards a Sustainable Tourism. Until today, although most of researches show that costumers/visitors prefer tourism products that are respecting the environment and have social responsibility [13, 14], the transition to a more eco-friendly tourist product has not been achieved mainly due to the following reasons:

- The hurdle of the new
- Economic cost of renovation or energy upgrade
- Not efficient communication or bad marketing
- General Government policy missing or not communicated effectively

The two new legislations give the opportunity to fight against these restrains. There is a clear turn on the government's policies to more environmental friendly tourism products and services. This develops a new Sustainable tourism scheme, where gradually the hotels that do not progress in terms of competiveness, quality of services and social responsibility will be not selected by the visitors. Additionally, to the "market hand" the new legislations set up the minimum rules and all hotel/apartments for rent owners should comply with the new standards. Taking in mind that more EU standards are set up in most of the products sold in EU, in order to improve quality, procedure and environmental footprint, then in the Greek tourism industry, as a part of EU, the road of service improvement is now more wide open than ever.

Finally, the introduction of eco-certifications due to their requirements generates more opportunities and advantages for the Greek tourism industry, which will be presented in the following paragraphs after a short review of the current eco-certification status.

4. Eco-certificates and the status of the Greek ecocertifcation on tourism industry

Criterion 10.1 gives considerable points (which can be also combined by adopting more than one certification) for the development of environmental management systems and sustainable tourism policies. It is divided in three different subcategories, mainly due to the different origin, nature and result of certification.

On sub-criterion 10.1a the certification by ECOLABEL, EMAS, and ISO14001 is awarded by 200 points. There are mainly two reasons for dividing criteria 10.1a and 10.1b. The first one is that ECOLABEL and EMAS have EU validity and the ISO is internationally recognized while the other certifications of 10.1b are certifications of private bodies mainly. The other distinction is between process and performance. Certificates listed on 10.1b are awarded on hotels which comply with a baseline of standards towards to sustainable or ecotourism, while the process is not always sufficient for energy saving or sustainability and depends on self-regulations.

There are numerous different sustainable tourism certification systems, awards and ecolabels. Only the "Eco Label Index" [15] search tool lists 426 different green logos globally, 52 of them certifying tourism products and services, without listing few of the most known on hotel eco-certifications or management systems. The most well-known eco-tourism label logos are presented in Figure 3; In the light green rectangle the 24 eco-labels for products/services (general) in Greece (according to [15]) are gather together, while in the dark green rectangle the most famous green certifications only for hotel industry in Greece are included. There are several studies describing the different eco-certificates for hotels [16-19], while more information for each one can be found on the relative websites. Their penetration to each country depends on several parameters, such as the country's special culture and requirements, the promotion by the Tour Operators, and others.

Reasonably, the plethora of different certificates makes confusion to hotel owners and visitors/costumer about how they differ and which one is appropriate for each business. It is beyond this study to present in detail every aspect of each certificate.

Figure 3: Different green certification logos.

However, in most certificates there are many similarities on general aspects and differentiate between each other on qualitative features. The common characteristics are:

i) Voluntary membership accompanied by a published environmental commitment

ii) compliance with local regulations

iii) well - defined standards and criteria usually according to the environmental management system for energy, water, pollution, etc.

iv) scoring, reporting, periodic auditing for renewal or verification system as a guarantee that standards are met

v) facilities to provide technical assist to organizations to achieve goals

vi) Transparency and publicity

vii) recognition and awarding the use of a logo which is recognized by consumers, differentiating the sustainability

viii) Eco-certificates provide numerous benefits for the certified hotels in terms of marketing, sustainability and money saving, as it will be presented in the paragraph 4.

Even before the legislation of the two new tourism laws, there was an increase on the eco-certified hotels in Greece. Table III summarizes the certified hotels from each eco-certification, according to the officially published data on the websites of the certification bodies. Only around 250 hotels are currently certified by at least one eco-certificate in Greece. This number is even less than 1% of the existing hotels in Greek territory, while globally the eco-certified hotels are more than 14% (2013) [14]. The main reason is again economic crisis and that the Greek islands “sell” easily their unique “sun and sea” product. However, the eco-certified number is increased more than 20% during the last year and it seems that there is a clear increasing trend. The new laws will contribute definitely on the better and faster penetration of eco-certification in the Greek tourism industry.

5. Benefits of certification for sustainable tourism

Certification is only one of the tools for motivating hotel businesses and visitors to improve their environmental, social, and/or economic performance. According to the Travel website TripAdvisor which has surveyed over 35,000 travellers and accommodation owners from around the world to compile the TripAdvisor TripBarometer report, 79% of travellers worldwide say that eco-friendly practices are important to them [14]. The adoption of certification from a reliable certification body ensures the quality and sustainability of the hotel and helps tourism businesses to be distinguished from others that make empty statements.

The certification procedure benefits the business itself, the costumers and the society. Table V summarizes the multiple benefits of certification for sustainable tourism and the interactions. For each benefit of the certified hotel, a relative benefit arises for clients and society. Therefore, each row of Table V can be read for example for row one as: Eco-certification procedure helps hotel industry to self-improve and results in better services provided to the clients and benefits for environment and local communities.

6. Proposals - Conclusions

Eco-certified hotels contribute to the environmental protection and reduce the energy footprint of the hotel building, which, as already mentioned, has large ecological impact. Especially, in Greece where most of hotels are small medium enterprises and due to the crisis not many new buildings are constructed, there is a need of renovation of the existing hotel buildings in an eco-friendly way. Until now, this was partially promoted by the implementation of the Energy Performance of Buildings Directive (EPBD) after the launch of the new “Regulation of Energy Performance of Buildings” (KENAK) in 2010 [11]. The minister decision set the minimum requirements in order a new or renovated building receive the Energy Performance Certificate (EPC).

Table 4: The number of certified hotels and B&Bs by each certificate.

Green Globe	1
Green Key	130
Travel life	38
Ecolabel	2
Green leaders	several
NeZEH	1 (EU funded Program with pilot case)
other	

Table 5: Correlation of multiple benefits of certification for sustainable tourism for the parties involved.

Hotel industry	**Visitors/ clients**	**Society/ government**
Self-improvement	Better services	Benefits for the environment and local communities
Education	public awareness	protect market niches as ecotourism or sustainable tourism destinations
Process development – better operation	Better services	
Reduction of operational costs (water, electricity, and fossil fuels)	Better quality of service	Lowers the regulatory costs of environmental protection.
Access to new, more efficient technology	Better quality of service	Protect the environment
Access to low cost financing	Continuously development and upgrading of services and buildings	Likely to continue offering benefits for the long term
Marketing – reputation & popularity	Environmentally & socially responsible choices	
Social responsibility – relative actions	Alerts to the environmental and social issues of each place. Act more respectfully or even contribute to solutions	Raises industry standards in health, safety, environment, and social stability
Local economic benefits	Give back to society, reduce poverty	Respect local culture and provide real economic and social benefits

Of significant importance are the policy interactions for promoting energy efficiency in the Hellenic sectors of buildings in general, with the two new legislations for hotels in particular.

In order to achieve energy efficient hotels, several actions should be carried out. The relevant technologies and solutions can be gathered in the following five groups: energy management, reduction of heating and cooling demands, equipment efficiency, system efficiency and renewable energy system installation.

The economic crisis, the political uncertainty, and the overtaxiation make difficult to the Greek hotel owners to invest more than the “necessary” in their hotel building facilities.However, there is some good news:

a) The Greek hotel industry rises [8-10]

b) Most of the energy efficiency and sustainable actions can be financed by EU co-funding programs. Especially hotel industry is always included in the strategic sectors at every National Strategic Reference Framework (NSRF). The main targets are to make the Greek tourism industry more competitive, more sustainable and enrich the tourism product. It worth mentioning that a special program has been launched in the previous NSRF for “Green tourism” and more than 100 project financed with more than 17 million €.

c) Greek banks have commercialized special products of “green renovation”.

d) The two new legislations for hotels and apartments for rent clearly demonstrate the strategic plan to integrate the actions arising from KENAK, improve the energy efficiency of the hotel buildings and enrich the sustainability of the Greek tourism industry product. The requirements described in the laws have to be applied in every hotel/apartment until 31.12.2017. This deadline will accelerate the slow turn of the Greek tourism industry to more Sustainable services.

One of the most important issues addressed in the two new legislations is the optional certifications of environmental management systems and sustainability as highly rewarded criteria for first time by a national regulation. Even better, the law not only is not against affiliating more than one certification program, but, on the contrary, rewards with multiple points the affiliation of multiple certificates in order to achieve a better score on the star/key pointing system. Moreover, with visitors/clients becoming more eco-friendly and eco-wary, the sensible hotel businesses will align with at least one certification program and its certified sustainability efforts will set it apart from all the others who have done nothing. Additionally, the benefits for the hotel when obtaining an eco-certificate are numerous and fascinating, as presented in the relative section. The investment to achieve and retain a green certificate is depreciated fast and gives back multiple times the investment in terms of cost reduction, environmental protection, local economy support and new clients.

Another significant profit for the Greek tourism industry by adopting sustainable practices is that this will lengthen the season. As already presented in paragraph 2, the main weakness of Greek tourism industry is the seasonality, which otherwise is standing very high on the European and Global market (TOP 10 and TOP20 respectively) [8,9]. However, looking closer in Figure 2, an increase appears even on the revenues of “off season” quarters (1^{st} and 4^{th}). This has been partially achieved by industry self-improvements and by the strategic actions and policies carried out during recent years. Still, additionally to the strategic policies, several more aspects have to be fulfilled in order to achieve the goals:

- Political and economic stability
- Long term planning
- Achieving an appropriate pace of development
- Access to low cost financing by banks
- Ensure that tourism respects the society, the environment and the local destination specificities and set the relative limits
- Compliance of the laws and standards both by hotel owners and by the government
- Use of new technology which incorporates the best available knowledge
- continuous best effort
- education and public awareness
- A European or national eco-certification or standard might be a worthwhile addition to the green certification mix.

Most of Greek and EU tourism strategic plans try to anticipate the above aspects and reinforce the tourism product in terms of competitiveness, sustainability and simplify procedures. The introduction of the new tourism laws is one more step at this direction and sets a new status with new possibilities and opportunities and contributes to the transition from the old model of “Sun and Sea” with voluntary environmental engagements, to a diversified, multi-disciplinary and Sustainable tourism.

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Identification of knowledge needs on climate policy implications through a participatory process

by

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Abstract

Climate change mitigation efforts are currently intensified at an international level, as parties focus and coordinate their efforts towards an international agreement. Within this constantly changing political scenery of negotiations, policy makers need improved knowledge transfer and uptake, in order to be able to design solid policies and develop clear understanding of options and their possible impacts. This paper presents a methodology for identifying knowledge gaps and implications of possible directions of EU and international climate policies, through a participatory approach of high-level stakeholders' engagement, involved directly or indirectly in the process of policy making. Stakeholders were identified through tailor-made mapping, contacted, invited and engaged in the consultation procedure. The final group of key stakeholders consisted of 39 experts, with a balanced representation of 14 European countries, several types of organisations and sectors and mainly occupied at high-level governmental positions, NGOs, research institutes or the business sector. The proposed methodology consists of a preparatory dialogue with stakeholders, followed by bilateral or group interviews facilitated by a questionnaire developed for this purpose. Results are then presented to stakeholders and validated through a series of workshops. The final outcomes are also analysed statistically in order to lead to the identification of priority issues of knowledge need. This participatory procedure allowed the identification of a series of sectors, where climate policy is expected to focus on in the future and specific topics upon which knowledge gaps are expected to appear, as well as a specification of a set of requirements regarding knowledge presentation. A key element of this approach is the consideration of high-level stakeholders' feedback on their specific area of expertise, instead of general public engagement, therefore leading to more accurate results.

1. Introduction

The international community has currently intensified its activity towards a collective response to climate change (Dröge and Spencer, 2015). Mitigation efforts have been focused on limiting global average temperature increase to less than 2°C compared to pre-industrial levels, by reducing greenhouse gas emissions (UNEP, 2010). Moreover, in light of the forthcoming 21st Conference of the Parties (COP) to be held in December 2015 in Paris, adaptation of societies to existing climate changes is also in the spotlight of future negotiations (Haites et al. 2013, Morgan et al. 2014). According to the outcomes of the Climate Conference of Cancun in 2010, such efforts must take into consideration the situation of each party, its needs and potential (UNFCCC, 2015c, d, e).

Developed countries face a great challenge in restructuring their industrialized economy into a decarbonized system and adopting new consumption and production patterns. Developing economies, on the other hand, are concerned that a low-carbon oriented route might jeopardize their economic development aspirations and endanger their efforts to escape poverty. Intended Nationally Determined Contributions (INDCs) that outline the post-2020 climate actions that parties intend to take under a new international agreement, are being prepared and submitted (UNFCCC, 2015a, b, Dröge and Spencer, 2015). The way in which climate change measures should be embedded in domestic economic, environmental and social priorities, however, is not strictly defined. INDCs will be summarized and published by the United Nations Framework Convention on Climate Change (UNFCCC) secretariat in advance of COP 21, in order to give an indication of the cumulative impact of all these efforts, as the international community has not yet reached consensus on the way the cost of mitigation efforts and the level of ambition will be distributed among parties.

However, as countries focus and align their endeavours towards the achievement of a binding global agreement on climate, the constantly changing political scenery of climate negotiations imposes the need to provide policy makers with solid and accurate knowledge (Ecologic, 2014). The internationally shifting policy scenery that creates uncertainties about the shape of future, policies could have an impact on European Union (EU) policy and decision makers. EU policy makers face uncertainties regarding different possible international climate policy scenarios and the impacts they could entail for EU society, business, Member States and EU as a whole, in terms of economy, society and the environment (Moarif, 2015, Climate Strategies, 2014). An evidence-based approach is needed in order to enable them deliberate on these different scenarios and even learn from design and implementation of climate policies worldwide.

As a consequence, exchange of information about climate policy and knowledge transfer among stakeholders need to be facilitated in order to offer clear understanding of current regimes, their possible directions, implications and consequences and to render them capable of taking well-informed, consolidated decisions based on up-to-date reliable facts (Ecologic, 2014, Fujiwara, 2013, Karakosta et al. 2010, Doukas et al. 2010).

The first step of achieving such a cause is to identify knowledge needs among stakeholders, concerning both, knowledge gaps as well as knowledge presentation requirements. Knowledge gaps can either mean lack of awareness of existing knowledge, or actual absence of scientific analysis regarding an issue.

This paper presents a methodology for identifying knowledge gaps on implications of possible directions of EU and international climate policies, through a participatory process of high-level stakeholders' engagement. This participatory procedure allows the identification of a series of sectors, where climate policy is expected to focus in the future and the definition of specific topics upon which knowledge gaps are expected to appear. Specification of a set of requirements regarding knowledge presentation also emerges as an outcome. A key element of this approach is the consideration of high-level stakeholders, involved directly or indirectly in the process of policy making and capable of providing feedback on their specific area of expertise, therefore leading to more accurate results.

Following this introductory section of the paper, a literature review is provided on the integration of participatory processes in knowledge need identification. The proposed methodological approach is then presented, offering a step-by-step analysis of the successive stages. Results deriving from the methodology application are outlined, as well as relevant further discussion, while conclusions are drawn at the final section of the paper.

2. Integration of participatory processes in knowledge need identification

The element of active involvement of a group of people in the process of decision making constitutes the core characteristic of a participatory approach. The synthesis of the group varies depending on the topic addressed and can be comprised by regular citizens, experts, government members, industry representatives or stakeholders of any kind with an interest in specific policies (Slocum, 2003, Mc Taggart 1997, Pedrosa et al. 2006, Weaver and Cousins 2004).

Participation of stakeholders consists in the process of affecting and sharing control over certain initiatives, as well as the decisions and resources that influence them (African Development Bank, 2011). According to the aim of the approach, stakeholders can participate at different levels. The objective of the process could be simple conveyance of knowledge that would imply a one-way participation, or consultation, which requires bi-directional participation. It could also be the fostering of active participation, calling for a partnership in which all interested parties would actively debate (Slocum, 2003), (Biggs, 1989).

A participatory process initially contains the identification of suitable stakeholders and relevant information provision. In the case that multi-directional participation is desired, the researcher should gather their feedback and listen to their opinions and involve them in the decision-making process. The results would then contribute to their capacity-building in order to render them capable of managing their own self-development (African Development Bank, 2011). As validated by Krywkow et al. (2008), four main phases can be recognized in participatory processes:

- Preparation, including the analysis of the problem and the stakeholder layer, as well as the development of a draft plan of the participatory process;
- Publication, during which stakeholders become initially familiar with the problem and the plan;
- Dialogue, through which stakeholders are provided with more solid information and contribute their knowledge and additional input on unraised issues;
- Response, closing the process by educating participants and validating the results.

According to Pedrosa, et al. (2006), participatory approaches can be useful tools in facilitating a wide range of different purposes. Firstly, they can effectively frame the identified problems and map the associated causes and effects, as well as possible future actions and developments, based on stakeholders' opinions.

Their application can also improve available information, facilitate communication and support participation towards knowledge production, as well as enhance policy-making with views that may not have been taken into account. The participation of multidisciplinary stakeholders also offers diversity to the analysis, as people characterized by different levels of expertise and of various backgrounds are represented and taken into consideration.

Participatory approaches can also lead to the optimization of existing processes in the field of learning, by making stakeholders aware of risks and possible implications of the situation under examination and by pointing out knowledge gaps and limitations.

Participatory processes have been widely applied on a diverse range of topics and problems, deriving from different fields of research. Such topics may range from assessing ethical aspects of certain activities, fostering dialogue among stakeholders of different groups (Kaiser and Forsberg, 2001), to the improvement of working by engaging workers in participatory ergonomic processes (Laitinen et al. 1998). Regarding climate and environmental issues, Scholza et al. (2004) have applied participatory analysis in order to integrate local ecological knowledge into marine protected area policy planning processes.

Indicators of progress monitoring in the field of sustainable development have been identified through participatory process application (Fraser et.al, 2006, Chiranjeewee and Harald, 2012) while participation of stakeholders has also been used for identifying and prioritizing policy-relevant research questions in natural resource management (Petrokofsky et al., 2010).

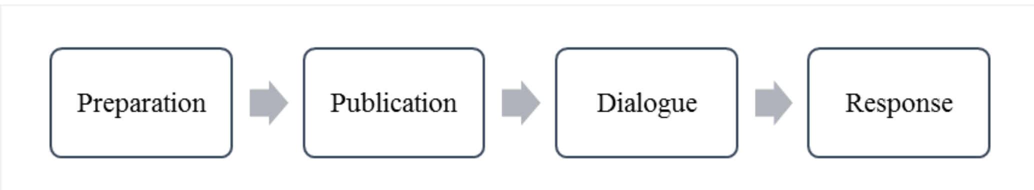

Figure 1: Main phases of participatory processes.

In the field of knowledge need identification, a limited number of studies that integrate participatory approaches have been developed. Indicatively, Palacios-Agundez et al. (2014) identified a knowledge gap on the synergies and trade-offs between biodiversity and carbon storage, during a participatory process conducted to develop a community vision for a region's sustainable future. Dicks et al. (2013) engaged representative participants from industry, environmental NGOs and nature conservation agencies into a collaborative exercise of identifying knowledge needs regarding insect conservation in the UK. An extensive list of knowledge needs was initially developed and later collaboratively refined and narrowed-down through a three- stage participatory process in order to produce the final top priority knowledge needs. A participatory methodology has also been developed in the context of a collaboration among UNFCCC, the United Nations Environment Programme (UNEP), the Global Adaptation Network (GAN) and the International Centre for Tropical Agriculture (CIAT) towards the identification and prioritization of knowledge gaps in climate change adaptation in the particular area of the Andes, by engaging multidisciplinary groups of stakeholders (Jarvis, 2015).

Knowledge needs and gaps, however, are more often identified by extensive literature review and use of existing bibliography, articles and reports on the field of study that is under examination (Wisdom et al. 2006, Frymus et al. 2013, Ezzati & Kammen, 2002, Wijnhoven et al. 2009, Chapman et al. 2009).

As a result, to the best of our knowledge, never in the past had a participatory approach been designed and applied in order to identify knowledge needs and priorities on EU and international climate policy implications, by consulting with high-level experts involved in the process of policy making itself. The participatory approach developed and presented in this paper employs tools such as questionnaires and structured interviews with identified high-level experts in order to derive preliminary results on key knowledge needs and priorities on climate policy implications, after analysing the feedback acquired. The results are then presented to stakeholders during thematic workshops and validated through the sessions. Key topics where knowledge needs arise are finalized and a set of requirements regarding knowledge presentation is defined.

3. Methodological approach

3.1 Overview

The methodological framework introduced by this paper consists of a series of concurrent and consecutive steps, as illustrated in Figure 2 and analysed in the following paragraphs. An initial desk analysis identified a range of priority issues related to climate policy making that served as a starting point for the participatory process. In parallel, key stakeholders mapping was conducted in order to form a database of potential participants. Preparatory material was subsequently developed in the form of a questionnaire, in order to be completed individually by stakeholders and also to facilitate discussion during interviews. Stakeholders were then invited to partake in the procedure and their interest was confirmed. Self-filling in of questionnaires and conduction of interviews took place in parallel. Feedback analysis provided preliminary results that were presented to selected stakeholders during thematic workshops conducted within the framework of the EU-FP7 "Mobilizing and transferring knowledge on post-2012 climate policy implications (POLIMP)" project. Results' review and validation through the workshops led to the identification of a finalized set of knowledge gaps and needs on EU climate policy implications.

Desk Analysis: Initial Key Topics identification

A range of knowledge gaps will be identified for a series of issues of priority, related to climate policy making. The final determination of these issues will be conducted in collaboration with stakeholders and through their participation. However, a range of priority issues had to be initially set as a starting point for discussion.

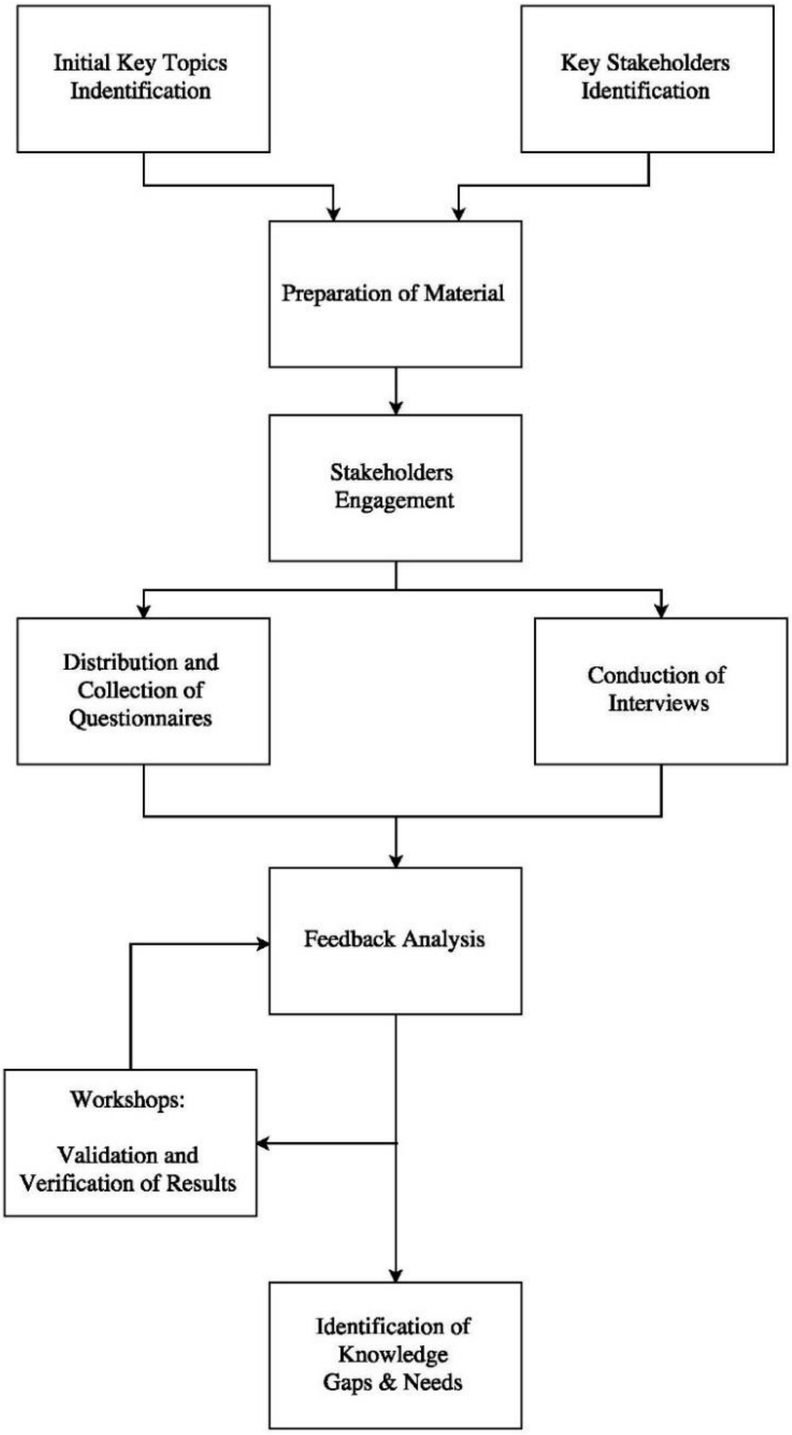

Figure 2: Stages of the proposed methodology for identification of knowledge gaps and needs.

A desk analysis including extensive literature review, as well as close monitoring of current developments in climate policy, led to the identification of eleven main topics, constituting an initial thematic area, based on which, the knowledge gap identification procedure was structured. Further examination on current policy developments on the above main topics and of possible projections of their future development published or estimated, enabled the recognition of further possible issues of core importance and interest for the following years. Such issues regard, among others, different aspects in the framework of which analysis can be performed, sectoral breakdown of main topics and different phases of policy making. Thirty relevant issues of interest were identified, while 4 to 6 corresponded to each main topic. Several issues appeared in more than one issues. The relevant issues of interest and their adjacency to the main topics of interest identified are presented in Table 1.

Stakeholders Mapping

Stakeholder participation in the UNFCCC negotiations has continuously increased over time. A wide range of governmental stakeholders interact on multiple levels (international, multilateral, national and sub-national) and provide different types of inputs. (Michaelowa et al. 2013). Apart from government representatives, other groups of interested parties also get involved in a direct or indirect way, in the UN climate change negotiations.

The issue of climate change has an impact on several aspects of life and the economy, and as a result, a large number of diverse interest groups try to influence the negotiations and have been actively involved in them (Willetts, 1996; Charnowitz, 1997; Raustiala, 2001; Willetts 2002; Betzold 2012, Michaelowa et al. 2013), although their role at the negotiations is only observatory and does not involve any partake in the decision making process.

Such categories of observer organizations include UN bodies and secretariats, such as UNEP and the United Nations Development Programme (UNDP), specialized international agencies, Intergovernmental Organizations (IGOs) and Non-Governmental Organizations (NGOs).

Stakeholder selection is crucial for the outcome of any participatory process (Kok et al. 2007). The EU is the only regional integration organization recognized as a party to the UNFCCC and the Kyoto Protocol itself. Being unique in all aspects, the EU cannot be considered as a 'state' or as an 'international institution', as it is a coalition of supranational along with intergovernmental attributes (Hix, 1999, Michaelowa et al. 2013).

Table 1: Main topics and relevant issues of interest.

Main Topics	**Relevant Issues**					
Renewable Energy	Support Systems	Costs & Benefits	Acceptance	Grids	Environment Impacts	
Energy Efficiency	Policy Mix	Costs & Benefits	Buildings	Industry	Barriers	
Transport	Technology & Innovation	Costs & Benefits	Policy Mix	Barriers	Drivers	
Emissions Trading	Implementation	Costs & Benefits	Technology Innovation	Reform of EU-ETS	International Context	
Industry	Policy Mix	Costs & Benefits	Green IT	Potential	International Context	
Adaptation	Financing Instruments	Mainstreaming	Costs & Benefits	Public Participation	Evidence Base	
Agriculture & Forestry	Bioenergy & Biomass Use	Land Use Change	Consumption Patterns	Valuing Ecosystem Services	Increasing Farm Efficiency	Support
Financing	Financing Needs	Costs & Benefits	Policy Mix	International Context		
International Climate Negotiations	Mitigation	Finance	Mechanisms	Adaptation	Regime & Institutions	
Energy Policy	Energy Markets	Costs & Benefits	Technology & Innovation	Grids	Security Of Supply	Risks & Uncertainty
EU Climate Policy	Post-2020 Targets	Costs & Benefits	Policy Mix	Link To Energy Policy	International Context	

Therefore, it was considered necessary to include a wide variety of stakeholders representing all four groups suggested as essential for participatory processes: policy makers, business representatives, citizens, and experts (Andersen and Jaeger 1999, Kok et al. 2007)

The list of stakeholders was drawn up by the contact database compiled within the framework of the POLIMP project. This fact ensured that selected participants would be actively involved in the field of climate policy and would be directly or indirectly impacted by the future direction of international climate policy making and the way it affects EU climate policy making.

Preparation of material

The knowledge need analysis is performed via a descriptive survey, where a small sample of the concerned population, is used to describe the wider concerned group that, in this case, includes policy makers and other stakeholders in European climate policy (Ecologic, 2014). In order, however, to be able to draw generalised conclusions from the findings of the knowledge need analysis, it is needed to design and employ an appropriate research scheme and methodology (Oppenheim, 1992).

Interviews are reported to have some advantages over plain questionnaire-completion by the participants themselves (Phellas et al. 2011). The interviewer can explain questions that the respondent has not understood or ask for further elaboration of replies. The interview is more flexible and gathers information that is more sensitive to contextual variations in meaning. Completion of questionnaires, however are less prone to bias that can be introduced by the interviewer and are more time-efficient for the respondent, as well as the researcher himself, while enabling the acquisition more data of quantitative nature (Phellas et al., 2011, Ecologic, 2014).

The methodology proposed in this paper involves the preparation of a tailor-made questionnaire for the identification of knowledge gaps regarding climate policy implications for the EU. This questionnaire was used both for direct completion by stakeholders and as a guide for the conduction of interviews. It is envisaged that this combination of the two methods also combines makes the most of their advantages. The questionnaire was also developed in an online form in order to facilitate stakeholders in their responses and also to serve as preparatory material for interviewees who wished to be informed on the interview structure beforehand. In addition an online completed form enables the easier and more credible analysis of responses, with the use of online analytics tools.

The questionnaire was compiled in English, as it was a common language of communication among stakeholders. It initially contained some general questions about the frequency with which additional information is needed to help stakeholders in their work, the exact task they need it for, as well as their success in finding it.

The second section of the questionnaire was targeted to achieving better understanding on the way interested parties search for additional information and how they intend on using it. These questions regarding searching and use of information mainly focused on search techniques and tools, sources of information, desired presentation and form of acquired information, as well as the language they are found in.

The third and main part of the questionnaire was dedicated to the knowledge needs themselves and followed a top-down approach to specify as much as possible existing knowledge needs. As previously mentioned, the identification of knowledge needs was structured on eleven main topics, defined by literature review. Stakeholders are, at this stage, requested to declare their area of expertise, by choosing one or two out of the eleven main topics. For each of this main topics, a series of relevant issues (4 to 6) were presented, as they were identified in Table 1.

Stakeholders had to select two to three of these issues that they consider of great importance and that they envision to be personally focusing on the most in the next years. At this point, stakeholders were asked to contribute by specifying the additional information they expect to be seeking for, per selected issue and to rate a predefined list of subtopics per issue on a scale from 0 to 5, according to the extent that they personally expect to be seeking additional information on.

A zero response corresponded to “I will not need additional information about this” while a five meant: “I expect to need a high amount of additional information about this”, respectively. The abovementioned top-down session is illustrated in Figure 3.

During the final session, stakeholders were asked to express their point of view on a series of questions regarding knowledge needs in society as a whole. Main subjects concerned their opinion on whether lack of knowledge impedes policy design, as well as whether they personally acknowledge the existence of real gaps in scientific knowledge. The session concluded with the provision of some additional information of personal and professional nature, regarding stakeholders' nationality, age and mother tongue.

Stakeholders Engagement & Participation

Identified key stakeholders were invited to collaborate and provide their insights through their participation in interviews or by filling in the online questionnaire. An initial contact by e-mail was followed by an official invitation upon positive reply, accompanied by relative introductory and informative material. Stakeholders then confirmed their participation and stated their preferred way of involvement.

Telephone communication was established with participants that accepted a bilateral interview in order to make necessary arrangements, according to their availability. In the case where completion of questionnaires was selected, these were received by e-mail within a pre-set timeframe, or electronically retrieved by the dedicated online page.

Interviews were conducted with 12 stakeholders, while 27 stakeholders filled in the online questionnaire. The structure of the interviews and the online questionnaire was similar. Considering the nature of both methods, the expert interviews have focused more on qualitative information and further analysis with regard to the methods for searching information, the needs for types of knowledge presentations and the knowledge needs themselves.
On the other hand, the online questionnaire resulted in more quantitative data, identifying the range of knowledge needs that exist among stakeholders.

Stakeholders that contributed to the process came from 14 different Member States of the EU, while 11% came from countries outside the EU. Participants from Western Europe populated 53% of the sample, while 19% were from Central and Eastern Europe and the rest 17% from the Southern part of the continent.

Although the main target audience constituted of policy makers within the EU, it is recognized that stakeholders from non-EU countries can also impact policy design at an EU and wider level. For the majority of participants, their country of origin coincides with their country of residence. Belgium, however, forms an exception: of the six stakeholders who declared Belgium as their residence, only two were Belgian citizens.

Level 1: Main Topics

Question*: Which are your areas of expertise, from the list provided?*

Choose 1-2 of 11

Level 2: Relevant Issues within the areas of expertise

Question: *Which issues do you expect to be focusing on during the following 3 years?*

Choose 2-3 of 4-6.

Level 3: Subtopics (per issue, within each area of expertise)

Question: *To what extent to you personally expect to be searching for additional information on each subtopic?*

Rate on a scale from 0 “I will not need additional information” to 5 “I expect to need a high amount of additional information”.

Figure 3: Levels of questions regarding knowledge needs, structured by a top-down scheme.

However, with Brussels hosting the headquarters of many European institutions, this fact can be justified.

From a demographic point of view, the sample was populated by women at a 36% rate. The vast majority of participants was aged between 30 and 50 years old, while 8% was younger and 13% older that than age group. Linguistically, German were the most frequently declared as mother language among stakeholders, followed by Dutch, English, Greek and Polish. Approximately 60% claimed to have average, or higher competency in English, while 59% claimed to be proficient.

The stakeholders are employed at different types of organisations. 34% of the respondents work for NGOs, 24% for governments at European, Member State level or at subnational level. A further 24% is occupied in the business sector (including commercial consultancies), while 10% are employed by research and institutions. The remaining 8% works for other types of organisations.

Feedback Analysis

Responses to interviews as well as questionnaire submissions were collected and statistically analysed in order to identify knowledge needs and derive conclusions. Although the expert interviews focused more on qualitative information as well as providing feedback regarding the methods for searching information, knowledge presentation requirements and the knowledge needs themselves. On the other hand, the online questionnaire resulted in more quantitative data, identifying the range of knowledge needs reported by respondents.

Regarding the stakeholders' area of expertise, it was observed that "Renewable Energy" and "EU Climate Policy" were the most popular main topics, followed by "International Climate Negotiations", "Energy Policy" and "Energy Efficiency". The full configuration of selected areas of expertise is illustrated in Figure 4. After narrowing down the areas of expertise that were mostly selected, the most popular relevant issues per main topic were identified. Issues with little or no selection by stakeholders were discarded, as it was considered that stakeholders will not be focusing on them in the following years. For the most popular relevant issues, several subtopics were rated from a scale from 0 to 5, according to the extent to which stakeholders expect to be searching for additional information on. Scores per subtopic were calculated, by multiplying each score of the scale with the frequency it was selected by stakeholders. An aggregated score derived from this procedure, according to which, subtopics with the highest scores were collected and listed. This list of subtopics within issues of areas of expertise, were identified as knowledge needs at a preliminary level.

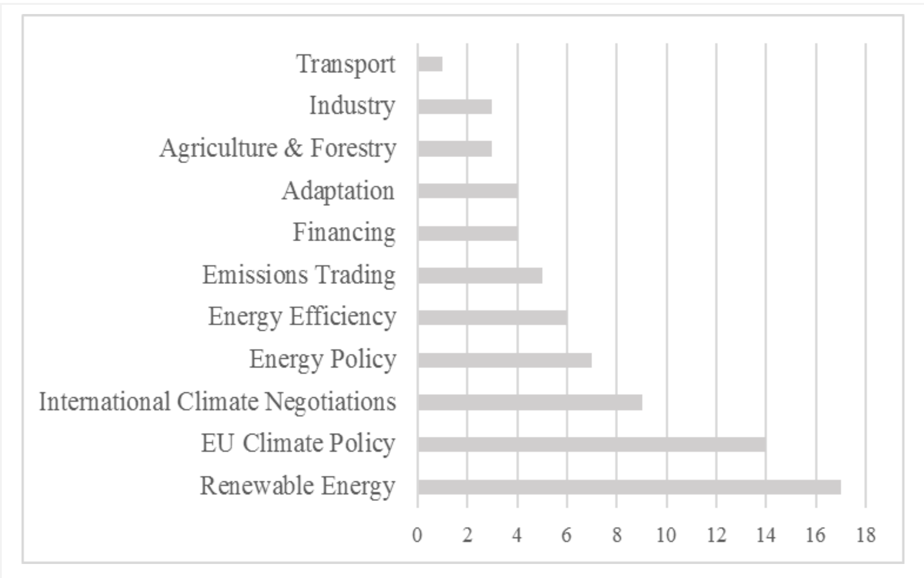

Figure 4: Stakeholders' selected areas of expertise.

However, in order to consider the list finalized, a verification of results was necessary. It was decided to validate these preliminary results through consolidation with stakeholders in thematic workshops, organized within the framework of the POLIMP project. The procedure is described in detail in the following paragraph.

Validation and Verification of Results through workshops

Workshops go beyond information-sharing in order to resolve differences, build consensus, pursue solutions, take decisions and plan actions (World Bank, 1996). In the case of the proposed methodology, preliminary results were verified and refined according to feedback provided during three thematic workshops. The workshops were organized within the framework of the POLIMP project and each of them was dedicated to one of the three climate policy fields: "Financing for low carbon technology - the renewable energy example", "Public acceptance of technology options and risk management" and "The role for emissions trading in low-carbon technology deployment".

Stakeholders were presented with the results per thematic area during special sessions and were encouraged to study them, comment on them and give a final overview. Results were subsequently rephrased or modified when considered necessary, while the option of adding or eliminating certain subtopics was considered. The emerging list of results was validated and finalized according to participants' feedback.

4. Results and Discussion

4.1 Key knowledge needs and priorities

The application of the methodology described in the previous section resulted in the identification of a series of knowledge needs and priorities per area of expertise. The finalized outcomes, as they were defined after the validation procedure through workshops, are presented by main thematic area in Table 2.

4.2 Knowledge presentation requirements

Although stakeholders are from a diverse national background, they stated that it is not important to them if information is presented in their native language or in English. They most frequently defined pdf files as their preferred type of knowledge presentation, with html pages being the second most popular choice. Good illustrations are appreciated, although not as the main source of information, but as complementary material to a text. Links to background information on issues under examination were stated to facilitate stakeholders and are therefore welcome as sources for further reading, while videos are not commonly appreciated. Another important outcome is that information should be accessible and printable by desktop computers or laptops, since these are the main devices that stakeholders use, while tablet computers and smartphones are not so widely used to access such information.

4.3 Discussion

The identification of knowledge needs constitutes the first step towards enhancing understanding of possible directions of climate policies among policy makers and other stakeholders and enabling them to form well-informed, consolidated decisions. The range of knowledge needs identified has to be effectively addressed by providing interested parties with suitable, to-the-point information, covering the gaps and meeting their requirements, as they were specified through the participatory procedure.

The proposed methodology was proven to be fruitful and efficient in fostering participation and revealing knowledge needs and priorities on climate policy implications. A further perspective for development would involve the engagement of a wider and larger range of stakeholders to the procedure in order to ensure that the sample is typical of the general group that is desired to be reflected. The conduction of more workshops or the introduction of small group meetings could also enhance the verification of preliminary results, thus ensuring accuracy of the final outcomes.

Although the application was focused on climate policy implications, the methodology has been designed and structured in an adequately generic way that enables its implementation in further fields of interest, relevant to climate policy or of different background.

Table 2: Key knowledge needs and priorities.

Prioritized Main Topics	Knowledge Needs
Renewable Energy	▪ Cost-effectiveness of support schemes for renewable energy ▪ Costs development of renewable energy technologies ▪ Harmonisation of support schemes for renewables within and across EU member states ▪ Smart grids
Emissions Trading	▪ Further harmonization of emissions trading scheme implementation across the EU ▪ Price stabilisation mechanisms, backloading, changes to the linear reduction factor ▪ Potential reform and impacts of links to other emissions trading schemes around the world
EU climate policy	▪ Interaction of different climate policy instruments and different targets ▪ Cost-effectiveness of targets ▪ Carbon-pricing instruments (ETS, taxation) ▪ Actions in other parts of the world, compared to the European Union
Financing	▪ Incremental additional investment required in specific sectors ▪ Mobilisation of private financial flows ▪ Innovative finance schemes in an international context
International Climate Negotiations	▪ Climate finance generating mechanisms, innovative climate finance schemes ▪ Types and timescales of climate change mitigation targets ▪ Vertical integration between decision-making levels
Agriculture & Forestry	▪ Sustainability criteria for biomass ▪ Indirect land use and LULUCF accounting ▪ Carbon sequestration ▪ Fertiliser, manure and livestock management
Energy Policy	▪ Electricity market design ▪ Energy price developments in different world regions, and its impacts
Industry	▪ Competitiveness: carbon leakage impacts and related exemptions; ▪ Sectoral innovation scope, reduction potential and costs.
Energy efficiency	▪ Effectiveness of existing energy efficiency policy; ▪ Possible energy saving obligation schemes and financing options; ▪ Energy efficiency measures savings potential; ▪ Access to capital for energy efficiency measures.
Adaptation	▪ Institutional setup and organisation of mainstreaming of adaptation ▪ Methodologies for estimation of costs and benefits of adaptation measures ▪ Effective tools and best practices for raising public awareness and public participation ▪ Indicators for the evidence base for adaptation policy decisions
Transport	▪ Increasing efficiency through intelligent transport systems ▪ Efficient integration of modal networks

Available information could be collected by a wide range of up-to-date sources and synthesized into well-structured articles, as a next step. Concentrated and organized knowledge in that form could be communicated to stakeholders during conference presentations, dialogue sessions, workshops and meetings, in order to foster information exchange and knowledge transfer among interested parties. Finally, it is envisaged that the web integration of such articles into a knowledge platform would facilitate their access by stakeholders and enable the creation of an online community of knowledge.

5. Conclusions

An effective response to climate change is currently high on the political agenda among the world's nations. Climate change mitigation efforts are currently intensified at an international level, as parties focus and coordinate their efforts towards an international agreement, while adaptation to climate change is in the spotlight of climate negotiations, in anticipation of the forthcoming 21st Conference of the Parties (COP 21).

However, this changing and versatile political scenery of negotiations creates a wide range of possible directions and potential implications of policies on EU level, thus impeding solid policy and decision making. It necessitates further access to improved knowledge transfer and uptake for policy and decision makers, in order to render them capable of developing clear understanding of current regimes, their possible directions, implications and consequences and to support them in taking well-informed, consolidated decisions based on up-to-date reliable facts.

This paper provided an analysis, based on elaborated stakeholders' assessment that resulted in the identification and prioritization of a series of knowledge gaps within main climate policy related topics.

Proposed Methodology: The methodological framework introduced a participatory process of high-level stakeholders' engagement, involved directly or indirectly in the process of policy making. A range of priority issues was initially identified through desk analysis and key stakeholders were selected and invited to partake in the process.

A questionnaire was developed to serve as a guide for expert interviews or for direct completion by stakeholders through an online form. Twelve bilateral interviews were conducted, while 27 questionnaires were submitted by stakeholders and collected for analysis. Preliminary results were validated through interaction with stakeholders during a series of workshops and the final knowledge needs emerged as an outcome.

Knowledge Gaps Identification: Emphasis was identified to be placed on the topics of Renewable Energy, Emissions Trading and EU climate policy, which were the most popular ones, followed by Financing and International Climate Negotiations. The issue of cost-effectiveness was generally considered as a priority aspect of interest within the main areas of expertise, while the involved policy mix also raised concern among stakeholders.

The results from the proposed approach can be considered as realistic, since they were subsequently validated through a series of workshops, where stakeholders reflected upon the derived list of knowledge needs.

Although the approach adopted assisted this specific problem, the analysis provides a basis for supporting a wide range of applications in the field of priorities' identification and even expanding to decision making problems. Future research efforts could therefore be placed on the participation of stakeholders in the evaluation and selection of policy pathways and sustainability strategies, in the process of climate policy decision making and even spread to the assessment of the public acceptance of different schemes identified.

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Analyzing policy interactions for promoting energy efficiency in the Hellenic sectors of buildings and transport

by

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Abstract

Policy interactions are important parameters for the successful implementation of policies, measures and policy instruments. The parallel implementation of a number of policy instruments has the potential to create synergies or conflicts that maximize or prevent the achievement of their anticipated outcomes. This paper analyses three cases of policy interactions between two policy instruments for promoting even more the energy efficiency outcomes in Greece for two sectors, buildings and transport. The case studies refer to existing policy instruments linked directly and indirectly with energy and are: i) “Energy labelling” and “Green Public Procurement” (building and transport sector); ii) “Regulation for the Energy Efficiency of Buildings (KENAK)” and the “Specific Program for the Development of Photovoltaic systems on buildings and specifically on their lofts and roofs” (only for building sector); iii) “Planning policy instrument for Intelligent Transport Systems” and “Emission standards (Euro 5 and Euro 6)” (only for transport sector). The analysis is conducted through four levels (objectives, target groups, rules-influencing mechanisms and implementation network). Within each level the policy interaction is examined of how it affects: i) the performance of each policy instrument and ii) the behavior of end-users. Conclusions discuss policy recommendations for improving the outcomes of each case study.

1. Introduction

Policy interactions contribute essentially to the successful parallel implementation of policies, measures and policy instruments since they have the potential to create synergies or conflicts that facilitate or prevent respectively the achievement of the anticipated outcomes. This paper presents cases of positive policy interactions between two Policy Instruments (PIs) for promoting even more the Energy Efficiency (EE) outcomes in Greece for two sectors, buildings and transport. The case studies refer to existing PIs that are linked directly and indirectly with energy. There are no officially recorded outcomes or evaluations for the parallel implementation of these PIs. The paper is structured as follows: first, the types of policy interactions are presented. Then the case studies are described. The types of the policy interactions for the case studies are analysed. The last session is about conclusions and recommendations for improving the performance of the examined PIs based on the analysis of their policy interactions.

2. Policy interactions

Policy interaction is the situation that occurs when parallel-implemented PIs exert on each other multi-dimensional and multi-scaled interactions that end up either interfering and constraining or complementing and reinforcing performance mutually or separately (Konidari and Mavrakis, 2006).

Their identification and analysis is based on the design characteristics of PIs. These characteristics are classified in the following four categories (Mavrakis and Konidari, 2003): i) *Objectives* which are the set of explicitly mentioned and forecasted outcomes of the instrument. They are divided into primary and secondary. ii) *Target groups* which are entities that fall under the instrument and are obliged to comply with its requirements. iii) *Implementation network* that is the set of pertinent public and private authorities assigned with specific duties (diffusion of information, conduction of controls, etc.) for the successful implementation of the policy instrument. iv) *Rules and influencing mechanisms* that refer to all legal and financial arrangements used for compliance, coercion, encouragement and persuasion of target groups towards the fulfilment of objectives.

Based on these classification categories there are four respective forms (mentioned also as levels) of interactions each one of which is divided into others (Konidari and Mavrakis, 2006):

i) *Interactions due to objectives*. Two PIs interact due to objectives if: a) They share the same primary objectives; this interaction form is named primary to primary (p–p). b) one primary objective is the same with a secondary objective; interaction form is named primary to secondary (p–s). c) They share the same secondary objectives; interaction form is secondary to secondary (s–s) (Konidari and Mavrakis, 2006).

ii) *Interactions due to target groups*. These interactions occur when PIs are imposed at the same target groups or when operations of other sectors, linked with the specific target groups of the two examined instruments, are affected. The first form of interaction is named direct target group interaction, while the second indirect (i–i) (Konidari and Mavrakis, 2006). Using TP1 and TP2 to denote the set of target groups in policy instrument 1 and 2, respectively, three possible combinations for direct interaction occur as described by the following relationships. First, if TP1 $\subseteq$ TP2 then (TP1 $\cap$ TP2)=TP1 or if TP2 $\subseteq$ TP1 then (TP1 $\cap$ TP2)= TP2 (One Set PArticipation, os–pa). Second, if TP1 $\cap$ TP2 = TP3 and TP3 $\subseteq$ TP1 or TP3 $\subseteq$ TP2 (Partial PArticipation, p–pa). Third, TP1 = TP2 (full participation, f–pa). If TP1 $\cap$ TP2 = { $\varnothing$ }, then there is no direct interaction, but there may be indirect interaction (Konidari and Mavrakis, 2006).

iii) *Interactions due to rules-influencing mechanisms*. Two forms are encountered within this level, trading and regulative interaction (denoted by t and r, respectively). Two market-based PIs interact under t when rules for the same trading commodity (emission permit, green certificate, etc.) or market regulations of commodities of one instrument are affected due to the respective ones of the other (Konidari and Mavrakis, 2006). r is defined as interaction due to similar or same rules and influencing mechanisms of the two PIs regarding regulatory issues. These issues concern sanctions, subsidies, allocation procedures, counting and crediting (Konidari and Mavrakis, 2006).

iv) *Interactions due to implementation network*. This interaction form occurs in the following cases. First, when the same competent authority has full responsibility for implementing both instruments; the form is named full responsibility interaction (f–r). Secondly, is the named partial responsibility interaction (p–r)} when two or more authorities are assigned partial responsibilities for implementing both instruments. Third, different authorities are responsible for the equivalent number of different PIs and the form is named different responsibility interaction (d–r) (Konidari and Mavrakis, 2006).

Out of these four types of policy interactions the two first are more important. That is why the policy interaction analysis starts by the identification of the first type of policy interactions due to objectives and continues with the second one. If two PIs interact under objectives and target groups, then there is strong policy interaction between them (Konidari and Mavrakis, 2006).

Case studies

The selected for policy interaction analysis Hellenic case studies are:

- "*Energy labelling*" and "*Green Public Procurement*" (building and transport sector) – Direct link with energy;
- "*Regulation for the Energy Efficiency of Buildings (KENAK)*" and the "*Specific Program for the Development of Photovoltaic systems on buildings and specifically on their lofts and roofs*" (Only for building sector) – Direct link with energy;
- "*Planning policy instrument for Intelligent Transport Systems*" and "*Emission standards (Euro 5 and Euro 6)*" (only for transport sector) – Indirect link with energy.

They were selected because of:

- the amount of available information about them compared to other national PIs (for all three cases).
- the significant market share that Greece has in the European solar market (for the second one).
- Their relation to energy efficiency (their outcomes support the promotion of energy efficiency practices and technologies) (for all three cases).

3. Policy interactions for the case studies

Policy interactions are explored under each of the aforementioned levels.

First level of policy interaction: Interaction due to objectives

1st case study: The Energy Labelling [84] Directive aims to address the negative impacts of products on the environment depending on how they are made, used and disposed of by 'pulling' the market towards more energy efficient products (European Commission, 2015). The objectives for fulfilling this aim are (European Commission, 2015): i) Increasing EE and the level of environmental protection; ii) informing consumers about EE and other resources use of products through an energy label, and encouraging them to buy more energy efficient ones; iii) Ensuring the free movement of energy-related products in the European Union.

For the Hellenic case, the Ministerial Decision 12400/1108/29 (Government Gazette 2301 B, 14.10.2011 [85]) sets as primary objective - in line with the aforementioned objectives of the Directive – to have end-users able to select more efficient products through an enacted framework for: i) providing information to end-users through labeling and ii) quoting uniform information regarding the product (energy consumption and occasionally other basic resources during usage) and supplementary information about products related with energy.

The purpose of the second PI, the EU Green Public Procurement (GPP), is to use the purchasing power of the EU Member States governments to stimulate the markets for goods and services with lower impacts on the environment (BIO Intelligence Service, 2013). Energy efficient products and services are promoted for use by the public sector.

The policy interaction is positive since both PIs through their objectives (primary and secondary) aim to support energy efficient products and services.

2nd case study: The objectives that KENAK serves are the: i) reduction of energy consumption for heating, cooling, lighting, production and use of hot water with the simultaneous ensuring of comfort conditions for the indoor spaces of buildings; ii) improvement of the energy performance of buildings in Greece, considering: a) outdoor

[84] and the Ecodesign Directive

[85] http://www.google.gr/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=2&cad=rja&uact=8&ved=0CCkQFjABahUKEwjxv_GOz5HHAhUJORQKHdKrAX8&url=http%3A%2F%2Fwww.ydmed.gov.gr%2Fwp-content%2Fuploads%2F2011_09_10_diminiaio.doc&ei=4tXBVfHGEonyUNLXhvgH&usg=AFQjCNFSqq8d5JaYRHWaeMdvBaHCMGeA8Q&bvm=bv.99261572,d.d24 and http://www.et.gr/idocs-nph/search/pdfViewerForm.html?args=5C7QrtC22wFYAFdDx4L2G3dtvSoClrL8zS83ZvoDVVQtiDow6HlTE-JlnJ48_97uHrMts-zFzeyCiBSQOpYnTy36MacmUFCx2ppFvBej56Mmc8Qdb8ZfRJqZnsIAdk8Lv_e6czmhEembNmZCMxLMtZqO3PZEZmZ4PAm4MxQaM4YkkPuOjFktfnSx0GKTOsdy

climatic and local conditions and b) indoor climate requirements and cost-effectiveness.

The "*Specific Program for the Development of Photovoltaic systems on buildings and specifically on their lofts and roofs*" was set in force by a Joint Ministerial Decision No. 12323[86] (Government Gazette 1079 B, 04.06.2009 [87]). Law 3851/2010 (Government Gazette 85 A, 04.06.2010[88]) had relevant provisions with more important that for the feed-in-tariffs. Law 4023/2013 (Government Gazette 235 A, 11.11.2013[89]) has also provisions that refer to PV systems on buildings. The objective of the "Specific Programme [90] " is to contribute in the achievement of the national RES penetration target. It is the combination of two types of PIs: i) a regulatory PI due to the rules for the installation of the PV systems and ii) a financial PI due to the feed-in-tariffs for the Photovoltaic (PV) systems.

The target of total energy savings due to the installation of PV systems in the buildings sector for the production of domestic hot water use is estimated to 4.128 GWh until year 2020 (Build Up Skills – Energy Training for Builders, 2013). The expected installed capacity of PV systems on lofts-roofs is expected to be by year 2020 at 1.150MW (Build Up Skills – Energy Training for Builders, 2013).

The two PIs (KENAK and the regulatory part of the "Specific Programme") interact positively through their common secondary objectives. The financial PI of the "Specific Programme" reinforces this type of policy interaction.

<u>3rd case study:</u> The objectives of Directive 2010/40/EC about the Intelligent Transport Systems (ITS) are: i) establishment of the necessary specifications to ensure accessibility, exchange, reuse and update of road and traffic data for the provision of real-time traffic information services in the European Union (European Commission, 2014). ii) Optimal use of road, traffic and travel data continuity of traffic and freight management ITS services; ITS road safety and security applications; linking of the vehicle with the transport infrastructure; facilitation of traffic management. Furthermore, according to this Directive, it is expected that the ITS application[91] (to the road transport sector and its interfaces with other modes of transport) will contribute significantly to improved environmental performance, efficiency, including EE, safety and security of road transport, including the transport of dangerous goods, public security and passenger and freight mobility, ensuring also the functioning of the internal market and increasing the levels of competitiveness and employment.

The purpose of the emissions standards "Euro 5 and Euro 6" is to limit the pollution caused by road vehicles and support emission reduction actions in transport by introducing stricter limits on polluting emissions. These limits are applicable to light road vehicles, particularly with regard to emissions of particles and nitrogen oxides.

The two PIs share common secondary objectives which are the improvement of environmental performance (reduction of polluting emissions) and of EE (support of emission reduction actions). This results to positive policy interaction under objectives.

Second level of policy interaction: Interaction due to target groups

<u>1st case study:</u> The target groups of the Hellenic "Energy labeling" include end-users in households and producers of the respective products. This PI is applied to products that have significant effect (direct or indirect) on

[86] http://www.desmie.gr/ape-sithya/adeiodotiki-diadikasia-kodikopoiisi-nomothesias-ape/periechomena/timologisi-energeias-apo-ape/

[87] http://www.cres.gr/pvcatalog/FEK_1079_2009.pdf or http://www.deddie.gr/Documents2/%CE%A6%CE%A9%CE%A4%CE%9F%CE%92%CE%9F%CE%9B%CE%A4%CE%91%CE%99%CE%9A%CE%91/eidiko%20programma%20steges/nomothesia/%CE%A6%CE%95%CE%9A%201079_4-6-2009.pdf

[88] http://www.ypeka.gr/LinkClick.aspx?fileticket=pnhppGnURds%3D

[89] http://www.ypeka.gr/LinkClick.aspx?fileticket=6FFnUN2JqSg%3d&tabid=555&language=el-GR

[90] The term "Specific Programme" refers to the *Specific Program for the Development of Photovoltaic systems on buildings and specifically on their lofts and roofs*

[91] ITS applications should be without prejudice to matters concerning national security or necessary in the interest of defense.

energy consumption and depending on the case of other resources during their use. It is not applied to: i) second hand products; ii) to transportation means of persons or merchandise; iii) on the indicative signal or the equivalent label for security reasons that is attached on the product.

For the GPP the target groups are public[92] and private entities that sign contracts covering: energy efficient computers, office furniture from sustainable timber, low energy buildings, recycled paper, cleaning services using environmentally friendly cleaning products, electric, hybrid or low-emission vehicles, electricity from renewable energy sources (European Commission and ICLEI – Local governments for Sustainability, 2011).

There is no direct policy interaction under the target groups of the two PIs since they are different. For "*Energy Labelling*" the target group consists of end-users (citizens) coming from the building and the transport sectors, while for GPP the target groups are public entities. Producers and manufacturers of such products and services – whose participation is optional, particularly for the GPP - are benefitted indirectly by the implementation of both PIs. So, there is an indirect positive policy interaction.

2nd case study: *KENAK* is imposed on the following categories of buildings: i) Households of different types such as detached houses, apartments and apartment complexes; ii) Multi-apartment buildings; iii) Offices; iv) Educational buildings; v) Hospitals; vi) Hotels and restaurants; vii) Sports facilities; viii) Buildings for Wholesale and retail trade services; ix) Any other category of buildings that are consuming energy.

The "*Specific Programme*" concerns PV systems with power up to $10kW_p$ for buildings used as households or for housing small businesses. It will be in force until 31 December 2019 and covers the whole Hellenic territory. Natural persons that are non-traders and natural or legal persons that are traders (of very small businesses) can participate at the "*Specific Programme*" if they own a space at which they can install a PV system. The only condition is that there has to be an active connection for electricity consumption in the name of the PV owner at the building where the system is installed.

The two PIs interact directly between the target groups of the "*Specific Programme*" ie households of different types (ie detached houses, apartments and apartment complexes), multi-apartment buildings, offices, hotels – restaurants, buildings for wholesale and retail trade services and any other category of buildings that are consuming energy. It is a partial participation as described in the "policy interactions" session.

It is characterized as positive policy interaction based on the following justification. Despite the economic recession, the installation of PV systems on building roofs was significant (Build Up Skills – Energy Training for Builders, 2013). The share of PV systems that were installed on roofs when compared to the whole Hellenic PV market demonstrated an increase from 4% in year 2010 to 19% during the first six months of year 2012 (Build Up Skills – Energy Training for Builders, 2013). This increase continued (Table 2). By April 2013, the installed capacity grew up to $341MW_p$ (HELAPCO, 2013).

Additionally, although photovoltaics are characterized as a relatively new technology for the Hellenic residential market, more than 40.000 systems were installed in residential buildings up to 2013, resulting to increased installed capacity (from 47 MW_p in 2007 to 1.536 MW_p in 2012 and to 2.579 MW_p in 2013) (Tsalikis G. and Martinopoulos G., 2015). Greece is among the ten top PV markets globally (10th in 2011 and 2012, 9th in 2013)(IEA, 2014).

3rd case study: The introduction and usage of ITS forms the following set of target groups: public authorities, private service providers (satellite links, internet, dedicated cable networks etc), road operators, private companies that develop and purchase the necessary equipment (traffic cameras, loop detectors), companies that own, elaborate and provide data and end-users (travelers, all categories of drivers (professional drivers, taxi drivers, drivers in public vehicles, elderly people etc)) (Hellenic Republic, Ministry of Economy, Infrastructure, Shipping and Tourism, 2015; European Commission, 2014; TISA, 2014).

[92] Public sector, first and second level of local authorities, companies whose stock share belongs to the public sector or local authorities - Public transport sector

Under the emissions standards the target groups are: i) vehicle manufacturers and ii) owners of vehicles (categories[93] M1, M2, N1 and N2, with reference mass not exceeding 2.610 kg[94]). These vehicles include, among others, passenger vehicles, vans and commercial vehicles intended for the carriage of passengers or goods or certain other specific uses (for example ambulances), provided that vehicles are equipped with engine-spark ignition (gasoline engines, engines with natural gas or Liquefied Petroleum Gas - LPG) or compression ignition (diesel engines).

The end-users (drivers of all vehicle types, private and public) are the common subset of the two target groups that benefit from the implementation of both PIs. Owners of vehicles with technology of Euro 5 and 6 when using ITS save travel time, consume less fuel and emit less. It is partial participation. No information is available for understanding if the number of end-users increased or remained the same due to the implementation of both PIs. The policy interaction is neutral.

Third type of policy interaction: Interactions due to rules - influencing mechanisms

1st case study: The Energy Labelling (or Eco-labelling) standards can be used as preconditions for the tenders of the GPP. So, the implementation of the GPP is facilitated while the implementation of the Energy Labelling standards is reinforced. The reasons are: i) energy or eco-labelling has a significant potential to contribute to an effective reduction of environmental impacts linked with economic activities due to its criteria which consider environmental impacts that products may have in their life-cycle (Domingues A.R. et al., 2015); ii) they inform consumers/users so as to select products energy efficient or least harmful to the environment because independent third parties narrow the information gap by assuring consumers/users about which product meets those energy or environmental standards (Domingues A.R. et al., 2015).

This is a positive “r” policy interaction between rules-influencing mechanisms of the two PIs.

2nd case study: Within the framework of the “*Regulation for the Energy Performance of Buildings (KENAK)*” and the provisions of Law 3851/2010[95] (Government Gazette 85 A, 04.06.2010[96]), the use of RES in buildings and particularly the production of domestic hot water use by solar systems is obligatory for new buildings, while for totally renovated buildings the needs for hot water can be covered partially by solar thermal systems with the minimum percentage of annual solar share defined at 60% (YPEKA, 2014). This obligation is not applied for the uses that are exempted by the KENAK or when needs in domestic hot water use are covered by other decentralized energy supply systems based on RES, Combined Heat and Power (CHP), tele-heating systems (regionally or building block scale), heat pumps whose seasonal performance factor must be higher than 3,3 (YPEKA, 2014).

The Joint Ministerial Decision for the “*Specific Programme*” sets also the rule that “part of the thermal needs in domestic hot water use under the household of the PV owner needs to be covered by renewable energy sources (ie solar thermal systems and solar water heaters). The PV owner should not receive public financial support due to the Development-Investment Law or European financial mechanisms or any other funding resource so as to participate at the “*Specific Programme*” (Joint Ministerial Decision No. 12323).

Rules for the feed-in-tariffs, bills and payments are also defined. In 2010 the amount of the feed-in-tariffs was 550 EUR/MWh (Law 3851/2010). New adjustments followed. The feed-in-tariffs (financial policy instrument of the “*Specific Programme*”) were a strong incentive for the penetration of PV systems installed on lofts-roofs (HELAPCO, 2013). The target groups that fall under both PIs benefitted the most. Furthermore, the reduction of the average investment cost for PV systems with installed capacity up to 10kW$_p$ was

[93] http://www.dft.gov.uk/vca/vehicletype/definition-of-vehicle-categories.asp

[94] defined in Annex II to Directive 70/156/EEC

[95] The law is about “Accelerating the RES development and confronting climate change - other provisions for issues under the responsibility of the MEECC

[96] http://www.ypeka.gr/LinkClick.aspx?fileticket=pnhppGnURds%3D

another significant factor for this penetration. The reduction was 64% comparing prices in year 2010 and 2013 (HELAPCO, 2013).

So, 3851/2010 (Government Gazette 85 A, 04.06.2010[97]) which was devoted to the RES development linked RES and EE. The law formed a favorable context especially for photovoltaic installations on buildings, taking into consideration the very high prices for the generated electricity by these installations (550 EUR /MWh) when the maximum electricity price, for the household sector, for that period according to consumption ranged from 56,25 to 91,55 EUR /MWh (Christidou C. et al., 2014). PV investments under these conditions had pay-back periods shorter than six years (Christidou C. et al., 2014). This is positive "t" and "r" policy interactions between rules-influencing mechanisms of the two PIs.

3rd case study: Presidential Decree No. 50 (Government Gazette 100 A, 27.04.2012[98]) incorporated Directive 2010/40/EU[99] (dated 7 July 2010) "*on the framework for the deployment of Intelligent Transport Systems*[100] *in the field of road transport and for interfaces with other modes of transport*" into national legislation, but the document presenting the "*National Strategy for the Intelligent Transport Systems, 2015-2025*" was released by the Ministry of Economy, Infrastructure, Shipping and Tourism only this year (March 2015) (Hellenic Republic, Ministry of Economy, Infrastructure, Shipping and Tourism, 2015). This document aims to identify shortages for the ITS, to present the relevant national needs and to define a set of required principles for the ITS implementation (Hellenic Republic, Ministry of Economy, Infrastructure, Shipping and Tourism, 2015). The document serves as a Roadmap for planning, implementing, operating and maintaining the ITS.

The Ministry of Economy, Infrastructure, Shipping and Tourism (MEIST) (former Ministry of Development, Competitiveness, Infrastructure, Transport and Networks) supports centrally the availability of real-time traffic data which are accessible by the private sector for a fee (Ministry of Development, Competitiveness, Infrastructure, Transport and Networks, 2012).

There are emission limits for each category of pollutant emissions and for the different types of vehicles. According to provisions of EC Regulation 715/2007, the Member States shall lay down the provisions on penalties "applicable for infringement by manufacturers" according to their obligations under the Regulation. The respective penalties must be effective, proportionate and dissuasive. Offences subject to a penalty include: a) making false declarations during the approval procedures or procedures leading to a recall; b) falsifying test results for type approval or in-service conformity; c) withholding data or technical specifications which could lead to recall or withdrawal of type approval; d) use of defeat devices; and e) refusal to provide access to information.

There is no policy interaction under this category for the two PIs.

Fourth level of policy interactions: Interactions due to the implementation network/ governance structure

1st case study: The Hellenic Ministry of Environment and Energy[101] (one of its former names was Ministry of Environment, Energy and Climate Change (MEECC[102])) monitors and supervises the implementation of measures for achieving the national indicative energy savings target through the provision of energy services and other measures to improve EE, and prepares a report on their results (2nd NEEAP, 2010; 3rd NEEAP, 2014). It has also the administrative, managing and executive responsibility of implementing the EE requirements of the "Energy Efficiency Action Plans" and relevant incentives and other

[97] http://www.ypeka.gr/LinkClick.aspx?fileticket=pnhppGnURds%3D

[98] www.yme.gr/getfile.php?id=4653

[99] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:207:0001:0013:EN:PDF

[100] Intelligent Transport Systems (ITS) are advanced applications that integrate telecommunications, electronics and information technologies with transport engineering in order to plan, design, operate, maintain and manage transport system. ITS provide innovative services relating to different modes of transport and traffic management and enable various users to be better informed and make safer, more coordinated and 'smarter' use of transport networks.

[101] http://www.ypeka.gr/Default.aspx

[102] http://www.cres.gr/kape/calendar/progr_ypapen_8_6_15.pdf

measures to improve EE and those relating to the public sector.

MEECC is responsible for implementing the "*Energy labelling*", and specificaly, the General Secretariat of Industry at the Ministry of Reconstruction of Production, Environment and Energy (former name also)). The Public Economic Services, the Service of Special Audits of the Ministry of Finance, Hellenic Police, Chambers and Regions will also contribute for the market monitoring if the pertinent authority decides their involvement.

The MEECC was assigned also as the authority responsible to design the National Policy and to draw a National Action Plan for promoting the GPPs (Law 3855/2010 - Government Gazette 95 A, 23.06.2010 [103]). MEECC will need to cooperate with other Ministries and bodies of the public and private sector for proceeding with the necessary legislative settings and measures for implementing the PI.

For the better coordination of these efforts an eleven member Interministerial Committee was established [104] . Its Members are: The Minister of Economy, Infrastructure, Shipping and Tourism (Head of Committee), The Minister of Finance, The Minister of Productive Reconstruction, Environment and Energy (Former MEECC), The Minister(s) who supervise(s) each of the Public Bodies that are examining the implementation of Public-Private-Procurements (PPP) projects, under their competencies.

There is a direct policy interaction (of full responsibility) since the MEECC is mainly responsible for implementing both PIs. This policy interaction can be characterized as negative due to lack of information about their implementation. This is justified as follows: i) There is still no national action plan about the GPP[105]. Greece, along with Croatia, Estonia, Hungary, Luxemburg and Romania has not submitted such a plan. This situation imposes administrative burden to the implementation network. ii) there are no tenders with criteria related to Energy or eco-labelling or EE[106] on the Hellenic web-page for PPP due to inadequate implementation network (lack of skills and knowledge to use the energy or eco-labelling standards under the GPP, lack of relevant studies, available perhaps but non-accessible information for the public through web-sites). This second reason is significant since public authorities are expected to be open and transparent about the management of public funds and assents (Domingues A.R. et al., 2015). The interaction can become positive if the necessary actions are undertaken (establishment of a pertinent authority with qualified staff etc).

2nd case study: The two main entities responsible for the implementation of both PIs are the MEECC and Center for Renewable Energy Sources and Saving (CRES) [107]. CRES is the national centre for RES, Rational Use of Energy & Energy Saving. It is supervised by MEECC and has financial and administrative independence. It provides advice and assistance to MEECC on matters of RES/RUE/ES national policy, strategy and planning, is entitled to conduct dissemination and training campaigns as well as awareness raising campaigns on RES and ES. The main instruments used are, training activities, specialized events and production of material (technical guides, promotional publications, training software etc).

The support provided by CRES, particularly through studies, action plans and national reports, involves the fulfilment of national obligations under the National Energy Efficiency Action Plan (NEEAP) and generally, under national and European legislation, relating to the EE of buildings, energy saving, renewable energy sources and cogeneration issues. CRES has a session on its web-site providing information (http://www.cres.gr/services/istos.chtm?prnbr=24762&locale=el) about a spectrum of issues related to EE (Buildings, transport, metering, GHG emissions, energy inspections/audits, certifications of materials and systems).

103 http://www.ypeka.gr/LinkClick.aspx?fileticket=AxgQsUVAUjA%3d&tabid=506

104 http://www.sdit.mnec.gr/en/information

105 http://ec.europa.eu/environment/gpp/action_plan_en.htm

106 http://www.sdit.mnec.gr/en/information/PPP/procedures

107 http://www.cres.gr/kape/index.htm

CRES has developed and completed a catalogue with institutes that are activated in RES and EE services and products. The purpose of this effort was to support the Hellenic market and to inform consumers and investors about these types of market activities. The "Catalogue of Hellenic Energy Professionals" includes information about the type of activity of the involved companies and professionals, the category of RES, the relevant technology that is in use and contact data. However, there is no indication if this catalogue is updated (the date on the site is year 2007).

The type of policy interaction is not clear due to the lack of information. It can be characterized as neutral, since the performance of each policy instrument is not affected and the behavior of the end-users has not changed due to this implementation network.

3rd case study: The same authority is responsible for the implementation of both PIs, ie the Ministry of Economy, Infrastructure, Shipping and Tourism (MEIST).

For the planning policy instrument of ITS, the pertinent national authority will be the Department of Planning and Development of Transport that is under the General Directorate of Transport of the Ministry of Economy, Infrastructure, Shipping and Tourism (Hellenic Republic, Ministry of Economy, Infrastructure, Shipping and Tourism, 2015). This Department is assigned with the following responsibilities (Hellenic Republic, Ministry of Economy, Infrastructure, Shipping and Tourism, 2015):

- Implementation of the "National Strategy and Architecture for the ITS". It is also responsible for the update and specialization of this strategy when these tasks are required;
- Installation of the implementation rules presented in national and European regulation documents for ITS;
- Monitoring of the progress for implementing the actions that derive from the national and European regulation documents for ITS;
- Operation of the Advisory Committee[108] for ITS and of the ITS Observatory[109];
- Supervision of the registries with data required by the national and European regulation documents for ITS.

One more entity that is part of the implementation network for the ITS policy instruments is the Institute for the Management of Information Systems "Athena" which has developed and maintains the website www.geodata.gov.gr. It provides national support through a central point for collection, search, distribution and visualisation of information, e.g. bus routes (Ministry of Development, Competitiveness, Infrastructure, Transport and Networks, 2012).

However, there is an overlap by entities such as Municipalities, OASA [110] and the Egnatia Motorway in the performance of necessary actions (ie for implementing an integrated combined public information system for traffic, parking places and routes; informing public transport passengers etc) (Ministry of Development, Competitiveness, Infrastructure, Transport and Networks, 2012). Defined roles and responsibilities for planning and coordination of such actions are not allocated clearly across the various levels of government (central government, local government) and transport operators (Ministry of Development, Competitiveness, Infrastructure, Transport and Networks, 2012).

[108] The aforementioned Advisory Committee for ITS provides periodically or whenever that is necessary, consulting services to the Department of Planning and Development of Transport (Hellenic Republic, Ministry of Economy, Infrastructure, Shipping and Tourism, 2015).

[109] The ITS Observatory records the ITS actions, evaluates them through appropriate indexes, the implementation outcomes and the ITS performance so as to draw objective conclusions for the progress of their implementation in Greece and the level of coordinated penetration of the ITS applications. The ITS observatory is under the supervision of the Department of Planning and Development of Transport (Hellenic Republic, Ministry of Economy, Infrastructure, Shipping and Tourism, 2015).

[110] The Athens Urban Transport Organization (OASA) is a metropolitan entity for urban transportation in Athens and was re-established with law 3920/2011 (OASA, 2012). For improving the polluted atmosphere of the greater's Athens area, OASA 110 replaced buses and trolley buses with new technology vehicles.

Other obstacles for the ITS implementation in the country are: i) Insufficient collaboration between public (central and regional) authorities and private entities; ii) lack of information for transport operators about the ITS and how they could implement them successfully, producing benefits for enterprises (Ministry of Development, Competitiveness, Infrastructure, Transport and Networks, 2012).

For the second PI the Directorate "Vehicles Technology" of the MEIST is responsible for these issues. However, there are no available information about its implementation.

The current policy interaction is negative due to the overlap of responsibilities and the lack of clear responsibility distribution. The policy interaction can become positive if the aforementioned obstacles are confronted.

4. Conclusions

The outcomes are presented in table 1. The first case study has an overall positive policy interaction as discussed through the analysis in all four levels. The second case study is also an overall positive policy interaction situation, while the third one can be characterized as a neutral policy interaction.

The negative policy interaction is encountered under the fourth level – policy interactions due to implementation network/governance structure. Coordinated activities, defined and concrete responsibilities among the pertinent entities have the potential to increase the performance of the PIs.

Particularly, for the third case the two PIs will probably create a promising positive synergy, but empirical evidence to quantify this potential is not yet sufficient (European Commission, 2009). ITS for fuel consumption and/or emissions will allow monitoring and feedback so as to influence driving style and vehicle behavior (Ministry of Infrastructure, Transportation and Networks, 2014; European Commission, 2009).

The cases in which a positive policy interaction was identified can provide even more sufficient outcomes if the identified obstacles are confronted ie careful design of rules-influencing mechanisms and coordinated distribution of responsibilities for the entities that form the implementation network.

The establishment of authorities whose responsibilities are oriented exclusively to the achievement of the objectives of a specific PI and to the monitoring of its implementation will improve the current situation. From this point the presented approach can be used for understanding the performance of PIs and identifying their most effective combinations.

Table 1: Types of overall policy interactions for the three case studies.

	Case study		
Interaction due to	**1**	**2**	**3**
Objectives	Positive	Positive	Positive
Target groups	Positive	Positive	Neutral
Rules-Influencing mechanisms	Positive	Positive	Neutral
Implementation network	Negative	Neutral	Negative
Type of total policy interaction	Positive	Positive	Neutral

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Energy and Climate Change

Regional Electricity Demand in Turkey: Dynamic Spatial Panel Data Analysis

by

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Abstract

Since the seminal work of Anselin (1980), many theoretical and empirical studies have considered spatial effects as an important type of interaction effects. However, for the analysis of electricity demand, few studies consider these effects in their analyses among the huge number of studies. This study aims to contribute to the literature on the electricity demand analysis by considering spatial dependency among the regions and provinces of Turkey. We perform analysis both at the NUTS-3 and NUTS-2 levels. In this study, our purpose is to analyse the factors affecting the electricity demand and to obtain income and price elasticities by employing two different data sets: i) panel data on the 65 provinces of Turkey covering the period from 1990 to 2001, ii) panel data on the 26 subregions of Turkey covering the period from 1990 to 2001 and from 2004 to 2011. In the context of dynamic spatial panel data model, per capita electricity consumption is modelled as a function of per capita gross domestic product, electricity end-use prices, urbanization ratio, heating and cooling degree days allowing for cross-sectional heterogeneity, dynamics, trends, and spatial clusters in the electricity demand, simultaneously. Our results for NUTS-3 level indicate that electricity demand is inelastic with respect to income both in the short run and the long run. Further, we find that short run electricity demand is price inelastic, however, long run electricity demand is found to be price elastic. We obtain the similar results for the analysis at the NUTS-2 level over the period from 2004 to 2011. However, findings show that both in the short run and long run, electricity demand is inelastic with respect to income and price at the NUTS-2 level for the years between 1990 and 2001. As a conclusion, our results suggest that in the short run, pricing policies alone cannot be so much effective to decrease electricity consumption, but, in the long run, these policies become much more effective and policy makers should consider the spatial effects while making energy policies.

Key words: Electricity consumption; dynamic spatial panel data model; spatial effects

1. Introduction

Electricity is indispensable for the industrialized societies to ensure high living standards, manufacturing, economic growth, and development (Kirschen, 2003). Because power plant projects are mostly capital-intensive and require long lead times, it is very difficult to expand electricity generation capacity, simultaneously, to meet the electricity demand increases. In addition, the increased environmental awareness and political and economic concerns related to the high level of external dependency for energy show the importance of demand side energy policies. In order to implement effective policies and perform consistent demand projections, the determination of the factors affecting the electricity demand is very essential (Narayan and Smyth, 2005 and Carlos et al., 2009). Beginning by the pioneering study of Houthakker (1951), in the literature, there are many studies on the estimation of electricity demand. According to Dahl (2011), for the electricity demand estimation, there have been more than 450 studies. In addition, among the various survey studies for the electricity demand beginning by Taylor (1975), one recent survey is performed by Heshmati (2012) which identifies the main issues discussed in the electricity demand literature as endogeneity of electricity prices, functional form, nonlinearity, specification, estimation and type of data. However, in the literature, there is not so much study including the spatial effects.

In this research, we aim to analyze the factors determining the electricity demand and to obtain the price and income elasticities. For this purpose, we employ panel data on the provinces and regions of Turkey covering the period from 1990 to 2001 and the period between 2004 and 2011. At the province level, Akarsu (2013) and Akarsu and Gaygısız (2013b) used the same dataset to investigate the effects of the economic volatility and other factors affecting the electricity demand by employing dynamic panel data model for Turkey. Different from the previous studies, we extend the study by including spatial dependency among the provinces to our model in order to analyze the spatial effects across the provinces, and also, we do not analyze the effect of economic volatility. We utilize spatial panel data techniques in order to capture cross-section heterogeneity, dynamics, trends and spatial clusters in the electricity demand, simultaneously. According to Chakir et al. (2003), biased estimates for coefficients can be resulted from time series and cross section studies as they do not control for individual heterogeneity, however, in panel data, one can consider individual heterogeneity. In addition, we allow for spatial effects in order to account for the spatial spillovers and spatial clusters in the electricity consumption resulted from the socio-economic relations between the provinces and regions (Gomez et al., 2013).

In the literature, for aggregate electricity demand, there are some studies at the regional level employing panel data, for example, Hsiao et al. (1989), Diabi (1998), Atakhanova and Howie (2007), Ma et al. (2008), Ohtsuka et al. (2010), and Ohtsuka and Kakamu (2013).

However, among these studies, only Ohtsuka et al. (2010) and Ohtsuka and Kakamu (2013) incorporate spatial interactions into their models. Ohtsuka and Kakamu (2013) compare the forecasting performance of VAR(1) model and SAR-ARMA(1,1) model and their result show that VAR model have better forecasting performance.

Table 1: Econometric Total Electricity Demand Studies for Turkey.

Author	Data	Method/ Model	Variables	Income Elasticities		Price Elasticities	
				Short-run	Long-run	Short-run	Long-run
Soysal (1986)	1963-1981 TS	MLR OLS	GNP at constant prices, corrected electricity price, time	1.839		-0.0683	
Bakırtaş et al. (2000)	1962-1999 TS	Linear ECM	per capita real income	0.667	3.134		
Akan and Tak (2003)	1970-2000 TS	ECM	Income, price	0.630	1.8098	-	-0.2212
Erdoğdu (2007)	1984:Q1-2004:Q4 TS	PAM	real electricity prices, real GDP per capita	0.057	0.414	-0.04	-0.29
Maden and Baykul (2012)	1970-2009 TS	Cointegration model, ECM	per capita GDP, electricity price	0.168	0.928	-1.440	-6.85
Akarsu and Gaygısız (2013b)	1990-2001 65 provinces Panel Data	PAM	per capita GDP, real electricity price, urbanization ratio, heating and cooling degree days, volatility	0.379	0.838	-0.174	-0.385

Source: Author's own elaboration. Note: MLR: Multiple Linear Regression, OLS: Ordinary Least Squares; PAM: Partial Adjustment Model; ECM: Error Correction Model.

In addition to these studies, for residential electricity demand, Gomez et al. (2013) investigates the presence of spatial dependence between Spanish provinces using spatial econometrics techniques. They find the presence of the significant spatial effects from the estimation of static SARAR model. Furthermore, up to our knowledge, there is no any study for Turkey which considers spatial effects in the aggregate electricity demand. Table 1 lists the studies analyzing the total electricity demand for Turkey. Table shows that dynamic models are employed by all the studies except Soysal (1986) and different elasticity estimates are obtained based on the explanatory variables, time period and method employed. We aim to contribute to the literature by considering spatial interactions among the regions and provinces for Turkey.

In our model, we explain per capita aggregate electricity demand as a function of electricity price, per capita income, urbanization ratio, and weather variables; and restrict our attention to the aggregate level following the arguments of Pouris (1987) to obtain more stable relation and unbiased elasticities for the total economy. A priori, we expect positive effects of income, urbanization, and weather variables as higher level of economic activity, greater access to electricity, increased use and purchase of electrical appliances, and higher requirement for cooling and heating lead to increase in the electricity consumption; whereas, negative effect of electricity price on the electricity consumption are expected based on the producer theory and the law of demand in the consumer theory, for ordinary and normal goods.

The organization of the paper is as follows. After the introduction, in section 2, we introduce the empirical model and discuss the methodological issues. In section 3 and 4, after giving information on the data used for the empirical study, estimation results are presented for the data on the NUTS-3 level and NUTS-2 level, respectively. In the last section, we conclude.

2. Model and Methodology

2.1 Empirical Model

We analyze the following model which is built based on the economic theory and the empirical literature;

$$pcec_{it} = f(pcgdp_{it}, rep_{it}, uratio_{it}, hdd_{it}, cdd_{it}) \quad (2.1)$$

where, i=1,...,N and t=1,...,T are subscripts for cross-sectional units and time periods. In equation (2.1), we model per capita electricity consumption ($pcec_{it}$) as a function of per capita gross domestic product ($pcgdp_{it}$), real electricity price (rep_{it}), urbanization ratio ($uratio_{it}$), heating degree days (hdd_{it}) and cooling degree days (cdd_{it}). We assume identical consumption behavior across all the electricity consuming groups, perfectly elastic electricity supply, and perfectly elastic electrical capital equipment supply and do not allow for the possibility of inter-fuel substitutions. A priori, we expect positive effects of income, urbanization, and weather variables as electricity consumption increases by the higher level of economic activity, greater access to electricity, increased use and purchase of electrical appliances, and higher requirement for cooling and heating, on the other hand, negative effect of electricity price is expected based on the producer theory and the law of demand in the consumer theory, for ordinary and normal goods.

Electricity provides services only through the use of appliances, machines and equipment; therefore, electricity demand is a derived demand. Furthermore, it is essential to distinguish between short run and long run effects of the factors affecting the electricity demand. In the short run, because of the fixed stocks of electrical appliances, equipment, and machines, and some other factors of production, electricity demand is determined by the factors which only lead to changes in the utilization rate of this fixed electrical equipment stock. However, in the long run, size of stock and efficiency of electrical appliances, equipment, and machines can change due to the change in the economic and technological factors.

The time series properties of the data were not considered by the earlier studies after the works of Houthakker (1951) and Fisher and Kaysen (1962) and they have heavily employed partial adjustment model to distinguish between the long run and short run effects of the determinants of electricity demand (Amusa et al., 2009). For the analysis of the effects of the income, electricity price, urbanization ratio and weather variables, as we have data constraints, in this study also we estimate a dynamic panel data model based on the partial adjustment mechanism under the assumption of homogeneous slope coefficients across the provinces, in addition, allow for the spatial effects. Inefficient, biased, and inconsistent estimates can be obtained as a result of the ignorance of spatial effects. By introducing a partial adjustment process and spatial effects, we employ the following dynamic spatial panel data model considered by Elhorst (2005)[111];

$$\ln pcec = \alpha_1 \ln pcec_{-1} + X\alpha_2 + D_{\mu}\mu + D_{\tau}\tau + \varepsilon,$$

$$\varepsilon = \lambda W \varepsilon + u$$

(2.2)

where X = (lnpcgdp lnrep uratio hdd cdd), lnpcec, lnpcgdp, and lnrep are the natural logarithms of pcec, pcgdp and rep, respectively. μ, τ and λ are province specific fixed effects, time period specific effects and spatial autocorrelation coefficient, respectively. W is spatial weight matrix. In order to check for the robustness of results, we consider different types of weight matrices, such as, binary (queen) contiguity weight matrix, symmetric spatial weight matrix, row-stochastic spatial weight matrix, diagonal weight matrix with (i, i) equal to (1/ $\sqrt{sum\ of\ \text{ith row}}$), weight matrices based on nearest 2, 3 and 4 neighbors and lastly, weight matrix based on power distance weights given by ($w_{ij}=d_{ij}^{-1}$) where d_{ij} is the distance between ith and jth provinces based on economic centers. The coefficients on per capita gross domestic product and real electricity price give income and own price elasticities invariant at any levels of an explanatory variable, as the model is in the double-logarithmic functional form. If income elasticity is smaller (larger) than unity, then the electricity is a necessary (luxury) good. For equation (2.2), the coefficients on the explanatory variables are the short run (direct effect) parameters. If we divide these short run parameters by (1-α_1), we can obtain the long run (direct effect) parameters.

2.2 Methodology

In order to estimate dynamic spatial panel data model given by equation (2.2), we employ Maximum Likelihood (ML) estimator as suggested by Das, Kelejian, and Prucha (2003) and Elhorst (2005) assuming that all the variables are exogenous. When the time dimension is short, it is mentioned that first cross section of observations contains important amount of information. Therefore, ML estimation is based on unconditional likelihood function which requires the specification of the marginal distribution of initial values and thus, pre-sample values of exogenous explanatory variables. In order to solve this problem, Elhorst (2005) considers two approximations: Bhargava and Sargan (1983) (BS) approximation and another approximation proposed by Nerlove and Balestra (1996) (NB) and Nerlove (1999) or Nerlove (2000). In this study also, we estimate the model by using these two different approximations. Furthermore, Elhorst (2005) discusses that the parameter estimates, obtained from the unconditional likelihood function of the first differenced fixed effects dynamic panel data model which is further extended to include spatial error autocorrelation, for the lagged dependent variable and exogenous explanatory variables are consistent. For detailed information and the log-likelihood functions maximized for each of the approximation, one can refer to Elhorst (2005). Numerical iterative optimization is based on golden section search and parabolic interpolation.

3. Analysis at NUTS-3 (Provinces) Level

3.1. Data

For the analysis, we use annual balanced panel data on 65 provinces of Turkey between the years 1990 and 2001.

Because of the unavailability of province level data for GDP after 2001 and for sectoral electricity consumption before 1990, the period for the analysis is restricted between 1990 and 2001. The data set includes per capita electricity consumption (pcec), per capita gross domestic product (pcgdp), electricity end-use prices (rep), urbanization ratio (uratio), heating degree days (hdd) and cooling degree days (cdd). Data sources are given in Table 2.

[111] For the other models employed in the literature, one can refer to Elhorst (2012).

Table 2: Data Sources.

Data	Data Source
Total Electricity Consumption (kWh) Sectoral Electricity Consumption (kWh) Sectoral Electricity End-use Prices (TL/kWh)	Turkish Electricity Distribution Company (Co. Inc.)
Population, GDP, urban population	TURKSTAT Database
Average daily temperature[1]	Turkish State Meteorological Service
İstanbul Chamber of Commerce (İTO) wholesale price index (general, 1968=100)[2]	Electronic Data Delivery System of CBRT

[1] Average daily temperature is used for the calculation of hdd and cdd variables.
[2] İstanbul Chamber of Commerce (İTO) wholesale price index (general, 1968=100) is used for deflation of GDP and electricity end-use prices.

Before analysis, we make some arrangements in the data as follows;

1. We interpolate gaps in the total population and urban population by using exponential function method as described in Kocaman (2002).

2. After 1989, some towns have gained province status. Therefore, we rearrange the data on total population, urban population, total and sectoral electricity consumption and GDP by adding the data values on new provinces to the provinces that they were disjoined based on the information obtained from the website of Ministry of Justice.

3. We obtain the electricity end-use price by taking the weighted average of each sector's electricity end-use prices. Weights are the electricity consumption share of each sector out of total electricity consumption.

4. Urbanization ratio is calculated as the ratio of urban population to the total population for each province.

5. In order to obtain per capita values, we use populations of each province over the period.

6. We calculate heating and cooling degree days by the method described by Turkish State Meteorological Service for each day and province based on the following formulae (Şensoy and Ulupınar, 2008);

$$HDD_i = \begin{cases} (18°C - T_{mi}) & if \ \mathrm{T}_{mi} \leq 15 \\ 0 & if \ \mathrm{T}_{mi} > 15 \end{cases}, \ \mathrm{i=1,...,365}$$

$$CDD_i = \begin{cases} (T_{mi} - 22°C) & if \ \mathrm{T}_{mi} > 22 \\ 0 & if \ \mathrm{T}_{mi} \leq 22 \end{cases}, \ \mathrm{i=1,...,365}$$

(3.1)

where, T_{mi} is the average daily temperature. In order to obtain annual values (hdd and cdd), we sum the daily $\mathrm{CDD_i}$ and $\mathrm{HDD_i}$ values.

7. We transform the data on per capita electricity consumption, per capita real gross domestic product and real electricity end use price using natural logarithm.

We present the descriptive statistics and pairwise correlations for all the variables in Tables 3 and 4. We observe high and positive correlation between lnpcec and lnpcgdp. Other pairwise correlations are all near to or smaller than 0.5. Pairwise correlations between all the explanatory variables indicate that there is no evidence of high collinearity among them.

Figure 1 displays the geographic distribution of per capita electricity consumption for Turkey in the years 1990 and 2001 at the province level. Figure shows similar electricity consumption in the neighboring provinces for both years, thus spatial interdependence among these provinces which can be due to the socio-economic interactions among the provinces. We calculate Moran's I statistic using binary contiguity (queen) weight matrix for years 1990 and 2001 given in Table 5. This statistic also supports the evidence of spatial effects in the per capita electricity consumption. However, when we analyze the change of Moran's I statistic between the years 1990 and 2001, we observe a decline in the value and significance of statistic which can be interpreted as a weakening of interactions among the provinces.

Table 3: Summary Statistics (Observations: N=65, T=12).

Variable		**Mean**	**Std. Dev.**	**Min**	**Max**
lnpcec	overall	6.595369	0.757331	4.57975	8.868191
	between		0.715726	5.040345	8.294726
	within		0.261762	5.807487	7.329725
lnpcgdp	overall	4.51865	0.493763	3.157	5.922141
	between		0.470469	3.36499	5.791121
	within		0.159957	3.964092	5.209798
lnrep	overall	-5.75458	0.133309	-6.15367	-5.41734
	between		0.017696	-5.82204	-5.71455
	within		0.132146	-6.13709	-5.42408
uratio	overall	0.521487	0.121312	0.27	0.92
	between		0.118381	0.310833	0.910833
	within		0.030007	0.418154	0.628154
hdd	overall	2390.004	877.007	526.4	5671.1
	between		848.3005	757.6583	4852.217
	within		244.3132	1518.154	3444.388
cdd	overall	260.0574	246.6466	0.3	1165.8
	between		240.994	5.658333	1033.4
	within		59.80418	65.64077	450.8408

Notes: Variation over time (across provinces) is defined by within (between) variation. Overall variance is decomposed as within and between variance. Minimum and maximum of panel series are given by columns min and max for overall (x_{it}), between ($\overline{x_i}$) and within ($x_{it} - \bar{x}_i + \bar{x}$). N shows the number of provinces. T is the time series dimension for each province.

Table 4: Correlation Matrix.

Variable	lnpcec	lnpcgdp	lnrep	uratio	hdd	cdd
lnpcec	1.00					
lnpcgdp	0.87	1.00				
lnrep	0.27	0.23	1.00			
uratio	0.49	0.49	0.20	1.00		
hdd	-0.52	-0.55	-0.12	-0.30	1.00	
cdd	0.18	0.14	0.12	0.27	-0.63	1.00

Figure 1: Geographic Distribution of per capita Electricity Consumption across Provinces for Turkey (1990 and 2001).

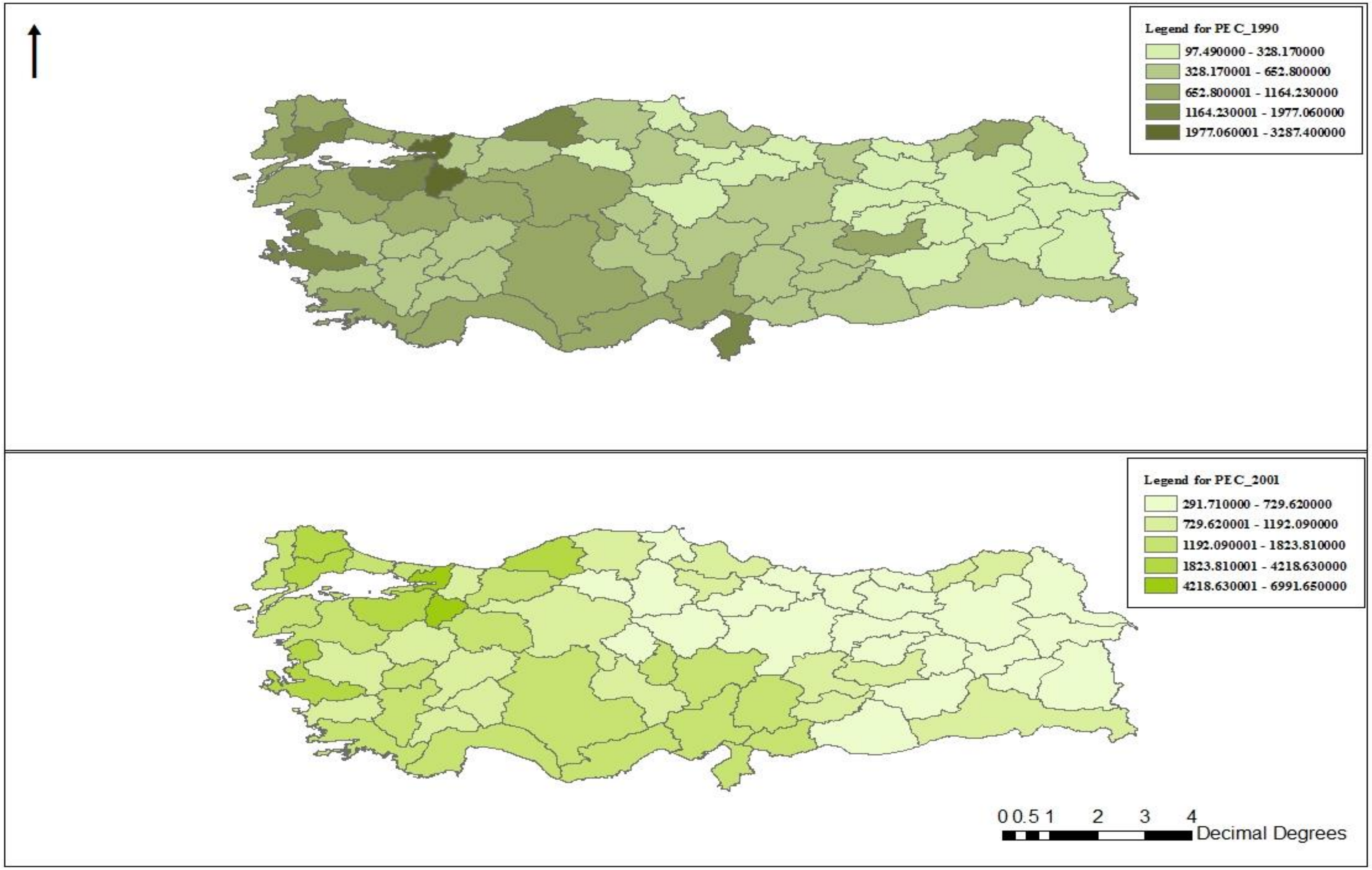

Table 5: Moran's I of per capita Electricity Consumption for years 1990 and 2001.

Year	Moran's I	E(I)	Std(I)	z-value	p-value
1990	0.3071	-0.0156	0.0732	4.4060	0.0004
2001	0.2521	-0.0156	0.0718	3.6987	0.0040

Table 6: Estimation Results of Dynamic Spatial Panel Data Model for Electricity Demand of Turkey (65 provinces over the period from 1990 to 2001).

	Binary (Queen) Contiguity Weight Matrix		Symmetric Spatial Weight Matrix	
lnpcec	**B&S**	**N&B**	**B&S**	**N&B**
$lnpcec_{-1}$	0.731984*** (23.9649)	0.54950*** (18.0713)	0.731984*** (23.9649)	0.757879 (0.000000)
lnpcgdp	0.16734 (0.011052)	0.81223*** (9.372679)	0.169648 (0.011685)	0.090094*** (3.993122)
lnrep	-0.303477 (-0.00353)	-0.33081 (-1.48689)	-0.299558 (-0.00363)	0.091544 (0.631029)
uratio	0.920284 (0.009075)	0.58931** (2.148893)	0.928159 (0.009488)	0.800502*** (4.849865)
hdd	-0.000031 (-0.00285)	0.00000 (0.000991)	-0.000032 (-0.00298)	-0.000012 (0.000000)
cdd	0.000034 (0.000976)	0.00000 (-0.00018)	0.000053 (0.001534)	0.000025 (1.022303)
Wε	0.02396*** (1.332497)	-0.07244*** (-1.62008)	0.000273 (0.003081)	0.049023 (0.819191)
log-likelihood	3317.295	-499.415	3276.83	-636.572

Notes: *, **, *** shows the statistical significance of coefficient at 10%, 5% and 1% significance levels. t-values are in parentheses. B&S and N&B stand for Bhargava and Sargan (1983) and Nerlove and Balestra (1996) approximations.

3.2. Empirical Results

In Table 6, we present the estimation results of dynamic spatial panel data model for electricity demand of Turkey employing different approximations for the first observations and weight matrices [112]. We assume that all the explanatory variables are exogenous. Estimations are performed by ML estimation method and codes written by Elhorst (2005) in Matlab program.

In order to check for the robustness of results, we present the estimation results for two different specifications of spatial weights matrix. We find that different specifications of weight matrix lead to different results. However, according to maximized log-likelihood values, binary contiguity weight matrix is superior to the symmetric spatial weight matrix. Therefore our results are based on the estimation using binary (queen) contiguity weight matrix. Results also differ according to the approximation for the first observations. However, results show evidence of significant spatial effects for both approximations with different signs. Elhorst

[112] In order to save space, Table 6 only shows the results of estimations which are statistically significant and theoretically consistent. Results based on the other weight matrices can be provided upon request.

(2005) finds that Nerlove and Balestra (1996) approximation is better than the Bhargava and Sargan (1983) approximation based on the comparison of the forecast performance of the estimator using the first cross section of observations according to each approximation. According to Figure 1 and Moran's I statistic, we expect positive spatial correlation among the provinces, i.e. spatial clustering. The results indicate negative spatial correlation for Nerlove and Balestra (1996) approximation which is contrary to our expectation. Therefore, our conclusion is based on the estimation results for Bhargava and Sargan (1983) approximation. We cannot find statistically significant effects of any economic factor. Moreover, results indicate that electricity demand is inelastic with respect to income both in the short run and in the long run with the following short run and long run elasticities, 0.16734 and 0.62437, respectively. Although short run electricity demand is price inelastic (short run elasticity is -0.30348), long run electricity demand is found to be elastic with respect to price (long run elasticity is -1.13231). The comparison of our results with the previous studies shows that our results are in line with the findings of the past studies employing partial adjustment model except for long run elasticities. Hsiao et al. (1989), Diabi (1998), Erdoğdu (2007), and Bhargava et al. (2009) have found that short run electricity demand is income and price inelastic. However, findings of Hsiao et al. (1989) and Bhargava et al. (2009) indicate that long run electricity demand is elastic with respect to income and inelastic with respect to price.

4. Analysis at NUTS-2 Level (26 Regions)

4.1. Data

Different from the previous section, we use annual balanced panel data on 26 regions of Turkey between the years 1990 and 2001 as well as over the period from 2004 to 2011. For the years between 1990 and 2001, we reaarange the data employed in the Section 3 at the province level based on the region definitons for NUTS-2 level[113]. On the other hand, for the years from 2004 to 2011, we use Gross Value Added (GVA) instead of GDP because of data unavailability. The data set includes per capita electricity consumption (pcec), per capita GVA (pcgva), per capita gross domestic product (pcgdp), electricity end-use prices (rep), urbanization ratio (uratio), heating degree days (hdd) and cooling degree days (cdd). Data sources are given in Table 7.

We follow the similar steps to prepare the data for the analysis as in the Section 3;

1. We interpolate the gaps in the total population and urban population by using exponential function method as described in Kocaman (2002).

2. We obtain the electricity end-use price by taking the weighted average of each sector's electricity end-use prices. Weights are the electricity consumption share of each sector out of total electricity consumption.

3. Urbanization ratio is calculated as the ratio of urban population to the total population for each region.

4. In order to obtain per capita values, we use populations of each region over the period.

5. We calculate heating and cooling degree days by the method described by Turkish State Meteorological Service for each day and province based on the following formulae (Şensoy and Ulupınar, 2008);

$$HDD_i = \begin{cases} (18°C - T_{mi}) & \text{if } T_{mi} \leq 15 \\ 0 & \text{if } T_{mi} > 15 \end{cases}, \text{ i=1,...,365}$$

$$CDD_i = \begin{cases} (T_{mi} - 22°C) & \text{if } T_{mi} > 22 \\ 0 & \text{if } T_{mi} \leq 22 \end{cases}, \text{ i=1,...,365}$$

(4.1)

where, T_{mi} is the average daily temperature. In order to obtain annual values (hdd and cdd), we sum the daily CDD_i and HDD_i values for each province. In order to calculate the regional values, we take the weighted average of each provinces' HDD and CDD where weights are surface area of each province.

6. We transform the data on per capita electricity consumption, per capita real gross domestic product and real electricity end use price using natural logarithm. For the period between 1990 and 2001 (period between 2004 and 2011), Tables 8 and 9 (Tables 10 and 11) show the descriptive statistics and pairwise correlations for all the variables, respectively.

[113]Regions definitions for NUTS-2 level is taken from TURKSTAT.

Table 7: Data Sources.

Data	Data Source
Total Electricity Consumption (kWh) Sectoral Electricity Consumption (kWh) Sectoral Electricity End-use Prices (TL/kWh)	Turkish Electricity Distribution Company (Co. Inc.) and Turkish Electricity Transmission Company
Population, GDP (TL), GVA (TL) for 2004-2011, urban population, surface area (km-square)	TURKSTAT Database
Average daily temperature[1]	Turkish State Meteorological Service
Regional consumer price index (2003=100)[2]	Electronic Data Delivery System of CBRT

[1] Average daily temperature is used for the calculation of hdd and cdd variables.
[2] Regional consumer price index is used for deflation of GVA and electricity end-use prices for 2004-2011 and we use İstanbul Chamber of Commerce (İTO) wholesale price index (general, 1968=100) for years between 1990 and 2001.

Table 8: Summary Statistics for the years between 1990 and 2001 (Observations: N=26, T=12).

Variable		Mean	Std. Dev.	Min	Max
lnpcec	overall	6.762911	0.690242	4.928898	8.217164
	between		0.661542	5.337876	7.802483
	within		0.232972	6.167722	7.376816
lnpcgdp	overall	-9.21365	0.471593	-10.4631	-8.15451
	between		0.457226	-10.1277	-8.36643
	within		0.144009	-9.64265	-8.72696
lnrep	overall	-5.75077	0.129133	-6.08358	-5.42843
	between		0.016146	-5.78308	-5.71652
	within		0.128155	-6.05676	-5.43637
uratio	overall	0.562696	0.138331	0.335	0.924
	between		0.13851	0.398275	0.912017
	within		0.025081	0.499421	0.626721
cdd	overall	312.8231	271.333	17.09724	1021.684
	between		269.6345	56.95075	915.4641
	within		59.07887	122.5872	451.8839
hdd	overall	2329.942	858.4146	680.7891	5232.81
	between		842.8309	856.0028	4412.877
	within		227.2381	1834.805	3149.875

Notes: Variation over time (across regions) is defined by within (between) variation. Overall variance is decomposed as within and between variance. Minimum and maximum of panel series are given by columns min and max for overall (x_{it}), between ($\bar{x}_i$) and within ($x_{it} - \bar{x}_i + \bar{x}$). N shows the number of regions. T is the time series dimension for each region.

Table 9: Correlation Matrix for the years between 1990 and 2001.

Variable	lnpcec	lnpcgdp	lnrep	uratio	hdd	cdd
lnpcec	1					
lnpcgdp	0.8932	1				
lnrep	0.2796	0.2442	1			
uratio	0.4495	0.5591	0.177	1		
hdd	-0.5757	-0.5582	-0.1293	-0.3356	1	
cdd	0.1009	0.0019	0.0901	0.2014	-0.6696	1

Table 10: Summary Statistics for the years between 2004 and 2011 (Observations: N=26, T=8).

Variable		Mean	Std. Dev.	Min	Max
lnpcec	overall	7.465155	0.5788445	5.969629	8.57697
	between		0.5676441	6.281327	8.466511
	within		0.1540695	7.07934	7.914846
lnpcgdp	overall	4.07946	0.3947751	3.217144	4.792941
	between		0.3956425	3.334876	4.716727
	within		0.0678806	3.770769	4.327248
lnrep	overall	-6.725477	0.0935777	-6.969631	-6.536192
	between		0.030516	-6.781206	-6.668251
	within		0.08864	-6.932051	-6.589759
uratio	overall	0.6567346	0.1355203	0.4618	0.9899
	between		0.1338101	0.4713	0.9439125
	within		0.032651	0.5516721	0.7553721
hdd	overall	2200.902	831.8285	484.5551	4497.175
	between		817.8568	758.9622	4212.056
	within		213.7018	1362.951	2575.019
cdd	overall	362.1124	290.5942	26.36103	1111.58
	between		288.0787	70.27398	996.6456
	within		65.28406	197.7617	542.5086

Notes: Variation over time (across regions) is defined by within (between) variation. Overall variance is decomposed as within and between variance. Minimum and maximum of panel series are given by columns min and max for overall (x_{it}), between ($\overline{x_i}$) and within ($x_{it} - \bar{x}_i + \bar{x}$). N shows the number of regions. T is the time series dimension for each region.

Table 11: Correlation Matrix for the years between 2004 and 2011.

Variable	lnpcec	lnpcgdp	lnrep	uratio	hdd	cdd
lnpcec	1					
lnpcgdp	0.8153	1				
lnrep	-0.0142	0.0392	1			
uratio	0.4319	0.5736	0.1202	1		
hdd	-0.5335	-0.3734	-0.0518	-0.3361	1	
cdd	0.0336	-0.2289	-0.1891	0.1455	-0.6651	1

Table 12: Moran's I of per capita Electricity Consumption for years 1990, 2001, 2004, 2008 and 2011.

Year	Moran's I	E(I)	Std(I)	z-value	p-value
1990	0.4002	-0.0400	0.1277	3.4478	0.00130
2001	0.4141	-0.0400	0.1292	3.5141	0.00125
2004	0.4192	-0.0400	0.1281	3.5838	0.00087
2008	0.4378	-0.0400	0.1273	3.7527	0.00044
2011	0.4547	-0.0400	0.1293	3.8234	0.00042

Pairwise correlations are all near to or smaller than 0.5 indicating that there is not any high collinearity among the explanatory variables. Same conclusion is valid for the period over 2004 and 2011, however, we observe high correlation between lnpcec and lnpcgdp as expected. In Figures 2 and 3, we present regional distribution of per capita electricity consumption for Turkey in the years 1990, 2001, 2004, 2008 and 2011 at the NUTS-2 level. We observe that neighboring regions have similar electricity consumption values for all the years under consideration indicating spatial interdependence among the regions.

For the same years, Moran's I statistic is given in Table 12 which is calculated using binary contiguity (queen) weight matrix. Based on this statistic also, we can conclude that there is significant spatial effects in the per capita electricity consumption and over the period, value and significance of Moran's I statistic increases showing a boost in the spatial interactions among the regions.

4.2. Empirical Results

We estimate the model given in 2.2 by employing NUTS-2 level data for two separate time periods, as between 1990 and 2001 and between 2004 and 2011 and using ML estimation method as well as different approximations for the first observations as described by Elhorst (2005) and two weight matrices[114] assuming that all the explanatory variables are exogenous. Estimation results are given in Tables 13 and 14 for the period between 1990 and 2001 and between 2004 and 2011, respectively. We obtain different results using different specifications of spatial weight matrix and different approximations for the first observations, thus our results are not robust to the specifications of weight matrix and approximation for the first observations. In Tables 13 and 14, we give estimation results for weight matrices which are associated with the highest log-likelihood values. As we expect positive spatial correlation among the regions, our conclusions are based on the estimation results with positive spatial effect, however spatial effects are not statistically significant. Our results suggest that over the period between 1990 and 2001, only income and cooling degree days variables have statistically significant effects on the electricity demand using diagonal weight matrix.

However, for the period between 2004 and 2011, we find significant effects of price and cooling degree days variables using diagonal weight matrix. In Table 15, we present the long run and short run elasticities for the two time periods. Estimation results show that electricity demand is inelastic with respect to price and income in the short run and the long run over the period from 1990 to 2001. On the other hand, for the period between 2004 and 2011, short run and long run electricity demand is income inelastic, short run electricity demand is found to be price inelastic but in the long run, findings show that electricity demand is price elastic based on the results using weights formed by considering nearest three neighbours. Comparison of our results with the previous studies shows that results are in line with the findings of the past studies employing partial adjustment model only for short run as we discussed in Section 3.2.

5. Conclusion

In this study, we examine the factors affecting the electricity demand accounting for spatial effects employing the panel data on the provinces and regions of Turkey over the period from 1990 to 2001 and also between the periods 2004 and 2011. Our analysis is based on the spatial panel data techniques. We estimate the dynamic spatial electricity demand model by Maximum Likelihood Estimation method which is shown to give more accurate results than the Generalized Method of Moments (GMM) (Elhorst, 2005).

Findings indicate the evidence of spatial effects for the province level analysis. However, as we introduce the spatial effects by using spatial error model, we cannot obtain the indirect effects (spatial spillover).

[114] In order to save space, Tables 13 and 14 only show the estimation results which are selected based on log likelihood value, statistical significance and theoretical consistency. Results associated with the employment of other weight matrices can be provided upon request.

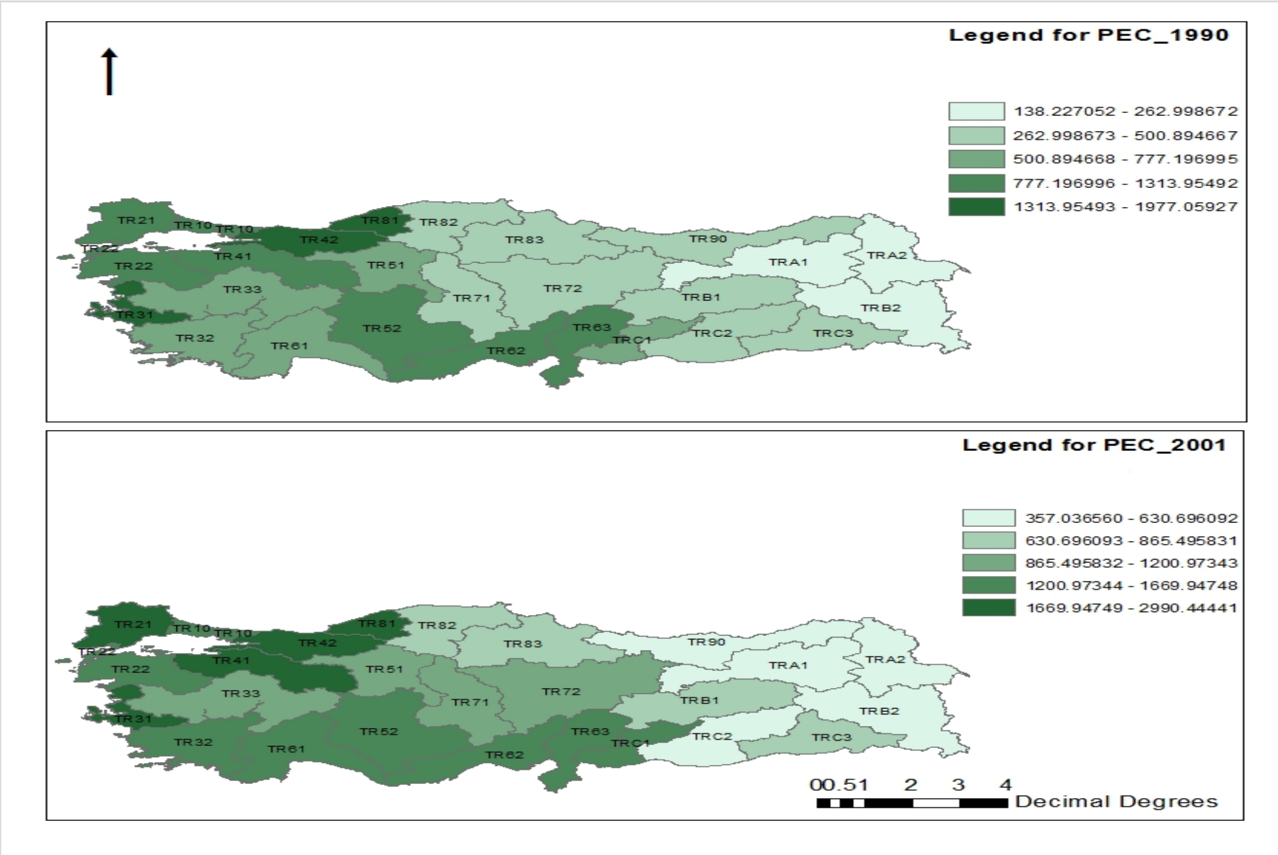

Figure 2: Geographic Distribution of per capita Electricity Consumption across Regions for Turkey (1990 and 2001).

Table 13: Estimation Results of Dynamic Spatial Panel Data Model for Electricity Demand of Turkey (26 regions over the period from 1990 to 2001).

	Diagonal Weight Matrix (with (i, i) equal to (1/sqrt(sum of ith row))		**Weight Matrix based on nearest 3 neighbors**	
lnpcec	**B&S**	**N&B**	**B&S**	**N&B**
$lnpcec_{-1}$	0.731984*** (15.1564)	0.703889 (0.0000)	0.731984*** (15.156689)	0.744129 (0.000000)
lnpcgdp	0.163487 (0.0068)	0.107522** (2.3506)	0.163487 (0.006824)	0.071455 (1.578175)
lnrep	-0.24326 (-0.0026)	0.046437 (0.2700)	-0.243297 (-0.002570)	0.034388 (0.257163)
uratio	0.000003 (0.0002)	0.000009 (0.0000)	0.000003 (0.000173)	-0.000002 (0.000000)
hdd	0.000031 (0.0006)	0.000032 (0.6255)	0.000031 (0.000617)	0.000009 (0.153414)
cdd	0.941014 (0.0057)	0.990081*** (3.8498)	0.940966 (0.005723)	0.889615*** (3.393598)
Wε	-0.99783*** (-8.5387)	0.347433 (0.0000)	0.000132 (0.001183)	-0.150347* (-1.933029)
log-likelihood	1255.0604	-311.23052	1255.0484	-311.81147

Notes: *, **, *** shows the statistical significance of coefficient at 10%, 5% and 1% significance levels. t-values are in parentheses. B&S and N&B stand for Bhargava and Sargan (1983) and Nerlove and Balestra (1996) approximations.

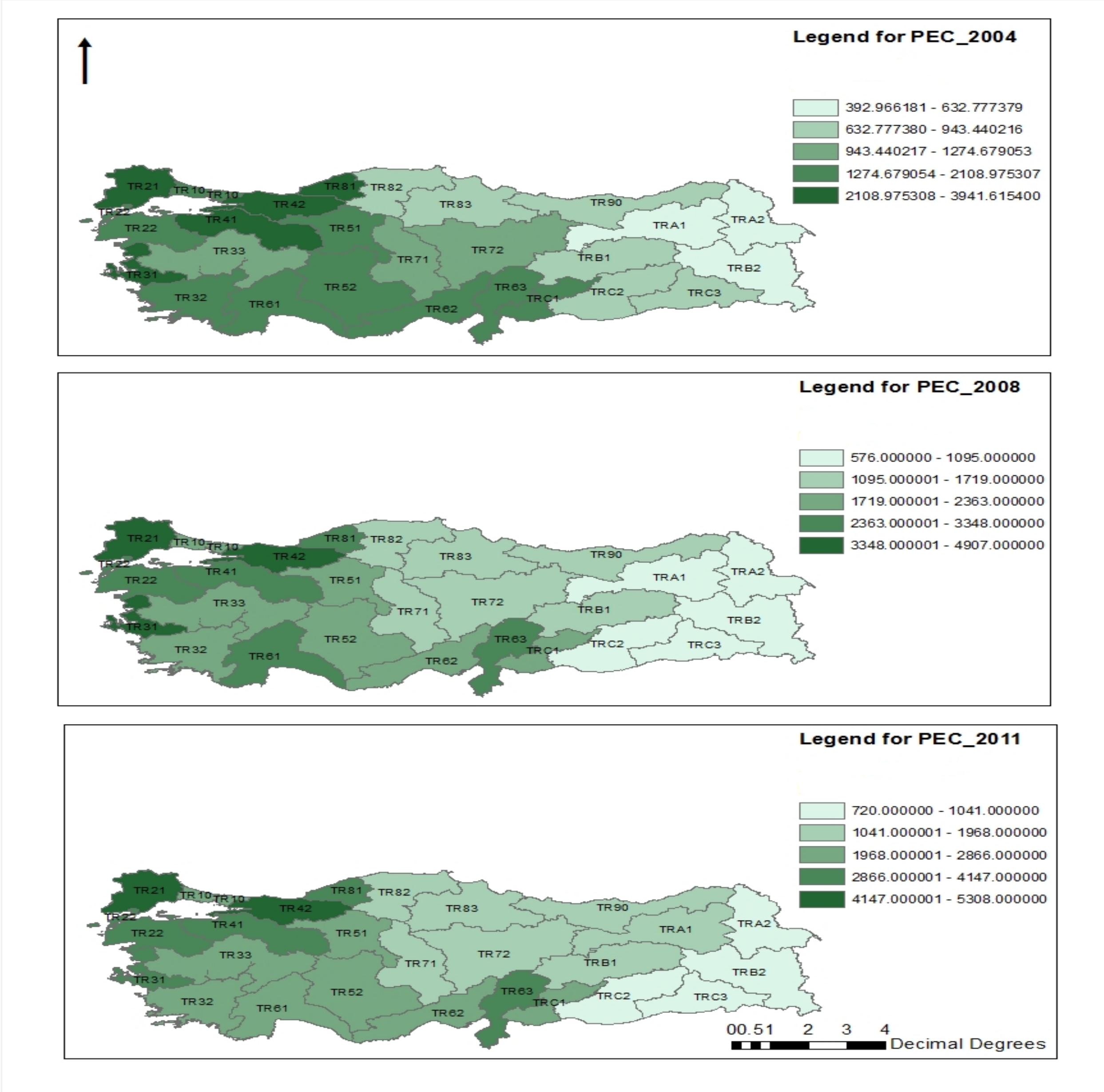

Figure 3: Geographic Distribution of per capita Electricity Consumption across Regions for Turkey (2004, 2008 and 2011).

Table 14: Estimation Results of Dynamic Spatial Panel Data Model for Electricity Demand of Turkey (26 regions over the period from 2004 to 2011).

	Diagonal Weight Matrix (with (i, i) equal to (1/sqrt(sum of ith row))		**Weight Matrix based on nearest 3 neighbors**	
lnpcec	**B&S**	**N&B**	**B&S**	**N&B**
$lnpcec_{-1}$	0.7319*** (13.9923)	0.6033*** (8.2626)	0.7319*** (13.9925)	0.624 (0.000)
lnpcgdp	0.1560 (0.0023)	0.1003 (0.6979)	0.1560 (0.0023)	0.091 (0.000)
lnrep	-0.4248 (-0.0047)	-0.3879** (-2.2441)	-0.4248 (-0.0047)	-0.351*** (-48.926)
uratio	0.0003 (0.0050)	0.0003 (1.7398)	0.0003 (0.0050)	0.000 (0.000)
hdd	0.0000 (0.0007)	0.0000 (0.3181)	0.0000 (0.0007)	0.000 (0.000)
cdd	-0.5455 (-0.0045)	-0.5618*** (-2.5783)	-0.5455 (-0.0045)	-0.530 (0.000)
Wε	-0.9978*** (-6.8115)	0.1313 (0.0000)	0.0001 (0.0010)	-0.069 (-0.667)
log-likelihood	803.13652	-233.31642	803.12793	-231.6902

Notes: *, **, *** shows the statistical significance of coefficient at 10%, 5% and 1% significance levels. t-values are in parentheses. B&S and N&B stand for Bhargava and Sargan (1983) and Nerlove and Balestra (1996) approximations.

Table 15: Long run and Short run Price and Income Elasticities.

	Period from 1990 to 2001		**Period from 2004 to 2011**	
	Long Run	**Short Run**	**Long Run**	**Short Run**
Income	0.3631; 0.6099	0.1075; 0.1635	0.2528; 0.5818	0.1003; 0.1560
Price	0.1568; -0.9078	0.0464; -0.2433	-0.9778; -1.5845	-0.3879; -0.4248

We cannot find significant impacts of any economic factors for the period between 1990 and 2001 at the province level; however, from the analysis at NUTS-2 level, findings show the statistically significant effects of income and cooling degree days variables over the period between 1990 and 2001 and also significant impacts of price and cooling degree days variables covering the period from 2004 to 2011 using diagonal weight matrix. Furthermore, estimation results show that electricity demand is inelastic with respect to income and price in the short run, and therefore electricity is a normal good and a necessity. However, long run electricity demand is found to be price elastic and income inelastic.

As a conclusion, in the short run, pricing policies alone cannot be so much effective to decrease electricity consumption, however, in the long run, these policies become much more effective and in addition, spatial effects should be considered while making energy policies at the regional level. Because, the energy policy related to only one province can affect other provinces. Furthermore, policy makers should support pricing policies by the diversification across energy resources and energy efficiency programs.

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A study of building thermal models for use in the analysis of energy sector coupling

by

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Abstract

Coupling of the heat and electricity sectors is key to the transformation towards a renewable-based energy system. It will provide the flexibility needed to cater for the intermittent nature of renewable generation and result in more efficient operation. Therefore, a holistic approach in energy planning that tightly integrates the demand and supply of heat and electricity is crucial particularly at the city level. This study focuses on the thermal simulation of buildings at a large urban scale. One of the main challenges deals with the computational complexity that involves difficult trade-offs between data availability, output resolution, model accuracies and computational time. This paper presents a comparative study of two building thermal modelling approaches using a typical residential building as an example. The modelling methods that are examined are i) a low-order RC model and ii) a complex multi-zonal model using the simulation software EnergyPlus. The study compares the modelled indoor temperatures by the two methods and examined the effects of three input parameters namely solar radiation, internal thermal mass and internal heat gains on both the indoor temperature and heating load. The study shows that the simplified RC method has great potential for applications in large-scale urban modelling, although further work is needed to improve the RC model used in this study to operational capacity.

Keywords: Heat demand modelling, residential sector, building simulation, thermal low-order models

1. Introduction

The European Commission (2014) has recently set a new target for the integration of renewable energy. By 2030 the share of renewable energy consumption should reach at least 27%. This transformation implies the need for a flexible energy system that can account for the intermittent character of green energy sources. Urban energy planners are currently lacking modelling tools for integrating both electricity and heat sectors at high spatial and temporal resolution. The main challenges are data availability and computational complexity. In this paper we compare two different building thermal models: a low-order RC model and a complex multi-zonal model developed in EnergyPlus. The aim is to understand the performance of simplified RC models and shed light on their further development.

2. Literature review

Forecasting the energy demand of the residential sector at a city scale has been developed following two different approaches: the top-down and the bottom-up. Each methodology aims to answer different questions. Top-down models extrapolate aggregated data to infer total energy consumption whereas bottom-up models derive energy demand from basic components and scale up the results to larger entities. While the former is used to study the link between energy consumption and other factors such as climate change, building stock characteristics or GDP, the latter method is more appropriate for energy supply planning and for identification of energy saving potentials (Swan & Ugursal, 2009). These demand models can be further split into sub-categories that will be further introduced below.

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In this study we aim to implement an energy demand modelling tool at high spatial and temporal resolution into a Geographic Information System (GIS), therefore the review of previous work will mainly focus on techniques related to these aspects.

2.1 Top-Down Approach

Top-down models were first used during the energy crisis of the 1970s and consider the built environment as an energy sink (Mohammadi, de Vries, & Schaefer, 2013). The energy balancing is based on national standard profiles or historical consumption values. The first models were econometric models integrating macroeconomic indicators relative to prices and incomes. Hirst et al. (1977) estimated the annual energy consumption according to the changes in the housing ownership. Zhang (2004) compared the values of Unit Energy Consumption (UEC) of China to the ones of USA, Canada and Japan and identified a potential similarity in the evolution of the Chinese residential sector to the North American and Japanese one. Later top-down models integrated technological parameters and initiated a new category. Technological models rely on appliance ownership, technological progress or structural changes (Johnston, 2003).

2.2 Bottom-Up Approach

Bottom-up models follow disaggregated calculations to mathematically describe the energy demand in detail and are therefore better suited to analyze energy efficiency standards (Böhringer & Rutherford, 2006). They are categorized in two subgroups, statistical and engineering, and require various input-parameters to account for individual end-uses. The results are then extrapolated using weighting factors to represent the energy demand at larger scale (Swan & Ugursal, 2009). The crucial limitation of bottom-up approaches is the necessity for a large range of data, which is often not available at city scale.

Engineering models are based on building physics and thermodynamics and do not require historical values to estimate energy consumptions. Some of the drawbacks of such methods are the computational complexity and the need of very detailed input-parameters. Nevertheless these methods can provide urban planners and utility suppliers with analysis and forecasts of energy consumption at high temporal resolution. High resolution models are of increasing interest when it comes to study the performance of new technologies, especially due to the intermittent character of renewable energy generation. (S. Taylor, Allinson, Firth, & Lomas, 2013).

2.2.1 Archetype Approach

The sampling and the archetype methods are simplified engineering methods widely used for the prediction of energy consumptions at larger scales. These methods categorise buildings into a manageable set of typologies to represent the actual housing stock (Swan & Ugursal, 2009). Orehouning et al. (2014) studied the effect of simplification in dynamic building simulations on a larger scale. They predicted the energy consumption of a neighborhood composed of 100 buildings following two simulation approaches: in the simplified approach, the 100 buildings were clustered into 6 categories depending on the building age and use type, while in the detailed approach all 100 buildings were modelled with the software CitySim. The input parameters were taken either from on-site survey and data collection or assumptions based on the construction year and national standards (SIA, 2011). The resulting heat demand from the clusters was extrapolated to the overall floor area of the neighborhood. Hourly heating loads were roughly estimated from the total yearly demand. The simulation results were finally compared to measured consumptions of the neighborhood. The simplified approach achieved a deviation of 25% while the detailed approach only 8% from the measured yearly demand. Moreover, modelling of the energy demand with standardized occupancy data is better suited for the simplified approach because it levels out the uncertainties of individual behavior. The main drawback of the archetype method is that it is not suitable for high spatial and temporal simulations.

2.2.2 Artificial Neural Network

Moving forward to more complex bottom-up approaches, "Neural Network" is introduced. Neural Networks belong to the statistical approaches and are especially relevant to this paper owing to its particularity of predicting energy consumptions at high temporal resolution without information on the geometries and the thermal properties of buildings (Foucquier, Robert, Suard, Stéphan, & Jay, 2013).

Artificial Neural Networks (ANN) simulate the way a biological neural network works by “learning” from previously known situations to forecast the results for new situations. The network is based on the rule of layers: Input, hidden and output layer. Each layer contains a set of neurons, which are interconnected with neurons of the next layers. The complexity of the model increases by adding layers to each category. Depending on the available database and the purpose of the study, “input”-neurons and “output”-neurons can be respectively added. This is why the quality and completeness of the database, from which the model should learn, is essential. Neto and Fiorelli (2008) compared energy simulations between EnergyPlus and an ANN-model based on the feed-forward approach. Both methods were applied on a university administration building and a parametric study was conducted leading to the conclusion that, humidity and solar radiation have a lower influence than the external temperature on energy consumptions when using the ANN method. While in the case of the EnergyPlus complex simulations the internal heat gains show a significant effect on the results. Regarding the overall comparison to measured consumptions, the EnergyPlus simulation showed an error of ± 13% for 80% of the tested database of a 54-day period between January and March, while the ANN achieves an average error of about 10% when separating the networks for workdays and weekends.

After developing a first network to study the electrical consumptions of appliances, lighting and cooling, Aydinalp et al. (2004) trained two neural networks with values from more than 1300 households to analyse the energy consumption for space heating (SH) and domestic hot water (DHW). The input data were taken from the Survey of Household Energy-Use from 1993 (SHEU). To test the networks, a dataset of more than 400 households was used. With a prediction performance of R^2=0.91 for SH and R^2=0.87 for DHW, the NN method achieved a better prediction than the engineering models developed using the same input parameters. However, the main drawback of the ANN method is the lack of interpretability and the necessity for the model to learn from a large amount of historical data (Foucquier et al., 2013). ANN are mainly useful in the case of when the relationship between input-output is not known or difficult to model (Deutsches Institut für Normung e.V., 2015). In the case of building thermal simulation, the physical processes behind are well established. Therefore ANN offers little advantages in this respect. Nevertheless, ANN represent a great potential for improving the knowledge on the behavioral occupancy influencing the energy consumptions.

2.2.3 RC Modelling

In order to overcome the challenge of computation and parametrization requirements of complex building models but still conduct dynamic simulations with high resolution, researchers looked into simplifying the physical description of a building with an analogy to electrical network models. The thermal behavior of a building is illustrated with resistances and capacitances (RC). Lauster et al. (2014) developed a second-order RC-models based on VDI 6007 (VDI, 2012) that can be used for city district simulations. Their methodology consisted of a comparison between the second-order model and a first-order model based on EN ISO 13790 (ISO, 2008) using measured data and 12 test cases given in the VDI 6007 guideline. In the first-order model all thermal masses of the building are represented by one capacitances while in the VDI-model one capacitance represents the inner walls and another represents the outer walls. The heat transfer in the walls is represented by two resistances in both models. Convective and radiant heat gains are also considered in this work. The parametrization was in accordance with standards SIA 2024 (SIA, 2011) and DIN 1946-6 (Deutsches Institut für Normung e.V., 2009). In all the tests against the first-order model, the experimental data or the reference model from the guideline, the VDI-model developed by Lauster et al. achieves high agreement.

The low-order thermal model from Lauster et al. was further used by Wolisz et al. (2014) in a combination with 3D city models to tackle the challenge of data collection at larger spatial scale. They studied the possibility to combine building data from building information models (BIM) and city information from Geographic Information Systems (GIS) into one information model for modelling and simulation of city districts. The concept is called City District Information Modelling (CDIM) and can be used not only to investigate the energy use but also generation, distribution and supply. The first step was to simulate a building with well-known parameters, the BIM-level and then to simulate the same buildings but parameters identified through assumptions based on e.g. remote data collections or building typologies (IWU, 2005). The last step was to include information about the neighborhood from the CDIM to the BIM-level scenario. Aspects such as use of PV-energy from the neighbors, characteristics of the ground or possibility to connect to the district heating were also analysed. The study revealed the importance of district information in creating efficient local energy management accounting for "smart" integration of renewable energies. A difference of up to 67% in the primary energy demand was identified between the scenario with parameters based on assumptions and the CDIM-scenario.

The low-order RC-modelling technique is a relatively new approach in urban thermal modelling. Researchers have recognized its promising potential to overcome the computational complexity and time-consuming character of engineering approaches for analyses at city district level. However, further improvement is still required for this method (Moritz Lauster, Fuchs, Teichmann, Streblow, & Müller, 2013).

Regarding building energy simulation, the choice of the method relies on aspects such as the purpose of the analysis, the expected resolution of the energy consumption or the constraints resulting from input-data availability. Each of the previously presented approaches has its own advantages making them suitable for urban energy planning but also a set of limitations that still have to be addressed. The RC-model approach, enabling high temporal resolution and low computational complexity at the same time, is appropriate to tackle the challenge of sector coupling and flexible integration of renewable energies in urban energy planning.

3. Methodology

3.1 Case study building

The case study building is a 3-storey mid-terrace built in the period of 1958-1968 (Figure 1), which represents one of the common dwelling types in Germany. The building consists of a basement, 2 floors above ground and an attic that sum to a total floor area of 396m2. The building is north-south oriented with windows on both facades that result in an average window-to-wall ratio of 16%.

A simplified RC model and a detailed EnergyPlus model are developed to simulate the indoor air temperatures of the 1st floor living zones without a heating system (Figure 2). In addition, the EnergyPlus model is extended to calculate the sensible heating load required by the entire building.

3.2 Complex EnergyPlus model

Comprehensive input data are used in the EnergyPlus model to reflect a high degree of building details. The thermal properties of the construction materials are inferred by the type and construction year of the building. The building is attached to adjacent buildings on the east and west sides, heat transfer through the adjacent walls is assumed to be negligible in this study. Realistic occupancy patterns and appliances usage that take into account variations over the week and the year are applied. The calculation of internal heat gains follows detailed appliance use schedules with fractions of sensible, latent and radiant heat dissipation based on (DIN, 2003) and (Zangheri, Fernandez Boneta, & Müller, 2014).

Each living zone is assumed to contain 50m2 internal walls and interior furnishings with a total surface area of 14m2. For the heating load calculations, a standard heating regime was applied to both living zones with a setpoint temperature of 20oC during the day (6:00-23:00) and 17oC at night.

The simulations are performed in an hourly basis using weather data of Munich.

Figure 1: The case study building (coloured) in between two adjacent buildings.

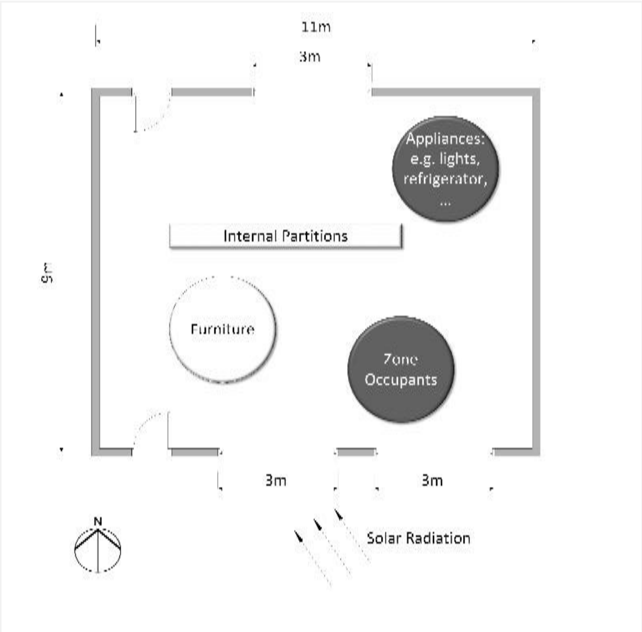

Figure 2: Floor plan of the first floor living zone.

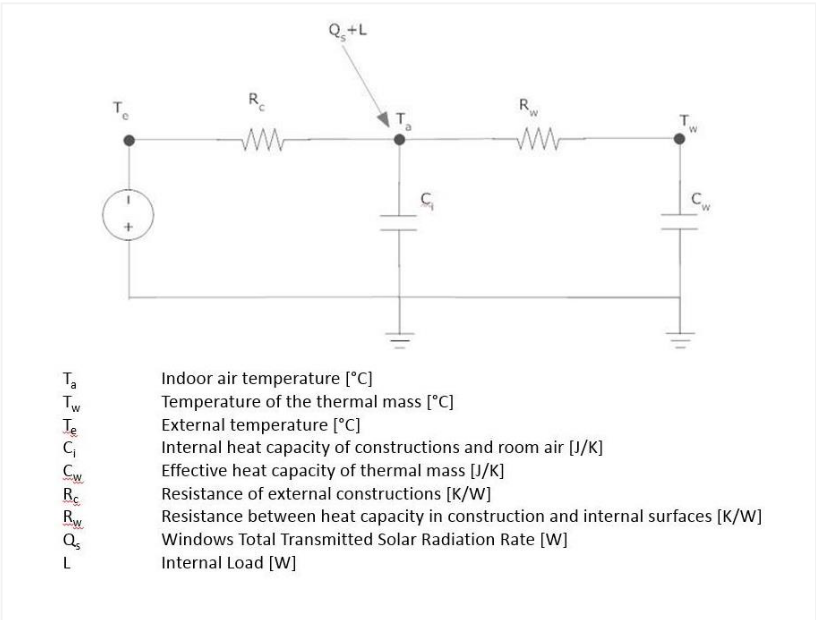

Figure 3: 2R2C model of the 1st floor living zone.

3.3 Simplified RC model

The simplified model is derived from the electrical network analogy, where the building is represented as a network of R (thermal resistance) and C (thermal capacitance). This approach reduces the input to a handful of parameters, which makes it viable for large-scale urban study. In this study, a 2R2C model is developed based on (Z. T. Taylor, Gowri, & Katipamula, 2008) to represent the 1st floor living zone (Figure 3).

The 2 resistors (Rs) are resistance of external constructions (Rc) and resistance between heat capacity in construction and internal surfaces (Rw). Whereas the 2 capacitors are the effective heat capacity of thermal mass (Cw) and internal heat capacity (Ci), which is composed of the following elements:

$$C_i = C_a + C_f + C_{ip} \qquad (1)$$

With C_a = heat capacity of room air [J/K]

C_f = heat capacity of furniture, assume heated to the internal air temperature [J/K]

C_{ip} = heat capacity of interior partition walls, assumed heated to the internal air temperature [J/K]

These Rs and Cs are estimated based on the material properties of the building fabric that is consistent with the EnergyPlus mdoel and the calculations are with reference to (Deutsches Institut für Normung e.V., 2015; Nielsen, 2005; Perera, Pfeiffer, & Skeie, 2014). Other input parameters include external air temperature (Te) , solar heat gain (Qs) and internal heat gains from occupants and appliances (L). In order to simplify the modelling process, Qs and L are gathered from the outputs of the complex EnergyPlus model. The effects of these input parameters on indoor temperatures, heating load and the performance of the RC-model are examined in the following sections.

4. Results and Discussion

4.1 Base Case Scenario

Figure 4 shows the indoor temperatures simulated by the complex EnergyPlus model and the simplified RC-model over a period between November and February. Table 1 shows the resulting R^2 and root-mean-square deviation (RMS Δ) between the two methods. The modelled indoor temperatures are generally in good agreement as confirmed by a high coefficient of determination (R^2=0.873).

Figure 5 shows the cumulative frequencies of modelled indoor temperatures by the two methods. Overall, the prediction by the RC-model tends to be higher than that of the EnergyPlus model in the base case scenario. Based on the EnergyPlus model, the total heating load required by the 1st floor living zone is 4647 kWh over the simulation period.

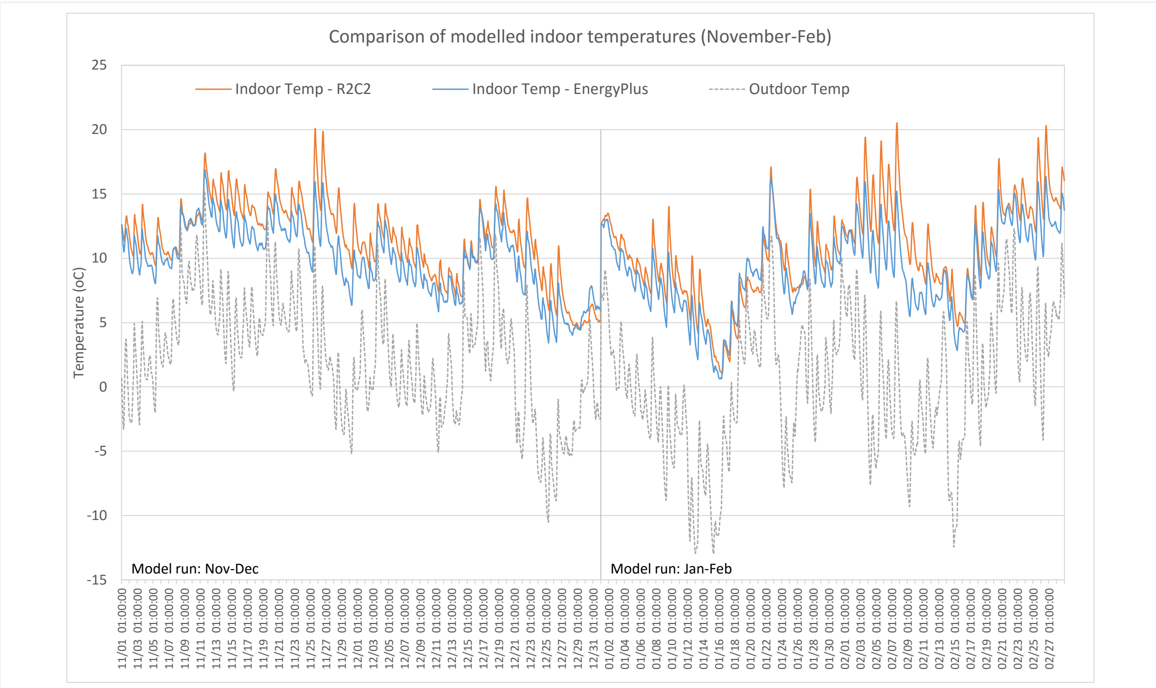

Figure 4: Indoor air temperature simulated by EnergyPlus (blue) and RC-model (red) with outdoor temperature (grey) in the background.

Table 4: Comparison of indoor temperatures simulated by EnergyPlus and RC-model in the base case.

	RMS Δ	R^2
Nov	±1.95	0.76
Dec	±1.54	0.86
Jan	±1.36	0.87
Feb	±2.46	0.85
Overall	±1.86	0.87

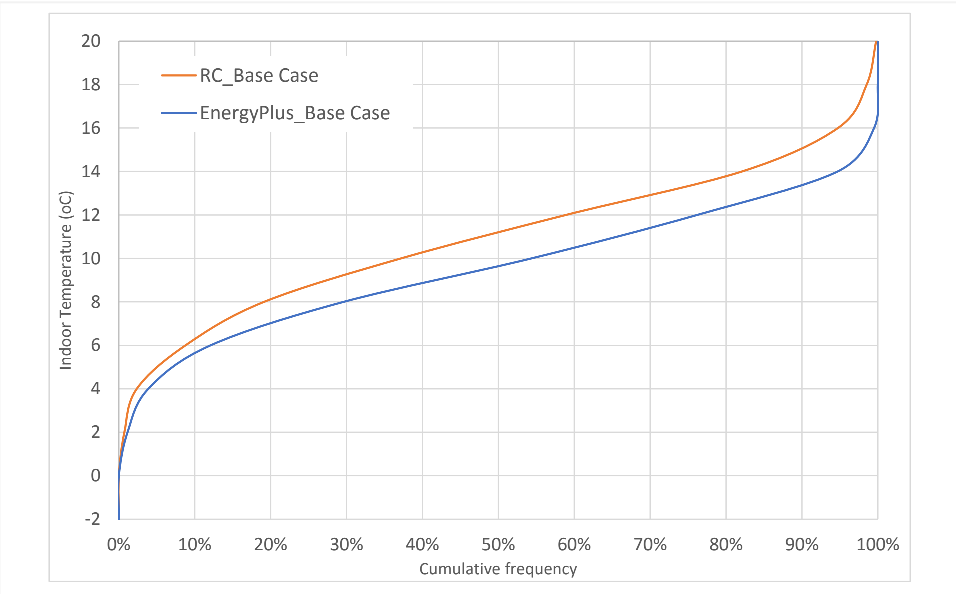

Figure 5: Cumulative frequency curves of modelled indoor temperatures: EnergyPlus (blue) and RC-model (red).

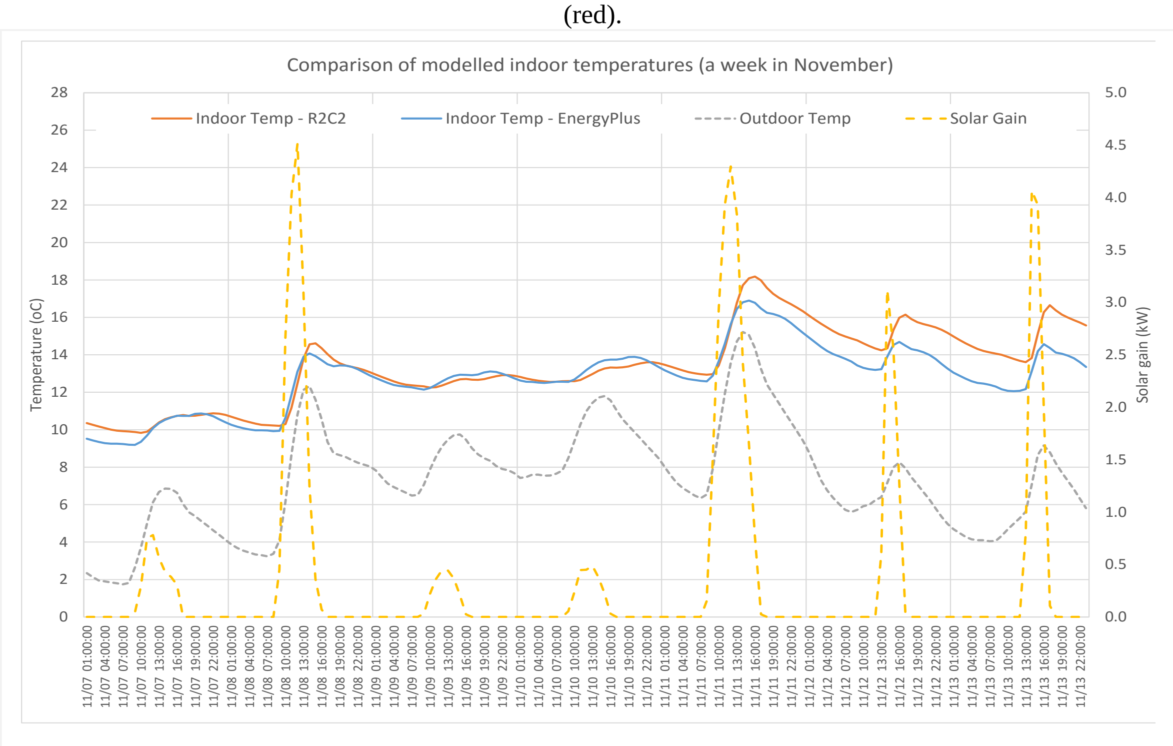

Figure 6: Modelled indoor temperature in the base case: EnergyPlus (blue), RC-model (red), outdoor temperature (grey) and solar heat gain (yellow).

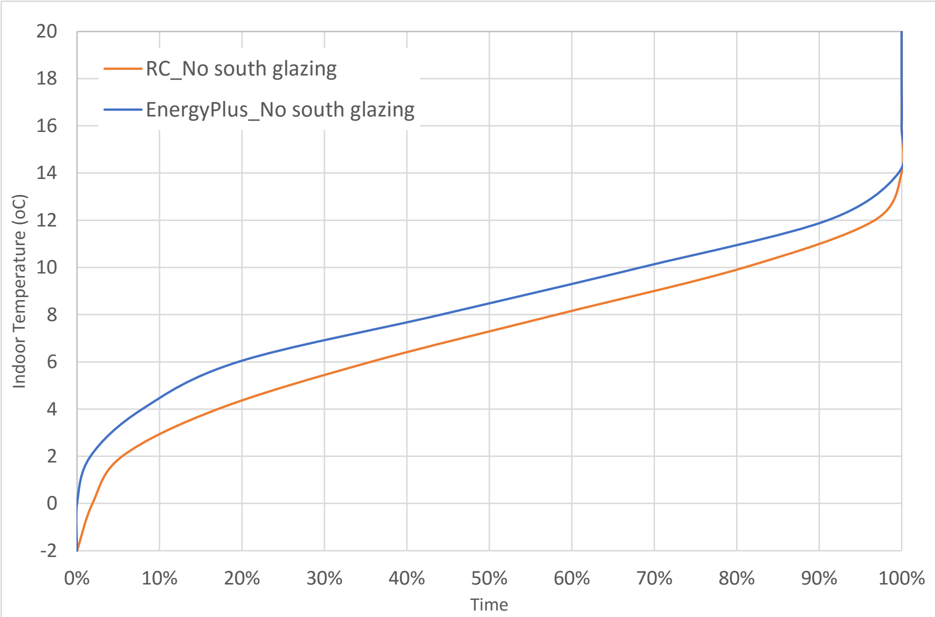

Figure 7: Cumulative frequency curves of modelled indoor temperatures without south glazing: EnergyPlus (blue) and RC-model (red).

4.2 Effects of Solar Radiation (Qs)

In heat demand modelling at urban scale, exact information on window glazing is often not available and to gather such information building by building will demand significant data collection. Both window area and orientation have an important effect on solar heat gain, which in turn affect the indoor temperature and heating load.

Figure 6 shows the modelled indoor temperatures over a week in November in the base case scenario. Larger discrepancies between the RC and EnergyPlus models are observed at times when solar heat gain is high.

In order to further examine the effects of solar radiation, two scenarios are tested: i) removing the north-facing window (4.5m2) in the living zone and ii) removing the south-facing windows (9m2) in the living zone. According to the EnergyPlus model, the former scenario reduces the heating load of the living zone by 4.8% whilst the latter increases the heating load by 10.5%.

Figure 7 shows the cumulative frequencies of modelled indoor temperatures by EnergyPlus and RC models without south glazing (scenario 2). In comparison to the base case scenario (Figure 6), a larger drop in the modelled temperatures is observed in the RC-model than the EnergyPlus model. The results suggest that the RC model is over sensitive to variations in solar heat gain.

In the 2R2C model representation applied in this study (Figure 3), the solar radiation components are significantly simplified to a single input Qs. In view of the present findings, further development of the RC model particularly with regard to the treatment of the solar radiation components is needed to improve the model performance.

4.3 Effects of internal heat capacity (Ci)

As shown in equation 1, internal heat capacity is composed of 3 elements: room air, internal walls and interior furnishing. Similar to window glazing, information on thermal mass of internal walls and furnishing is often not available. Therefore, the calculations of Ci relies on a number of assumptions and in some cases the contributions of internal walls and interior furnishing are omitted altogether. To examine the effects of internal thermal mass on the performance of the RC model, two scenarios are tested: i) omitting the heat capacities of internal walls and interior furnishing in the calculation of Ci and ii) doubling the surface area of internal walls and interior furnishing. Although the variation in internal thermal mass has negligible effects on total heating load (-0.1% in both scenarios), higher internal mass exerts a dampening effect on indoor temperatures. Without internal mass, indoor temperatures are prone to external variations that can lead to large temperature swings.

Figure 8 shows the modelled indoor temperatures over a week in November where internal walls and interior furnishing are neglected (scenario 1). Substantial temperature swings are observed in the RC-model which correspond to the variations in solar heat gain. Furthermore, the RC-model becomes more sensitive to the variations in internal gains as revealed by the peaks in evening hours, which correspond to the occupancy and appliance schedules.

The results suggest that appropriate representation of internal heat capacity is important in RC modelling particularly in low-order models, where the complex thermal dynamics is captured by a small number of Rs and Cs.

4.4 Effects of internal heat gains (L)

In the base case scenario, internal heat gains are modelled based on detailed occupancy and appliance schedules. However, these high level of details are not normally available for large-scale urban studies. Simple representation of internal heat gains is commonly used in urban-scale modelling. For example, DIN 4108-6 (Deutsches Institut für Normung e.V., 2003) recommended the use of a constant value of 5W/m². We examine the effect of internal heat gains on heating load in two scenarios: i) using the DIN recommended constant 5W/m² throughout the day and ii) assuming no internal heat gain. Based on the EnergyPlus model, the heating load is increased by 11% and 23% in the two scenarios respectively.

The two scenarios are simulated by the RC-model and the results are shown in Table 2. The coefficients of determination are high in both scenarios. Nevertheless, the 1st scenario results in a relatively high RMS deviations which is unexpected. Further investigation is needed to understand the cause of this discrepancy.

5. Conclusion

Simplified building energy modelling with low computational complexity can play a valuable part in energy system modelling at large urban scales. In this paper we developed a low-order 2R2C model to simulate the indoor temperature of a case study building.

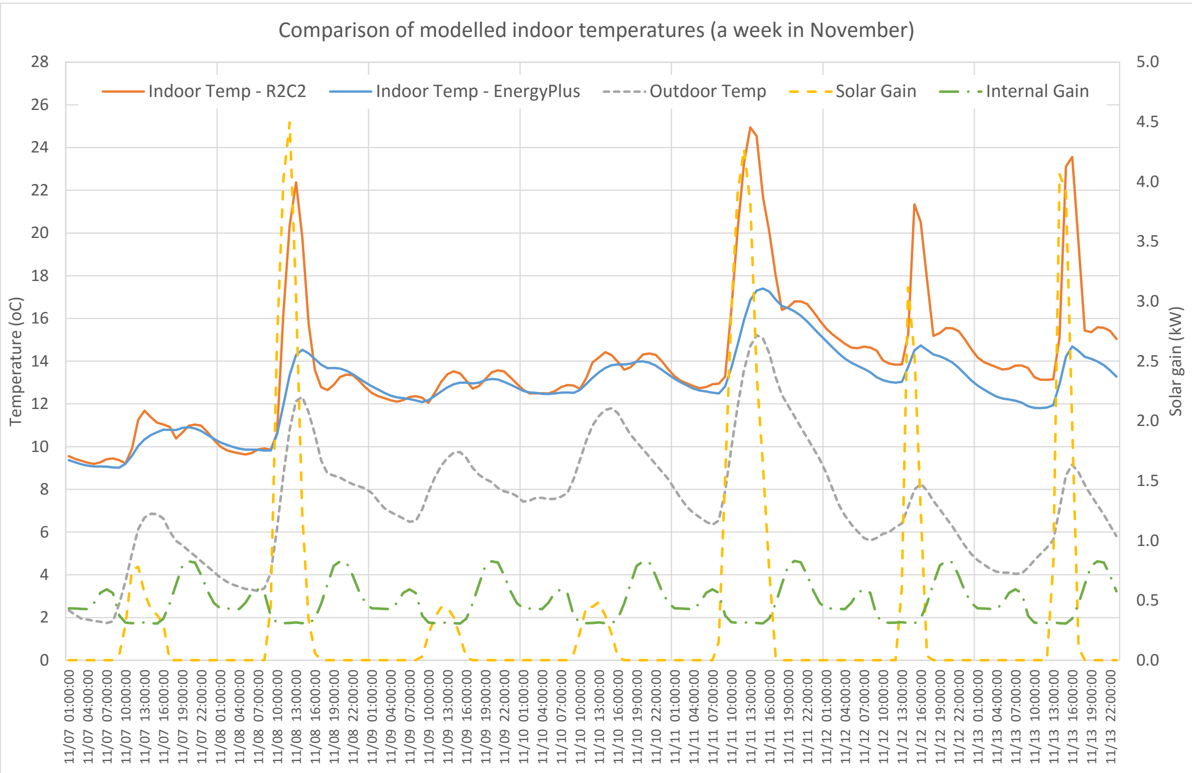

Figure 8: Modelled indoor temperature without internal walls or furnishing: EnergyPlus (blue), RC-model (red), outdoor temperature (grey), solar heat gain (yellow) and internal gains (green).

Table 2: Comparison of indoor temperatures simulated by EnergyPlus and RC-model with different internal gain assumptions.

	DIN value 5W/m²		No internal gain	
	RMS Δ	R^2	RMS Δ	R^2
Nov	±2.68	0.75	±1.37	0.76
Dec	±2.30	0.87	±2.08	0.86
Jan	±1.94	0.87	±2.29	0.84
Feb	±3.25	0.85	±1.60	0.85
Overall	±2.57	0.87	±1.88	0.87

We compared the modelled results with those produced by a complex EnergyPlus model. Furthermore, we studied the effects of three input parameters of the RC-model namely solar radiation, internal thermal mass and internal heat gains.

Overall, the RC model performs fairly well with $R^2 \geq 0.8$ in most cases. Nevertheless, some simplifications made in the 2R2C model particularly related to the treatment of solar radiation components may have undermined the model performance. The RC-model is sensitive to variations in internal heat capacity. Therefore, appropriate representation of internal thermal mass is crucial in RC-modelling.

The study shows that the simplified RC method has great potential for applications in large-scale urban modelling. Further work is undergoing to advance the current model to operational capacity. The model will be extended to include the simulation of heating load. In addition, we aim to increase the temporal resolution of the model to sub-hourly levels. Eventually, the RC model will be interfaced with a GIS system to extract spatio-semantic building data as inputs. It will be coupled with a high resolution electricity model to allow integrated study of urban energy systems taking into consideration the intermittent and flexible character of renewable energy sources.

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Problems encountered in Albanian power system by connection of new power generation units

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Abstract

In recent years, the interest of building small hydropower plants by operator's working in the field of energy production in Albania has increased. The connection of these generation units to the power system has exhibited several advantages, for example, the reduction of transmission power losses, the continuous electricity supply and the increase of power lines transmission capacity. On the other hand, during the operation of small hydropower plants some problems are encountered. One problem is the voltage level at several nodes of the power system which is greater than the nominal value. Another problem which is observed is the existing power lines, particularly in the case when they operate at rated power, are fully loaded. In this paper, the current status of a part of Albanian power system is analyzed in order to find the reasons which cause these anomalies and the ways to overcome them. The new generation units are not followed by the required investments in the transmission and / or distribution network; therefore, the structure of the present transmission network is not very compatible with them. Based on data of the Transmission System Operator power transformers installed at new substations have not On Load Tap Charger (OLTC). Based on the theoretical analysis, we recommend that new power transformers must be with OLTC and new transmission lines are necessary in order to create ring/loop system instead of the radial distribution system.

Key Word: energy efficiency, SHP, power losses, voltage level

1. Introduction

During the last decade in Albania are built several small hydropower plants with a total capacity about 400 MW [Çelo M., 2013]. Small hydropower plants built in Albania have improved power quality, reduced total power losses in transmission lines and increased the efficiency of electricity consumption. Power generation from small hydropower plants is directly linked to the strategic objectives for the evaluation and development of unused hydropower capacity in Albania through private investment partnership or concessionary. The presence of local generation in a distribution system affects the system itself. It is observed that the distribution generation alters the power flow within the system, and it can no longer be considered as a system with unidirectional power flow [Khoan T., 2005]. On the other hand, the distribution system has been designed based on the assumption that the power flow is unidirectional [Barker P.P., 2000]. Hence, the presence of the small hydropower plants, will obviously impact the power distribution system operation and control. Moreover, there are observed fluctuations of the node voltages at areas in which small hydropower plants are built.

In this paper we have studied the impact of the power quality in Skrapari region when small hydropower plants are connected at power system. The configuration of the power system distribution network is radial while the network is amortized in a large part. The renovation of the distribution network is carried out mainly in urban areas such as Tirana, Fier, Berat, Gjirokastra, Elbasan, Shkodra etc. by replacing the 35/10 kV or 35/6 kV voltage distribution network with ones of 110/20 kV. The improvement of power quality, reduction of the energy technical losses and safety increase of the final consumers are the results of this renovation.

In addition to the above improvements, several problems are observed in the connection of small hydropower plants at electrical distribution network [Bastiao F., et al. 2008]. In some cases, the capacity of a new connected hydropower station exceeds the capacity of the power transformer installed at the electrical distribution network. The existing distribution system is scheduled to supply a rural area which results in lower energy demand. Due to the above mentioned, an increase of technical losses and voltage variations at distribution system is observed. Also, another problem encountered is the connection point of a new small hydropower plant to the electrical distribution network. Usually, in order to determine the generation capacity, the private investistors perform a detailed analysis and respective feasibility (technical and economic) study; however, on the other hand, they rarely analyze the capacity of the electrical distribution network. Therefore, the distribution network in many cases does not support the new generation capacities of the small hydropower plants. Another target of this paper is the recommandation on the ways to overcome the problems encountered in the electrical distribution network of the Skrapari region.

2. A brief history of the development of small hydropower plants in Albania

The first electrical power station in Albania was built in 1920. During the last period of the 30' of last century, 14 turbogenerators and a small hydropower plant with total capacity of 3400 kW has been built in Albania [Simeon K., 1998]. During the second half of the last century were built several thermo and hydropower units of medium and large capacities. Among them are two hydropower stations on Mat river with installed capacities of 25.6 MW and 24 MW, three hydropower stations on Drin river namely Komani (1972) with capacity of 600 MW, Fierza (1984) with capacity of 500 MW and Vau i Dejes (1974) with capacity of 250 MW. Also, in rural areas were built many small hydropower plants which produce energy during winter and spring seasons. Most of them are built with a canal deviation and their capacity depends by water flow and height. In Albania in the end of 90' of the last century, the power capacity of small hydropower plants was around 10% of the total generation units. The capacity of each of them is between 100 to 400 kW.

After the 90's, most of the small hydropower plants were out of service due to their amortization and lack of proper maintenance. This situation in Albania continued until 2000 and no new hydropower plants have been built during these years. Following this year, the privatisation schemas in energy production, tranmission and distribution network have started. During the last decade, the interest of private investitors concerning small hydropower plants has increased, thus around 80 concessionary contracts for the construction and operation of small hydropower plants has been approved with total installed capacity around 400 MW and annual energy production of 1,827 GWh. The estimated investment for the construction of the plants is about 289 million euros. Nowdays, there is a number of private companies licensed to produce electricity while 90 small hydropower plants are already operating [Bardhi A., et al. 2014]. Graph 1 presents the number of small hydropower plants for the period 2011 to 2015 classified based on the voltage level of connection to the power system. Table I shows the annual production of small hydropower plants connected at the 35 kV distribution network; whereas Table II shows the annual production of small hydropower plants connected at the 10 kV distribution network [KESH., 2014].

Furthermore, the annual production is presented for each region of Albania seperately. As shown from table I and II, the annual energy production has increased due to the connection of new small hydropower plants during the last years.

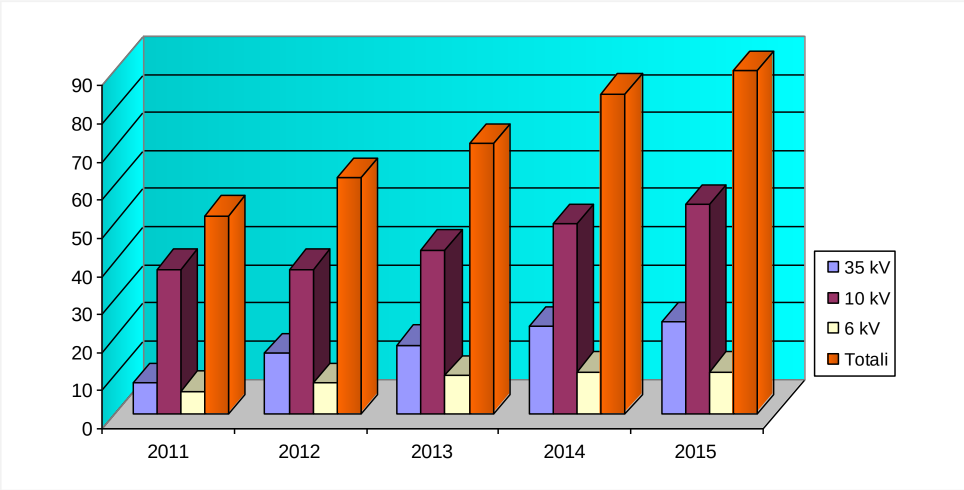

Figure 1: SHPs built from 2011 to 2015.

Table 1: Energy annual production of SHP (35 kV).

No	Region	Energy Annual Production			
		2011 kWh	2012 kWh	2013 kWh	2014 kWh
1	Tirane	35,518,610	35,518,610	35,518,610	35,518,610
2	Fier	31,042,291	33,438,444	50,136,750	45,688,475
3	Gjirok.	29,962550	59,851,102	53,023,582	28,189,924
4	Berat	10,644,869	23,413,459	29,280,293	30,667,730
5	Elbasan	22,575,251	46,404,599	53,459,932	43,352,289
6	Korce	8,642,718	17,834,463	25,475,072	34,644,855
7	Kukes	–	–	15,114,050	14,784,140
8	Burrel	16,419,400	34,869,620	54,333,089	39,553,260
Total		154,805,689	246,519,077	309,488,032	300,390,466

Table 2: Energy annual production of SHP (< 35 kV).

No	Region	Energy Annual Production			
		2011 kWh	2012 kWh	2013 kWh	2014 kWh
1	Tirane	–	–	–	13,150,988
2	Fier	–	–	–	–
3	Gjirok.	1,635,440	5,254,670	5,271,660	8,097,650
4	Berat	1,518,849	2,608,956	2,702,816	2,256,556
5	Elbasan	11,487,467	13,943,270	17,072,578	15,669,348
6	Korce	17,465,319	15,855,486	19,206,944	20,868,914
	Shkoder	4,744,673	5,513,792	8,280,400	10,662,954
7	Kukes	7,330,450	10,009,118	24,520,317	46,839,194
8	Burrel	5,838,650	8,772,599	15,276,894	19,382,382
Total		50,020,847	61,957,891	92,331,608	136,927,986

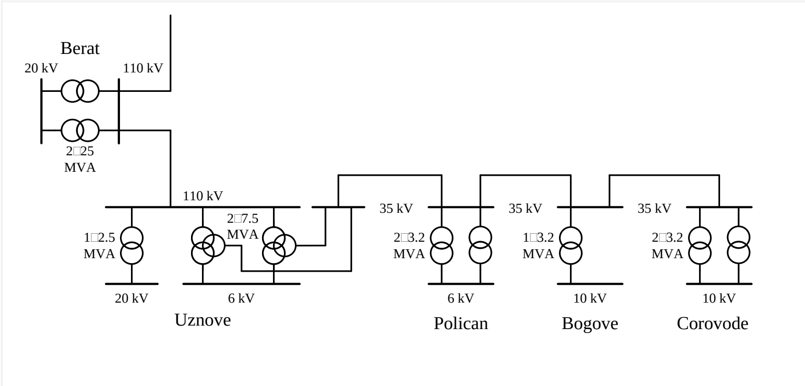

Figure 2: Schematic of power system Skrapari region.

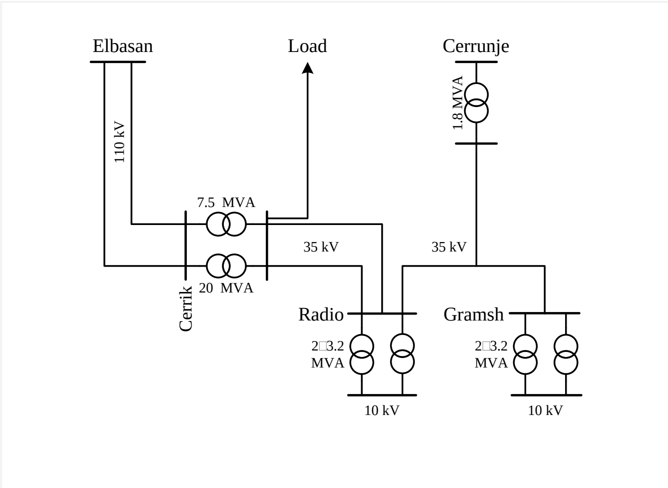

Figure 3: Schematic of power system Gramshi region.

However, the energy production of the plants depends on the climatic condition. For example, the energy production by small hydropower plants in 2014 is greater than previus years, because it is a wet year. In some cases, espacially plants with canal deviation, not all of the water flow can not utilized. Actually, the number of small hydropower plants connected to the power system of Albania and injecting energy in it is about 90. The installed power capacity of these small hydropower plants is about 190,971 kW.

The energy production by small hydropower plants during the period of January–May 2015 was 306,493,742 kWh or approx. 11% of total energy purchased by the system distribution operator.

3. Problems encountered by the connection of new power generation units

Small hydropower plants built in Albania have improved power quality, reduced total power losses in the transmission lines and increased the efficiency of electricity consumption.

Apart from the avantages emphasized above, in some cases, the connection of small hydropower plants has caused different problems to the power system. These energy resourses are built in rural areas where the distribution system is of radial form. The Figs. 2 and 3 represent the power system electrical diagram in which small hydropower plants are connected. As shown by the diagrams, the distribution power system is radial with transmission line voltage level of 6, 10 and 35 kV. In rural electric power system, no investments have been performed. This situation does not correspond to the increase of electricity consumption demands. Also, the regional power network has been put in trouble due to the connection of new energy resources.

The energy production by small hydropower plants in some cases is upper than nominal power of transformers installed at regional substations. The transmission lines are overloaded which can cause interruption of the final consumers electricity supply. Most of the rural transmission lines are designed only for householder's consumption with low flow of energy levels. Due to the injected energy in the power system by small hydropower plants the power losses have increased.

Another problem encountered is that the voltage level in some power system nodes are upper than nominal or allowed values.

Also a serious problem appeared at the distribution system is the connection point of small hydropower plant. Private investitors have performed a deep study on determining the installed capacity of hydropower plant but not correlating it to the capacities of the existing transmission lines or substations at the regional distribution system. Some of the small hydropower plants are connected at a point of the distribution system with limited capacity of energy transmission; which does not allow them to fully exploit the production capacity.

The new energy resourses are developed in all of the Albanian territory. These developments are realized in indepedent form and not in good acordance with investments of Distribution System Operator. The construction and connection to the power system of new small hydropower plants, unaccompained by investments in increase of the capacities of the transmssion lines and the substations, in the many cases has brought anomalies to the power system. The indicators such as overvoltage, frequently switching off of transmission lines, overloaded lines etc. are worsening. Often, the new small hydropower plants, due to limited transmission lines capacities of distribution system, operate under their capacities.

4. Analysis of distributition system of Skrapari region

In order to emphasize the problems encountered at the distribution power system in cases of new power generation connections, we have analyzed the power system of the Skrapari region. In the last years four small hydropower plants have been built in this area.

This region is supplied with electricity by the Uznova substation of 110/35/6 kV, by 35 kV transmission line built since 1968, Uznove – Polican – Bogove – Corovode. The transformers installed at the Uznova substation are not On Load Tap Charger (OLTC). The Skrapari regional power system schematic is shown at Fig. 4. Table III presents the length of transmission lines (*L*) section in kilometer, cross section of conductor, total resistances (*R*) and reactances (*X*).

As shown by the electrical diagram represented in Fig. 4, Skrapari region is fed by a 35 kV radial transmission lines, which is amortized and has a low transmition power capacity. Initially, we have analyzed the Skrapari regional power system prior the constructino of the small hydropower plants. The regional power system is analyzed at different loads in order to calculate the transmission power losses and voltage nodes. To perform the calculations the NEPLAN software is used. This data is presented in table IV. From this table one can see that the voltage levels are below the levels allowed by international and nacional standards. The voltage level at Corovoda is 84% of its nominal value. The total power losses at transmission line and transformers are 811.5 kW.

As a conclusion for the regional power system of Skrapari, we can state that the power quality indicators as voltage levels or voltage fluctuation are poor. Also, the transmission line is loaded at maximal capacity. The small hydropower plants built at Skrapari region are connected to the distribution system at 35 kV. The table V shows the data of each small hydropower plant and their respective connection point to the power system. The total installed capacity of small hydropower plants is 23,420 kW.

Table 3: Parameters of the transmission lines.

Line	Section [mm2]	Length [km]	R [Ω]	X [Ω]	I_{max} [A]
L_110_41	240	20	2.44	8.54	842
L_30_14/2	70	16.5	7.16	6.46	225
L_30_14/3	70	6.4	2.77	2.50	225
L_30_14/4	70	13.1	5.68	5.12	225
L_FQ1 &2	110	4	1.03	1.47	318
L_HEC_FQ1&2	110	14	3.62	5.14	318

Table 4: Voltage nodes without small hydropower plants.

Nodes	Nominal Voltage [kV]	Value of node voltage [kV]	Value of node voltage [%]
System 110 kV	110	110	100
B10kV_Bogove	10	8.75	87
B10kV_Corovode	10	8.48	84
B110kV_Uznove	110	109.43	99
B20kV_Uznove	20	19.87	99
B_110kV_Berat	110	109.43	99
B35kV_Bogove	35	30.67	87
B35kV_Corovode	35	29,79	85
B35kV_Polican	35	31.22	89
B35kV_Uznove	35	33.65	96
B6kV_Polican	6	5.24	87
B6kV_Uznove	6	5.83	97

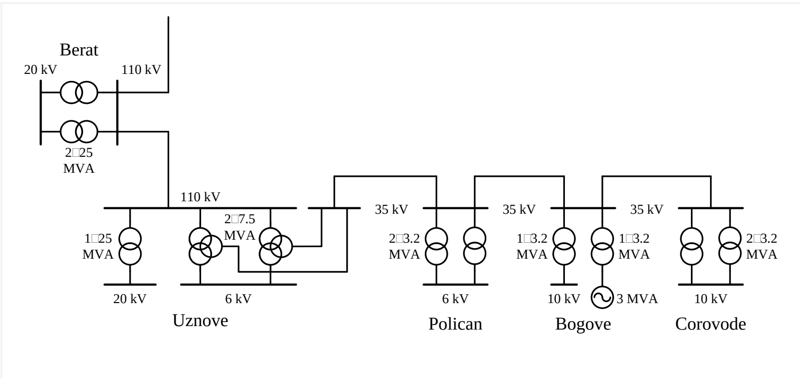

Figure 4: Electrical diagram of power system, Skrapari region.

Table 5: Data of small hydropower plants at Skrapari region.

Area	Name of SHP	Nominal voltage [kV]	Nominal power [kW]	Node of connection
Skrapar	Bogove	35	2.500	Bogove
	Faqekuq 1,2	35	6.720	Corovode
	Vlushe	35	14.420	Corovode

Table 6 shows the simulation data of the regional power system with small hydropower plants operated at rated power. The calculations are performed for the worst scenario, where the consumption is at minimal level. This scenario corresponds in midnight time and rainning weather. Also, in this case, the power flow in the transmission line changes direction, from Corovoda to Uznove. As shown in Table 6, the voltage at some power system nodes are upper than the nominal value. The largest voltage value in the distribution system is at Corovoda node of about 127% of its nominal value. The total transmission power losses are 121.5 kW. In this scenario, the Distribution System Operation (DSO) requires the private operators to reduce the energy production by their generation units to sustain a stable energy flow.

Specifically, due to high voltage level at the Corovoda node, the small hydropower plant of Vlushe, with installed capacity 14.2 MW and connected at 35 kV, is allowed to produce only 4 MW from Distribution System Operators during the day and 2 MW during the night, when the energy consumption is at minimal value.

Table 6: Voltage nodes with small hydropower plants, the worst scenario.

Nodes	Nominal Voltage [kV]	Value of node voltage [kV]	Value of node voltage [%]
System_110 kV	110	110	100
B10kV_Bogove	10	11.83	118
B10kV_Corovode	10	12.73	127
B110kV_Uznove	110	110.44	100
B20kV_Uznove	20	20.07	100
B_110kV_Berat	110	110.44	100
B35kV_Bogove	35	41,42	118
B35kV_Corovode	35	44.58	127
B35kV_FQ1	35	45.01	126
B35kV_FQ2	35	44.96	126
B35kV_Polican	35	39.78	113
B35kV_Uznove	35	35.79	102
B6kV_Polican	6	6.81	113
B6kV_Uznove	6	6.07	101

Table 7: Voltage nodes of regional power system when Vlushe small hydropower plant operates with 4 MW.

Nodes	Nominal Voltage [kV]	Value of node voltage [kV]	Value of node voltage [%]
System_110 kV	110	110	100
B10kV_Bogove	10	10.41	104
B10kV_Corovode	10	10.77	107
B110kV_Uznove	110	110.05	100
B20kV_Uznove	20	20	100
B_110kV_Berat	110	110.05	100
B35kV_Bogove	35	36,44	104
B35kV_Corovode	35	37.70	107
B35kV_FQ1	35	38.21	109
B35kV_FQ2	35	38.15	109
B35kV_Polican	35	35.71	102
B35kV_Uznove	35	34.07	97
B6kV_Polican	6	6.11	101
B6kV_Uznove	6	5.89	98

Table VII represents the voltage level at the power system nodes when the Vlushe small hydropower plant operates at 4 MW capacity. As shown in the table, the voltage level at different power system nodes is almost at nominal value. The total transmission power losses are around 811.5 kW.

5. Conclusion

In this paper we analyzed the problems caused in the regional distribution system by the connection of small hydropower plants. In some nodes of the power system, the voltages can take upper than nominal values, making possible to act overvoltage relay, therefore to swich off the transmission power line. When the small hydropower plants operate at rated capacity, the power flow changes direction. Furthermore, in cases when the transmission lines are loaded at maximal capacity, their posibility to be swiched off is increased. The distribution transmission lines capacity is limited due to amortization, so we recommand imediately to renovate the transmission lines and the substations.

In order to overcome the problems encountered by the connection of small hydropower plants to the power system is necessary that the works of the Distribution System Operator, Transmission System Operator and small hydropower plants Private Investitors must be in line with each other. The Distribution System Operator must invest in regions which present new hydropower plants construction opportunities in order to increase the transmission line capacity and instal new power transformers at the respective substations.

Due to the rapid increase of the small hydropower plants number connected to the distribution system is necessary to establish a Dispaching Center in order to monitor and analyse on line the power parameters as active and reactive power production, nodes voltage level, frequency etc. This would serve for a real evaluation of the small hydropower plants impact in real time to the distribution network and increase the level of accuracy in terms of planning a sustainable distributed network.

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Energy Use Optimization in Cities: Innovative Technological Solutions for the Local Authorities

by

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Abstract

Cities are expected to play a key role in the implementation of Europe 2020 and its flagship initiatives, as well as to address climate and energy challenges using technologically innovative approaches. Taking into consideration that local authorities represent the closest administration to citizen, they need to lead relevant actions towards energy-efficient neighbourhoods. In this context, the aim of this paper is to present innovative technological solutions for the local authorities (web-based Decision Support System and integrated Web Portal) that assist them to optimize the energy use in their premises and reduce CO_2 emissions. The Decision Support System combines and integrates five heterogeneous data sources (weather conditions, social mining, buildings' energy profiles, energy prices, energy production), in order to propose specific action plans to the local authorities. For integrating these heterogeneously structured and formatted data, a holistic interoperability solution using Semantic Web technologies has been implemented. The Web Portal provides energy management services to the local authorities through a web-based platform. The available data from metering units are handled by the following tools: "Green Buildings", "Green Pillars", "Green Pole" and "Green Electric Vehicle Station Support". Depending on the volume of data to be analyzed and the complexity of analysis, the Web Portal integrates suitable software for the management of different user groups, the content, the processing and presentation of data collected.

1. Introduction

The European Union (EU) had always put high in its agenda activities related to the attainment of economic growth and prosperity. In the context of Europe 2020 strategy, a comprehensive strategic approach has been put forward for the next decade to foster smart, inclusive and sustainable growth in Europe and to provide a framework for the EU to emerge strengthened from the current financial and economic crisis. The EU Climate and Energy Package has set very ambitious targets for sustainable development, known as the "20-20-20" targets for 2020.

One of the major challenges that EU faces within the scope of sustainable energy development is the increasing energy demand patterns of cities. There are plenty of reports stating that cities are responsible for about 70-80% of energy use and energy-related CO_2

emissions (IPCC, 2014; World Bank, 2010; IEA, 2009). Cities are expected to play a key role in the implementation of Europe 2020 and its flagship initiatives, as well as to address climate and energy challenges using technologically innovative approaches.

Taking into consideration that city authorities represent the closest administration to the citizen, they need to lead relevant actions towards energy-efficient neighbourhoods (Marinakis et al., 2015). Cities are turning to advanced technologies to become Smart Cities. The term "Smart City" is used to describe Information and Communication Technological (ICT) solutions for cities and to highlight ICT importance and potential in helping the city to develop competitive advantages. (Kramers A. et al, 2014). Towards this direction, integrated, transparent and comprehensive approaches are required to provide cities the tools and methods they need to achieve significant reduction of energy consumption and CO_2 emissions through the significant contribution of advanced Information and Communication Technology (ICT) tools (Doukas et al., 2015; Androulaki et al., 2015).

In this context, the aim of this paper is to present the following innovative technological solutions for the local authorities that assist them to optimize the energy use in their premises and reduce CO_2 emissions:

- Web-based Decision Support System that combines and integrates heterogeneous data sources, in order to propose specific Action Plans to the local authorities.
- Integrated Web Portal that provides energy management services to the local authorities through a web-based platform.

Apart from the introduction the paper is structured along three sections. The second section is devoted to the web-based Decision Support System (DSS) and the third section to the integrated Web Portal ESCOCITY. The fourth section provides a comparative analysis of these tools. The last section summarizes the main conclusions drawn up from this paper.

2. Web-Based DSS

The proposed DSS relies on the integration of heterogeneous data sources using Semantic Web technologies, in order to suggest short-term Actions Plans for public authorities with the goal of reducing energy consumption. It has been developed within the framework of the project financed by the European Commission, titled "OPTIMising the energy USe in cities with smart decision support systems (OPTIMUS)".

2.1 Multidisciplinary Data Sources

First of all, the following data capturing modules have been developed (Capozzoli et al., 2014):

- *Weather forecasting module:* This module captures data concerning the upcoming weather conditions.
- *De-centralized sensor-based module:* This module provides input on the energy consumption of some important buildings in the city, through sensors that will be installed in main municipal buildings.
- *Social data module:* This module collects input from people and end-users, concerning their thermal sensation.
- *Energy prices module:* This module collects data concerning energy prices available from energy producers in the city.
- *Renewable energy production module:* This module collects data concerning the production of energy from any renewable energy sources available to the city.

Typically, these data are generated by different sources, such as physical sensors installed in buildings (e.g. energy consumption), national agencies (e.g. weather forecast, energy prices) and web services (e.g. web applications). Moreover, the data belong to different sectors (e.g. climate, energy costs) and have different characteristics (e.g. units of measure, aggregation level, data encoding).

2.2 Data Integration Process

For integrating these heterogeneously structured and formatted data, it was necessary to implement a holistic interoperability solution using Semantic Web technologies. A data integration process has been established to fulfill the requirements and particularities of the DSS architecture, as follows (Sicilia et al., 2015):

- *Data Translation:* The data capturing modules translate the data from the original format into RDF according to a global ontology.

- *Data Communication:* The RDF data are sent to the DSS using a publish-and-subscribe model (Ztreamy server).
- *Data Contextualization:* The Semantic Service receives the RDF triples and processes them.
- *Data Storage:* The Semantic Service uploads the final RDF triples on a triple store (e.g. Virtuoso server).

2.3 Prediction Models & Inference Rules

With reference to the data elaboration process through the DSS engine, each suggested action of the DSS is obtained through a modelling process that involves both prediction models (through data mining techniques, grey and black model approach) and inference rules. In this process both monitored and predicted data are utilized.

Forecasting the behaviour of the buildings in an accurate manner becomes necessary for the implementation of the Action Plans provided by the DSS. In this respect, the following prediction models have been developed to forecast:

- Energy Production;
- Indoor Temperature;
- Energy Consumption;
- Energy Prices.

The prediction models have been implemented as RapidMiner processes running on a RapidAnalytics server.

The inference rules are structured as a logical function (e.g. if/then) or as a mathematical model. The inference rules are able to describe the system (building, technical systems etc.) on the basis of an expert knowledge and provide the optimization criteria for a specific action. Moreover, specific actions are associated to different strategies that allow optimizing, on one hand, a single indicator and, on the other hand, a combination of indicators.

2.4 Action Plans

DSS combines and integrates all the multidisciplinary data sources, in order to propose specific Action Plans for the public authorities. These Action Plans refer to energy optimization in buildings, however, examining them not as isolated entities, but within the cities energy context. Taking into consideration their interaction with energy systems, a number of the proposed Action Plans can also foster efficient management of energy flows at a broader level, integrating energy demand (buildings), energy production (RES) and storage sources.

The proposed DSS includes the following Action Plans (Capozzoli et al., 2015):

- *Action Plan 1 – Scheduling and Management of the Occupancy:* Reduction of the building energy consumption by changing the location of building occupants, so as to use the minimum number of thermal zones and turn off the heating/cooling system in the empty zones.
- *Action Plan 2 – Scheduling the Set-Point Temperature*, integrating the following inference rules:
  - Support of the energy manager in adjusting the temperature set-point, taking into consideration thermal comfort parameters. The target is to optimize energy use, while maintaining comfort levels in accepted ranges (using the Predicted Mean Vote - PMV - index).
  - Reduction of the building energy consumption and/or optimizing the thermal comfort by setting the indoor set point temperature according to adaptive comfort concept.
- *Action Plan 3 – Scheduling the on/off of the Heating System:* Optimization of the boost time of the heating system taking into account the forecasting of the outdoor air temperature and the occupancy of the building.
- *Action Plan 4 – Management of the air side economizer:* Assessment of the free cooling options.
- *Action Plan 5 – Scheduling the PV Maintenance:* Detection of the need for maintenance of the PV system and communication with the user with an alert prompting for appropriate maintenance actions; identification of abnormalities and possible problems can be facilitated.

- *Action Plan 6 – Scheduling the Sale/Consumption of the RES Electricity Produced:* Optimization of the selling/self-consumption of electricity produced by a PV system considering different scenarios of energy market.
- *Action Plan 7 – Scheduling the Electricity Storage in the Energy Network:* Determination of the energy source to cover the demand, considering battery charging, PV production and the grid.

An overview of the DSS interface is provided in Figure 1.

3. Integrated Web Portal

The proposed Web Portal aims to provide energy management services to the local authorities through a web-based platform. It has been developed within the framework of the project ESCO Smart City Energy Plan (ESCOCITY), co-financed by the General Secretariat for Research and Technology (GSRT) of the Hellenic Ministry of Culture, Education and Religious Affairs.

3.1 The Web Portal Architecture

In order to be easily applicable and customizable, the platform has been implemented in a modular environment.

The Portal's design is based on open source tools, so that no license fees are required for its implementation. The necessary equipment for the installation of the Web Portal consists of:

- Metering devices, which measure the energy data, and;
- The central gateway with an integrated OPC server, which collects the measured data by MODBUS protocol.
- The gateway manages and sends the data to the central MySQL database.

The platform integrates data analysis software, in order to calculate energy indicators by handling two types of data:

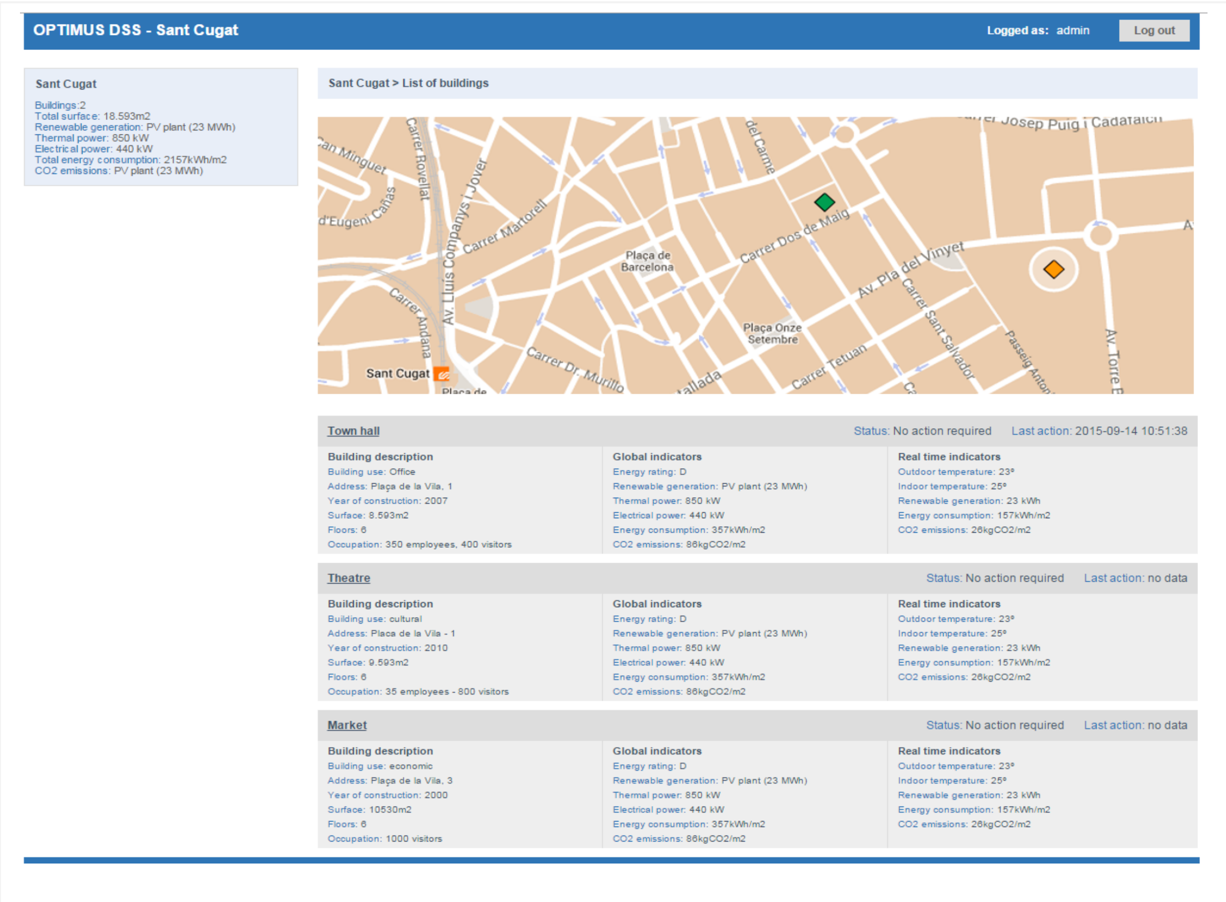

Figure 1: Web-based DSS Interface.

- *Static data*, related to the main characteristics of each element, e.g. a building's surface area, and change rarely. These data are inserted by authorized users though appropriate forms.
- *Dynamic data* that change with a frequency and are collected by the metering devices.

The core of the Data Analysis Tool is "Plotalot", which is used to make charts and graphs presenting the data collected, or the indicators which are calculated from them.

3.2 *The web portal functionalities*

Depending on the volume of data to be analysed and the complexity of analysis, the Web Portal integrates suitable software for the management of different user groups, the content, the processing and presentation of data collected. The ESCOCITY Web Portal is addressed to the following users groups:

- Mayor and advisors.
- Municipal technical services.
- Municipal accounting services.
- Municipal employees.
- Citizens/Public users.

Each user group has jurisdiction at specific areas of the energy management platform along with the relevant rights (Marinakis et al., 2015). An overview of the main characteristics per user group is presented in Figure 2.

The data is collected from the appropriate metering equipment and are handled by the following platform tools (Marinakis et al., 2015c):

- *Green Buildings Tool* collects, analyzes and presents data concerning the buildings' energy management (building's energy consumption, environmental impact, economic impact etc.).
- *Green Pillars/Pole Tool* focuses on the street and road lighting control, by the following:
    - voltage control supplied to the lighting circuit;
    - operating lights efficiently by user defined time schedules;
    - collecting data on street lighting, analyzing the lamps' failures and reports crucial data for the user.

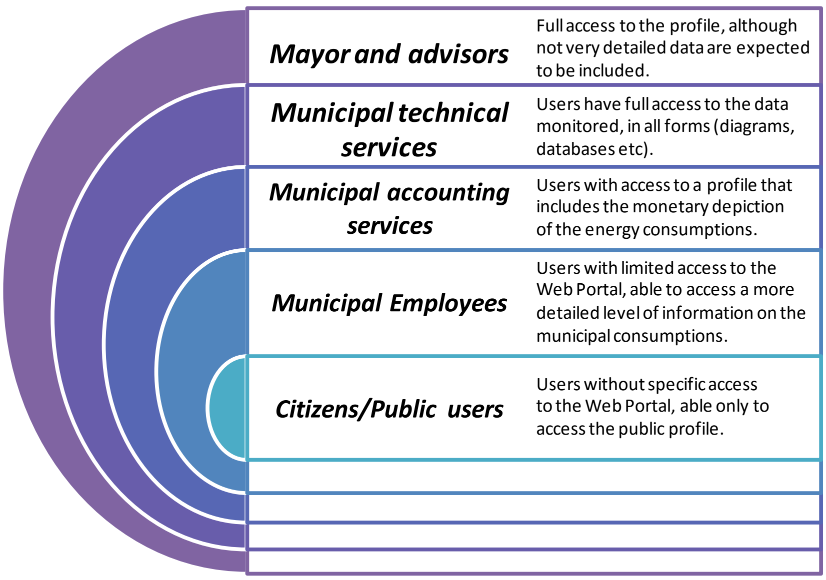

Figure 2: Users Groups.

Figure 3: ESCOCITY's platform homepage.

Table 1: Comparative Analysis of Web-based DSS and Web Portal.

	Web-based DSS	Web Portal
Data integration process	x (developed using Semantic Web technologies)	X (Central gateway and OPC server, by MODBUS protocol)
Weather forecasting	x (data capturing module)	-
Social data	x (data capturing module)	-
Energy prices	x (data capturing module)	-
De-centralized sensor-based	x (data capturing module)	x (from metering devices)
Renewable energy production	x (data capturing module)	x (from metering devices)
Data processing	x (prediction models and inference rules)	-
Energy management	-	x (including alerts)
Proposed actions	x	-
Web environment	x	x
Buildings	x	x
Lighting	-	x
Vehicles	-	x
RES production, storage, etc.	x (linked to the buildings)	x

- *Green EV Station Support Tool* processes data for EV charging stations, namely those parking spaces where EV supply equipment will be used to charge vehicles.

An overview of the platform's home page is presented in the figure3.

4. Comparative Analysis

An overview of the main advantages of each tool is provided in Table 1. More specifically, both tools have a web-based environment and data integration process, in order to collect data from different sources. The DSS collects data from five multidisciplinary sources though the relevant data capturing modules developed. The Web Portal collects data from metering devices, which measure the energy data in the municipal buildings and the relevant infrastructures.

Furthermore, another difference is that the DSS processes the data through prediction models and inference rules, in order to propose specific short term Action Plans to the end users. On the other hand, the Web Portal uses the collected data to perform energy management, providing alerts to the end users for the proper operation of the city's infrastructure.

Finally, the Web Portal addresses all the municipal buildings and infrastructures, street lighting, electric vehicle. The web-based DSS gives particular emphasis on the municipal buildings and the renewable energy production and storage linked to the buildings.

5. Conclusions

Since cities can influence over 70% of the total ecological footprint they have to take innovative actions in order to assist the implementation of Europe 2020 initiatives. One of these actions is to foster energy efficient neighbourhoods with the use of innovative ICTs. Currently there are plenty of energy related data available in the cities, but there are no established methodologies and validated tools to collect, integrate and analyse them.

This paper presented two innovative ICT solutions, namely the web-based DSS and the integrated Web Portal.

- DSS achieves the collection of data from five heterogeneous data sources (weather conditions, social mining, buildings' energy profiles, energy prices, energy production), integrates the using Semantic technologies, and proposed short term Action Plans to the local authorities.
- The Web Portal collects and integrates data from buildings and infrastructures of a given municipality, based on the available tools "Green Buildings", "Green Pillars", "Green Pole" and "Green Electric Vehicle Station Support". The Portal's users are classified into five different groups each one with relevant rights and responsibilities.

The impact of the DSS and the Web Platform is expected to be demonstrated in real life pilot case studies. The web-based DSS is being validated through pilot applications in three different cities: Savona (Italy), Sant Cugat (Spain) and Zaanstad (The Netherlands). The Web Portal is being validated through pilot operation in three cities in Greece, namely the municipalities of Moshato-Tavros, Nikaia-Rentis, and Rhodes.

Acknowledgment

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Fuzzy Cognitive Maps and Zero Energy Building Technologies

by

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Abstract

In recent decades, renewable energy sources and energy saving have been in the centre of interest for scientists and engineers. Buildings are consuming a large amount of primary energy and they could not be excluded from energy saving research.

Zero Energy Building (ZEB) is the latest goal in the field of energy efficiency and savings in buildings worldwide. The concept of ZEB is defined and reviewed. In addition, there is a brief discussion on its characteristics and the number of categories of ZEBs, which are met in literature. The method of Fuzzy Cognitive Maps (FCM) is used in order to model the operation of a ZEB. More specifically a simulation of ZEB operation was developed using the new method of levelled FCMs. The system variables were separated in three categories, the external variables, the production and consumption variables and the variables that contribute to energy balance. The Non Linear Hebbian Learning algorithm was used to train the FCM and adjust it to the operation of a ZEB. Two cases of ZEB operation are analysed, one for spring and one for autumn. Each variable and parameter of the building is considered as a concept and the model is developed considering the interaction between the concepts. Both production and consumption concepts were taken into account, setting the objective of energy balance.

The results are rather interesting, the method of levelled FCM is meeting the objective of the simulation successfully. The model's response is corresponding to the operation of ZEB and has the expected results both in spring and in autumn case. The results are briefly discussed giving motivation for further research and development.

1. Introduction

Energy is a core challenge faced by all regions of the world and especially by the EU member states. During the last two decades, both in Europe and in America, there has been a wide scientific interest on buildings, regarding their energy efficiency, their energy consumption and their emissions to the environment. After the release of the EU "Energy Performance of Buildings" Directive (EPBD) in 2010 and the Building Technologies Program released by the US Department of Energy (DOE), the issues mentioned above have started to become part of legislation all over the world. A particular interest has been turned to the Zero Energy Building concept (ZEB).

However, despite the fact that those issues are the same for all buildings, each country has its own policy and approach. There is a wide variation in energy demand, materials, designs, age and construction of buildings depending on different climate and geographical position. For those reasons, it is not easy to establish a specific approach on managing the buildings' energy issues. [1]-[2]

A **zero energy building (ZEB)**, also known as a **zero net energy** (ZNE) building, **net-zero energy building** (NZEB) is a building with zero net energy consumption, meaning the total amount of energy used by the building on an annual basis is roughly equal to the amount of renewable energy been created on the site. These buildings consequently do not increase the amount of greenhouse gases in the atmosphere. They do at times consume non-renewable energy and produce greenhouse gases, but at other times reduce energy consumption and greenhouse gas production elsewhere by the same amount [16].

Most zero net energy buildings get half or more of their energy from the grid, and return the same amount at other times. Buildings that produce a surplus of energy over the year may be called “energy-plus building” and buildings that consume slightly more energy than they produce are called "near-zero energy buildings".

Traditional buildings consume 40% of the total fossil fuel energy in the US and European Union and are significant contributor greenhouse gasses. The zero net energy consumption principle is viewed as a means to reduce carbon emissions and reduce dependence on fossil fuel and although zero-energy buildings remain uncommon even in developed countries, they are gaining importance and popularity.

The development of modern zero-energy buildings became possible not only through the progress made in new energy and construction technologies and techniques, but it has also been significantly improved by academic research, which collects precise energy performance data on traditional and experimental buildings and provides performance parameters for advanced computer models to predict the efficacy of engineering designs. Zero Energy Building is considered as a part of smart grid. Some advantages of these buildings are as follow:

- Integration of renewable energy resources
- Integration of plug-in electric vehicles
- Implementation of Zero-energy concepts

The zero-energy concept allows for a wide range of approaches due to the many options for producing and conserving energy combined with the many ways of measuring energy (relating to cost, energy, or carbon emissions) [17].

However all these make the whole ZEB concept complex and challenging. Modeling of these systems often result in very high-order models imposing great challenges to the analysis, design and control problems. All these challenges call for advanced system theories which will exhibit some intelligence and will therefore be useful to their human users. Today everybody agrees that new and advanced theories are needed in order to model, investigate and analyze these systems. Such an approach is the Fuzzy Cognitive Maps (FCM). FCM integrates the accumulated experience and knowledge on the operation of the system, as a result of the methods by which it is constructed. The use of FCMs in modeling, analyzing and controlling dynamic complex systems is still in its infancy and there is ample scope for further investigation and development [11]-[13].

In this paper the new and challenging problem of ZEBs is addressed. In section II, the basic characteristics of ZEBs are mentioned. The definition of ZEB is approached, although many definitions can be found in literature. The types of ZEBs as well as additional parameters and concepts are analyzed.

In section III, the control method of Fuzzy Cognitive Maps (FCM) is presented. This method was developed in the last three decades and it is similar to human reasoning. The basic equations and the training algorithm of Non-Linear Hebbian Learning are briefly presented.

Those are the tools for the simulation of ZEB using the method of leveled FCM and the algorithm of Non-Linear Hebbian Learning which is presented in section IV. The system of ZEB and its parameters are presented with a FCM. The applied equipment and the real characteristics of the building are presented in this section, setting the ground on which the simulation was implemented.

In section V the simulations for both spring and autumn cases are presented. The parameters of simulation are defined and the results are given with the respective diagrams. The results are discussed and analyzed, offering promising prospects for Greek climate.

In the last section some conclusions are provided and a short discussion is given on ZEB research topics that could be pursued in the future. There are many aspects of ZEBs that need to be discovered and much more of them that should be improved.

2. General information on zero energy buildings

Zero Energy Building (ZEB) is based on the concept of a building which, within its boundaries, produces as much energy as it consumes, usually on an annual basis. Renewable energy sources, located on or near the building, are used in order to produce the required energy with a reasonable cost and without polluting the environment. ZEB is a challenging research subject since the way that the desirable energy balance is achieved has not yet been exactly specified.

There is an absence of specific characteristics and equipment requirements. This leads to a variety of approaches, depending on each country's legislation, goals and energy policy. In addition, the owner, the designer and the engineer are those who define the desired conditions inside the building, the undesired characteristics and determine the operation parameters. They set priorities and requirements and their plan is the leading to the final approach of ZEB.

Apart from the energy balance, which is asked from a ZEB, specific comfort conditions should be achieved in order to provide a healthy environment for people who live, work or are hosted inside. Thermal comfort mainly depends on subjective evaluation but there are also some environmental parameters, such as air temperature, air velocity, radiant temperature and relative humidity, which define the limits of thermal comfort and are commonly accepted.

In order to achieve those comfort conditions buildings mainly consume electrical energy. Other types of energy which are consumed, such as thermal, are usually produced either by converting electrical energy or by passive techniques, such as solar heating or geothermal energy. The utility of each building is another important factor for its energy requirements. There are three categories of buildings according to their use: 1) commercial, 2) public and 3) residential buildings. Each category has its own needs, equipment restrictions and in some cases intervention limits. Last but not least, geographical position of each building affects the energy requirements. In regions with hot climates the buildings need a large amount of energy for air-conditioning and cooling, whereas in cold climates they need a large amount of energy for heating. [3]-[6]

Focusing on the electrical energy, a ZEB is characterized by its relation to the grid. In the case that a connection to the grid is not accessible and buildings are not connected to it they are called autonomous or stand-alone ZEBs. On the other hand ZEBs which are connected to the grid are separated in three categories:

- **Nearly Zero Energy Building (nZEB)** is a ZEB connected to the grid which has nearly zero energy balance. This means that the consumed energy is slightly higher than the produced energy.
- **Net Zero Energy Building (NZEB)** is a ZEB connected to the grid which has zero energy balance. In that occasion the consumed energy is equal to the produced energy.
- **Net plus or Positive Energy Building** is a building with positive energy balance. The positive energy building consumes less energy than it produces and the excess energy is supplied to the grid.

As it was mentioned above, the energy balance is usually considered on an annual basis. However, in some cases a monthly basis is used in order to make calculations. Grid connected ZEBs provide power to the grid during the days that the produced power exceeds the required and, during days that the produced energy is less than the required they are supported by taking the extra required amount from the grid.

The energy production mainly comes from renewable energy sources, but when those sources are not enough to satisfy the load, conventional energy sources might be used as well. The energy sources may be on the building, on its site or at a distance.

In addition to the energy balance and its parameters, there are some factors which cannot be neglected during the simulation of ZEB operation. The most important of those are:

- The size and the construction materials of the building.
- The utility.
- The geographical position.
- The 'regional climate levels' or 'microclimate'.
- The available renewable energy sources.
- Unpredicted parameters.

There are two kinds of unpredicted parameters. The unpredictability of human actions is the first kind. There is a subjective factor which can change the designer's initial estimations. For example, if we consider that the reference internal temperature for a house is 25ºC. But the house wife wants to open the windows in order to clean them. That activity cannot be predicted and it was not taken into consideration by the designer, although it decreases the internal temperature lower than the reference value. The second kind of unpredicted parameters are the weather conditions. Although nowadays the weather forecast is very accurate and highly reliable, still there is a percentage of incorrect prediction.

For all the above reasons, the modeling and simulation of ZEBs should be based on intelligent control methods, which can manage complex systems, with many parameters. Intelligent control methods have been used in the last decades in a variety of applications and their success is proven. Fuzzy Cognitive Maps is a method of intelligent control which has been developed in 1980s and is rather promising for applications such as ZEBs. [7]-[10]

3. Fuzzy Cognitive Maps

Fuzzy Cognitive Maps (FCMs) are a combination of fuzzy logic and neural networks. They are a method of modeling complex problems, based on human reasoning. A human can make a decision even if a problem is uncertain or ambiguous, using his experience and assessment ability. FCMs are based on that reasoning. They are a graphical presentation of the problem, as it is shown in Fig.1. Each parameter (variable) is presented with a node and it is called "concept". The interaction between concepts and the way they affect each other are presented with "weights". The number of concepts, the kind of interaction between them and the values of the weights are determined by experts, who know the dynamics of the system and the way it reacts to various changes.

Concepts take values in the interval [0, 1] and weights belong in the interval [-1, 1]. The sign of each weight represents the type of influence between concepts. Between two concepts Ci and Cj there could be three cases:

- *wij*>0, an increase in Ci causes an increase in concept Cj, and a decrease in Ci causes a decrease in concept Cj.
- *wij*<0, an increase in Ci causes a decrease in Cj, and a decrease in Ci causes an increase in Cj.
- *wij*=0, there is no interaction between concepts Ci and Cj.

The amount of influence between the two concepts is indicated by the absolute value of *wij*. During simulation, the value of each concept is calculated using the following rule:

$$A_i(t) = f\left(A_i(t-1) + \sum_{\substack{j \neq i \\ j=1}}^{n} A_j(t-1) \cdot w_{ji}\right) \tag{1}$$

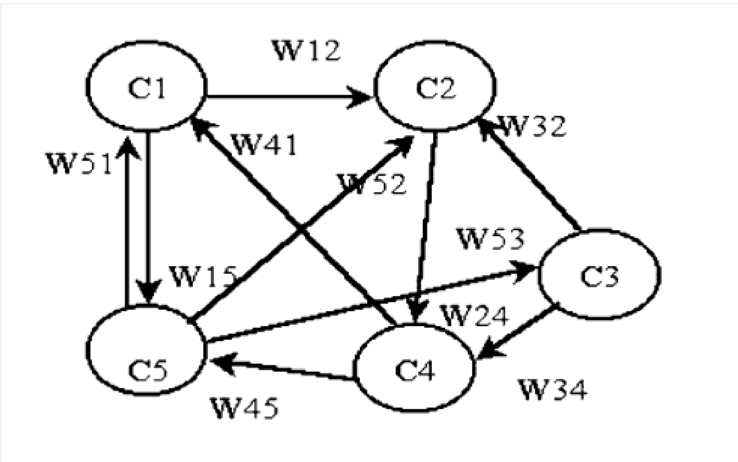

Figure 1: Fuzzy Cognitive Map.

Where t represents time, n is the number of concepts and f is the sigmoid function given by the following equation:

$$f = \frac{1}{1+e^{-\lambda x}} \qquad (2)$$

In which $\lambda>0$ determines the steepness of function f.

Usually in problems there is a number of concepts and A and W are matrices. The FCM concepts take initial values and then they are changed depending on the weights and the way the concepts affect each other. The calculations stop when a stable state is achieved and the values of concepts do not change furthermore.

Based on neural networks, FCMs have a non-linear structure. The algorithm of Non-Linear Hebbian learning is used in this paper to train ZEB FCM to predict the energy balance. The algorithm uses a learning rate parameter $\eta\kappa$ and a weight decay parameter γ, in order to calculate updated weight values, changing only non-zero weights that the expert gave, and then update the concept values. The Non-Linear Hebbian learning algorithm is based on the equation:

$$w_{ji}^{(k)} = \gamma \cdot w_{ji}^{(k-1)} + \eta_k A_i^{(k-1)} (A_j^{(k-1)} - (w_{ji}^{(k-1)}) w_{ji}^{(k-1)} A_i^{(k-1)}) \qquad (3)$$

There is more detailed information on FCMs and Non-Linear Hebbian Learning algorithm in references [11]-[13].

4. Modeling ZEB with a Leveled FCM

In this paper a three leveled FCM (Fig.2) will be used to model the operation of a ZEB. As it was mentioned in previous paragraph, a ZEB is a complex system with many variables and parameters. The interaction between variables was determined by an expert, who knows exactly how the system responds, which variables are affected and to what extend, each time an alteration happens. Each system component is considered as a concept and the weights between them are determined by the expert. In this paper the ZEB was considered to be of residential use and the parameters that each concept represents are the following:

C1: Photovoltaic System

C2: Wind Turbine

C3: Lighting

C4: Electrical/Electronic Devices

C5: Heating

C6: Cooling

C7: Solar Radiation

C8: Wind Velocity

C9: Windows

C10: Natural Light

C11: Shading

C12: Internal Temperature

C13: External Temperature

C14: Geothermal Energy

C15: Total Production

C16: Total Consumption

In the first level there are concepts C7-C14, which represent the weather conditions and the parameters which affect the values of the higher level concepts. Those are the Factor-concepts. In the second level there are concepts C1-C6, those are the Selector-concepts. C1 and C2 are the energy production units, and C3-C6 are the energy consumption parameters. In the third level C15 and C16 are the output values, total production and total consumption. The most important consideration of a ZEB is the Energy Balance, which is given by the equation:

Energy Balance=Total Production–Total Consumption

The amount of energy that each concept produces or consumes was considered based in [15], in order to determine the linguistic values of the concepts and to specify the weights.

More specifically:

- C1 (PV): Output Power 0-10KW → Concept value 0–1.
- C2 (Wind Turbine): Output power 1KW → Concept value 0-0.1.

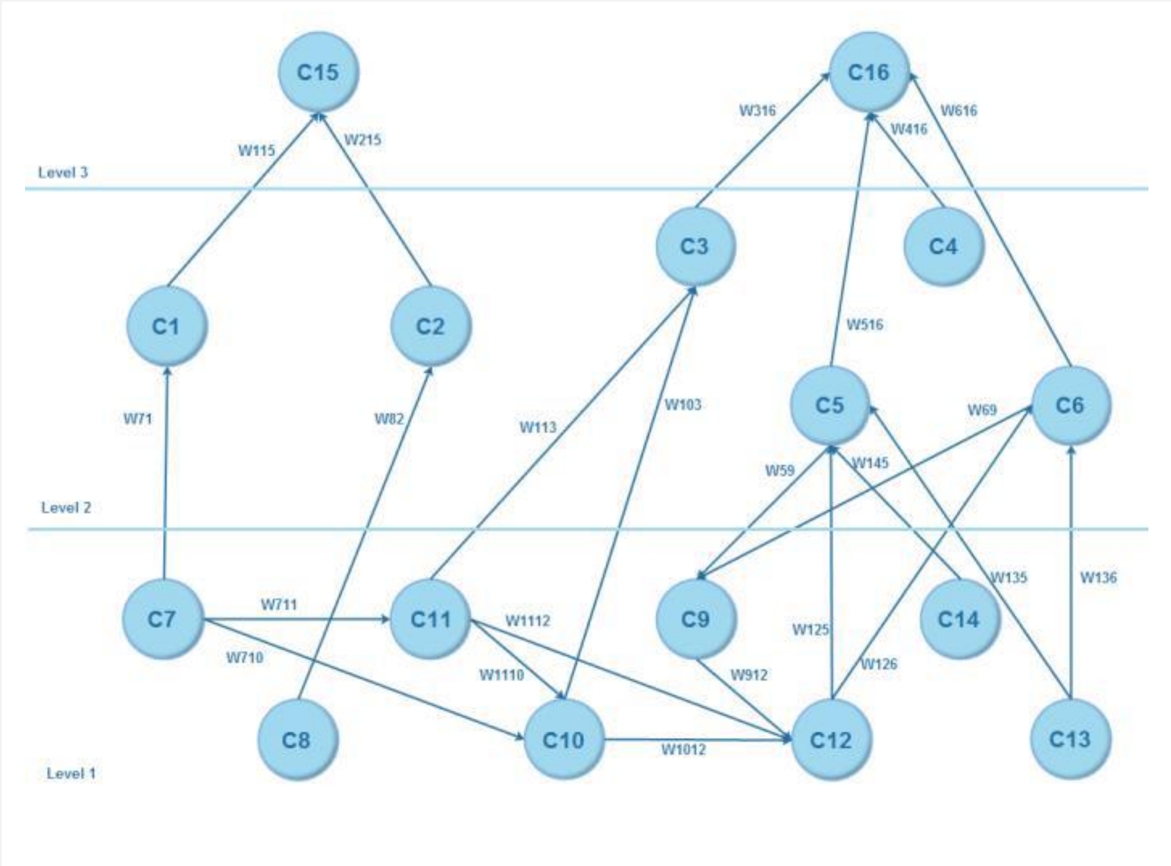

Figure 2: Modeling a residential ZEB using a Three Level FCM.

- C3 (Lighting): It is estimated that the house has 15 light bulbs, and each bulb has power consumption 20W. An average use of the lighting is estimated, using 4bulbs × 3h/day, giving a total consumption in lighting equal to 240W/day → Concept value 0-0.024.
- C4 (Electrical/Electronic Devices): The devices that a typical house has are:
  - ✓ Fridge: 90W/h→2160W/day
  - ✓ Electric Oven: 2000W/h
  - ✓ PC: 300W/h, average use 3 hours per day
  - ✓ Electric Iron: 1000W/h
  - ✓ Vacuum Cleaner: 1000W/h
  - ✓ TV: 41W/h
  - ✓ Washing Machine: 2800W/h
  - ✓ Electric Water Heater 80lt: 4000W/h.

    Considering an average day, using the fridge 24h, the electric oven 1h, the PC 3h, the vacuum cleaner 1/2h and the electric iron 1h, the average consumption for the devices is equal to 6560W/day → Concept value 0-0.656.
- C5 (Heating): 2 Air Condition 1000W/h, average use 2h, average consumption 4000W/day → Concept value 0- 0.4.
- C6 (Cooling): 2 Air Condition 1000W/h, average use 2h, average consumption 4000W/day → Concept value 0-0.4.

Concepts C7-C14 vary between 0 and 1, since their contribution is considered only linguistically.

5. Spring and Autumn Simulations

In the simulation procedure two cases were considered. In the first case the operation of a ZEB was simulated for a typical spring day and in the second case for a typical autumn day. Both cases were taking into account the weather conditions in Greece and the building was considered to be used for residential purposes.

Greece is a country with temperate climate. Usually, during winter the temperature is low, the wind is strong and it is rather rainy whereas in summer the temperature is high and the wind velocity is very low. During spring usually the temperature is medium and the wind velocity rather low whereas in autumn the temperature is medium to low and the wind quite strong.

- **SPRING**

The weight matrix in the case of spring operation is shown in Table 1. As it was mentioned above, weights take values in the interval [-1, 1] and they represent the interconnection between the concepts. Weights W7-11, W9-12, Q12-6, W12-9, W13-6 and W13-9, which are in "bold" type, are those which are different in spring and autumn operation. All the other weights are common for spring and autumn, since they are parameters of the same system.

In order to have a good approach of the building's operation during spring, the initial values were set appropriately, approaching the Greek climate. Solar radiation has been set medium and wind velocity very low. As a consequence the PV energy production has been set to medium and wind turbine energy production has been set very low. Those parameters define the total energy production and total energy consumption of the building. The concepts which have been associated to the weather conditions determine the values of natural light and shading, which were set to medium.

Finally the concepts which are associated to the building's energy consumption are the lighting of the building, which was set to low, the electrical and electronic devices, set to medium, heating, which is zero in spring, and cooling which is very low.

Using the above initialization, the weight matrix in Table 1 and the Non-Linear Hebbian learning algorithm, during the simulation of spring operation of the ZEB, the result was the diagram in Fig.3.

In that diagram, the above curve represents the total production and the bottom curve is the total consumption. It is assumed that during spring the building can satisfy its own energy needs and have a positive energy balance. A positive balance is reasonable in the case of spring, since the climate in Greece is rather sunny and without extreme temperatures. Those conditions offer a satisfactory amount of energy production and do not require energy consumption for heating or cooling. As a consequence the consumed energy is not very high.

- **AUTUMN**

The weight matrix in the case of autumn operation is shown in Table 2. Weights W7-11, W9-12, Q12-6, W12-9, W13-6 and W13-9, which are in "bold" type, are those which are different from spring operation and all the other weights are common for both cases. A cloudy autumn day has been considered in this case. Solar radiation has been set to low and wind velocity to medium. As a consequence the PV energy production has been set to low and the wind turbine energy production has been set medium.

Natural light and shading were set to low. The concepts associated to the buildings energy consumption were set with the same values as in the case of spring, given the fact that the operation of a house does not change a lot within a year. The only difference, regarding the energy consumption, is that in autumn cooling is not used at all but heating might be used a little. So the concept of cooling has been set to zero and heating has been set to very low.

Using the above initialization, the weight matrix in Table 2 and the Non-Linear Hebbian learning algorithm, during the simulation of autumn operation of the ZEB, the result was the diagram in Fig.4.

In Fig.4 the above curve represents the total energy production and the bottom curve represents the total energy consumption. As in the case of spring, from the autumn diagram it is assumed that the building can also satisfy its own energy requirements during autumn.

Table 1: Weight matrix in the case of spring operation.

TABLE 1																
SPRING																
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**C16**
C1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,8	0
C2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,2	0
C3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,1
C4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,3
C5	0	0	0	0	0	0	0	0	-0,5	0	0	0	0	0	0	0,15
C6	0	0	0	0	0	0	0	0	-0,5	0	0	0	0	0	0	0,15
C7	0,95	0	0	0	0	0	0	0	0	0,6	**0,05**	0	0	0	0	0
C8	0	0,85	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C9	0	0	0	0	0	0	0	0	0	0	0	**-0,03**	0	0	0	0
C10	0	0	-0,3	0	0	0	0	0	0	0	0	0,01	0	0	0	0
C11	0	0	0,3	0	0	0	0	0	0	-0,2	0	-0,01	0	0	0	0
C12	0	0	0	0	0	**0,1**	0	0	**0,3**	0	0	0	0	0	0	0
C13	0	0	0	0	0	**0,15**	0	0	**-0,1**	0	0	0	0	0	0	0
C14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2: Weight matrix in the case of autumn operation.

TABLE 2																
AUTUMN																
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**C16**
C1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,8	0
C2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,2	0
C3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,1
C4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,3
C5	0	0	0	0	0	0	0	0	-0,5	0	0	0	0	0	0	0,15
C6	0	0	0	0	0	0	0	0	-0,5	0	0	0	0	0	0	0,15
C7	0,95	0	0	0	0	0	0	0	0	0,6	**-0,1**	0	0	0	0	0
C8	0	0,85	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C9	0	0	0	0	0	0	0	0	0	0	0	**-0,1**	0	0	0	0
C10	0	0	-0,3	0	0	0	0	0	0	0	0	0,01	0	0	0	0
C11	0	0	0,3	0	0	0	0	0	0	-0,2	0	-0,01	0	0	0	0
C12	0	0	0	0	**-0,35**	0	0	0	**0,2**	0	0	0	0	0	0	0
C13	0	0	0	0	**-0,15**	0	0	0	**-0,1**	0	0	0	0	0	0	0
C14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

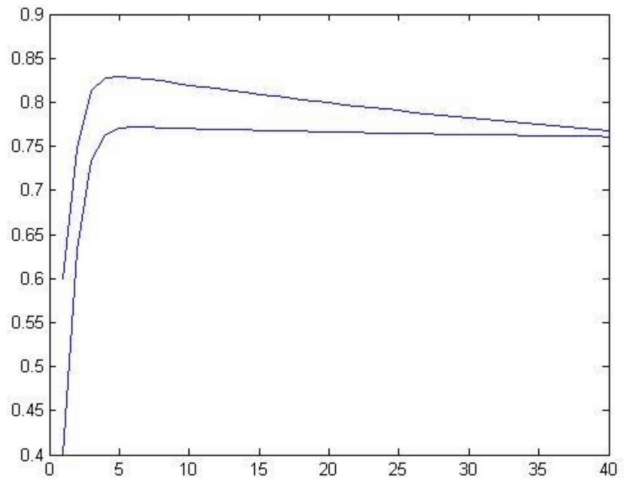

Figure 3: Spring Operation of ZEB.

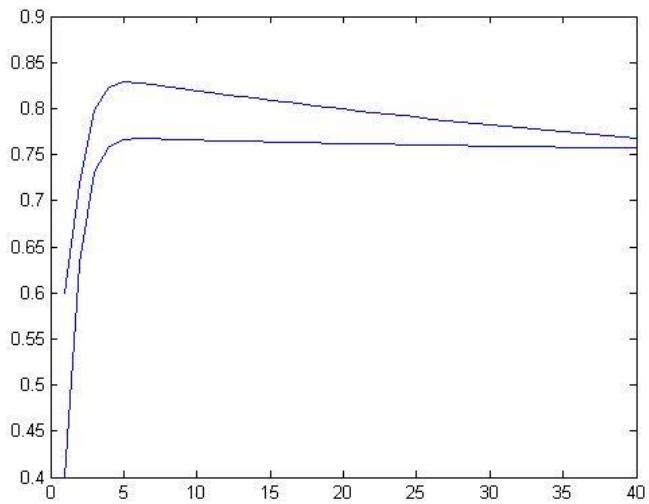

Figure 4: Autumn Operation of ZEB.

6. Conclusions and Future Research

The method of ZEB attracts scientists' and engineers' interest all over the world. However, buildings are complex systems, they have many parameters and their operation depend on many external factors. As a result, modeling and controlling buildings is a difficult and complicated process.

In order to be able to control the complex system of a ZEB in real time operation, the first step is to make its model and simulate its operation. The term of control includes not only the achievement of reference concept values but the ability of the system, in this case the building, to adjust when a sudden change occurs.

This paper approached only the part of simulating the ZEB operation and it is a first step towards the direction of modeling the building during its real time operation. The method of FCMs simplified the system's complex operation and made it look like a simple graph. The simulation results have shown that FCMs have the potential to model a ZEB.

Furthermore, this paper was based on the operation of a ZEB located in Greece. Both cases of spring and autumn led to the conclusion that Greek climate is appropriate in order to achieve the successful operation of ZEBs and, perhaps in many cases, of positive energy buildings. This offers to scientists and researchers appropriate conditions to develop and test models or real systems, upgrade their expertise and take their science one step further, applying it to the society and protecting the environment.

There is ground for further research concerning various cases of buildings. This paper focused on residential buildings but in our societies there other types of buildings as well. Public, commercial and industrial buildings are some of the categories which need to be researched. Each category has its own specific characteristics. There are significant differences on the operation, the type of used equipment and the amount of the consumed energy in each building category. As a conclusion, each type of building should be treated in a different way, and that would be an interesting challenge for further research.

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New Advanced Technology Methods for Energy Efficiency of Buildings

by

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Abstract

Energy consumed by buildings represents a large part of the world's total energy consumption with a total share of 40%. This is the reason why energy efficiency of buildings has become a very important scientific field. For the purpose of this paper a critical review of old and new methods of controlling the parts of a building's automation and thus achieving energy savings are compared, analyzed and presented. The method of Fuzzy Cognitive Maps (FCM) and its significant impact on the improvement of the management of a building is being presented. FCMs is a new soft computing method which combine neural networks and Fuzzy Logic. They have been used with very promising results in many fields such as medicine, transportation, manufacturing agriculture, food industry and energy. In this paper the use of FCMs is exploited and specifically used in issues of energy efficiency of buildings. Obtained results, simulation and experimental, for case studies where FCMs were used in buildings, of residential and commercial use, in Southern Greece will be presented. Software tools based on the aforementioned applications will be briefly presented. In the near future these tools are going to be integrated in even more buildings thus giving us real data which can and will be used in future research for moving from high energy consumption to Net-Zero Energy Buildings (NZEB).

Key words: Conventional Control, control strategy, heating ventilating and air-conditioning system, fuzzy logic, neural networks, fuzzy cognitive map.

1. Introduction

Technology has been characterized through the different stages of civilization as the "vehicle" that will lead us to technological advances in the future. The change rate of technology is nowadays greater than any other time in human history. Technology enters not only to our lives and our work but also into our houses. The last two decades the concept of an Intelligent Building and the technology applications associated with its development gather a constantly increasing attention. Many definitions have been proposed in order to describe what an Intelligent Building really is, however, as the construction industry and communication technology develop, they change the way the concept of the Intelligent Building is being approached.

It is very difficult to form a single conception of what an Intelligent Building really is as there is not a universally accepted definition. However all the efforts that have been made in order to form the aforementioned definition, led to the determination of three categories which are based on different approaches and which are mentioned below:

1. Performance based definitions
2. Service based definitions
3. System based definitions

For the aim of this paper we are going to use the definition given by the European Intelligent Building Group (EIBG) which states that intelligent is a building which offers its users the most effective environment and on the same time uses and manages its resources in a manner that ensures the reduction of the cost due to the use of equipment and facilities (Wang, 2009).

The structure of the paper is as follows: In section two Intelligent Buildings are being reviewed. In section three we describe the

Building Energy Management Systems. In section four the conventional and fuzzy control methods with regards to HVAC systems are being compared and contrasted and an application of Fuzzy Cognitive Map on a BEMS is being presented. Finally in section five conclusions regarding this review are being summarized.

2. Intelligent Buildings (IBs)

Energy consumption in buildings represents a great part of the world's total use of energy with a total share of about 40%. The International Energy Association predicts that electricity usage for residential buildings will grow by 25% by 2020. For this reason along with the energy crisis, energy efficiency becomes a crucial issue as it contributes not only to the reduction of the fossil fuels consumption but also to the decrease of the global warming phenomenon (D.Kokolotsa et al. (2001)). This effort is mainly focused not only to the increase of the use of renewable energy sources but also to the more optimal use of the building equipment through the formation of Building Energy Management Systems (BEMS). BEMS refers to a computerized system which attempts to control energy consumption of every operation in a building, such as heating, ventilation, lighting and air quality e.t.c. Through such a system we are trying to achieve the lower possible energy costs and the maximum environmental protection while on the same time the comfort needs of the building's users will be satisfied (Mpelogianni et al. (2014)).

Nowadays, the scope of the definition of an IB has been extended to include 'learning ability' and 'performance adjustment from its occupancy and the environment' (Wigginton and Harris, 2002; Yang and Peng, 2001; Wong et al., 2005). This means that it should be able to adjust not only to the required conditions, but also to the preferences of its user. (Wong et al., 2005). In other words, the concepts of self-correction or fault tolerance are being introduced and are considered as important parts of this research. For this purpose "artificial intelligence" and fuzzy logic and fuzzy cognitive maps in particular, are the means of creating robust control tools that resemble human intelligence methods (Nikolaou et al.), which allow our efficiently control such complex systems.

According to Wong et al. (2005), the previous researches on Intelligent Building (IB) have dealt with three aspects of research including advanced and innovative intelligent technologies, performance evaluation methodologies, investment evaluation analysis.

A lot of research has been done on first category. According to Wong et al. (2005), this research has focused on the advanced development of system integration, network protocol and building subsystem services, which include HVAC control, lighting control, fire protection system, security system and communication system.

A large amount of IBs contain three levels of system integration as the top level (dealing with the provision of various features of normal and emergency building operation as well as communication management), the middle level (performing by the building automation system(BAS), energy management system(EMS), etc.) which control, supervise and coordinate the Intelligent Building subsystems, the bottom level (it contains subsystems) (Wong et al., 2005). Building performance evaluation is a very important procedure which offers valuable feedback on the performance of building resources and equipment for future improvement (Wong et al. (2005)). Based on Wong et al. (2005), the development of Intelligent Buildings has been tangible and there has been much tendency to improve its limits and complexities. In general technology associated with intelligent building development consists of the integration of four systems as a Building Automation System (BAS), a Telecommunications System (TS), an office Automation System (OAS), a Computer Aided Facility Management System (CAFMS) (Wong and So, 1997). The most important part of each IB is a sophisticated BAS (Wong and So, 1997).The expansion of BAS includes information from all aspects of Building Systems, working toward the Intelligent Building's goal (Kastner et al., 2005).

3. Building Energy Management System (BEMS)

The Building Management System (BEMS) is a part of the BAS and is of outmost importance for the control of the building. As heating, cooling and domestic hot water production are three operations that consume great amounts of energy the need for the design of a system that can efficiently control these parts and thus reduce the energy consumption is being underlined. In recent years, the quality and complexity of mechanical and electrical systems in buildings have been increased.Building automation systems are suitable for integrating the buildings subsystems like lighting control fire alarm, HVAC systems. monitoring, controlling and managing the modern structures with complex control functions (Stein, Jiang, 2005). According to Carlson (1991) a BAS is a more effective and efficient control tool to be used for building. Automatic control of indoor parameters is provided by Building automation systems (BAS), which is mainly used in order to control the HVAC system. An efficient HVAC control offers great energy savings and cost reduction. (Kastner et al. (2005)).

A BAS is an integration of several subsystems, the purpose of these subsystems is to provide better understanding of the building's performance through measuring building energy consumption, optimizing system running strategy and improving system management (Jiang, 2005). Merz et al. (2009), stated that building automation is the computerized measurement, control and management of building services. Although, the building automation and the building control may at first appear the same, this definition shows that building control is a part of building automation. After the early 1970s, when the oil price was increased, the need for power-saving arose and highlighted the need to relate automation related to energy managing (Kastner et al., 2005). Control of active systems like HVAC was applied significantly for BEMS to save energy and cost (Doukas et al., 2007).

3.1 HVAC systems, an introduction

As we mentioned above, the HVAC system is an active subsystem in BAS. Due to its large impact on power and energy consumption, the knowledge of the operation as well as the structure of such a system is of outmost importance (Tashtoush et al., 2005). Tashtoush et al. (2005) stated that energy efficiency and internal climate conditions are most important issues that have to be taken into consideration when designing HVAC systems. A heating, ventilating and air conditioning system consists of several subsystems such as an indoor air loop, a refrigerant loop, a chilled water loop, a condenser water loop, an outdoor air loop (Lei et al., 2006; Wang et al., 2006). Because each loop consists of many dynamical variables, the HVAC system is a nonlinear time-variable system with disturbances and uncertainties (Lei et al.,2006; Wang et al., 2006).

Hence, it is very difficult to obtain the mathematical model of the HVAC system (Tashtoush et al., 2005) and consequently design the appropriate controller (Lei et al., 2006; Wang et al., 2006). 50% of the total used energy in buildings is consumed by HVAC systems. Due to the great amount of energy consumption by HVAC systems, designing a robust controller could help the achievement of a considerable amount of energy (Huang et al., 2006).

4. Control Strategies in Building Automation

One of the first and most important goals when developing control systems and especially if this system is a building is the minimization of energy consumption (Dounis and Caraiscos, 2009). A lot of research has been down and many studies have been published on different ways to control a building's automation. These studies categorized the control techniques as follows: conventional methods (Classical methods, Digital methods, and Fuzzy methods), and computational intelligence techniques, agent-based intelligent control systems (Dounis and Caraiscos, 2009). It should be noted that the combination of the aforementioned categories is unavoidable.

4.1 Conventional control systems in buildings

According to Dounis and Caraiscos (2009) conventional control of buildings has been carried out using the following methods or some combinations of them: Classical controllers, Digital controllers and Fuzzy controllers. Due to the advances in recent building structures, nonlinearity and uncertainty have increased, thus making the mathematical description of the system and consequently the control using Classical methods; which require the mathematical model of the system, very difficult.

Bardossy et al. (1995), stated that the base of automatic control is engineering control theory. Processing of inputs and feedbacks from the previous state is used by control algorithms in order to optimize the control of the system in the next time step. Due to incomplete observation of the state of the process or inaccuracies during measurements, the control of complex systems is tremendously unwieldy (Bardossy et al., 1995). In other words, classical control methods which are based on mathematical description of the system are vulnerable to inaccurate and noisy inputs or feedbacks, making them really cumbersome.

According to Astrom and Wittenmark (1996) in digital control, a digital computer is used for real-time control of system. Digital control utilizes the digital or discrete technology instead of analog components which exist in classical control systems, one of the basic reasons why digital technology replaced analog was the cost. The numbers of control loops increase the cost of analog system, linearly. Despite the large initial cost of digital system, the cost of additional loop is small and that is the reason why digital control is suitable for large installation. Informational and technological development era increases the system's complexity, involving system's mathematical model and in addition integration of some systems is so difficult and sometimes impossible.

On the other hand, the control strategies like classical control which are used as mathematical model to define the relationship between inputs and outputs of system are very difficult to apply when dealing with mathematical model of non-linear or uncertain information systems. In comparison with other conventional methods fuzzy controllers offer better response and have been successfully applied in case of complex nonlinear and time varying conditions (Kristl et al., 2007).The design of fuzzy controllers is similar to the human way of thinming (Kristl et al., 2007). The advantage of this controller is a linguistic instead of a mathematical model (Kristl et al., 2007) which is described by experts (Eftekhari and Marjanovic, 2003).

4.1.1 Importance of fuzzy logic technique in a BAS

As the complexity of electrical and mechanical equipment in buildings increases, the mathematical modeling of systems becomes more difficult and sometimes impossible mainly because of the nonlinearities and uncertainties of the system. In these cases fuzzy logic techniques gave a new perspective and showed a lot of advantages over other conventional approaches. Fuzzy logic techniques have been successfully implemented in most cases due to their flexibility and intuitive use (Kristel et al., 2007). Fuzzy logic techniques are based on the system's goal and control preferences rather than the way it works or reacts on a particular problem (Zhang, 2007). That is the reason why, for a complex, integrated system with many non-linearities, such as a BAS, the method of fuzzy logic is used to offer control of the various parameters of the building.

4.1.2 Fuzzy logic control versus conventional controls

A considerable amount of research has been done on classical control methods. These studies show that classical control is being applied in a large number of cases successfully. Classical control is implemented in many cases however in complicated systems with complicated mathematical models which demand real time control this method has a lot of disadvantages. In order to solve this kind of problems, other control methods, like fuzzy control, which use simple mathematical modelling, have been applied (Dounis and Caraiscos, 2009). Thus, for a complex, integrated, non-linear system, such as a building fuzzy logic techniques are more appropriate and efficient. According to Zilouchian and Jamshidi, 2001, the comparison of control loop behavior aiming to the optimization of an HVAC system, between a Direct Digital and a Fuzzy Logic Controller, shows that the use of fuzzy logic needs less control time than versus Direct Digital control. The big overshoot is a reason of large control time (Tc) in Digital controller. As a result of specific rules of fuzzy controller, process variables are brought to the new set point to avoid processing variable's overshooting. The course of supplying temperature of cooling system with PLC and FLC performing system shows fuzzy control optimizes the system's performance (Zilouchian and Jamshidi, (2001)). With the use of fuzzy control, considerable improvement is shown in the system behaviour and great reduction has been made on the cost of energy production.

Zilouchian and Jamshidi (2001) have also have used the two aforementioned methods to investigate the heating system of the building, in order to provide domestic hot water during summertime. Investigation shows for the same process that Heater by Direct Digital Control had four starts/stops while by fuzzy control had only one start/stop. A very significant result was that by fuzzy control has less pollution effects and also it shows the improvement of the system.

Releasing of the control mode of the heater by fuzzy controller is time-delay-oriented in which shooting the supply temperature over the set point is avoided and the number of the start/stop phases of the heater is reduced.

4.1.3 Disadvantages of BAS control according to the rule-based control methodology

According to Qiao et al. (2006), the accuracy of input and output variables is an important criterion in every control system including the ones using fuzzy logic. Even though fuzzy models can manage uncertain and inaccurate information better than their mathematical counterparts, accuracy is a major concern in most applications. In fuzzy rule-based methods for example, accuracy is related to the number of fuzzy grades in the membership functions.

Although increasing the number of the fuzzy grades can provide higher accuracy, it also increases exponentially the number of rules which results into a longer block of rules, which represent the given control strategy (Yam et al., 1999). There are two major disadvantages related to this aspect: longer runtime which results in lower speed, and lack of real-time response. Bardossy et al. (1995) stated that even if the speed does not play the most important role in the controller, a smaller number of rules can often be realized at a lower cost. In other words, in rule-based implementation, due to computational limits, the designer has to effectively compromise between the accuracy and speed of the system, or choose one of these two. It must be also noted that due to lower speed or longer runtime, fuzzy rule-based is far from the real-time control. When taking into consideration a typical BAS under fuzzy rule-based control, there are other shortcomings to be considered. There are usually four types of behaviours to be coordinated in BAS including safety behaviour, emergency behaviour, economy behaviour, and comfort behaviour. While the first three behaviours are usually predefined that is, by one or more experts, the comfort behaviour is dynamic and has to be learnt by the system with respect to the responses from the occupants in the building. Accordingly, several feedbacks have to be incorporated into the system for considering user's responses for generating appropriate control outputs. However, rule-base methods are not simply capable of receiving feedbacks for implementation of learning strategies (Park et al., 2000). According to Bardossy et al. (1995), in contrast to other fuzzy control techniques, fuzzy rule-based method is a quasi open loop procedure. Inclusion of feedbacks in development of the rules has to be avoided since it can exponentially increase the number of the rules. The main contribution of fuzzy modelling theory is its ability to handle many practical problems that cannot be adequately represented by conventional methods (Eftekhari and Katebi, 2008).

However, pure rule-based systems such as the model of Eftekhari and Marjanovic (2003) are not so efficient. Such systems are still subjected to errors due to lack of corrective feedbacks from the environment. An effective idea is to incorporate feedback information through closed loop control techniques such as direct feedbacks or learning strategies (Eftekhari and Katebi, 2008).

Therefore, fuzzy rule-based methods are not advantageous in BAS control due to their difficulties in inclusion of feedbacks which is a must in any BAS implementation. Inclusion of feedbacks or the increase of system accuracy can simply cause an exponential growth in the number of the rules that is, a huge block of rules. The worse consequence of such problems is the reduction of computation speed and lack of real-time response. Although fuzzy rule-based techniques are advantageous over conventional methods, there might be better alternatives when it comes to closed loop control of BAS. The problem of inclusion of user feedbacks in fuzzy BAS control without much negative effect on computation speed has remained as a challenging problem.

4.2. An Introduction on Artificial Neural Networks (ANN)

According to Xu and Shin (2008), the generic method to map or represent input and output relationships or patterns of nonlinear functions or data through a single or multiple layers of an interconnected group of artificial neurons is called artificial neural networks or simply neural networks. On the other hand, the algorithms and architectures of artificial neural networks are based on neurobiological system (Daponte and Grimaldi, 1998).

Lek and Guegan (1999), stated that the ANN is like a black box with a great capacity in model prediction and all of the characters are described in an unknown situation and capable to train the ANN. ANN is an attractive choice to control the nonlinear systems due to robustness and its ability to map arbitrary nonlinear functions (Wu and Li, 2008). The structure of simple neural network consists of three types of neurons: the input, hidden and output neurons. In other words, neurons are very simple processors similar to the biological neurons in brain which are connected by weighted links to other neurons to pass signals. Also, the output signals are transmitted from the outgoing connection of neurons and the output signals split into the number of branches that transmit the same signal to the next layer's neurons as an input of the neurons. Each neuron computes the weighted sum of the inputs signals and compares the result with threshold value.

4.2.1 Importance of Neural Networks control method in a BAS

Referring to Ghiassi and Saidane (2005), artificial neural networks are able to deal with both linear and nonlinear functional relationships. Nevertheless, neural networks are more implemented in nonlinear systems. Neural Networks advantages are: as many tasks could be performed by neural networks which could not by linear programs, the process can be continued when failure occurs without any problem due to the parallel nature, have ability to be implemented in many areas and applications, without any problem.

4.2.2 Disadvantages of BAS control according to the neural networks method

Although, they are more profitable advantages of neural networks, there are some disadvantages which cause decrease of the efficiency of this method. For example operating neural network requires training, due to the fact that different architecture of neural network from microprocessors needs to be emulated, and it takes long time to process large neural network. Due to the neural networks problems the need for efficient methodology to decrease the shortcomings of this method is reasonable.

4.3 Fuzzy Cognitive Maps (FCM) – An introduction

Fuzzy Cognitive Maps came as a combination of the methods of fuzzy logic and neural networks. They constitute a computational method that is able to examine situations during which the human thinking process involves fuzzy or uncertain descriptions. An FCM presents a graphical representation used to describe the cause and effect relations between nodes, thus giving us the opportunity to describe the behavior of a system in a simple and symbolic way. In order to ensure the operation of the system, FCMs embody the accumulated knowledge and experience from experts who know how the system behaves in different circumstances. In other words they recommend a modeling process consisting of an array of interconnected and interdependent nodes Ci (variables), as well as the relationships between them W (weights) (Kosko, (1993)).

Concepts take values in the interval [0, 1] and weights belong in the interval [-1, 1]. Fig.2 shows a representative diagram of a FCM (Wong et al. (2005)). The sign of each weight represents the type of influence between concepts.

There are three types of interconnections between two concepts Ci and Cj:

- wij>0, an increase or decrease in Ci causes the same result in concept Cj.
- wij<0, an increase or decrease in Ci causes the opposite result in Cj.
- wij=0, there is no interaction between concepts Ci and Cj.

The degree of influence between the two concepts is indicated by the absolute value of wij.

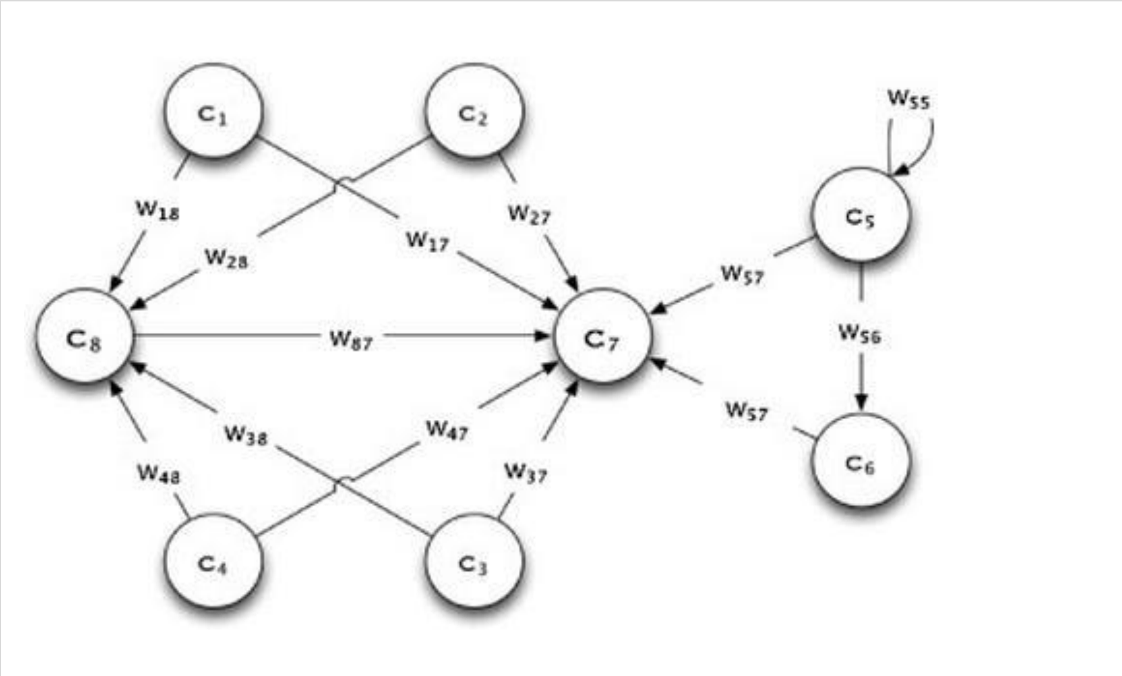

Figure 1: Fuzzy Cognitive Map.

During the simulation the value of each concept is calculated using the following rule:

$$A_i(t) = f\left(A_i(t-1) + \sum_{\substack{j=1 \\ j\neq 1}}^{n} A_j(t-1) w_{ji} \right) \quad (1)$$

Where t represents time, n is the number of concepts and f is the sigmoid function given by the following equation:

$$f = \frac{1}{1+e^{-\lambda x}} \quad (2)$$

Where $\lambda>0$ determines the steepness of function f.

The FCM's concepts are given some initial values which are then changed depending on the weights; the way the concepts affect each other. The calculations stop when a steady state is achieved; the concepts' values become stable (Kosko (1986), Anninou et al. (2013), Wong et al. (2005), Papageorgiou et al. (2004), (2008)). As causal patterns change and experts update the causal relationships between concepts, the use of Non Hebbian Learning (NHL) procedure helps the FCM to modify its fuzzy causal web (Papageorgiou et al. (2003)). Due to the non-linear structure of the FCM the NHL can contribute to its training and consequently to the prediction and control of the BEMS function.

In this algorithm the learning rule for FCMs integrates a learning rate parameter ηk, weight decay parameter γ, and the input/output concepts. The value of each concept changes through Eq. (1) whereas weight value is calculated using Eq. (3) i.e. the centroid deffuzification method.

$$u' = \frac{\int_u u \mu_{B'}(u) d(u)}{\int_u \mu_{B'}(u) d(u)} \quad (3)$$

Through the NHL algorithm, the only weights that change are the non-zero ones, all the other weights of the weight matrix Wji keep their initial zero value (Kannapan (2011)).

In this part of the paper we are going to develop the Fuzzy Cognitive Map which can also be used to control the BEMS as it was described in section 3 of the paper.

4.4 Fuzzy Cognitive Maps- An example

In this part of the paper, in order to prove the efficiency of Fuzzy Cognitive Maps in the control of complex systems, we are going to develop a FCM which is used to control a BEMS (Mpelogianni et al. (2015)).

4.4.1 System Descritpion

The Building Management System (BEMS) is a system of outmost importance for the control of the building. As heating, cooling and domestic hot water production are three operations that consume great amounts of energy we designed a system in order to reduce it. The system is shown in Figure 2, and consists of :

- A boiler for the domestic hot water storage.
- A storage tank for the storage of water for the heating and cooling of the building.
- A Photovoltaic Thermal Unit for the production of electricity and hot water.
- A Heat Pump (air to water) for heating and air conditioning needs of the building.
- A Floor Heating unit which can reduce the fuel needed by 30%.
- A Fan Coil Unit (FCU) to cover the rest of the cooling and heating needs.

Four circulators and triode valves are used to distribute the water to the various parts of the automation.

The control algorithm will focus on these valves and circulators in order to achieve the maximum energy savings.

4.4.2. Fuzzy Cognitive Map Construction

In order to have an accurate comparison we used as concepts the inputs and outputs of the previous algorithm, properly adjusted to meet the requirements of this control method.

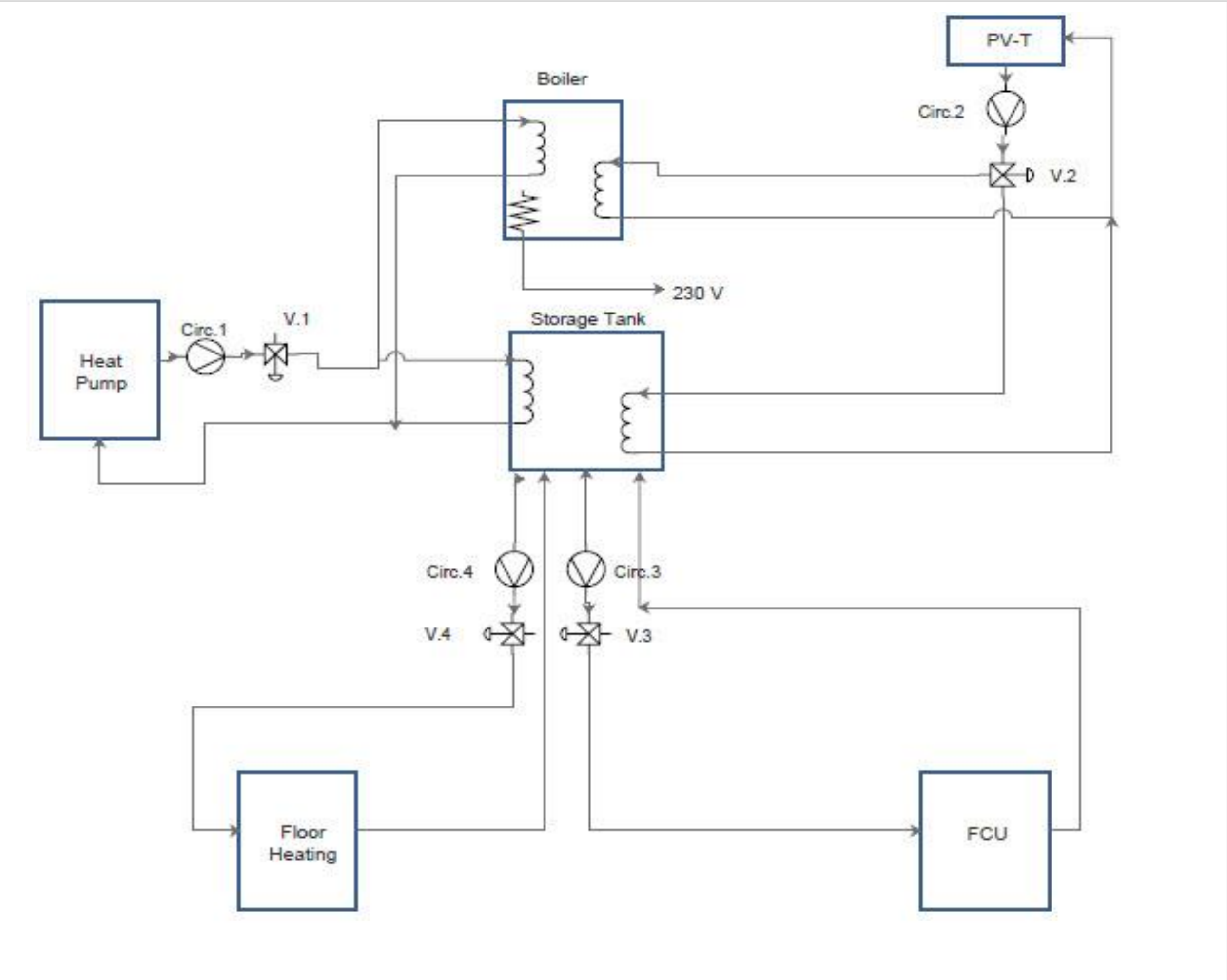

Figure 2: Building Energy Management System.

The concepts were divided into three categories; the input concepts, the medium output concepts and the final output concepts of the FCM.

The concepts as well as the category they belong to, are listed below.

Inputs:

- C1: PV-T Temperature
- C2: FCU Temperature
- C3: Floor Heating Temperature
- C4: DHW Demand
- C5: Contamination Flag

Medium Outputs:

- C6: Storage Tank Temperature
- C7: Boiler Temperature
- C8: Valve 1a
- C9:Valve 1b
- C10:Valve 2a
- C11:Valve 2b
- C12:Valve 3
- C13:Valve 4
- C14:Circulator 1
- C15:Circulator 2
- C16:Circulator 3
- C17:Circulator 4

Final Outputs:

- C18:Resistance Operation
- C19:Heat Pump Operation

Concepts 1-4 and 6-7 take values from 1to 4 (low, medium low, medium high and high). Concepts 5, 14-19 take OFF-ON values. Concepts 12-13 take the value AC which is the position of the value. Finally due to the fact that the valve position is a discrete value, valves 1 and 2 were divided to two separate concepts; the first having the one way positions and the second having the two way position.

Continuing the interconnection weights between nodes will be defined. This process will be undertaken by experts who in cooperation with each other will decide the interconnection weights. As part of this work the interconnections between the nodes emerged from an extensive study of the building's simulation based on real weather data. The values positive or negative will vary between the following ones:

W (weak): Very weak interconnection between the nodes C_i, C_j.
M (medium): Medium interconnection between the nodes C_i, C_j
S (strong): Strong interconnection between the nodes C_i, C_j
VS (very strong): Very strong interconnection between the nodes C_i, C_j.

These values will then be defuzzified (Groumpos (2011), Runkler (1997)) and a corresponding numerical value will be assigned to each one of them.

The Fuzzy Cognitive Map is presented in Figure 3.

The red dashed lines represent the relationship between the boiler and storage tank temperature with the concepts regarding the common position of the valves and acts only when it is necessary to send water to both directions.

5. Conclusions

In this paper, a review of control systems for energy management and comfort in buildings is presented. In the beginning of the paper, Intelligent Buildings where defined as achieving more comfort as well as energy management. To meet Intelligent Buildings goals, using control strategies is unavoidable. Next, the different control systems and their advantages and disadvantages over control parameters of the buildings are inspected.

According to investigation of control systems, the intelligent control systems are more developed for improving the energy efficiency of buildings. Finally, applying the combination of control techniques of fuzzy logic and neural networks is recommended to control buildings. The hybrid method of fuzzy logic and neural networks contain the robust characteristics of both methods.

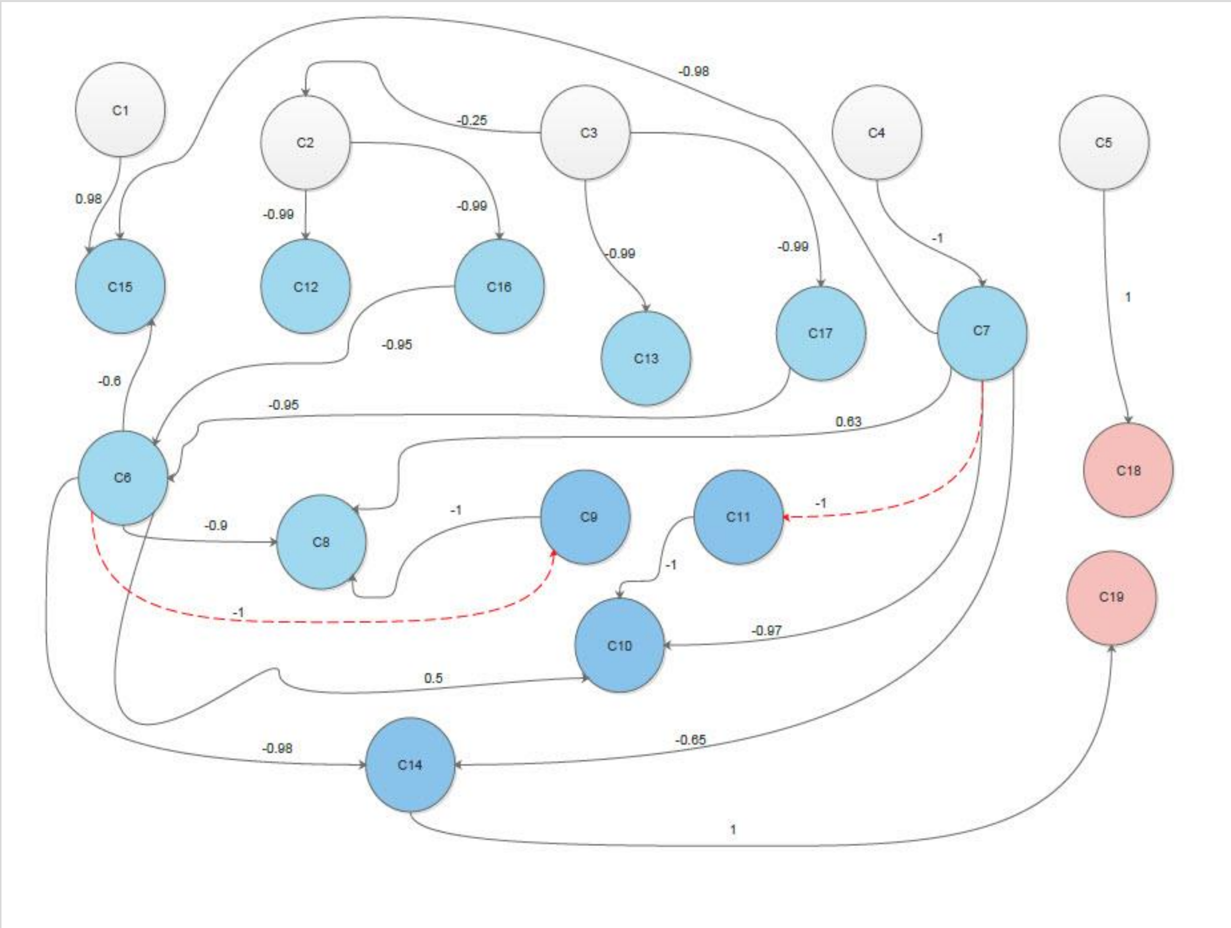

Figure 3: Fuzzy Cognitive Map.

In addition, the shortcomings of both methods are omitted in this method. Regarding the definition, characteristics and simplicity of mathematical model of FCMs, implementing the FCMs as a direct control is recommended in controlling the parameters in building automation systems to achieve more intelligence in building as well as more energy saving. As a result of the structure of FCMs, the run time of control process is declined. Due to the ability of FCMs in having learning strategy, the consumption of energy could be decreased.

Due to the fact that, the energy sources are limited and energy crisis, saving more energy is an important goal for using building automation systems. Therefore, The FCMs as a direct control system are proposed in order to get to the objectives of decreasing run time of control process and saving energy.

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Overview of behavioral, economic and institutional barriers to implementation of energy efficiency in the Hellenic building sector

by

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Abstract

According to EUROSTAT and the Hellenic Statistical Authority, the building sector (residential and tertiary) is among the most energy intensive sectors in Hellas. The energy saving potential in this sector is significant, but the largest part of it is still unexploited.

The penetration of energy efficiency technologies and practices is influenced by the behavior of the consumers, such as public servants, household owners, tenants and SMEs owners, among others. Their decision is determined by information/awareness, costs, plus behavioral factors. In Hellas, the information and data about the attitude of consumers towards the established energy efficiency policy instruments, technologies and practices is limited.

The paper presents the sector-specific mapping and analysis of behavioral, economic and institutional barriers to the implementation of energy efficiency in two governance levels (national and local/regional) through a literature review based on project and survey results, national, European and international official reports. In the national level, most of the official reports, funded research projects and published research papers are addressing the households, the public sector and the hotels. In the local/regional level, the barriers are mostly linked with the initiative of Covenant of Mayors and the implementation of SEAPs.

1. Introduction

The building sector is among the most energy and carbon intensive sectors in EU. It accounts for 40% of the energy consumption and for 36% of the CO_2 emissions[118]. The promotion of Energy Efficiency (EE) is expected to reduce these trends, mainly through two key EU Directives, the Directive about the Energy Performance of Buildings (2010/31/EU) and the Energy Efficiency Directive (2012/27/EU).

Furthermore EE will contribute to the European Union's (EU) energy security and its transition to a competitive low carbon economy (COM(2014) 520 final/23.07.2014[119]).

[118] https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings

[119] COM(2014) 520 final/23.07.2014. "*Energy Efficiency and its contribution to energy security and the 2030 Framework for climate and energy policy*". Available at: https://ec.europa.eu/energy/sites/ener/files/documents/2014_eec_communication_adopted_0.pdf

Table 1: EU energy and climate targets.

Year	Targets
2020	▸ 20% cut in greenhouse gas (GHG) emissions (from 1990 levels) ▸ 20% of energy from renewables ▸ **20% improvement in energy efficiency**
2030	▸ 40% cut in GHG emissions (from 1990 levels) ▸ at least a 27% share of renewable energy consumption ▸ **at least 27% energy savings compared with the business-as-usual scenario**
2050	▸ 80% cut in GHG emissions (from 1990 levels)

The EU targets for energy and climate change, presented at table 1, include also those for the improvement of EE.

Despite the undertaken measures for supporting EE investments, according to a European Commission analysis[120], a shortfall of 1%-2% in relation to the 20% target is expected in year 2020. This is partly related to the "energy efficiency gap" which refers to the failure of consumers to make cost-effective EE investments. In this context, the policies should be modified so as to reflect the end-user's behavior. Therefore, the policy makers will face new challenges in performing scenario analysis of the different EE policies by explicitly linking behavioral anomalies of the end-user to EE investments (Gillingham K. et al., 2013).

The end-user's behavior that influence both the purchase of equipment and the use of energy is determined by information/awareness, energy costs, plus social, educational and cultural factors (WBCSD, 2008). Consequently, there are barriers for the implementation of EE policies and technologies that are related to the aforementioned factors.

This paper presents the sector-specific mapping and analysis of behavioral, economic and institutional barriers to the implementation of EE in two governance levels (national and local/regional) through literature review. It is structured as follows: the first section refers to the Hellenic building sector, the second section refers to the behavioral, economic and institutional barriers that were mapped in this sector concerning EE technologies and policies and the third section presents the conclusions of the overview.

2. Hellenic building sector

The final energy consumption for the Hellenic building sector was 17,129 Mtoe in 2012, representing the highest energy consumption with 45% (residential and tertiary), along with the transport sector which had 37% (YPEKA, 2014).

Households account for 84% of the total building stock (72% of total surface) (Ministry of Environment, Energy and Climate Change, 2014). From the remaining 16%, 3,62% corresponds to offices, stores, educational buildings, hospitals and hotels (Ministry of Environment, Energy and Climate Change, 2014). Table 2 reflects the situation according to the 2011 census (YPEKA, 2014).

At national level, the Hellenic EE policy package for this sector includes a variety of policy instruments (regulatory, financial, dissemination, awareness and capacity building), Action Plans, Programmes and Initiatives, most of which derived from the transposition of EU Directives into the national laws. More specifically (Konidari P. et al., 2015):

— <u>Regulatory policy instruments</u>: Energy labeling, energy audits, Regulation for Energy Performance of Buildings – Minimum requirements of energy performance for buildings, metering, energy auditors, eco-design requirements, energy management systems;

[120] COM(2014) 520 final/23.07.2014

Table 2: Number of buildings by type (2011 census) (YPEKA, 2014).

Type	Number
Households	4.122.088
Hotels	8.309
Schools & educational centers	15.576
Offices & shops	152.550
Hospital & medical centers	1.742
Other	625.630
Total	**4.925.895**

- Dissemination and awareness instruments/informative policy instruments: energy performance certificate; Green Public Procurements, Voluntary agreements; information campaigns for certain programmes such as "Energy Efficiency at Household buildings";
- Economic policy instruments: taxation on energy products and electricity, Green Fund-subsidies, financial incentives (subsidies, financial exemptions), financial incentives for replacement of devices/systems;
- Policy instruments for the promotion of energy services: ESCO market promotion.

At local level, most of the EE policies are linked with the European Initiative "Covenant of Mayors" [121], which involves local and regional authorities that are voluntarily committing to increase EE and use of RES. One hundred ten (110) Hellenic municipalities are signatories of the Covenant, seventy-nine (79) of which have submitted their Sustainable Energy Action Plan (SEAP) and four (4) of which have already been at the stage of the results monitoring.

3. Barriers

A literature review was conducted using recent project and survey results, national, European and international official reports and published research papers, seeking for behavioral, economic and institutional barriers to the promotion of EE in the Hellenic building sector. The following analysis includes barriers that: i) were identified by the majority of the used for this paper references/different sources, ii) cover broader spectrum of technologies or practices and iii) were observed both in national and local level.

a. *Behavioral barriers*

The following behavioral barriers were identified based on the literature review.

Low level of environmental awareness

The Hellenic society is not yet sensitive enough towards environment, sustainability and energy conservation (Karkanias C. et al., 2010; Theodoridou I. et al., 2012). Low level of awareness regarding the environmental, economical, EE benefits and the concept of "sustainable and energy efficient building" influence greatly the energy refurbishment policies (Theodoridou I. et al., 2012). Research studies for certain regions in the country highlighted the fundamental role of energy awareness, combined with targeted information on technical and cost issues (Zografakis N. et al., 2012). More specifically:

- A research on low income households in the Kastoria prefecture regarding the use of energy saving practices showed that only one third of them select "A" energy class electrical devices and one quarter

[121] http://www.covenantofmayors.eu/index_en.html

use energy efficient lamps (Christidou C. et al., 2014).

- In Crete, a survey that included 685 companies showed that only 9,8% were using Inverter technology of air-conditioning split units (Tsagarakis P.K. et al., 2012).

Limited information for EE generally

This barrier is closely linked with the previous one. According to the Hellenic Ministry of Environment and Energy, consumers usually have insufficient information and education on the rational use of energy, leading to (YPEKA, 2010):

- installation of individual air-conditioning systems without technical study;
- use of poor performance devices;
- non maintenance of the heating system.

The Ministry attempted to confront this barrier with the "Energy Efficiency at Household Buildings" Program (YPEKA, 2010).

Incomplete or no information obstructs the use of cost-effective and energy-efficient technologies. The lack of readily available information and demonstration increases the investment costs for such technologies due to: increased search costs; increased investment uncertainty. In Hellas, empirical evidence was gathered with the use of questionnaires and face-to-face interviews during 2004 (Kounetas K. et al., 2011).

The same barrier is observed on hotel owners (Hotel Energy Solutions, 2011). There is low awareness for the costs and benefits of EE and RES technologies (Hotel Energy Solutions, 2011). It would be useful if they were informed about: i) appropriate technologies that could be applied in the different operating areas of the hotel such as restaurants, bedrooms, etc. (Hotel Energy Solutions, 2011), and ii) the policy framework or good practices from other countries (Maleviti E. et al., 2012; 2011).

Furthermore, there is lack of information among public servants and citizens regarding the energy consumption of the public institutes (CERtus, 2015). At local level, the financial instruments that could be used for the implementation of SEAPs were not known to most cities administrations (Christoforidis C. G. et al., 2013).

Incomplete and/or limited information for emerging innovative technologies

The European Commission identified a number of potential barriers for Small-Medium Enterprises (SMEs) and consumers in building sectors in EU Member States regarding the access to and the spread of EE technologies (Kounetas K. et al., 2011). This barrier is observed in SMEs mainly because of the limited availability of information, resulting from the limited resources compared to larger firms. Nevertheless, the argument that the level of information is technology specific is supported (Kounetas K. et al., 2011).

Aloofness due to negative past experience

Negative experiences are frequently observed in Europe (ENTRANZE, 2014). They are characterized either as fading (such as early not-so-convincing demonstrations of solar thermal systems and ground source heat pumps) or more persistent (such as opposition to mechanical ventilation - prerequisite for heat recovery; quality problems in thermal renovations; underperformance of air source heat pumps). These are observed for solutions which are still at initial stage and there are not enough relevant good examples and known experiences (ENTRANZE, 2014). There is also fear for still unknown technologies (Theodoridou I. et al., 2012).

Habits and living styles (comfort)

Working habits are very strong. Office equipment such as computers, automated teller machines, faxes and digital video recorders DVRs are usually on stand-by mode during the working hours due to heavy work pressure (Spyropoulos N. G., Balaras A. C., 2011). Consequently, potential energy savings in working buildings/spaces were not considered under the requirements of the Energy Performance of Buildings (Law 3661/2008 – Common Ministerial Decision

5825/9.4.2010) (Spyropoulos N. G., Balaras A. C., 2011).

The hoteliers believe that high energy use is necessary to ensure the comfort of guests (Hotel Energy Solutions, 2011).

<u>*Diverse socio-economic background & multilateral ownership*</u>

In Hellas, there are usually multi-family buildings with more than 10 apartment owners, leading to a mosaic of rarely converging opinions towards building renovation (Gelegenis J. et al., 2014; Theodoridou I. et al., 2012; ENTRANZE, 2014). Furthermore, difficulties for the decision on renovation are attributed to the different socio-economic background (Gelegenis J. et al., 2014).

<u>*Unwillingness to go beyond the minimum requirements*</u>

EE standards in building codes rarely refer to the optimal standards. Also, building owners and particularly hotel owners are unwilling to make EE interventions that go beyond the minimum requirements, established in building codes (Hotel Energy Solutions, 2011). Additionally, builders and designers are rarely motivated to go beyond the required EE standards, even more if such efforts will increase initial costs (Hotel Energy Solutions, 2011).

The aforementioned barriers are summarized in table 3.

b. Economic barriers

The literature review concluded to the following behavioral barriers.

<u>*Economic recession*</u>

It is one of the main economic barriers for supporting EE investments and policies at national and local level since it resulted in:

- limited resources and interest to provide loans from the side of banks, particularly for the deep renovation of public buildings towards nearly zero energy consumption which have big payback period (Theodoridou I. et al., 2012; CERtus, 2015); The bank loans in Hellas were significantly contracted, leading to a subsequent reduction of investments on building renovations. Indicatively, according to the latest data from the Bank of Greece, the net flow of credit to households was recorded negative from April 2010 and was estimated to reduce 202 million Euros in August 2014, while the growth rate of mortgage loans was at – 3,0% (YPEKA, 2014).

Table 3: Behavioral barriers in the Hellenic building sector.

Title	Related policy or technology	Type of subsectors & consumers
Low level of environmental awareness	Refurbishment, energy saving lamps, appliances “A”, inverter technology air-condition	Residential and Tertiary: residents and shop owners, hotel owners
Limited information for EE generally	Refurbishment, bio-climatic design, heating & air-conditioning systems, SEAPs	Residential and Tertiary: residents, public servants, and private company owners (such as hotels)
Incomplete and/or limited information for emerging innovative technologies	EE technologies	Residential and Tertiary: residents, public servants, and SMEs owners
Aloofness due to negative past experience	EE solutions at initial stage (eg. air-source heat pumps)	Residential and Tertiary
Diverse socio-economic background	Refurbishment	Multi-family households
Multilateral ownership	Refurbishment, thermal renovation	Residential and Tertiary: Apartment buildings/Blocks
Habits and living styles (comfort)	Refurbishment, stand-by mode of appliances	Residential and Tertiary
Unwillingness to go beyond the minimum requirements	EE solutions	Tertiary: mainly hotels

- poor loan capability of private investors (Theodoridou I. et al., 2012). The liquidity problems of the Hellenic businesses and banks hindered the implementation of the JESSICA initiative (Tsipouri L. and Athanassopoulou S., 2012).
- income decrease and change of consumption patterns of the population in the recent years, that put aside investments for energy renovations (YPEKA, 2014).
- limited national subsidies (Theodoridou I. et al., 2012). Despite the level of communication and the visibility of efforts for a programme/initiative in the media and in different communities, economic-based initiatives require substantial support from the government (CRISP project, 2012).
- important national budget cuts. For instance, this was the case of Center for Renewable Energy Sources and Saving (CRES) which is the national institute responsible for the promotion of EE and RES (Energy Efficiency Watch, 2013). Also, at local level, EE and RES investments through SEAPs were endangered due to budget cuts. Indicatively, Hellenic cities were succumbed to 40% cut from the government (Christoforidis C. G. et al., 2013).

Costly innovative technologies

Innovative technologies, especially those of Nearly Zero Energy Buildings (NZEB)(recent EU Directive) are still new for the market and costly, for instance solar cooling (CERtus, 2015).

In the public sector, the technical staff of the public buildings is reluctant to approve and proceed with the installation of new and innovative technologies, since there is lack of actual successful examples (CERtus, 2015).

Reluctance for investments with long payback period

The payback period of EE interventions is usually quite great (YPEKA, 2014). Some of the EE options are considered rather expensive making them of no practical interest from the point of market acceptability, particularly without any financial support, subsidies or other financial instruments (Droutsa K.G. et al., 2014). EE investments with long payback periods (more than 10 years), are characterized as unattractive (INTERREG IVC, 2014).

Building owners that rent their offices/apartments do not apply EE interventions such as installation of double-glazing windows due to the increased capital cost (Tsagarakis P.K. et al., 2012). On the other hand, tenants are discouraged to undertake such actions that go beyond the purchase of EE appliances, due to the long payback period and their temporary stay in the building (Tsagarakis P.K. et al., 2012).

An indicative example is the case of green roofs in Greece (Green roofs were supported by recent law and the national programme “Green roofs in public buildings” (refurbishment of buildings) that was launched in 2011). People were discouraged to proceed with the installation of green roofs due to the high initial investment (CRISP project, 2012).

Also at local level, the municipalities prefer investments with a payback period equal to their tenure of local administration (five years), since this period coincides with the financial planning. In any case they avoid making investments with a payback period more than 10 years (CERtus, 2015). For public schools, EE interventions that were cost effective and with very small payback periods were preferred by the school administration (such as: replacement of oil boilers with natural gas ones, thermal insulation of the hot water distribution pipes in the older buildings) (Dascalaki G. E., Sermpetzoglou G. V., 2011).

Still developing market for energy services

Currently, the Hellenic EE market lags behind those of other EU countries. The market for energy services (especially for the refurbishment of buildings towards NZEBs) is still developing. The access for all consumers and market players to integrated and highly qualitative energy services shows high potential for future growth in EE and will be a key priority for Greece's energy policy (RePublic ZEB project, 2015). The following barriers were identified (YPEKA, 2014):

- Lack of adequate renovations' supply chain service;
- Lack of energy labeling, energy standards and certification in construction materials;
- Lack of technical support and reliability of energy services;
- Lack of metering / direct mechanisms (such as smart meters) for the monitoring of energy savings due to renovation.

Limited financial incentives

State support for energy renovations and renewable heating and cooling systems appears to be lower in Greece than in similar south European countries (Italy and Spain) (ENTRANZE, 2014).

For the programme EXOIKONOMO (Energy Saving), the available budget was considered insufficient for the implementation of integrated EE plans that will cover the overall needs of municipalities (target group) (Remaco SA, 2010). This barrier could be overcome with the institutionalization of energy services contracts and third party financing (Remaco SA, 2010).

There is absence of incentives for the implementation of bioclimatic design (Karkanias C., 2010). Contractors have a negative attitude towards the adoption of EE technologies or practices such as the bioclimatic architecture, due to the use of costly building materials and the installation of passive energy systems, that results in smaller selling profit for them (Karkanias C. et al., 2010). The profit from designing and constructing a conventional building requires less time and reaches up to 160% of the construction cost, while the profit for the bioclimatic buildings is much smaller (Karkanias C. et al., 2010).

The majority of hotels face difficulties in getting financing for any types of investments (Hotel Energy Solutions, 2011). Due to their poor credit ratings, small- and medium- size hotels often serve costlier loans than the large or chain hotels (Hotel Energy Solutions, 2011). So, easier access to finance at viable interest rates is needed for most hotels so as to implement EE and RES technology investments, maybe through the development of innovative financial packages with low interest loans and/or performance guarantees (Hotel Energy Solutions, 2011).

Rebound effect

High income inhabitants live usually in relatively new buildings that show improved energy performance. Indicatively, only 8% of low income households live at buildings with isolation and double glazing windows, while the respective percentage for high income households is 64% (Association of Greek Contracting Companies, 2008). The improvement in the energy performance of the building's envelope and of heating system- as part of the EE measure of refurbishment of residential buildings - is being offset by the higher living and comfort standards of those inhabitants leading to higher energy consumption. It is representative that the very low income households have almost the same energy consumption for heating needs with the very high income households (Association of Greek Contracting Companies, 2008).

Hidden costs

There are hidden costs for the implementation of EE interventions apart from the net costs of the interventions themselves, such as management fees and other.

An indicative example was the JESSICA initiative, where significant management fees of the European Investment Bank led to the renegotiation of the financing agreement with commercial banks and the management fee was reduced to 1,2%, from the initially planned 1,9% (Tsipouri L. and Athanassopoulou S., 2012).

Also, it is difficult and time consuming for the municipality services to monitor and to be consistent with the legislation (for energy efficiency and particularly for the forthcoming new Directive concerning the nearly zero energy consumption) (CERtus, 2015). Particularly for public buildings there are numerous legislative and regulatory provisions that determine the procedure to conclude in study contracts and / or construction renovation projects (CERtus, 2015). The payment procedure for contracts (i.e. registration at the budget, credit commitment, decision of undertaking, etc) is very complicated and time consuming resulting to delays of payments and consequently to delay of works (CERtus, 2015).

The aforementioned barriers are summarized in the Table 4.

c. *Institutional barriers*

<u>*Lack of targeted legislation*</u>

According to the Ministry of Environment, Energy and Climate Change, the lack of relevant legislation for the past 30 years resulted in failure of integration of modern technologies in buildings, leading to (YPEKA, 2010):

- partial or total lack of insulation;
- obsolete frames;
- lack of sun protection of the southern and western sides;
- insufficient use of the high solar potential of the country;
- inadequate maintenance of heating / air-conditioning resulting to poor performance.

There is also still no defined national standard for conducting adequate and confirmed measurements regarding actual energy consumption in buildings (YPEKA, 2014).

Hellas has not yet defined the levels of nearly zero energy consumption according to EU Directive 2012/27/EC (CERtus, 2015).

Also, hoteliers do not adopt EE technologies or practices due to the lack of effective national policy in the sector of tourism (Pieri S. P. et al., 2015). This barrier along with the voluntary approach in which EE is pursued, set energy audits and reporting on the hotel environmental performance as a necessary initial step that will facilitate policymaking on EE (Pieri S. P. et al., 2015).

<u>*Tenure status*</u>

Hellas has a very large tenure quota, mainly for apartments, which can greatly influence the implementation of retrofitting measures (Theodoridou I. et al., 2012). Due to multiple ownerships, there is low implementation or even rejection of energy refurbishment measures (Theodoridou I. et al., 2012).

Unlike in the case of the Energy Building Certificate, the owners of an apartment in a multi-family building are not legally bound to proceed to retrofitting interventions (Theodoridou I. et al., 2012).

Consequently, if such interventions can be implemented partially, then the concerned party/owner can act on its will (Theodoridou I. et al., 2012).

Table 4: Economic barriers in the Hellenic building sector.

Title	Related policy or technology	Type of subsectors & consumers
Economic recession	EE solutions, NZEBs, SEAPs	Residential and Tertiary
Costly innovative technologies	EE and NZEB technologies such as solar cooling	Residential and Tertiary
Reluctance for investments with long payback period	Refurbishment, EE solutions such as green roofs, SEAPs	Residential and Tertiary
Still developing market for energy services	Refurbishment, construction materials	Residential and Tertiary
Limited financial incentives	EE solutions, bio-climatic design, SEAPs	Residential and Tertiary: residents, small-medium sized hotel owners
Rebound effect	Refurbishment	Residential: high income owners
Hidden costs	EE investments	Tertiary: SMEs

But when the retrofitting measures concern the whole building, the legal framework is not clear giving the following options (Theodoridou I. et al., 2012): i) according to the statute, the respective works are in force or simple majority could be demanded, ii) if one or more owners disagree to contribute to the respective costs, then the legal procedure for the ‘‘res judicata’’ could last even up to 3 years. Consequently, many owners avoid investing in energy upgrade. So there is a need for the revision of this legal framework. A suggestion would be to configurate the property pricing according to the energy performance characteristics, under a specific legal framework (Theodoridou I. et al., 2012).

The person who decides for the EE level of a building does not coincide with the person who bears the cost of energy consumption therein (e.g. the cost for the energy upgrade of a building under lease burdens the owner but the benefit from the energy savings is attributed to the lessee), known also as split incentives (YPEKA, 2014).

Complex administrative procedures

Legislation and procedures concerning EE in buildings (i.e. in nZEB) are complex and puzzling for the public, due to lack of dissemination actions (ENTRANZE, 2014). In addition, the legislation on Energy Efficiency of the building stock is relatively recent - entered into force in 2010 - while during the last years, numerous amendments to existing legislation were made, accompanied by a considerable number of ministerial decisions and circulars (YPEKA, 2014).

Bureaucratic procedures that hindered the implementation of publicly funded projects were reported in the following cases:

- “Green Neighborhoods Programme”, whose objective was the energy renovation of a low-income neighborhood in the broad area of Athens (Greece), with the participation of unemployed inhabitants, recruited and trained as installers and maintainers of their building (Request 2 Action project, 2012);
- “Green Roofs” initiative (CRISP, 2012);
- “EXOIKONOMO KAT OIKON” programme: there were up to 6-month delays in issuing the appropriate building permits for EE interventions as required by national law (Remaco SA, 2010).

Hellas has not yet defined the different levels of nearly zero energy consumption based on the different use of buildings (CERtus, 2015). There are time delays in updating the necessary documents for the implementation of the respective legislation. According to the new Direction of Energy Policy and Performance of the Ministry for Reconstruction of Production, Environment and Energy [122] (old name Ministry of Environment, Energy and Climate Change), the respective regulation is expected to be published by the end of 2015 (CERtus, 2015). It is also expected that the levels of nearly zero energy consumption for the existing buildings, apart from the governmental ones, shall not be mandatory unless radical renovations are made (CERtus, 2015).

According to the findings of the European project CERtus, at municipality level, the legal framework based on which the municipality could award a contract with a company of energy services is not concrete (CERtus, 2015). It is also difficult and time consuming for the municipality staff to monitor and to be consistent with the legislation for EE (CERtus, 2015). Particularly for the public buildings, there are numerous legislative and regulatory provisions that concern the study contracts and / or construction renovation projects (CERtus, 2015).

- Apart from the defined procedure of assigning a contract (under the EU Directive 2012/27/EC), the legislation that describes the payment procedure (ie registration at the budget, credit commitment, decision of undertaking,

[122] http://www.ypeka.gr/Default.aspx?tabid=230&language=el-GR

etc.) is very complicated and time consuming resulting to delays of payments and consequently to delay of works (CERtus, 2015).

- The technical services are obliged to follow a difficult and time-consuming procedure for the approval of any study or work for renovation (CERTus, 2015). These lengthy processes often lead to non-implementation of interventions.

The legislation for the EU Directive 2012/27/EC foresees that the tariffication for the study and construction of any type of intervention in public buildings should be done according to the Analytical Tariffication of Construction Works (ATCW) which differs significantly from the actual market prices due to the lack of regular update of catalogues for material and works (CERtus, 2015). The last update of the ATCW took place in 2007 (CERtus, 2015). Consequently, the list of the Analytical Tariffication of Construction Works does not include innovative systems and materials (CERtus, 2015).

<u>Ineffective urban and land planning / special building cases</u>

Due to the lack of urban and land planning in Hellas during the last 30 years, the majority of new buildings have been constructed in a very dense urban space (Karkanias C. et al., 2010). Vertical tall buildings with narrow vents along the floors, without any thermal insulation in walls and roofs and with very few features of traditional Hellenic architecture, dominated the decades of 1960s and 1970s (Karkanias C., et al., 2010). These buildings generated serious operational problems such as insufficient lighting and poor ventilation, apart from the high energy consumption and the subsequent operational expenses (Karkanias C. et al., 2010). Due to the lack of wide streets, big sites, and exposed facades, that limit the utilization of sun, the implementation of bioclimatic architecture is difficult (Karnanias C. et al., 2010).

Additionally, the situation is worsened since there are historic, traditional or cultural heritage buildings in Hellas, where no changes in the facade are allowed (the refurbishment of such buildings need to follow specific rules). That is why external thermal insulation is often not allowed to be installed. Although the internal insulation does not interfere with the facade, the internal system leads to non-negligible loss of indoor space and is related to high risk of moisture condensation (Kolaitis D. I. et al., 2013).

<u>Limited expertise and resources</u>

This barrier was mainly identified at municipality level. Although the Covenant of Mayors includes simple procedures, the municipalities' staff did not have the required experience (Christoforidis et al., 2013). Also, researchers have quoted the inability of rural Hellenic communities to build suitable SEAPs, due to inadequate financial capacity and/or human resources (Christoforidis C. G. et al., 2013). Furthermore, they insist that there is necessity for support to develop action plans and monitor SEAP's implementation.

<u>Lack of detailed data</u>

One of the considerable barriers in studying the energy performance and adopting energy efficiency technologies and practices in buildings is the lack of data and the diversion of management. The building users have no or incomplete information concerning the energy performance of their building, and consequently, they are not aware of how they can improve it (CERtus, 2015).

More specifically:

- At national level, the available data for Hellenic residential buildings is not sufficient so as to be used in building stock models or other relevant research studies (Dascalaki G. E. et al., 2011). There are data only for the insulation level (missing, partial or completely insulated) while there are no detailed reports on heat generation systems, domestic hot water or space heating systems, and no time series data are available for heat distribution systems (Dascalaki G. E. et al., 2011). The data gaps are attributed to the absence of systematic data collection (Dascalaki G. E. et al., 2011).
- In municipality buildings, the lack of a defined procedure or staff for the energy consumption monitoring

hinders the collection of energy data or any relevant information (CERtus, 2015; ADVANCE, 2014). This problem will be most probably overcome by a legislative provision soon to be published by the Central Government and will concern the appointment of an energy manager in municipalities (CERtus, 2015).

- In public buildings and particularly in schools, the collection of data on the actual energy consumption is a difficult task because (Dimoudi A., Kostarela P., 2009): i) heating costs are covered by the school budget which is under the responsibility of the school committees, that usually change every year and in many cases do not keep relevant records. ii) electricity costs are covered by the municipality.
- In the hotel sector, the respective managers cannot provide data on the energy consumption of hotel facilities due to lack of an organized record (Pieri S. P. et al., 2015). This attitude underestimates the value of energy monitoring and consequently the implementation of sustainable policies (Pieri S. P. et al., 2015; Maleviti E. et al., 2012; 2011).

Limited coordination among the different governance levels

In many cases, mayors signed the "Covenant of Mayors" during their election period, but afterwards they proved to be unfamiliar with the existing financial instruments to develop and implement the SEAP and the energy efficiency actions (Christoforidis C. G. et al., 2013). Additionally, the majority of municipalities' employees, along with citizens, were not informed about their mayor's initiative to sign the Covenant (Christoforidis C. G. et al., 2013). Consequently, there was substantially low support for the preparation of SEAP from the side of employees, while the communities themselves had limited or even no information about the initiative and its possible benefits for their region (Christoforidis C. G. et al., 2013).

The aforementioned barriers are summarized in the Table 5.

4. Conclusions

Approximately twenty different barriers were identified regarding the end-users behavior mainly towards EE technologies and practices for the Hellenic building sector. These barriers are equally distributed in the three main categories behavioral, economic and institutional.

The information barrier was present in two of the three categories through the following barriers: Limited information for EE generally (behavioral), incomplete and/or limited information for emerging innovative technologies (behavioral), lack of detailed data (Institutional), limited expertise and resources (Institutional).

Table 5: Institutional barriers in the Hellenic building sector.

Title	Related policy or technology	Type of subsectors & consumers
Lack of targeted legislation	NZEBs, modern EE technologies and practices	Residential and Tertiary
Tenure status	Refurbishment	Residential and Tertiary
Complex administrative procedures	Refurbishment, SEAPs	Residential and Tertiary: mainly public buildings
Ineffective urban and land planning/special building cases	Bioclimatic design, refurbishment	Residential and Tertiary
Limited expertise and resources	Refurbishment, bioclimatic design, SEAPs	Residential and Tertiary
Lack of detailed data	Refurbishment, SEAPs	Residential and Tertiary: households, public buildings, hotels
Limited coordination among the different governance levels	SEAPs	Residential and Tertiary

Additionally, during the literature review it was concluded that the information and the data about end-user's attitude to EE policy instruments, technologies and practices is limited. Consequently, the design of new adequate EE policy instruments needs to take into serious consideration the information barrier.

Although there are on-going socio-economic research efforts (studies, initiatives, programmes, dissemination actions) to overcome all these barriers (e.g. "Energy Efficiency at household buildings"), further research efforts are required for achieving the respective EU target for EE.

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Mapping of the main behavioral, educational, economical and institutional energy efficiency barriers in the Hellenic transport sector

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National policy & policy instruments

7

National policy	Policy Instrument (type)
GHG reduction actions in transport and promotion of energy efficiency	Incentives to replace old technology cars (Economic policy instrument)
	Green Public Procurements for transport (Voluntary approaches)
	Cycling and pedestrianism in the city (Planning and dissemination-awareness policy instrument)
	Improvement of infrastructure for electric vehicles (Planning policy instrument)
Promotion of EE	Eco-driving (Dissemination – Awareness – educational policy instrument)

8

Transport	Technologies
Road / Passenger	Vehicles: Gasoline, Diesel, Natural gas, hybrid vehicles, CNG, LPG, e-vehicles Replacing EURO 2-3 with EURO 4-5 engines
Road / Freight	Vehicles: Diesel, Natural gas Replacing light trucks of EURO 2 to EURO 5 engines
Rail	Electric and Diesel locomotives Updated standards coaches
Rail/ Freight	High comfort and speed wagons
Aviation	Fuel efficient A320/321 aircrafts Fuel efficient A319 aircrafts Reduced flaps Take off Reduced Acceleration altitude Idle versa on landing Sing engine shutdown

9

Barriers

Barriers
Factors influencing end-use

10

1. Gender
2. Age
3. Education level & Education level of the head of the household
4. Occupation
5. Environmental behavior

Barriers
List of barriers

11

Types of barriers	Barrier	Scale
Social Cultural Educational	Cruising traffic	Local
	Low penetration of ICT from elderly people	Local/National
	Disappointment for new transport systems	Local/national
	Lack of 'green transport behaviour	Local/National
	Old habits	Local/National
	Wrong perception of people towards their capacities on eco-driving	Local/National
	Lack of certified instructors and examiners for eco-driving	Local/National
	Low public awareness towards eco-driving	Local/National
	Negative public perception towards electric vehicles	National
	Low environmental sensitivity	National
	Limited knowledge on public transport	National
	Citizens' preference of private cars due to convenience and affordable running costs	National
	Perception of status symbol and good lifestyle	National

Barriers
List of barriers

12

Types of barriers	Barrier	Scale
Economic	Conflict of financial interest among different target groups	Local
	Financial crisis	National
	Non-renewal of fleet and infrastructure	National
	Unattractiveness of sector for investments	National
	Energy efficient solutions more expensive than conventional ones	National

13

Barriers
List of barriers

Types of barriers	Barrier	Scale
Institutional	Ineffective urban transportation planning	Local/National
	Non-integrated policies	National
	Low prioritization of EE	National
	Overlap of responsibilities	National
	Lack of support schemes	National
	Non-integrated of energy efficient modal shifts in urban planning	Local

14

Barriers
Assessment criteria of barriers

a) Number of different policy instruments linked with **same type of barrier**
b) Number of different resources identified in **same barrier**
c) Number of sub-sectors linked with **same barrier**
d) Easiness of barrier **confrontation**
e) Duration of barrier **appearance**

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Barriers
Assessed Transport barriers

Impact of Barriers	Barriers
Big	Cruising traffic
	Wrong perception of people towards their capacities on eco-driving
	Energy efficient solutions more expensive than conventional ones.
	Old habits
	Non-renewal of fleet and infrastructure
	Lack of certified instructors and examiners for eco-driving
	Ineffective urban transportation planning
	Low public awareness towards eco-driving

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Barriers
Assessed Transport barriers

Impact of Barriers	Barriers
Medium	Financial crisis
	Limited knowledge on public transport
	Citizens' preference of private cars due to convenience and affordable running costs
	Perception that owning and driving a private car shows the status symbol and good lifestyle
	Unattractiveness of sector for investments
	Lack of support schemes
	Non-integrated policies
	Non-integrated energy efficient modal shifts in urban planning

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Barriers
Assessed Transport barriers

Impact of Barriers	Barriers
Small	Low environmental sensitivity
	Low penetration of ICT from elderly people
	Disappointment for new transport systems
	Lack of 'green transport behaviour
	Conflict of financial interest among different target groups
	Negative public perception towards electric vehicles
	Low prioritization of EE
	Overlap of responsibilities

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Key findings

Eco-driving < old *habits (inefficiently driving)*

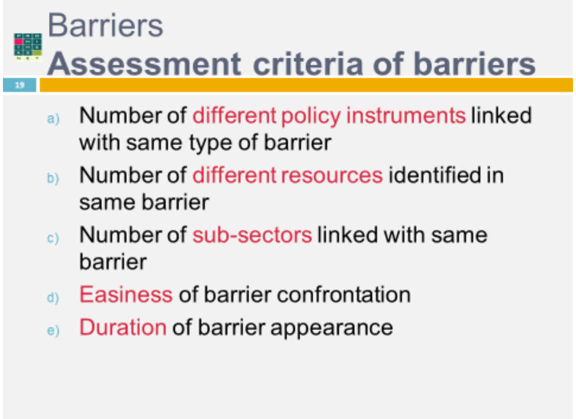
Perception of owning and driving a vehicle

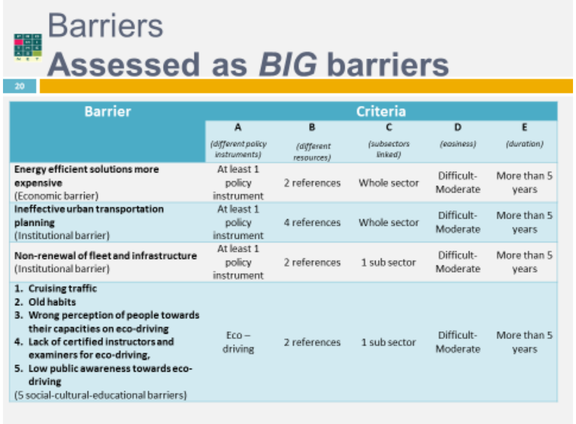
Public transport < *Convenience* and *Status* symbol of private cars

About e-vehicles market penetration…

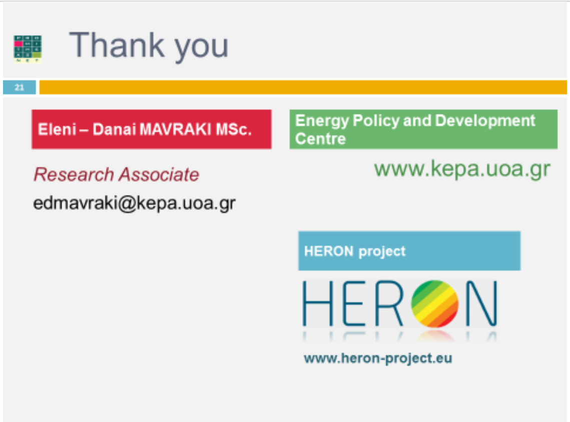
E-vehicles < negative public perception

Not robust yet technology – *lack of support* scheme





Barrier	Criteria				
	A *(different policy instruments)*	B *(different resources)*	C *(subsectors linked)*	D *(easiness)*	E *(duration)*
Energy efficient solutions more expensive (Economic barrier)	At least 1 policy instrument	2 references	Whole sector	Difficult-Moderate	More than 5 years
Ineffective urban transportation planning (Institutional barrier)	At least 1 policy instrument	4 references	Whole sector	Difficult-Moderate	More than 5 years
Non-renewal of fleet and infrastructure (Institutional barrier)	At least 1 policy instrument	2 references	1 sub sector	Difficult-Moderate	More than 5 years
1. Cruising traffic 2. Old habits 3. Wrong perception of people towards their capacities on eco-driving 4. Lack of certified instructors and examiners for eco-driving, 5. Low public awareness towards eco-driving (5 social-cultural-educational barriers)	Eco – driving	2 references	1 sub sector	Difficult-Moderate	More than 5 years



Renewable Energy Sources

Investigation of the Greek Wind Energy Market - Time-evolution: 1987-2014

by

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Abstract

Greece is considered to be one of the European countries with great wind potential. In this regard, significant efforts have been made to boost the investment and development of wind generation plants. As a result of the foregoing, the current installed capacity in wind power technology in Greece is 1.980 MW while the National target for 2020 is 7.500 MW. The comparison of those two sizes clearly shows the growth potential and prospects of wind energy investment in Greece. Such a development will result in increase of employment and income at a critical period for the Greek economy, while also contributing to achieving the 2020 targets and addressing climate change and environmental protection. The projected changes in the growth of the wind energy generation in Greece in the coming years will be affected by the objectives set by the European Union related to a possible turn to the green energy and climate change policy.

This paper presents the time evolution of the Greek wind energy market (1987-2014) through descriptive statistics and graphical presentations (from Hellenic Association of Wind Energy – HWEA, European Wind Energy Association – EWEA, Operator of Electricity Market – LAGIE SA, Hellenic Electricity Distribution Network Operator - HEDNO SA) of the installed capacity and the share of the wind energy in total electric consumption. Moreover it analyses the contribution in the environment, economy and society. Furthermore, attempts to examine the feasibility of the National target of 2020 and which are the main barriers. Finally, the research team tries to estimate the development of the wind energy market in Greece until 2020.

Keywords: wind energy, Greece, installed capacity, time evolution of the market, environment, economy, society.

1. Introduction

The wind energy industry is a proven recession busting industry and investment in the wind power sector should be seen as a way to restore Europe’s economy to health. Putting in place stable legislative frameworks which encourage the building, installing and operating of wind turbines has resulted in economic growth since the financial and economic crisis, and will continue to lead to economic growth [1].

The wind energy is not only a solution to climate change and a way to improve energy security, but also a way to boost economic development and competitiveness. As such, investment in the wind industry should be seen as a strategy to deliver economic growth and stable legislative frameworks to promote the development of the wind industry should be maintained and enhanced, even in times of austerity.

During the last 15 years, in the European Union the annual installations of wind power have increased from 3.2 GW in 2000, to 11.8 GW (Fig. 1) in 2014 at a compound annual growth rate of 9.8%. So, a total of 128.8 GW is now installed, an increase in installed cumulative capacity of 9.7% compared to the previous year, producing in a normal wind year, 284 TWh of electricity, enough to cover 10,2% of the EU's electricity consumption [2].

The European power sector continues its move away from fuel oil, coal and gas with each technology continuing to decommission more than it installs. Overall, during 2014, 26.9 GW of new power generating capacity was installed in the EU, 9.4 GW less than in 2013. Wind power was the energy technology with the highest installation rate in 2014: 11.8 GW, accounting for 43.7% of all new installations. Solar PV came second with 8 GW (29.7% of 2014 installations) and coal third with 3.3 GW (12.3%). No other technologies compare to wind and solar PV in terms of new installations (Fig.2).

In Greece, after almost of three decades the cumulative installed capacity in the end of 2014 was 1980MW (1,5% of the EU capacity), covering the 6,9% of the total national electricity consumption (3.7TWh) at a weighted average price of circa €91 per MWh. [3].

2. The status of the Greek wind energy market

According to the existing data (end of 2014) in Greece, there exist approximately 1980MW of installed wind capacity. In the figure 3, it is presented the cumulative installed wind capacity per year from 1987 to 2014. The average annual wind capacity since 1987 was 71 MW. In the figure 4 it is presented the annual installed capacity of period 1987-2014.

More precisely, this period will be separated in four different phases based on the capacity performance which in direct relationship with the policy and the regulatory framework.

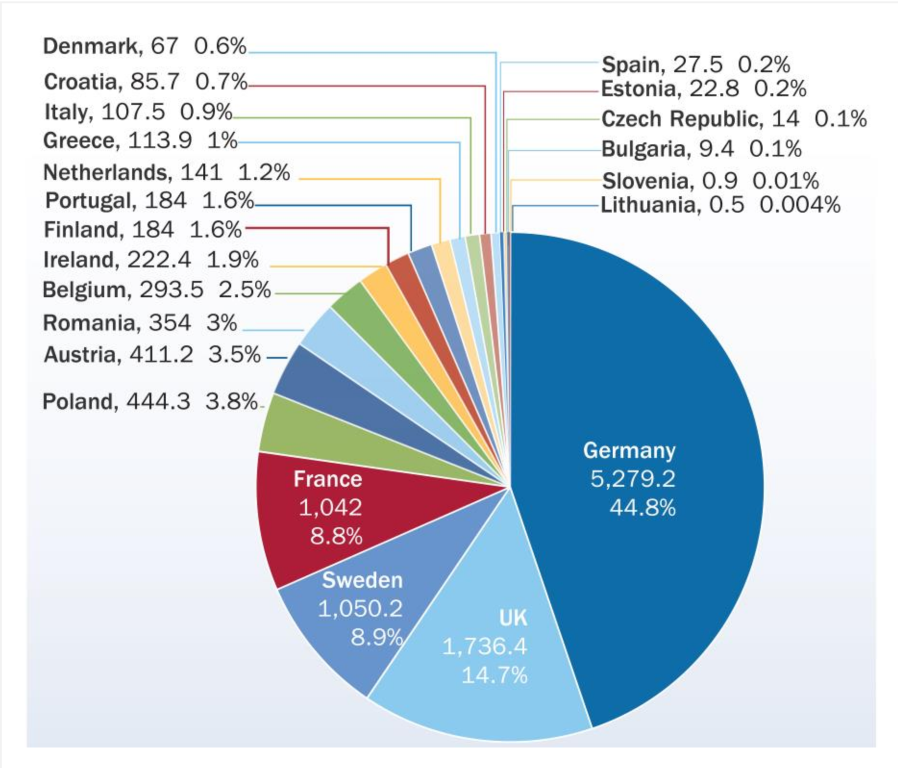

Figure 1: EU Member state market shares for new wind energy capacity installed during 2014 (MW).

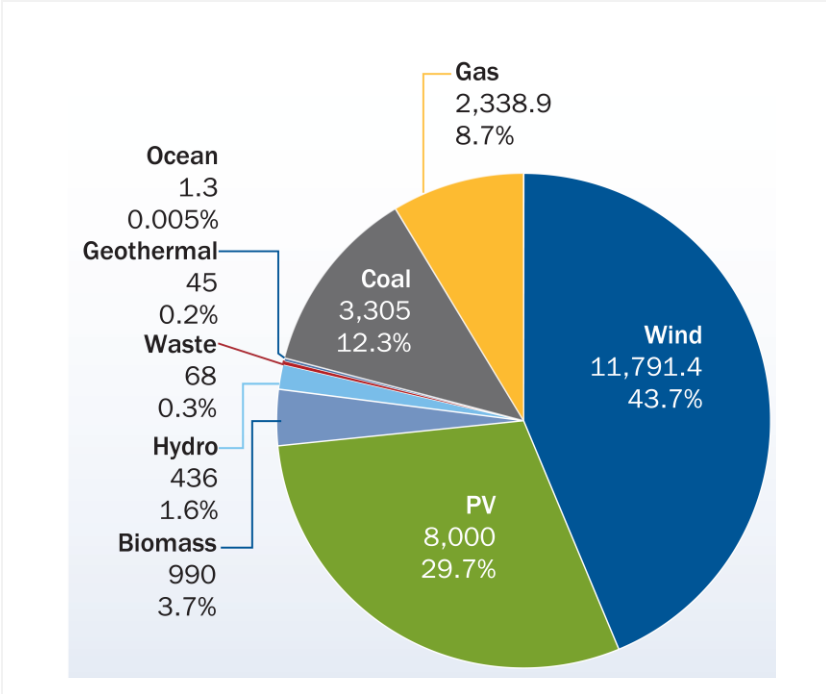

Figure 2: Share of new capacity installations in EU (MW).

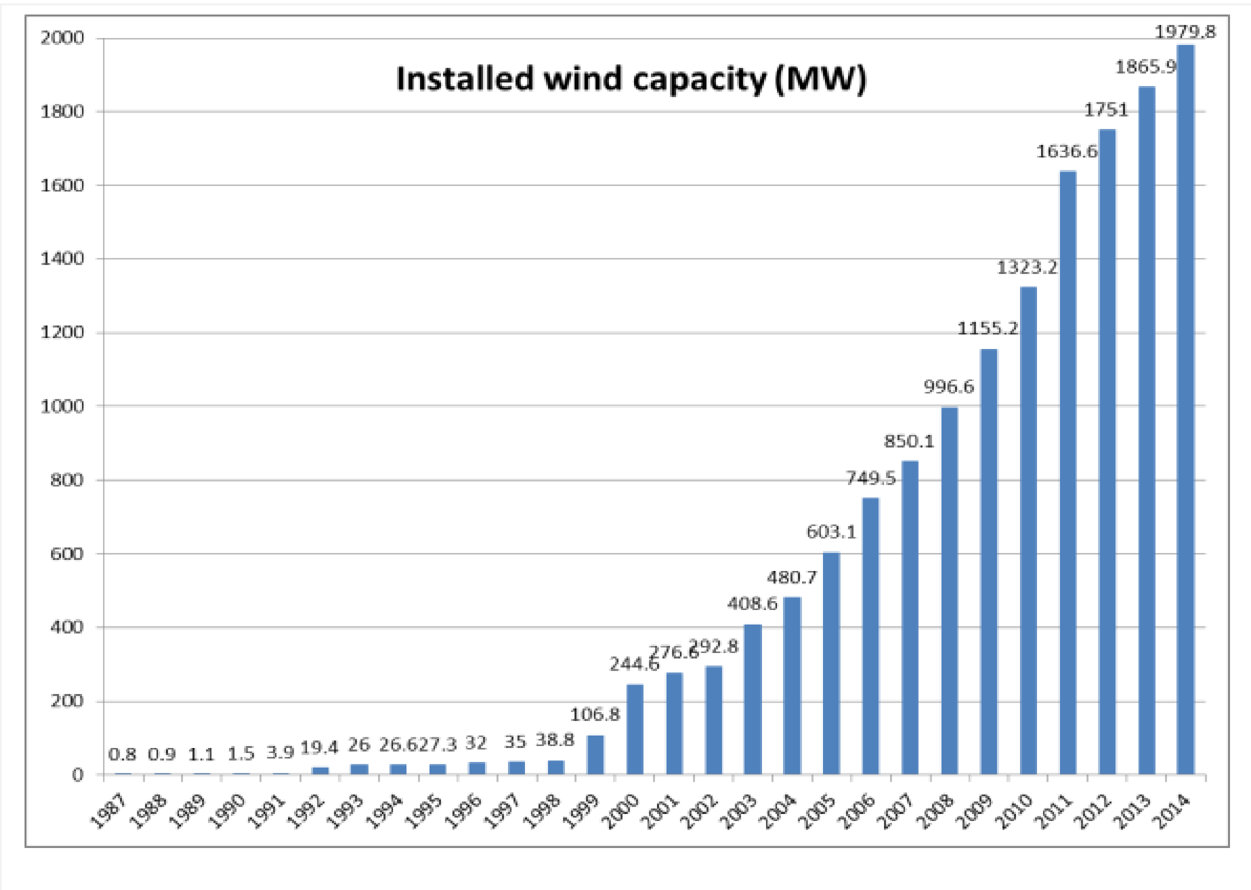

Figure 3: Cumulative installed wind capacity (MW) in Greece, 1987-2014.

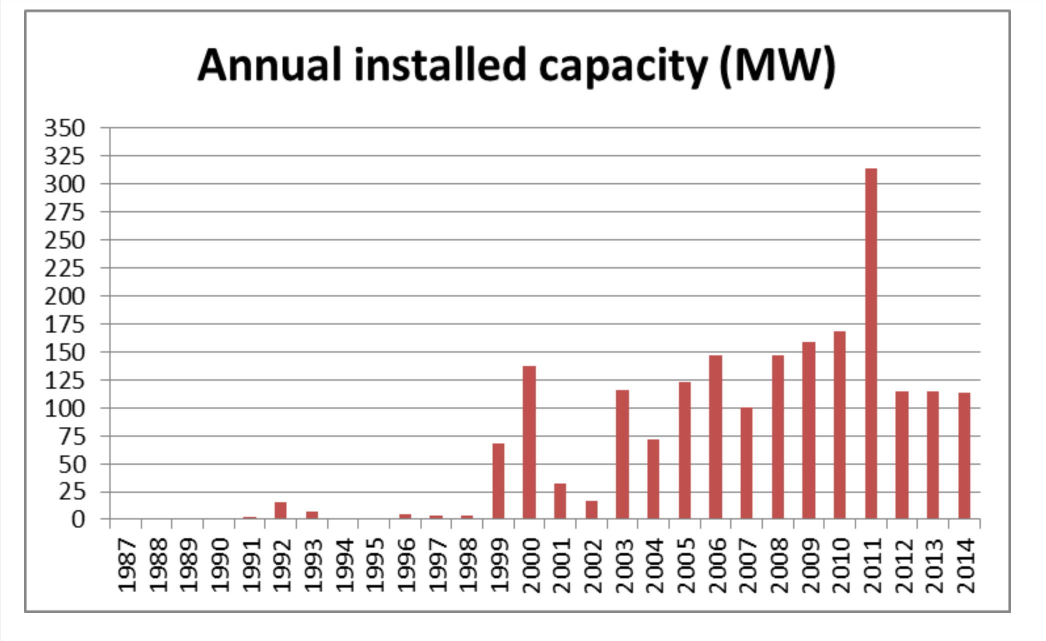

Figure 4: Annual installed wind capacity (MW) in Greece, 1987-2014.

2.1. Electricity sector maturation and introduction of feed in tariffs – authorisation of Independent Power Producers (1987-1998)

In this period the capacity increased to approximately 39MW and the wind industry is in an immaturity phase. In 1982, the PPC established the Alternative Energy Sources Department (PPC/DEME). The first commercial wind farm in Europe was built in Greece in 1983 on the island of Kythnos (five windturbines of 15 kW each).

In 1985, Law 1559/85 was instrumental in setting up the initial framework for electricity generation from renewable energy sources. In addition to the PPC, municipalities and other public-owned companies were permitted to set up renewable energy projects. Under this legal framework, the Greek Telecommunication Organisation established seven wind turbines, mostly in the islands of the Aegean Sea. However, the scheme met with limited success.

The special status granted to the PPC for electricity generation was limited for the first time under the provisions of the Law 2244/1994, which allowed independent power producers (IPPs) to produce electricity from renewable sources. The government also introduced a new feed-in tariff similar to the feed-in tariff laws in Germany during the same period. This Law also imposed an obligation on the IPPs to sell their electricity to the PPC on the basis of regulated power purchase agreements, and parallel, the Law imposed an obligation on the PPC to buy the electricity produced. This Law allowed the first privately owned windfarms. The first privately owned wind farms were developed between 1997 and 1998.

2.2. Electricity sector reform (1999-2005)

In this period the capacity increased to approximately 603MW and the wind industry makes the first steps to maturity. The average annual wind capacity of this period was 81 MW, but there are years like 2000, 2003 and 2005 with the new capacity exceeds 116MW (2000: 137.8 MW). The liberalisation of Greece's electricity sector started with the enactment of Laws of 2773/1999 and 3175/2003. Between 2001 and 2004 the completion of wind energy projects was delayed, largely due to the reforming and restructuring of the electricity sector.

2.3. Promotion of wind energy – legislation reform (2006-2011)

In this period the capacity increased to approximately 1637MW and the wind industry in Greece has passed a golden age of six years. These years were the best period for the wind energy development due to positive legislative changes, new feed in tariffs, national target for the share of renewables at 20,1% of net domestic power consumption by 2010 (Law 3468/2006). Also, the Special Spatial Framework for Renewables has been providing guidelines and criteria for renewable energy plants.

According to Law 3851/2010, the Greek National Renewable Energy Action Plan raised its commitments to produce 20% of the final energy consumption and 40% electricity generation from renewable sources by 2020, so the installed wind energy capacity would reach 7.5 GW by 2020. The establish of a new Ministry of Environment, Energy and Climate change in 2009, through new legislation accelerate the licensing procedures (Law 3851/2010 and Law 4014/2011 – new environmental law).

The average annual wind capacity of this period was 172 MW, with the best ever year of annual new wind capacity of 2011, which new 313MW have been installed as a result of maturity of many projects in the previous 5-6 years.

More information will be obtained from the IRENA-GWEC 30 Years of Policies for Wind Energy: Lessons from 12 Wind Energy Markets [4].

2.4. The wind energy market in financial crisis period (2012-today)

In this period the capacity increased to approximately 1980MW and the wind industry returns in stable lower annual rates of 114MW (37% of 2011).

This reduction was a result of financial crisis in Greece, the activity of investors in photovoltaic projects (tremendous expansion of PV capacity to 2.6GW between 2010 and 2013) and the reduction in feed in tariffs of new and existing wind energy projects (light haircut on FiTs, 7-year extension of their PPA, a 10% refund to Market Operator (LAGIE), revised feed-in-tariffs for new projects - Law 4254/2014 – called "New deal"). In addition the delays in payments of the producers, from the LAGIE and the political uncertainty in combination with the scenarios of return in local currency have landing the interest for the implementation of new windfarms. A special period has started on July of 2015 with the activation of capital controls and the banks closure of three weeks. Many problems have been presented in the construction of windfarms and a lot of investors have frozen their activities, waiting the signature of third Memorandum of the State and the international lenders (the tripartite committee led by the European Commission (Eurogroup) with the European Central Bank and the International Monetary Fund) and the recapitalization of the local banks. Summarizing, the status of wind energy in Greece in the start of September 2015 is absolutely frozen and there is investment uncertainty about the future.

3. The key market players

In the end of 2014, the Greek wind power sector had five main market players, with operating wind farms exceeding 100MW and a considerable pipeline of projects. The first tier includes the Athens Exchange listed renewables subsidiaries of two major construction groups; Terna Energy of GEK Terna Group (360,4MW) and Eltech Anemos of Ellactor Group (162,9MW- third place). In the second to fourth positions are renewable subsidiaries of three major European utilities; EDF EN Hellas (322,8MW); Iberdrola Renovables (250.7MW); and Enel Green Power (200.5MW). Together they account for almost 1.3GW of a total of 2.0 GW installed capacity (66%).

The second tier includes domestic players like PPC Renewables of Public Power Corporation (PPC) – 82,5 MW; RF Energy-60,4MW; Eunice – 59,8MW; Protergia of Mytilineos Group (35,6MW), and foreign investors like Acciona (43,6MW) Reninvest (38,9MW); Enercon – 29,9MW; Jasper Energy – 22,1MW; EREN Group 21,9MW. Moreover, local constructive and shipping companies (Intrakat, Iktinos, Themeli, Envitec, Libra), Greek investors (Enteka, Attica Ventures, WRE, Aerotechniki etc.) are active in wind energy market having in operation windfarms of approximately cumulative capacity of 220 MW [5].

4. Contribution in the environment, economy and society

4.1 Environment

Wind energy is one of the cleanest, most environmentally friendly energy sources. It has a long-term positive impact on the environment as: a. It emits no greenhouse gases, and therefore reduces the threat posed by climate change, the single largest threat to biodiversity; b. It emits no air pollutants, which cause acid rain; c. It emits no micro-particles (PM), which cause cancer and respiratory diseases; d. It uses almost no water, a resource that will be even scarcer in the future and e. windturbines are almost fully recyclable. CO_2 emissions and energy used to build turbines are the lowest among all power plants, after hydropower, as confirmed by the IPCC analysis on life cycle emissions of energy from its Special Report on Renewable Energies [6].

At the local level, wind energy can also have positive effects on biodiversity, and offers an opportunity to practice ecological restoration (creation of wildlife shelters).

Potential site-specific impacts on birds or bats can be avoided and minimised by careful planning and siting, or else mitigated or compensated. In fact, wind farm developers are required to undertake Environmental Impact Assessments to gauge all potential significant environmental effects and meet all requirements of EU legislation before construction can start. Birdlife International confirms their support for high wind and renewable use and 2030 targets in their report - Meeting Europe's Renewable Energy Targets in Harmony with Nature [7].

Wind energy can also be developed in protected Natura 2000 sites as confirmed by the European Commission in its Guidelines on Wind energy and Natura 2000 [8]. Due to official data from LAGIE [9] and HEDNO [10] the estimated annual net capacity factor of windfarms in Greece is estimated to 25%. So, in table 1 it is appeared the succeeded avoided pollutants for the installed wind capacity in the end of 2014 [11].

The direct economic benefit of the National Economy from the reduction of CO_2 is 38,6 million Euros per year (estimated cost: 10 Euro per tn).

4.2 Economy and society

The use of wind energy brings many economic benefits. Specifically:

- It reduces the exposure of our economies to fuel price volatility.
- It avoids the costs which society now bears in the form of pollution and fuel imports.

Approximately 75% of the total cost of a wind farm is related to upfront costs such as the cost of the turbine, foundation, electrical equipment, and grid-connection. Fluctuating fuel costs have no impact on wind power generation costs. A wind turbine is capital-intensive compared to conventional fossil fuel fired technologies such as a natural gas power plant, where as much as 40-70% of costs are related to fuel and operations and maintenance. The construction of a wind farm affects positively to the economy of the wider region where it is installed. In the case of mountain areas on the mainland, the presence of a wind farm on the one hand, does not affect existing land uses (mostly livestock) but also it is an important and guaranteed source of funds to local authorities, in whose limits are installed [12].

Additionally, the installation of a wind farm creates new permanent jobs locally. The staff that is responsible for monitoring the proper functioning of the system (wind turbines, substation, SCADA system) for immediate disconnection or reconnection of the windfarm to the grid, in emergency cases, hence for the maintenance. According to the study of the European Wind Energy Association (EWEA) «Wind Energy: The Facts", in February 2004, for the installation of a MW of wind energy requires 12 to 18 man-months of employment and for the operation and maintenance it is required 0,26 to 0,32 people.

Table 1: The avoided pollutants from the operation of windfarms (12/2014).

3.855.167	tn/year CO_2
70.300	tn/year SO_2
816	tn/year CO
5.443	tn/year NOx
227	tn/year HC
3.628	tn/year particles

The local staff need not be skilled, but simply to have a basic technical understanding (e.g. have dealt with garage). The staff shall be properly trained by the manufacturer, in the operation of -the wind turbines and safety rules. The operation, in the early years, is under the supervision of the manufacturer, but then this is not essential. In addition to these permanent jobs, it is created much more temporary jobs, due to the fact that workforce from a wider area is used during the construction of wind farm for the work execution.For the execution of infrastructure works usually it is used local contractors and construction companies. It is expected, therefore, that the installation of a wind farm is a growth pole of the wider area.

In parallel, it is created an increased use of local hotel infrastructure, catering facilities and other branches from the seasonal and permanent staff will be employed in the construction and operation phase of a wind farm. A report by EWEA [13] showed that for every megawatt of wind capacity 15,1 man-years for the construction of the equipment and development (1,2 man years for installation) and 0,4 man years per year of operation for maintenance and supervision of wind farms.

Data for Greece from operating wind farms have shown that during the construction phase it is created 1-1,5 man-years/MW (30-40% of this employment concerns local workforce), while during the twenty-year operation phase 6,5-8,0 man-years/MW (from 0,32 to 0,4 employees/MW, with 50-100% local workforce). In case that will be local production of wind turbines or installation of offshore wind farms, the estimated jobs will be more [14]. Due to EWEA report [13] in Greece (2008) jobs in wind energy are estimated to 1800.

Finally, it is extremely important to note that the direct economic benefit to the local municipal authorities, for electricity production from RES. According to the provisions of the legislation (Law 3469/2006), the operator of wind farms will pay special fee which corresponds to 3% of the sale price excluding VAT of the total energy produced to the System Operator.

The amounts corresponding to the above special duty attributed by 80% in the Municipality, where the administrative boundaries is installed the RES plant and 20% in the Municipalities, where the interconnection line passes from the wind farm to the System.

Analytically, the total amount of 3%, based on the installed capacity of 2014 (and net capacity factor of 25%) is 12,3 million Euro per year. The 1% goes to the domestic consumers of electricity where the windfarm has been installed, 1,7% (7,0 million Euro) goes to the windfarm's Municipality-ies and 0,3% (1,2 million Euro) to the Green Fund (Law 3851/2010).

5. National targets – Main barriers

5.1 National targets

In 2010 State endorsed its National Action Plan for Renewable Energy Sources for the time-frame of 2010 to 2020. The ambitious plan aim to reform the country's energy sector so that 20% of the primary energy use will be come from Renewable Energy Sources by 2020 (40% electricity, 20% heat and 10% transport).

In the electricity sector, major factor will be the wind energy (7.500 MW target values for 2020, and intermediate target of 2014 was 4.000MW). Instead of that, the cumulative wind energy capacity was approximately 2000 MW in the end of 2014. So, there was a deflection of 50% in 2014 target.

Based on the average of installation of wind capacity from 1987 to 2014 (71MW per year), it is needed 78 years to reach 2020 capacity target instead of 6 years (2098 instead of 2020). The annual new wind capacity will be 920MW from 2015 to 2020 instead of 114 MW of 2014. As it is clear a great excess in the annual installed wind capacity (more than 13 times) is necessary.

5.2 Main barriers

5.2.1 Financing and cash management problem of the electricity market

The unpaid consumer bills of 2 billion euros, although their height seems to have stabilized in the last year, the cash increase electricity market problem. For smoothing of payments to RES producers also needed to formulate a specific plan of future payments which will have an annual horizon and extended on a monthly basis in order to be able to program their obligations by producers.

Moreover, the substantial intervention in the bank loans to the banks, to take some of the burden incurred by the producers of RES the so-called “New Deal”.

5.2.2 Sustainability of Special Account RES (SARES)

The Law 4254/2014, the so-called “New Deal”, has managed to consolidate its accounting image of the SARES. Unfortunately the arrangements made great injustices involving at least two levels:

a) The weight of the consolidation of the SARES is not distributed equally and proportionally to all players that contributed to the creation of.

b) The weight distribution between the various categories of RES projects involves huge injustices.

5.2.3 New legislation on the mechanism of support of new investments RES

For the horizon from 2016 onwards should be noted that the European Commission (DG Competition) has put in place new guidelines of the European Commission on state aid in the energy and the environment. The central idea of these directives is that for the period 2017-2020 (and to some extent also for 2016) new RES investments should be strengthened through a mechanism Feed - in premium (FIP) and the amount of the premium (premium) will be determined through competitions [15].

A new support system based on the market should be introduced for new wind farms before the beginning of 2017. This new system is currently under development by the Ministry of Energy in cooperation with the German GIZ consultant. Expected to be completed by the end of 2015 and introduced in January 2016 [16].

5.2.4 Infrastructures

The development of infrastructure (grids, storage, etc.) is an important field of attracting European funds and funds under the European Energy Union, to be activated with priority for the benefit of the national economy and RES. The European Energy Union is a vision of unity through economies of scale, resource optimization and innovation which can give to Europe substantial energy independence and economic growth.

This vision requires infrastructure, the implementation of which would itself be a driving force for the economy. This infrastructure will be grid connections (islands of Aegean Sea, Crete, international connections) and storage systems (pumped storage systems, electrification etc.).

6. The way to 2020

Due to the current political and economic climate in Greece it is quite difficult to make reliable predictions about the way of RES plants until 2020. It is obvious that investors call for strong policy commitment, the emergence of a stable economic environment and a favorable support scheme for many years. These are some basic factors to maintain investor confidence in local wind power sector which continues to deliver considerable returns on investment despite the recent “New Deal” Law.

In April 2014 the European Commission adopted new Guidelines on State aid for environmental protection and energy for 2014-2020, which came into force on 1 July 2014. These guidelines and are applicable until the end of 2020. The new Guidelines are intended to assist the EU Member States to design State aid schemes that help them reach their climate change and energy sustainability targets without threatening to distort competition in, or otherwise fragment, the EU market.

The new Guidelines aim to better integrate renewables into the internal electricity market in a gradual way, introducing competition between different technologies. Feed-in tariffs will be progressively replaced by competitive bidding. During 2015-2016, Member States are expected to start implementing competitive bidding procedures for a small proportion of their new capacity from renewables. From 2017, operating aid to new renewable energy installations should, in principle, be granted through a competitive bidding process. The new Guidelines will have no effect on State aid paid to the owners of existing installations.

These owners will continue to receive State aid based on existing approved State aid schemes in order to maintain investors' legitimate expectations on the returns on their existing investments.

However, it is doubtful whether the current support scheme for wind power in Greece will remain applicable for new windfarms after 2016 given its feed-in tariff structure which is based on regulated prices. A market-based support scheme will have to being introduced for new windfarms from 2017. This new support scheme for renewables is currently under development by the competent Ministry of Productive Reconstruction, Environment & Energy in cooperation with German consultant GIZ. It is expected to be finalized by the end of July 2015 and rolled out by January 2016. Every month LAGIE [9] gives through informative reports its prediction for the predicted new wind capacity installations for the period of two next years month by month. In the figure 5 it is presented the predictions of LAGIE for 2015 until June of 2017.

The estimations of LAGIE (07/2015) is quite optimistic giving a new average annual wind capacity of 256 MW instead of 114 MW of the period 2012-2014. The prediction for the June of 2017 is 2491MW.

EWEA through a report from July 2014 [17] gives three scenarios for wind power installations (low, central and high) for Greece in 2020, low: 3000MW, central: 4500MW, high: 5000MW. The more optimistic scenario for Greece reaches the 2/3 of the national target for 2020.

The research team gives its predictions about the annual new installed capacity until 2020, working in wind energy market and having in mind the consequences of the banks closing for three weeks and capital controls in summer of 2015. The estimations are even low than the low scenario of EWEA, giving a prediction of 2500MW in 2020, only 1/3 of the national target. In the figure 6 it is presented the estimations of the research team.

7. Conclusions - Proposals

The way of installation wind capacity in Greece is clearly lower than the other European countries and the national targets. Nowadays, the political and economic instability, the danger of the Grexit and the capital controls are additional factors of the existing legislative, licensing and infrastructure barriers for the further development of wind energy market.

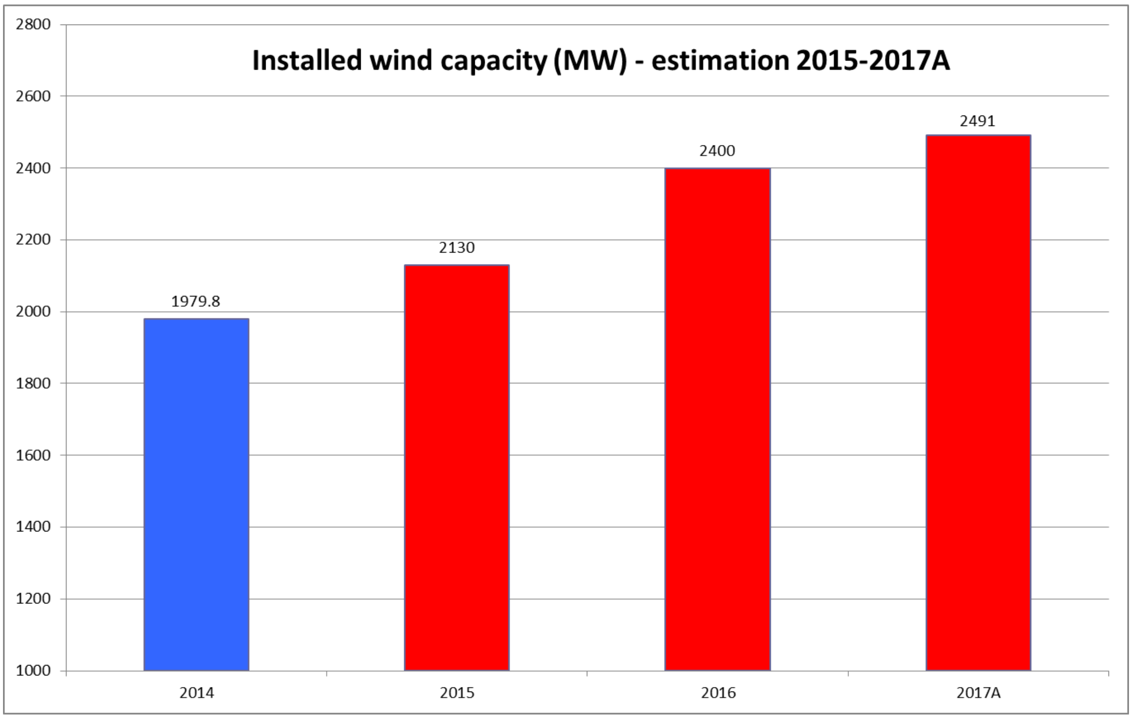

Figure 5: Annual installed wind capacity (MW) in Greece, 2014 - 6/2017.

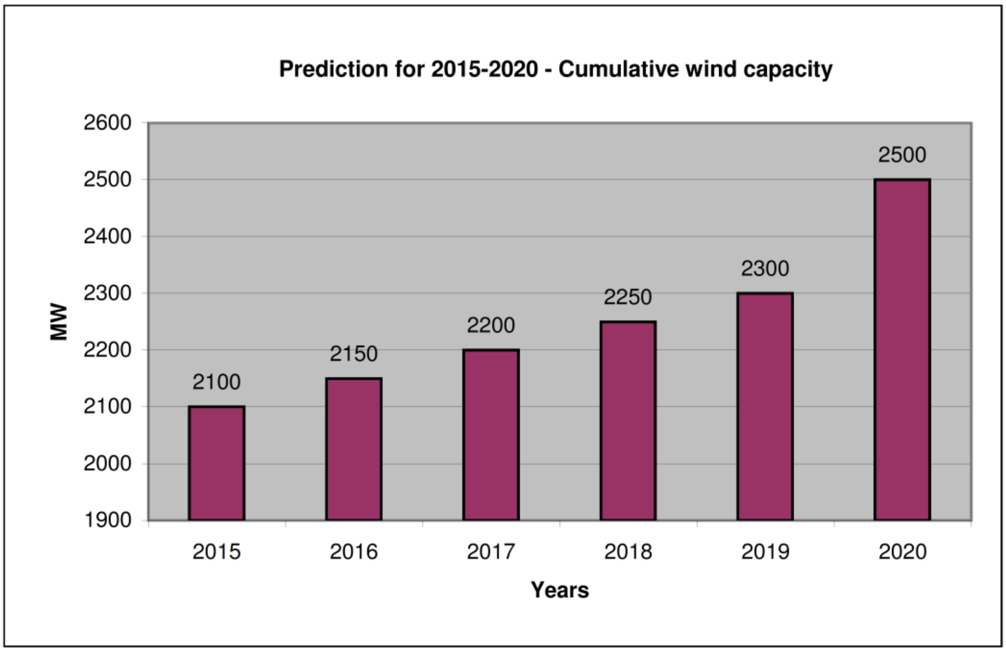

Figure 6: Predictions for annual installed wind capacity (MW) in Greece, 2015 - 2020.

It is needed to be updated the process for the completion of the legislation governing the market of electricity and the presentation of an updated time schedule for the way to the Target Model (New guidelines on State Aid for 2014-2020). In this framework it should be addressed comprehensively all the issues concerning the operation of the market to ensure cheap and secure energy supply and the sustainability of market players and investments.

It is clear that political will is needed and economic stability with a long-term support scheme for RES.

Moreover, a National Program of Technological Development in Renewable Energy and particularly in wind energy. Aim of this program will be the maximization of the local added value. This program could have two axes:

a. For the Greek industry, to drive in the direction of "smart specialization" (smart specialization), ie to develop specialized products of local and regional demand, e.g. blade repair techniques, intelligent condition monitoring systems and maintenance of windturbines etc.

b. For the attraction of foreign industry, will be examined seriously a program which will have target to be installed more than 7.5GW wind capacity until 2020, so to export energy as country. This program will be based on the local particularities, the grid connection of islands, the floating windfarms, the large scale pumped-store hydro plants for energy balancing thereby triggering other complementary sectors of Greek industry.

Finally, State should compose a new energy planning for the next 30 years taking into consideration the energy market and the needs of society. This planning must not commit the country to the dark future of fossil fuels but to offer competitive clean energy choices, renewable sources (such as wind energy) and energy saving.

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Incentives, profitability and diffusion of PV grid connected systems in Spain, 2004-2013

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Abstract

Spain has been one of the main photovoltaic markets in the EU during the last decade. However, its evolution has been uneven, having experienced a boom and bust cycle in the diffusion of the technology and the profitability of the new installations. Although there are rich strands of literature on the policy changes on one hand, and case studies about the profitability of different types of installations on the other hand, the development lacks a long-term analysis about the interrelationship between profitability, diffusion, and the policies carried out to try to shape them. Therefore, we present a long-term profitability analysis (by calculating the Internal Rate of Return) for three types of installations (small, medium and large-scale), and we link it on one hand with its determinants (electricity prices/Feed-in Tariffs and system prices), and with the diffusion of the technology for each segment on the other hand. The results exhibit that the "diffusion bubble" (June 2007 – September 2008) was previous to the "profitability bubble" (January 2009 - December 2011), showing the complex relationship between them, the differences between segments and the intrinsic difficulty of designing support policies for the implementation of rapid-evolving new technologies.

1. Introduction

Climate Change (CC) has emerged as one of the most pressuring issues for world development in XXI Century. Nowadays, we have scientific evidence that this phenomenon is being caused by human activity. According to the International Panel for Climate Change,

> "Anthropogenic greenhouse gas emissions have increased since the pre-industrial era driven largely by economic and population growth. From 2000 to 2010 emissions were the highest in history. Historical emissions have driven atmospheric concentrations of carbon dioxide, methane and nitrous oxide to levels that are unprecedented in at least the last 800,000 years, leading to an uptake of energy by the climate system." (IPCC, 2014:44).

> "Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, and in global mean sea level rise; and it is extremely likely to have been the dominant cause of the observed warming since the mid- 20th century. In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans. Impacts are due to observed climate change, irrespective of its cause, indicating the sensitivity of natural and human systems to changing climate." (IPCC, 2014:47).

The fact that human activity is causing CC, and the evidence of disruptive consequences for natural and social systems, commit socioeconomic structure to perform a transformation towards a low carbon economy in order to mitigate the magnitude and therefore the effects of climate change.

Electricity and heat production are the main drivers of Greenhouse Gas (GHG) emissions, accounting for 25% of the total. Together with "other energy" they sum up 34.6% of the total GHG emissions. If we consider the opportunities of transportation sector towards electrification (MIT, 2010; ERTRAC, EPoSS and SM, 2012; McCollum et al., 2014), we find that electricity generation is the most promising sector towards decarbonization of economic activity with a potential reduction of 48% of the total emissions (IPCC, 2014).

Within electricity generation, Photovoltaic (PV) technology is outstanding not only for its physical potential, but also for its cost evolution. The figure 1 shows the historical evolution of the PV technology since 1976 and the forecast for the coming decades. According to the previsions of the International Energy Assotiation, PV prices will halve between 2025 and 2040 (IEA, 2014).

The potential of PV regarding decarbonisation and energy security is the main reason for which countries have been incentivizing the diffusion of the technology through different mechanisms, as Feed-In Tariffs (FiTs), subsidies, soft loans, tenders, etc (EPIA and GP, 2011; REN21, 2015). But the diffusion caused by those incentives was not always evenly distributed. That is the case of Spain, which was the world leader in terms of PV deployment accounting for 45% of the world's installed capacity (ASIF, 2009). In 2014, however, Spain didn´t reach 1% of the global installed capacity (REN21, 2015).

In order to reach a balanced deployment of PV, it is essential to know how the different incentives affect the profitability of the PV investments, and how profitability is linked to the diffusion of the technology. In this paper, we will assess the profitability of PV investments in Spain during the last decade for three different segments: Residential, Commercial-Industrial and Utility. Due to the changes in the categories of PV systems established by the regulation, it is not accurate to define exactly those segments as such, so we will refer to small (SC), medium (MC) and large scale (LC), taking into account that they mainly refer to those categories, but not only. We calculate the Internal Rate of Return (IRR) for the three types of installations taking into account the incentives in place in each year. There were investment subsidies up to 40% mainly in 2004 and 2005 and soft loans at 3% interest rate, but the main incentive were the preferential prices for the electricity generated stablished by the FiTs.

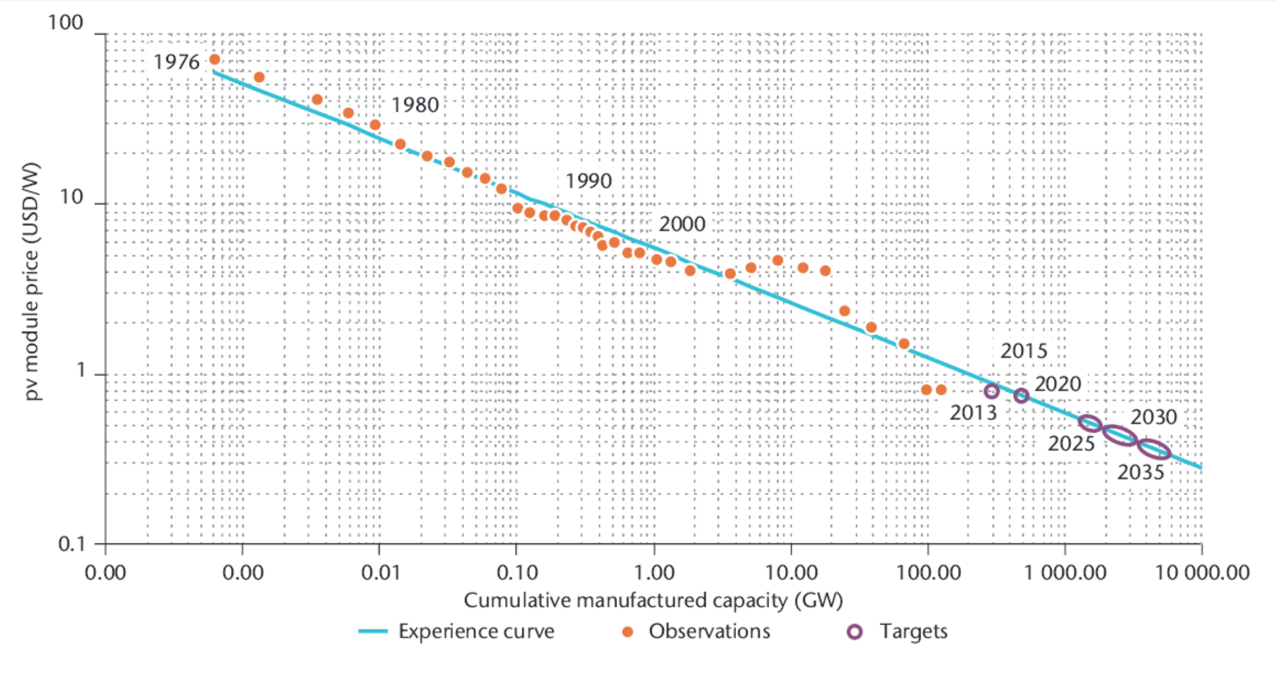

Figure 1: Experience curve of PV modules (*Source: IEA, 2014).*

In section 2 we review the methodology and the data used to calculate the profitability of the different types of installations. Section 3 presents the results of the Internal Rate of Return relating them to the diffusion of the PV technology and section 4 concludes.

2. Methodology and data

2.1. Methodology

There are many ways to evaluate the profitability of an investment. Nofuentes et al. (2002) review how different profitability indicators can be applied to Grid-connected photovoltaic systems (GCPVS). The most useful indicators are Net Present Value (NPV), Profitability Index (PI), Pay-Back Time (PBT), and Internal Rate of Return (IRR).

The NPV is simply the sum of all the cash flows of the investment lifetime (revenues less expenditures), discounted to the present. The investment is profitable when NPV>0. However, this indicator forces us to make an assumption about the discount rate, and it might not be suitable for comparison of investments with different initial costs and lifetimes, because it is an absolute value instead of a relative measure (as the IRR), and because the assumption about the discount rate implies an arbitrary discrimination based on the lifetime of the investment.

The profitability index (PI) is the ratio between the net present value and the Life Cycle Cost of the investment (LCC). It shows the same information than the NPV but relative to the cost of the investment.

PBT shows the time required to recover the money invested. It is a useful indicator but it dismisses the cash inflows received after that moment and it is not very useful for comparisons because it only provides information about the time to recover the investment, but not about the profitability of it. Finally, the IRR shows the discount rate at which the net present value equals to zero. It is the most useful indicator for several reasons: it does not force us to make any assumption about the discount rate; it provides a relative result easily comparable among different types of investment, and it is indeed the most popular indicator amongst investors.

The calculation of the IRR derives from the NPV equation (1). As we have already mentioned, it is sum of the present worth of the cash inflows during the lifetime of the investment (PW[CIF(N)]) less the Life Cycle

Cost of the investment from the user standpoint[123] (LCCusp)

$$NPV = PW[CIF(N)] - LCCusp \qquad (1)$$

The present worth of the cash inflows has two main components: the electricity price (Pu[€/kWh]), and the annual electricity yield of the system (Epv[kWh/kWpy]). Besides this two main elements we include the grid-access charge (RD 1544/2011) established in 2012 (γ[€/kWh]) and the 7% generation charge (RD 15/2012) established in 2013 (λ). The last element of eq. 2 depicts the effect of the annual escalation rate of energy prices (ε_{PU}[%]), the annual degradation rate of the system (dg[%]) and the discount rate (d[%]):

$$PW[CIF(N)] = (Pu - \gamma) * (1 - \lambda) * Epv * \frac{K_{PU} * (1 - K_{PU}^{N})}{1 - K_{PU}} \qquad (2)$$

Being N the lifetime of the investment (25 years), and K_{PU}:

$$K_{PU} = \frac{(1+\varepsilon_{PU}) * (1 - dg)}{1+d} \qquad (3)$$

On the other hand, the LCCusp comprises the present worth of the initial investment of the PV system (PW[PV_{IN}] [€/kWp]) and the present worth of the annual operation and maintenance (O&M) costs (PW[PV_{OM}] [€/kWpy]):

$$LCCusp = PW[PV_{IN}] + PW[PV_{OM}] \qquad (4)$$

The main parameters regarding the initial investment are the system cost itself (PV_{IN}[€/Wp]), the investment subsidy (PV_{IS}[€/Wp]) and the financial conditions: percentage financed (α), interest rate (i), and the maturity of the loan (Nl):

$$PW[PV_{IN}] = (1 - \alpha) * (PV_{IN} - PV_{IS}) + \alpha * (PV_{IN} - PV_{IS}) * i * \frac{(1+i)^{Nl}}{(1+i)^{Nl} - 1} * \frac{1 - q^{Nl}}{1 - q} \qquad (5)$$

q being:

$$q = \frac{1}{1+d} \qquad (6)$$

Finally, the present worth of the O&M costs is simply:

$$PW[PV_{OM}] = PV_{OM} * \frac{K_{PV} * (1 - K_{PV}^{N})}{1 - K_{PV}} \qquad (7)$$

ε_{OM} being the escalation rate of O&M costs and K_{PV}:

$$K_{PV} = \frac{(1+\varepsilon_{OM})}{1+d} \qquad (8)$$

In conclusion, we must calculate the discount rate (d) of *eq. 9* when NPV=0:

$$NPV = (Pu - \gamma) * (1 - \lambda) * Epv * \frac{K_{PU} * (1 - K_{PU}^{N})}{1 - K_{PU}}$$

$$-(1 - \alpha) * (PV_{IN} - PV_{IS}) + \alpha * (PV_{IN} - PV_{IS}) * i * \frac{(1+i)^{Nl}}{(1+i)^{Nl} - 1} * \frac{1 - q^{Nl}}{1 - q}$$

$$-PV_{OM} * \frac{K_{PV} * (1 - K_{PV}^{N})}{1 - K_{PV}} = 0 \qquad (9)$$

This methodology follows the developments and terminology of previous literature (Nofuentes et al., 2002; Talavera and Nofuentes, 2010; Talavera et al., 2014), and adds the effects of the recent generation and grid-access charges. But as important as the calculation itself, is the data embedded in it, which will be described in the following section.

We differentiate between three types of installations: Residential (R), Commercial-Industrial (C-I) utility (U). However, due to the many changes in the Spanish regulation, it is not possible to define stable categories for the whole period. Therefore, we assign residential parameters (interest rates and installation costs) to the R, commercial-industrial to the C-I and utility for the U. Likewise, we assign the higher FITs to SC, lowest to LC and medium to MC (between 2004-2006 when there was only two categories, the high FIT is assigned to SC, whereas the low FIT is assigned to MC and LC. In figure 2.1. we can see the different categories established by each Royal Decree (RD)

2.2. Data

According to the previous explanation, the data we need can be summarized in table 1, in addition to the grid access charge (RDL 14/2010 and RD 1544/2011: 0,5€/MWh), and

[123] The LCC can be considered either from the point of view of the system (excluding investment subsidies, soft loans or any other incentive), or from the point of view of the user including all available incentives (Nofuentes et al. 2002: 556). As we are interested in the investor's perspective we will analyze the LCC from the user standpoint.

the generation charge (RD 15/2012: 7% of electricity sales). Besides, we assume an annual degradation rate of the PV system to be 0.8% according to Dirk et al. (2012).

2.2.1. Electricity price

The electricity spot market in the Iberian Peninsula is managed by OMIE (*Operador del Mercado Ibérico de Energía*; *Operator of the Iberian Energy Market)*, which started its activity in the Spanish market in 1998, and since 2007 for the peninsula as a whole. The most representative price of the electricity market is the pool price, which represents the matching between supply and demand in the daily market. However, PV generators have enjoyed preferential prices until 2012 when the Renewables Moratorium came into force (RD 1/2012).

Financial incentives were in place in Spain since the RD 2818/1998, but it is not until 2004 that they began to have relevant effects on diffusion, thanks to the bureaucratic easing of the RD 436/2004 and the technological development of PV modules. From that date we can clearly differentiate three regulative phases (see figure X):

2004-Sept.2008: FiT: Feed-in Tariffs were the main financial incentive in this phase, accompanied some times with other incentives as investment subsidies and soft loans.

2004-Sept.2008: FiT: Feed-in Tariffs were the main financial incentive in this phase, accompanied some times with other incentives as investment subsidies and soft loans. We can differentiate two sub-periods within this phase: The first one under the RD 436/2004 established two types of installations: ≤100kW and 100KW-50MW, with almost double price for small-scale installations.

The second sub-period, characterized by the investment boom was brought about by RD 661/2007, which established three categories: ≤100kW, 100kW-10MW, and 10-50MW. Whereas the installations below 100kW and above 10MW maintained their previous levels, there was a substantial increase in the retribution of new medium-scale installations of between 100kW-10MW.

Oct.2008-Dec.2011: Quota + degression: Once the government realised of the high policy cost of the financial incentives due to the investment boom, a new regulation was announced (what led to an investment rush before it came into force) and passed, characterized by a new system of degression of the FiT rates always the new applications for installations surpass the 75% of the predetermined quota (RD 1578/2008). This RD also changed again the categories of the installations into type I.1. Rooftop ≤20kW; type I.2. Rooftop 20kW-2MW; and type II. Ground-mounted ≤10MW. At the same time, all tariffs were reduced and those for installations above 10MW were removed. A new RD (1565/2010) lowered again the tariffs in March 2010.

Jan.2012-up to now: Moratorium: The RD 1/2012 established a Renewables moratorium, since which PV electricity must be sold at market prices. Due to the claims against this policy the government passed a new RDL (9/2013) trying to guarantee a "reasonable profitability" (7,5%), whose practical application is not clear yet.

Previous literature has been assuming escalation rates for electricity prices in Spain within the range between 1,4 (PER, 2005) and 2,8% (Talavera et.al. 2014). We assume an average value of 2%, in accordance with Talavera et.al. (2010) and EPIA (2011).

2.2.2. PV yield

The data regarding the PV electricity yield of the systems is taken from the PVGIS project developed by the European Commission. It refers to the potential solar electricity [kWh/kWp] generated by a 1 kWp system per year with photovoltaic modules mounted at a horizontal inclination and assuming system performance ratio 0.75. The data represent the average of the period 1998-2011 (Šúri M., et al., 2007; Huld T. et al., 2014). Likewise, the efficiency of the system degrades at an annual rate of 0.8% (Dirk et al.,2012). The PV yield of the system, which is one of the main determinants of profitability, depends mainly on climate conditions (solar irradiation), technological development (efficiency, performance ratio and degradation rate) and mounting conditions (vertical, horizontal or optimal tilt).

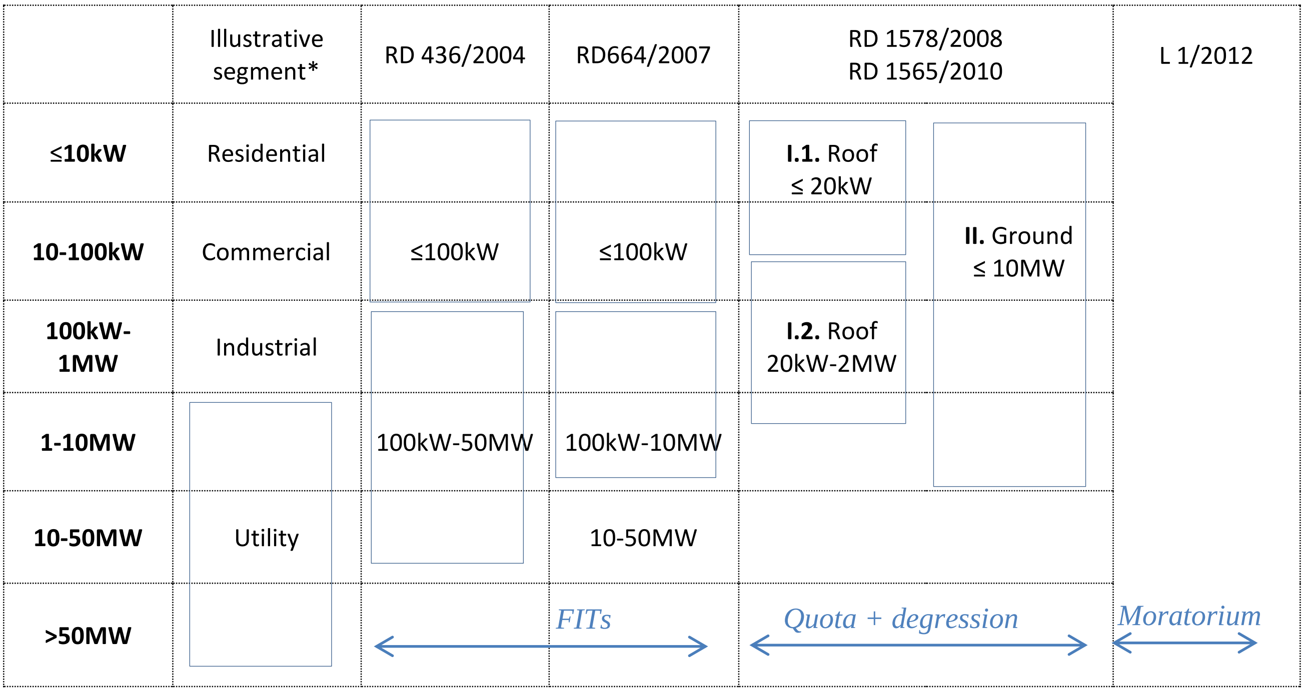

Figure 2: Categories of installations according to each Royal Decree (RD). *Source: own.*

Table 1: Parameters for the calculation of the profitability of GCPVS (e: estimation, a: assumption): *Source: own.*

	Abbreviation	Units	Description	Type	Source
LCC_{USP}	PV_{IN}	€/kWp	Initial investment (System cost)	e	IEA
	PV_{IS}	€/kWp	Investment subsidy	e	Minetur, IDAE
	i N	% years	Annual interest rate Loan duration	e a	ECB, IDAE UNEF
	PV_{OM} ε_{PVOM}	€ year %	Operation & Maintenance costs Escalation rate of O&M costs	a a	Literature Literature
PW CIF(N)	Pu ε_{pu}	€/kWh %	PV electricity price Escalation rate of PV electricity price	e a	RDs, OMIE Literature
	E_{PV}	kWhy	PV electricity yield per year	e	PVGIS

We assume the average irradiation for Spain and horizontal mounted system. Besides, to have a broad perspective of profitability ranges depending on those conditions, we also calculate a lower bound assuming minimum irradiation and vertical mounting, and upper bound considering maximum irradiation and optimal tilt.

2.2.3. Financial conditions

The financial conditions have a significant impact in the profitability of any investment. Previous literature has paid little attention to this factor, assuming either own capital investments or hundred per cent financed. According to the information provided by the Spanish PV Industry association (UNEF), we assume that 80% of the investment is financed and 10 years maturity. But the most critical factor of the financial conditions is the interest rate. We assume the average interest rates provided by ECB for the years 2005-2014**.** We differentiate between the three segments, taking the average interest rate for household purchase for SC (7.15%), the average for loans below 1M€ for MC (5.25%), and the average for loans above 1M€ for LC (3.78%).

During the years 2004 and 2005 soft loans have been provided by ICO and IDAE with an interest rate equal to the euribor-6months plus a maximum (premium for intermediary financial institutions) of 1,025 percentage points.

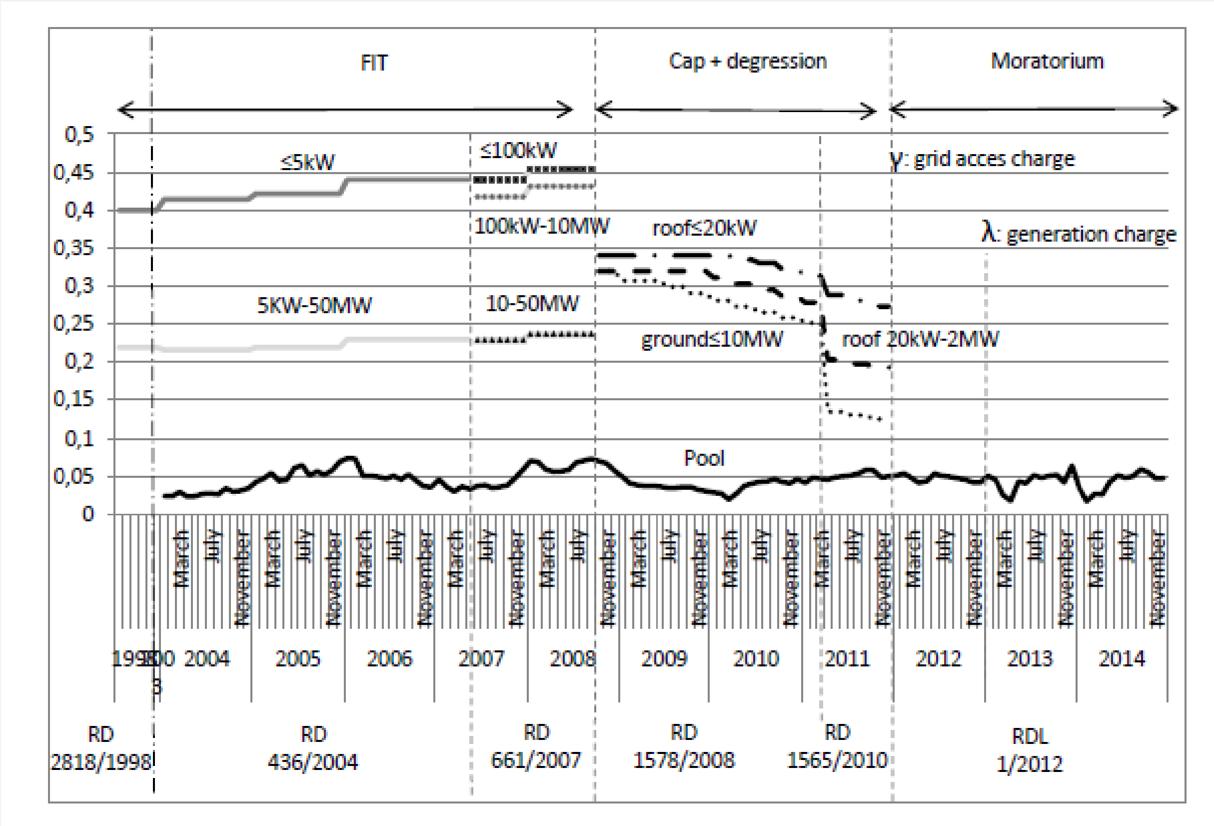

Figure 3: Retribution regimes for PV electricity generation and Pool price. €/kWh. *Source: RD 2818/1998, RD 436/2004, RD 661/2007, RD 1578/200RD 1565/2010 and OMIE.*

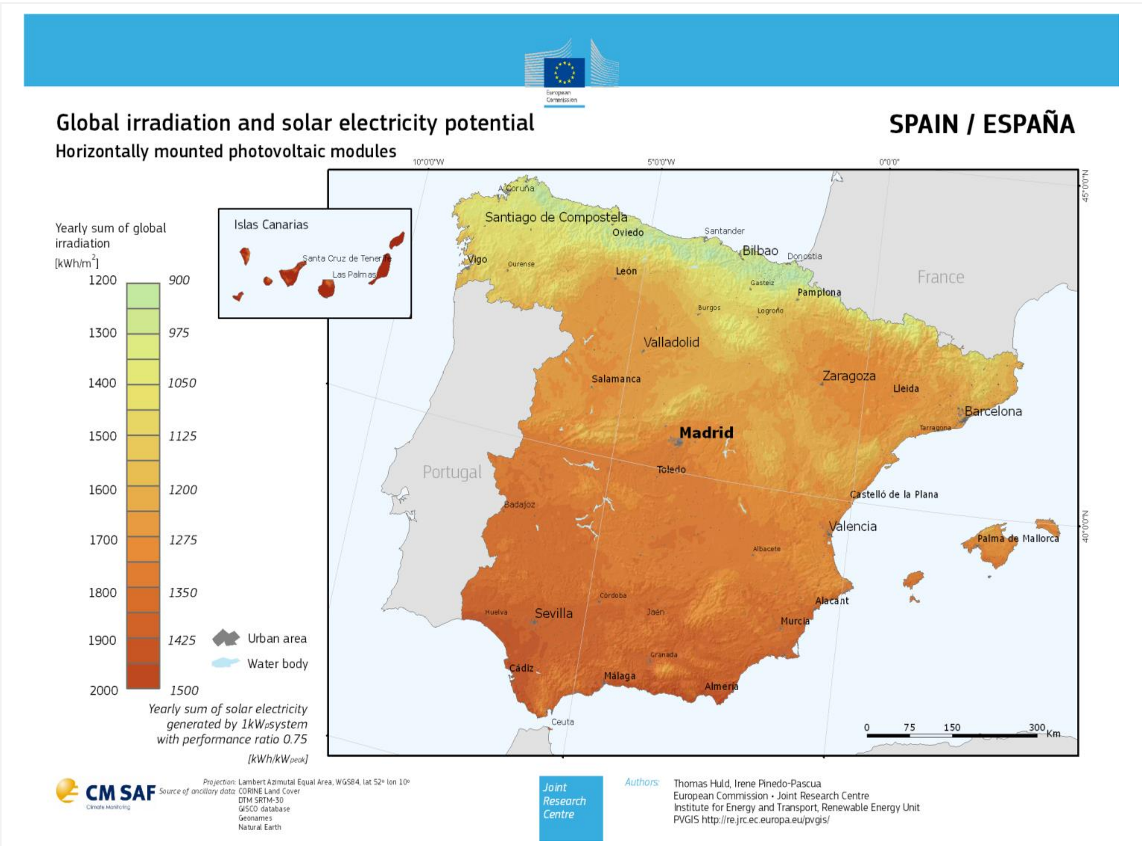

Figure 4: Map of Spain depicting the yearly sum of global irradiation and the yearly sum of solar electricity generated by a 1 kWp system with a performance ratio of 0,75. *Source: PVGIS*

As the Euribor of the period has been around 2%, we assume the soft loans to have an interest rate of 3%.

2.2.4. Costs

The data about initial investment (System prices) is provided by the International Energy Agency in their annual PV trends reports. These reports provide rough numbers, and only since 2011 they started differentiating between three categories (before there were only installations below and above 10kW).

There is no data about Spain for the years 2004 and 2005, so we estimate it from the values of the years 2003 and 2006 assuming a constant evolution. For the years 2006-2010 there are two ranks of prices: one for installations below 10KW and the other for those above that level. As we have three categories, we assume the lowest price per Watt for the large-scale (U), the highest for the small-scale (R), and the median for the medium-scale (C-I).

The data is expressed in €/W (nominal power), whilst the PV yield in our equation is expressed in kWh/kWp (peak power), so we must convert W into Wp. The ratio between the peak and nominal power is neither fixed nor standardized; it varies across installations [124]. According to a research carried out by the Spanish PV industry association, the peak/nominal ratio is 1,1 in the north of Spain and 1,15 in the south (ASIF, 2011:67). We therefore assume a ratio of 1,13 for Spain as a whole.

We must also include the Value Added Tax. In Spain, VAT has been modified twice during this decade: from 16 to 18% in July 2010, and from 18 to 21% in September 2012. We add the VAT for each year and assume 17% and 20% for 2010 and 2012 respectively.

Initial investment subsidies were in place mainly in 2004 and 2005, and amounted up to 40% of the installation cost. According to Bernal-Agustin and Dufo-López (2006:1111), in the year 2004 IDAE subsidized as an average, 27% of the cost of the installation for power ratings of less than 100kW, and 11% for installations greater than 100kW", althought there is not any official statistical comprehensive database about financial incentives (Both soft loans and investment subsidies). Thus, for each segment we will calculate an upper bound with all possible incentives (40% subsidy and 3% soft loan), and lower bound for installations with neither subsides nor soft loans.

Finally, there is consensus in the literature in the assumption of operation and maintenance cost (O&M) as 1% of the initial investment (Sick & Erge, 1996; Konen et.al., 2000; Talavera et.al., 2010; Talavera et.al. 2014). Likewise, and according to Talavera et al. (2010) we assume an annual escalation rate of O&M costs of 1%. To summarize, we can see all our assumptions and constant parameters in table 2.

3. Results

Figure 6 shows the results in four panels: The first panel presents the electricity prices determined by the FiTs and the pool price of the Spanish wholesale electricity market, at which new PV installations sold the electricity generated after the *Renewables Moratorium* in 2012. The three bold dashed lines represent the system change, from *FiTs* to *Quota + degression* in October 2008, and from *Quota + degression* to the *Moratorium* in January 2012.

The second panel shows the evolution of the system PV price (module, balance of system and taxes). As we can see, there was a slight peak between 2007 and 2008, which was caused by two factors mainly: an international factor derived from the shortage of silicon, and a national factor consequence of the high demand caused by the investment boom (see panel 4). The first and second panels show the main determinants of profitability, given climatic conditions and financing costs: electricity prices and system costs respectively. Panel 4 shows the

[124] Peak power vs. Nominal power: peak power is the quantity of kW installed in the solar panels, whilst nominal power refers to the power of the inverter (the device that transforms the energy generated by the panels into energy suitable for consumption). Peak power is usually higher than nominal power, as the inverter determines the bottleneck of energy fed into the grid. In other words, having a higher peak power than nominal power allows using the inverter at a 100% capacity longer than if both values were the same.

profitability determined by these two variables.

The two lines in years 2004 and 2005 for each segment represent the situation with neither investment subsidy nor soft loan (lower line), and with maximum investment subsidy (40%) and 3% soft loan (upper line). Only small installations with high subsidies and soft loans were profitable during those years. Between 2006 and 2008 the FiTs were designed to provide moderate profitability of between 0 and 5%. Looking together at panels third (profitability) and forth (diffusion: installed capacity) we can see the paradoxical situation happened in Spain during this period. We can see that the investment bubble happened when the profitability was designed to be moderate. Once the investment bubble started, the government established a quota and degression system aimed at containing the policy costs derived from the FiTs. However, provided that costs (panel 3) fell faster than the FiTs, profitability rocketed to up to 15% for the systems installed in 2010, and up to 24% for best-case installation (highest radiation, optimal tilt and minimal costs) Finally, since the passing of the Moratorium the PV market has been virtually paralyzed.

The diffusion bubble (June 2007-October 2008) happened before the profitability bubble (2009-2001). These diffusion bubble was probably caused by the negative evolution of the profit rate of the economy (it fell almost 10 percentage points in 2009 and 17 pp between 2008-2009 according to AMECO) and the capital flight from the collapsing construction sector (Del Rio & Mir Artigues, 2012 and 2014).

This made PV investments more attractive, as its profitability was guaranteed by the FiTs for 25 years in a moment of high uncertainty. Likewise, the announcement of the modification of the regulation caused a rush in installations due to the expectations that the new regulation would decrease the profitability of new investments or establishing a cap on the number of installations allowed under the framework of the FiTs. A quota on the installed capacity was in fact established, but the profitability did not decrease, but on the contrary it increased due to high fall of the system price (panel two).

In conclusion, the profitability bubble was not the cause of the diffusion bubble, but in some extent the consequence of it, since the higher demand contributed to increase PV system price, causing therefore a deeper drop of the PV system prices afterwards. Even although the government established measures to avoid windfall profits by lowering FiTs and establishing a degression rate on the FiTs, this system was not flexible enough to avoid the increase in profitability caused by a fast decrease of the PV system prices.

Table 2: Assumptions and constant parameters. Source: own.

Abrev.	Description	Value	Source
N	Investment duration	25 years	Talavera et.al. (2010, 2014)
Nl	Maturity of the loan	10 years	UNEF
α	Percentage financed	80%	UNEF
PV_{OM}	Operation and Maintenance cost	1% of PV_{IN}	Sick & Erge, 1996; Konen et.al., 2000; etc.
εPV_{OM}	Escalation rate O&M	1%	Talavera et.al. (2010)
εPu	Escalation rate electricity price	2%	Talavera et.al. (2010)
Epv	Electricity yield : - average irradiation, horizontal - min. irradiation vertical tilt - max. irradiation optimal tilt	kWh/kWpy 1165 671 1475	PVGIS: Šúri M., et al., 2007; Huld T. et al., 2014
γ	grid-access charge	0,5€/MWh	RDL 14/2010 and RD 1544/2011
λ	generation charge	7%	RD 15/2012
dg	Degradation rate	0.8%	Dirk et al. (2012)

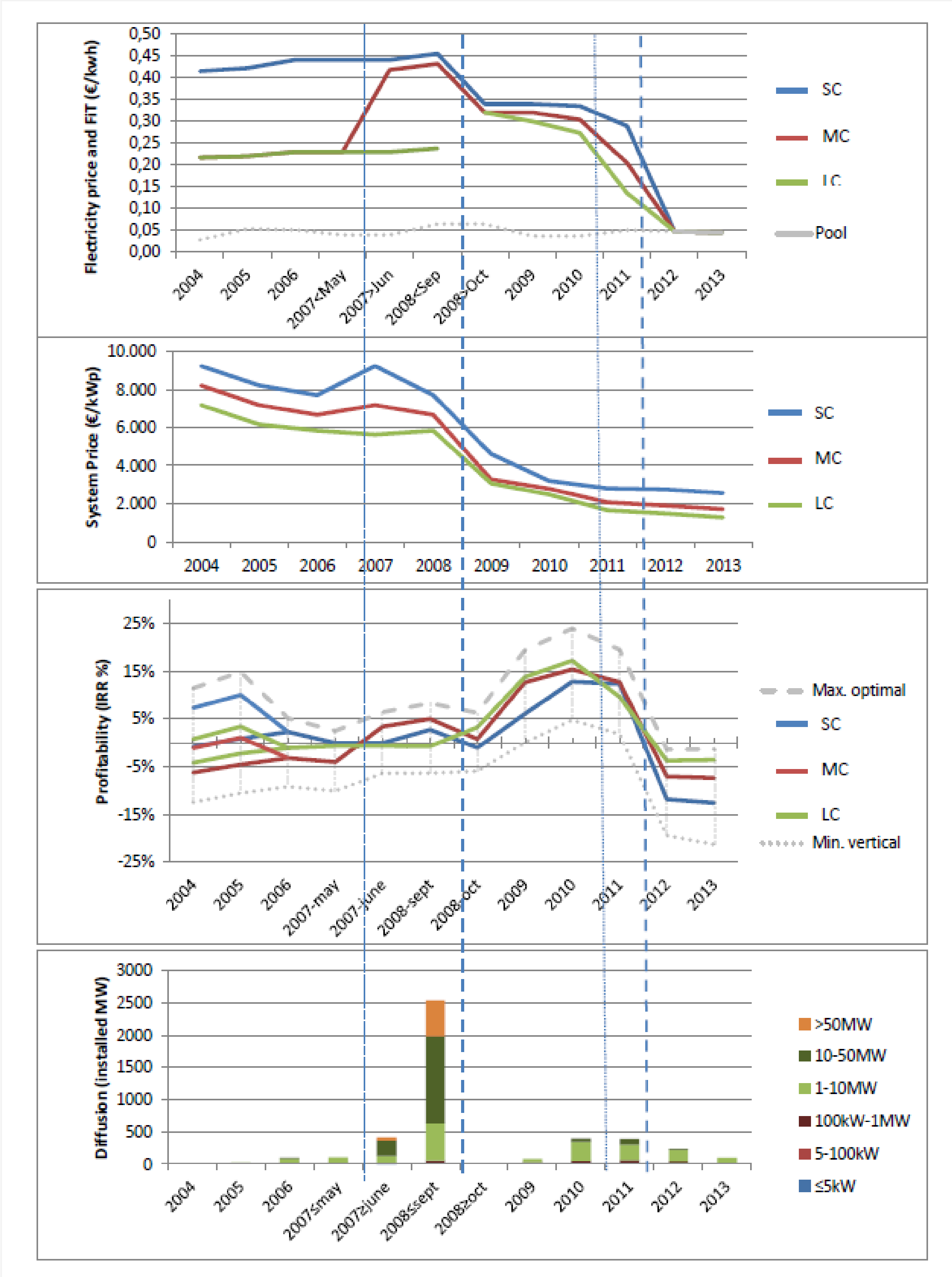

Figure 5: The evolution of the PV market in Spain between 2004-2013. Vertical dashed lines represent the change of support system: FiTs, Quota + degression and Renewables Moratorium (see figures 2 and 3). Dotted vertical lines represent a change in FiTs levels. Segments: small scale (SC), medium scale (MC) and large scale (LC). Panel 1. Simplified FiTs system (for detailed extension, see figure 3). Source: RD. Panel 2. PV system prices. Source: IEA. Panel 3. Profitability (IRR, %).Panel 4. Diffusion (Installed capacity, MW). Source: CNMC.

4. Conclusions

Contrary to what is commonly though, the profitability bubble (understood as general high profitability levels for all segments caused by the combination of high FiTs and declining cost), was not the cause of the diffusion bubble, but in some extent the consequence of it, since the higher demand contributed to increase PV system price, causing therefore a deeper drop of the PV system prices afterwards. Even although the government established measures to avoid windfall profits by lowering FiTs and establishing a degression rate, this system was not flexible enough to avoid the increase in profitability caused by a fast decrease of the PV system prices.

The causes of the diffusion bubble are manifold. The negative evolution of the profit rate of the economy (it fell 17 percentage points between 2007 and 2008) and the high uncertainty derived from the financial crisis made the PV investments more attractive, since their profitability was guaranteed for 25 years by the FiTs. In addition to that, the announcement of an upcoming new regulation caused a rush in installations because lower profitability was expected after the reform. In any case, the declining cost of PV was not the cause of the diffusion bubble, as it only happened in Spain after 2008, and the FiTs were designed to provide returns below 5%

More research is needed to have a clearer idea of the deeper causes of the diffusion bubble and the relationship between profitability and diffusion. In the case of Spain, this link is not clear due to the financial and regulatory shocks that affected the PV market during that time. That is why a comparison with other experiences would be fruitful to contrast the different policies and paths regarding the diffusion of the PV technology towards the decarbonization of the electricity generation.

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A Decision Support Model for Economic Evaluation of Offshore Wind Farms

by

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Abstract

Wind energy technology is one of the most competitive of the renewable energy technologies at global level, but to date, has not received enough attention regarding optimization process for economic evaluation of wind farms, by the researchers in both economics and engineering aspects. Most of the existing optimization models reflect aspects of engineering sciences, whereas the economic view has not been analyzed in the depth that it deserves.

So, this paper provides a decision support tool (DST) to analyze and evaluate the project value of (offshore) wind projects within the framework of cash flows over their lifetime and project finance. The DST is based on a discounted cash-flow model in combination with Monte Carlo simulation (MCS) in order to measure and manage the project risks, which is done by the assignment of probability distribution to specific elements of cash-flows model. Also, due to the different requirements of project developers and lenders additional financial key characteristics like the internal rate of return (IRR), profitability index (PI), debt service cover ratio (DSCR) and loan life cover ratio (LLCR) are calculated, in order to meet the standards of all stakeholders. A case study in the Aegean Sea, as an example, is presented, in order to validate the DST tool and simulation model. The results show that an investment in offshore wind project in the Aegean Sea is pretty profitable for project developers and lenders.

Keywords: decision support tool; economic evaluation; offshore wind energy.

1. Introduction

Offshore wind energy, as one of the most potent alternative energy resources, has been developed rapidly in the last twenty years. The technical aspects have been in the foreground for most of the time so that a continuous enlargement of wind turbines could be observed. In contrast to this development, there has been no comparable expansion of the amount of constructed offshore wind energy installations (KPMG, 2010). This is because the costs of such investments go up to two billion euros per wind park with the typical nominal power output of 400 MW. Another reason is the large number of significant risk factors (Koukal and Breitner, 2013).

To further international efforts of climate protection the European Commission set their own goals regarding the reduction of greenhouse gas emissions which are widely known as the 20-20-20. The current Renewables Directive defined that 20% of the total EU energy consumption shall come from renewable energy sources. In this context, member states have set up National Renewable Energy Actions Plans, in order to meet these goals. According to this Directive more and more offshore wind projects are being realized, with different incentive systems and feed-in tariff (Prassler and Schaechtele, 2012).

Currently, the most of the projects are carried out in the context of project finance which means taking into account the different concerns of all involvement parts. In this case, the lenders are of major importance, as projects depend to a great extent on a debt capital. The latter is only provided against the background of expected future cash-flows of a project. It is particularly important to consider numerous risk factors that are associated with these different requirements within the risk management in order to ensure the economic success of such projects (Kaplan and Garrick, 1981).

The aim of this paper is to provide a decision support tool (DST), which evaluates and analyzes the project value of (offshore) wind projects within the framework of cash flows over their lifetime and project finance. The DST is based on a discounted cash-flow model in combination with Monte Carlo simulation in order to measure and manage the project risks, which is done by the assignment of probability distribution to specific elements of cash-flows model. Also, due to the different requirements of project developers and lenders, additional financial key characteristics like the internal rate of return (IRR), profitability index (PI), dept service cover ratio (DSCR) and loan life cover ratio (LLCR) are calculated, in order to answer to the question as to whether a specific wind farm provides adequate returns for investors and sufficient debt service coverage from the side of lenders.

The combination of conflict analysis together with the DST tool leads to identification of favorable area for offshore wind energy (OWE) deployments in the Aegean Sea. The results show that an investment in the offshore wind project in the Aegean Sea is pretty profitable for project developers and lenders.

2. Literature Review

Publications that conduct economic evaluations of offshore wind parks are presented in this section. The aim of this, is to provide interesting studies from which approaches can be used to define a model and build a useful tool that takes all aspects that are mentioned above into consideration.

DREWAG (2005) present a discounted cash-flow model in order to evaluate the net present value (NPV) of three offshore wind farms in the Baltic Sea. They consider only pure corporate finance and do not take project risks into account. Levitt et al., (2011) performs an analysis of the breakeven price of electricity for offshore projects in various countries with a cash-flow model. Different financing concepts are presented as well as variances in the investment or operating costs within the sensitivity analysis. An examination of the influence of specific risk factors is not performed, neither financial key figures are calculated. KPMG (2010) provides multiple results of scenario analyses and takes project finance in combination with related key features into consideration. Also, in this study, a risk analysis is not performed. Prassler and Schaechtele (2012) conduct a comprehensive assessment of the financial attractiveness of offshore wind power markets in Europe. In this context, some economic parameters like the internal rate of return (IRR) are calculated and multiple scenarios are scrutinized. Aspects of project finance of the risk factors are not examined. Morthorst (1999) analyses whether there is a relationship between the expected profitability of a wind turbine and the annual increase in installed capacity in Denmark. He used the (IRR) as a measure of profitability. Santos et al., (2013) determines the best areas to install fixed and floating offshore wind farms, using spatial analysis of four economic indexes: (IRR), (NPV), (DPB) and levelized cost of energy (LCOE). Risk assessment is not provided. Oliveira (2010) makes an overview about the indicators of attractiveness like simple payback (SPB), discounted payback (DPB), net present value (NPV), internal rate of return (IRR) and benefit-to-cost ratio (BCR). The research concludes that these indicators must be used as a tool kit for wind energy project economic evaluation. Kaldelis et al., (2000) conducts a sensitivity analysis in order to show the impact of different parameters on the economic viability and attractiveness of a wind energy plant. An interesting approach is presented by Koukal and Breitner (2013). Their study addresses the demands of investors as well as lenders under simultaneous consideration in order to analyze and evaluate project value of offshore wind energy projects within the framework of project finance. In the same context, a research of Madlener et al., (2009) presents a cash-flow model on which MCS is applied. A comprehensive analysis of various risk factors and their influences on different parts of a project is performed.

The results of the literature review show that there is a lack of studies that address the demands of investors and lenders under simultaneous consideration in order to evaluate the project value of offshore wind projects. Consequently, a study that includes all financial data which are relevant for all interested parties is presented in this paper. Due to the closeness regarding the approach and content with the researches of the Madlener et al., (2010) and Koukal and Breitner (2013) this paper is based partly on their model.

3. Methodological Framework

3.1 Development of the Model

The definition of DST is broad and there is no universal definition besides stating that those tools are built to assist in decision processes and help to identify and solve problems. Usually a DST is a computer based support for management decision makers who are dealing with semi-structured problems (Center for Information Systems Research, 1978). A DST in the offshore context is designed to support the development, construction and operation of offshore wind farms. For instance, during the planning process a whole series of requirements from various fields show up (engineering, costs, financing, ecological environment, shipping, military, exclusion zones, properties, accessibility etc.) (Power, 2007).

From the side of project finance, a DST is possible to examine all financial aspects and influences of risk. As a basis of this DST a cash-flow model is set up. For the implementation of this cash-flow model, any table calculation software is suitable. In this study Microsoft Excel is chosen due to its simple and wide use.

3.2 Cash-flow Model

The basis of the DST is a cash-flow model. When performing a wind investment case analysis we turn to following key elements that need to be evaluated in order to properly understand the investment base case and measure uncertainty and project risks. Figure 1 illustrates the key elements and their relationships. The investment cash-flow consists of several individual cost parameters referring to the planning process and the construction period of offshore wind project.

The earnings within the operating cash-flow result directly from selling the produced energy. This depends on the theoretical full loads hours multiplied with the nominal power output of the wind park. Furthermore, the cash flow model makes use of some parameters with an influence of multiple factors in several years. An increase of all operating cost components is conducted by the inflation rate in every year. The sum of investment cash-flow, operating cash flow and taxes results in free cash-flow (See figure 1).

3.3 Discounted Cash-Flow Method (DCF)

The DCF method is based on the discounting of future cash-flows arising from operating activities of business. These flows will be created in the future and therefore are discounted at a discount rate that reflects the risk of future cash flows (IESE, 2007). The evaluation of a company by the DCF method can be carried out with three different approaches. The use of adjusted present value (APV) is a good choice as the cash-flows attributable to the investors are presented. The first part of the net present value in equation (1) represents the present value (PV) of all free cash-flows and the second part the present value of the tax shield of the project (Ruback, 2002). The latter defines an increase in the company's value as a result of the tax saving obtained by the payment of interest (Fernandez, 2004).

$$PV = \sum_{t=1}^{T} \frac{FCF_t}{(1+r_u)^t} + \sum_{t=1}^{T} \frac{T*[r_{D,t} * D_{t-1}]}{(1+r_{D,t})^t} \quad (1)$$

The present value of the tax shield is based on the multiplication of the tax rate r and the interest expense ($r_{D,t}$ $*D_{t-1}$) discounted with the cost of debt of the respective period.

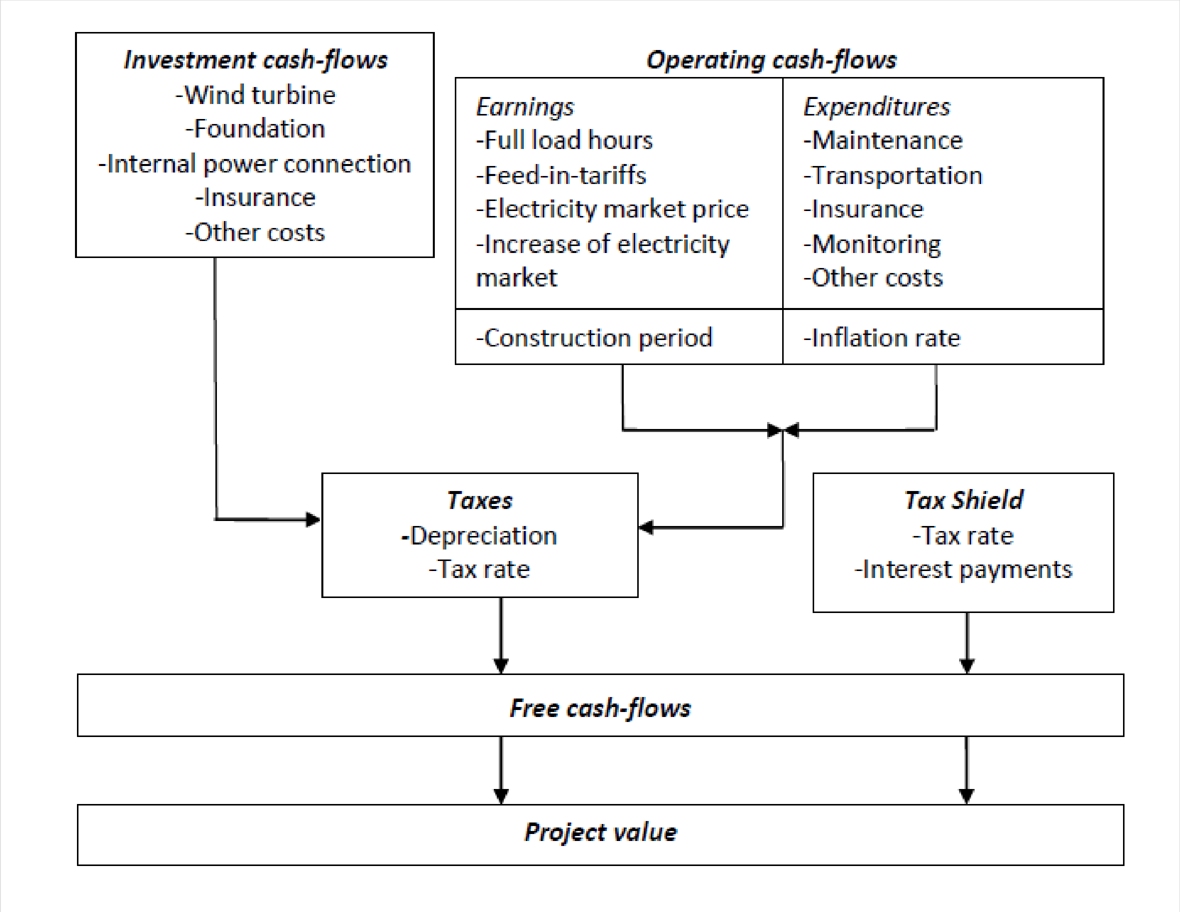

Figure 1: Key elements and their relationships.

The evident advantage over the other discounting methods is that it combines investment and financing decisions and allows the financing effects specific to a particular project to be incorporated into the analysis of that project (Brigham and Gapenski, 1996).

4. Financial Analysis

Capital budgeting refers to the methods that managers use to determine which projects should be selected and which projects should be rejected. So, in this context, it is important except for the evaluation of project value, to apply also budgeting decision methods, in order to evaluate a project, like IRR and PI.

The IRR is the discount rate that makes the NPV of all cash flows from a certain project equal to zero (equation 2) (Hederstierna, 2008). It indicates the interest yield an investor can reach with an investment (Brealey at al., 2011).

$$NPV(0) = -IC + \sum \frac{C(n)}{(1+IRR)^n} \quad (2)$$

$$PV = \frac{\text{PVof future cash flows}}{\text{Initial investment}} \quad (3)$$

Where c is the cost for n number of years and NPV (0) the net present value equal to zero. PI is an index that attempts to identify the relationship between the costs and benefits of a proposed project through the use of ratio (equation 3). A ratio of 1.0 is logically the lowest acceptable measure on the index. Any value lower than 1.0 indicates that the project's present value is less than the initial investment. As values on the profitability index increase, so does the financial attractiveness of the proposed project (Kaiser and Snyder, 2012).

$ADSCR_t = [ANCF_t / (\text{Annual Debt Repayment}_t)]$	(4)
$LLCR = PV(ANCF_{\text{t to the end year of debt}}) PV(\text{Annual debt repayment}_{\text{t to the end year of debt}})$	(5)

The relationship between project developers and lenders is characterized by the supply of debt capital and the regular payment of the loan. For the lenders it is important to have key figures that aim at the evaluation of the possibility of debt service coverage.

The debt service cover ratio is a key factor in deterring the ability of a project to pay its operation expenses and to meet its debt servicing obligations. This is used by bankers who want to know the annual debt service coverage of a project on a year-to-year basis as well as a summary ratio of the loan life cover ratio (Yescombe, 2002).

The annual debt service capacity ratio (ADSCR) is the ratio of the annual net cash flow of the project over the amount of debt payment due. It is calculated on a year to year basis as equation (4) shows.

Where $ANCF_t$ is annual net cash flow of the project before financing for period t, and annual debt repayment is annual interest expenses and principal repayment due in the specific period t of the loan repayment period. A ADSCR greater than 1 means the entity-whether the developers-have sufficient income to pay its current debt obligations. In contrast to this, a ADSCR less than 1 means it does not. Generally, the minimum ADSCR should be greater than 1.2. The overall project's loan life cover ratio (LLCR) is calculated as the present value of net cash flows over the present value of loan repayments from the current period t to the end period of loan repayment (Equation (5)).

Here, PV ($ANCF_{\text{t to the end year of debt}}$) and PV (Annual debt repayment $_{\text{t to the end year of debt}}$) are the sum of the present values of annual net cash flows and annual debt repayments, respectively, over the period of the current year t to the end of the loan repayment. The LLCR tells the banker if there is enough cash from the project to make bridge-financing in one or more specific periods when there is inadequate cash flow to service the debt (Jenkins et al., 2011). And in the case of LLCR, a LLCR greater than 1 means that the loan can be recovered. Generally, the minimum LLCR should be greater than 1.2.

5. Monte Carlo simulation & BetaPERT Distribution

As the presentation of the expected value does not give a sufficient basis for investment decisions due to inadequate considerations of possible risks, the model of MCS is presented. This aims at the presentation of a wide variety of different risk factors which have an effect on an offshore wind energy project.

In order to take MCS analysis and measure the effects of the risks, an individual probability distribution is set up for every factor within the investment and operating cash flows, as well as for the parameters with an influence on multiple factors.

Due to an insufficient database on risks in the offshore wind sector, BetaPERT Distribution is selected because it takes under consideration only three parameters: a minimum, a maximum and the most likely (mode) (Plequezuelo, 2003). The use of MCS in combination with PERT distribution can be used to identify risks in projects and cost models on the likelihood of meeting targets and goals across any number of project components. As with any probability distribution, the PERT distribution is limited by the quality of the inputs: the better your expert's estimates are the better results are derived from simulation (RiskAmp, 2015). The simulation results in a variety of different forms of every target variable.

6. Case Study

6.1 The area of study

Lesvos Island is located in the northeast of Greece, in the Aegean Sea. Its total area is 1636 Km^2, with 90436 inhabitants (census 2001).Electricity production in Lesvos is based on an autonomous grid, which is powered by a conventional oil station owned by the Public Power Corporation (PPC).

The island of Lesvos is selected for numerous reasons. First, as most of the Aegean islands, it exhibits an excellent wind potential (Kaldellis, 2005). Second, it displays an annual increase of electricity consumption at a rate of 6%, almost 50% more than the mainland rate. Moreover, due to geographic, technical, economic and social reasons, its interconnection to the mainland grid still remains under discussion (Kaldellis and Zafirakis, 2007). As a result, it bases its electricity supply on an autonomous power station, which cannot cover the peak demands sufficiently, especially during the summer period. The exact location of the offshore wind plant is determined by geographical information system (GIS). A set of environmental, economic, social and technical constraints, based on recent Greek legislation, identifies the potential site for wind plant installation. Furthermore, the area under consideration is evaluated by a variety of criteria, such as wind power potential, visual impact, compatibility with marine uses and electricity grid.

The assumptions regarding to the characteristics of the offshore wind plant are presented in table 1.

The wind turbine which is selected (Vestas V82) has a nominal output of 900 Kw and is placed in a semi-submerged floating structure. The structure consists of peripheral cylindrical and one central shaft connected by a metal mesh-grid of such geometry as to minimize the impact of waves. Also, the floating structure has an automatic control via GPRS for monitoring, and a remote control so that nobody’s presence is needed for its functioning. The anticipated annual energy output (subtracting the percentage of losses) is 3022.87 MWh. The lifetime of the project is up to 25 years.

Table 1: Assumptions of off shore plant.

Case study features		
Parameter	**Value**	
Wind energy plants	1	
Expected annual energy output	3022.87 MWh	
Nominal output	900 Kw	
Latitude	40^{0} 05’ 00, 28’’ B	
Longitude	25^{0} 25’ 13.97’’ E	
Average wind potential	6.6 m/sec.	
Average significant wave height	0.5 m	
Depth	60 m	
Distance from coast	6 Khm	
Tax rate	26%	
Investment and Operating costs		
Component	**Costs**	**Discount/Surcharge**
Cost of cable low voltage for connecting with transformer	12.608 €	-5&/+5%
Cost of underwater cabling medium voltage	95.672 €	-10%/+10%
Cabling cost land medium voltage	3.594 €	-5%/+5%
Cabling installation cost land	750€	-5%/+5%
Marine cabling installation cost	275.000 €	-10%/+10%
Cost of 2 transformers	50.000 €	-10%/+10%
Construction of platform	1.300.000 €	-10%/+10%
Cost of a wind turbine	1.160.000 €	-5%/+5%
Cost of anchoring and towing	100.000 €	-10%/10%
Maintenance (annual cost)	20.000 €	-25%+25%
Total	*2.997.624 €*	
Parameters with an influence on multiple factors	**Value**	
Annual inflation rate	1.5%	-20%/+50%
Net full load hours	3022,87	-20%/+10%

$$AVDSCR = \frac{DSCR_1 + DSCR_2 + ...DSCR_n}{n} = \frac{\sum_{t=1}^{n} \frac{CFADS_t}{K_t + I_t}}{n}$$	(6)
$$LLCR = \sum_{t=0}^{n} \frac{\frac{CFADS_t}{(1+i)^t}}{0_0} = \frac{NPV(CFADS_0 + CFADS_1 + ...CFADS_n)}{0_0}$$	(7)

The selling price of electricity produced by a wind farm according to Greek current legislation (L.3851/2010) is 99, 45 €/MWh plus 20% (YPEKA, 2010), as the project is carried out without the use of a public subsidy. The total cost of this offshore plant is *2.997.624 €.* This cost is divided into multiple cost components (investment and operating costs). (EWEA, 2009; BMU, 2011; Prassler and Schachtele, 2012). The indicative prices of cost components are based on the current market situation for the construction of such projects and literature. For the component operating cost (maintenance) an annual increase is assumed due to the annual inflation rate.

Conforming to the actual market situation for project finance, an equity ratio of 40% capital and 60% loan is assumed. A banking consortium offers a debt of 1.798.574,4 € with a lending rate of 5%. The inflation stands at 1.5 %. The annual revenue generated by the investment after subtracting the annual maintenance cost is set up to 340.749,30 €.

6.2 Project value of case study

In order to apply the APV method for the discounting of the project cash-flows, the NPV has to be found, according to equation (1). The NPV of the project 1.804.877, 745 € and the present value of the tax shield is 329.537 €. Consequently, the sum of these gives the APV, which is 2.134.415 €. (Table 2) The use of APV method is a way to measure the value of the leverage of the project and to get a better sense of the company's actual value.

Also, the attractiveness of the project is expressed through the IRR (equation 2), which is 10,411%, that is the discount rate that makes the NPV of all cash-flows of project equal to zero, The PI (equation 3) is 1,60%, and the repayment period of the loan is carried out in 11th year.

The economic evaluation from the side of project lenders is carried out through the ADSCR and the LLCR and equations (4) and (5). The calculations of indexes (cover ratio) are presented in table 3. The results of mean index DSCR (1.62) and the index LLCR (1,38) are calculated according equations (6) and (7).

Here, n is the time in which the loan must be paid, O_o is the remaining total loan for the time 0.

From table 3, it can be concluded that the available cash flows for the debt service are enough for the loan and interest payments every year and liquidity problems are not expected to appear. Also, due to the fact that the index is substantially greater than 1 from the first year, the creation of reserves is permitted from which can be covered short term obligations such as temporary revenue decline or the delay of revenue collection from the sold energy.

In conclusion, it is obvious from the evaluation of indexes that the project can serve the relevant loan, for the reason that both indexes are quite greater than 1.

Table 2: Expected project value.

		2015	2016	2017	……	2039
1.Investment cash flow	-2.997.624				……	
2.Operating cash-flows (earnings-expenditures)		340.749,30	340.749,30	340.749,30	…..	340.749,30
3. PV of cash-flows		324.523,1429	309.069,6599	294.352,057	……	100.624,2127
4. Project value (NPV)						***1.804.877,745***
5. Tax shield		23381,46	23381,46	23381,46	……..	23381,46
6.PVof cash shield		22268,06	21207,67	20197,78	…….	6904,61
7. Total PV of cash shield						***329537***
8.APV of the project						***2.134.415***

Table 3: Cover ratio calculations.

Year	***0***	***1***	***2***	***3***	***…….***	***11***
(a)*Operating cash-flow*		340.749,30	340.749,30	340.749,30	……	340.749,30
(b)*NPV of (a) 5% discount*	2.830.404,83	2.505.881,69	2.196.812,03	1.902.459,97	…….	
(c)*Loan repayments*		163.506,76	163.506,76	163.506,76	……	163.506,76
(d)*Loan outstanding*	1.798.574,4	1.635.067,64	1.471.560,88	1.308.054,12	……	0
(e)*Interest payments*		89.928,72	81.753,4	73.578,04	…….	8,175,34
(f)*Total debt service [(c)+(e)]*		253.435,8	245.260,16	237.084,8	……	171.682,1
ADSCR [(a)÷(f)]		1.34	1.38	1.44	……	1,98
LLCR [(b)÷(d)]	1.57	1.53	1.49	1.45	…….	1.22

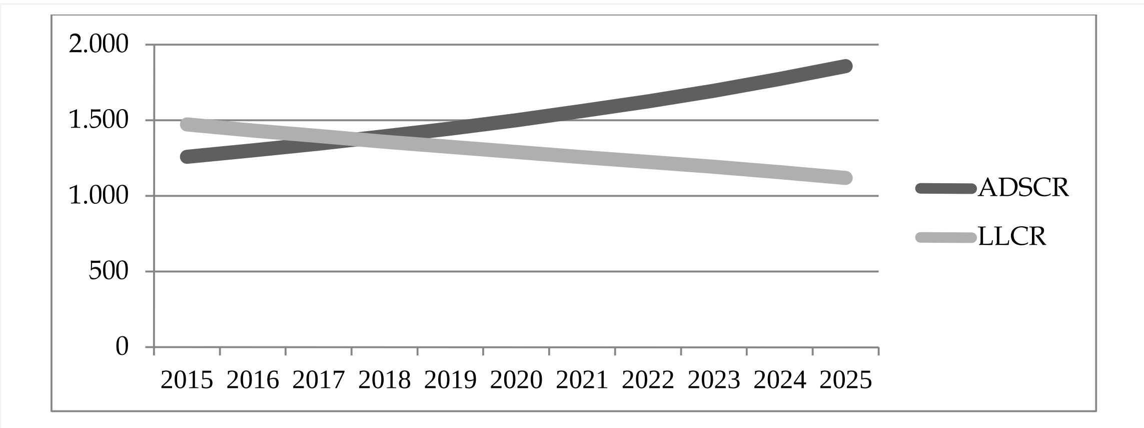

Figure 2: Key characteristics at a confidence level of 95%.

6.3 Probability distributions of case study

Due to the use of BetaPERT probability distributions for performing a MCS, it is necessary to specify a maximum, a minimum and a most likely value for every risky parameter. While all expected value of these parameters are used as most likely points of the probability distributions, the minimum and maximum points are calculated with the percentage discounts from and surcharges next to the expected values. These discounts and surcharges are presented in table 1 and are based on the research of Madlener et al., 2009 and Koukal and Breitner 2013. On the cash flow model the MCS is applied. 100.000 simulations were performed within 1200 seconds on an Intel Core I5, 4 GB Ram and Microsoft Windows 8 64 bit as operating system. The findings that can be derived from the simulation process are the following:

At a confidence level of 95% the project value is 1.941.439 €. Consequently, with a certainty of 95% the value of the project is at this or higher amount. In the same context, with a certainty of 95% the IRR of the project is at least 9, 89505% and the PI is 1, 54%.

In figure 2 the consequences of MCS on debt cover ratios are presented. The average DSCR is 1,523 and the average LLCR is 1,292. Lenders normally demand a value of the DSCR between 1.35 and 1.45 (KPMG, 2010). As it is observed from figure 2 most times the DSCR has a value greater than this range, reaching the year 2025 at 1,857. Also, the index LLCR is substantially greater than 1 which means that the project cash-flows offer adequate debt service coverage from the entire loan life (Figure 2).

7. Concluding Remarks

In this paper, a DST is presented in order to evaluate the project value of (offshore) wind projects within the framework of cash flows over their lifetime and project finance. Due to the different requirements of all interested parties (project developers and lenders) additional key figures are presented. From the side of project developers the DST provides a detailed presentation of all project expected cash-flows and calculation of project value, IRR and PI. On the other hand, from the side of the lenders, their aim is to cover the debt by the project cash-flows, through financial key figures like ADSCR and LLCR.

In order to measure and manage the project risks, a MCS is carried out through the assignment of probability distribution to specific elements of cash-flows. The results show the possible influence of the risks on the project value and other financial figures.

The results of the DST indicate that an investment into an offshore project in the Aegean Sea is profitable enough both for developers and lenders. A DST for such investments is very useful because it presents the key financial characteristics and gives an answer on the economic efficiency of offshore wind projects that are constructed and operated within the context of project finance.

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Effects of European Transnational Cooperation on the promotion of Renewable Energy and Energy Efficiency in IPA countries: The experience of MED Programme

by

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Abstract

European Territorial Cooperation (ETC) is an objective of the European Union (EU) Cohesion Policy and constitutes a key driver to reducing disparities in the Union's territory. ETC instrument integrates the participation of third countries, namely those included in the categories: Instrument for Pre-accession (IPA) and European Neighbourhood Policy Instrument (ENPI).

The ETC transnational programme for the Mediterranean area (MED Programme) covers ten member states of the European Union and three countries belonging to the IPA instrument: Bosnia and Herzegovina (B&H), Albania, and Montenegro[125]. In 2013, the MED programme approved eight transnational projects integrating IPA partners and addressing the use and promotion of renewable energy sources (RES) and energy efficiency (EE).

According to the current transitional period that entails concluding cycle 2007-2013 and opening 2014-2020, ETC evaluation aspects applied to specific thematic areas are essential for better implementing future strategies and learning from previous lessons. In this context, the purpose of this paper is to analyse the effects of ETC in the promotion of RES and EE in IPA countries by considering the experience of the MED programme. The methodological approach includes: (1) data gathering process (2) desk research and analysis of results and (3) validation of obtained results. The added value of this research represents supplementary evaluation input related to the ETC intervention in non-EU member states within the specific contexts of RES and EE.

Key words: EU Cohesion Policy, European Territorial Cooperation, IPA countries, Mediterranean, Renewable Energy and Energy Efficiency

1. Introduction

The INTERREG MED Programme is part of the ETC objective of the EU Cohesion Policy and is co-financed by the European Regional Development Fund (ERDF) and by the Instrument for Pre-Accession assistance (IPA) funds. The Programme main purpose is to contribute to the long term development of the Mediterranean area and to strengthen transnational cooperation among peoples of 57 regions in 10 different EU member states and 3 candidate countries: Albania, Bosnia-Herzegovina and Montenegro (Programme MED, 2011).

Article 86(4) of IPA Implementing Rules (EC, 2007) provides the possibility for candidate countries to participate in initiatives of transnational scale through the cross-border cooperation component[126]. In the MED Programme this cooperation has been possible through priority axes related to (1) innovation capacities, (2) protection of the environment and sustainable territories, (3) improvement of maritime accessibility, and (4) promotion of a polycentric MED development space.

In February of 2012, within the framework of priority axes (1) and (2), the Programme launched its fifth call for project proposals

[125] Croatia benefited from IPA funding but since its adhesion to the European Union the country benefits from European Regional Development Fund (ERDF)

[126] In the period 2007-2013 IPA implementation was based on five components: transition assistance and institution building, cross-border cooperation (CBC), regional development, human resource development and rural development.

focused on innovative technologies, know-how, promotion of RES, and improvement of EE. Nineteen transnational projects were approved of which 16 included partners of IPA countries. In total, 25 partners benefited from IPA funding (including Croatia) representing local and regional public authorities (PAs), energy agencies, economic development agencies, universities and port authorities. Related projects were carried out in about 2.5 years within the period 2013-2015 and addressed several challenges such as energy management; energy planning, implementation and monitoring; funding; public procurement; and private-public-partnerships (MED Programme, 2013).

With these cooperation projects, IPA partners received financial stimulus to boost action towards the accomplishment of RES objectives defined by national and macro-regional (Balkans) energy strategies. At national level, the strategy documents are the National Renewable Energy Action Plans (NREAPs) which define the priorities and types of action on sustainable energy for the next years. At transnational scale, all members of western Balkan region have subscribed to the energy community treaty (Energy Community, 2006) which establishes binding renewable energy objectives for 2020. For IPA members of the MED Programme, these objectives are summarised in table 1. As for energy efficiency, achieved levels are still low. Countries like Bosnia lack national regulation on energy efficiency; while Albania and Montenegro have recently integrated EE measures in their national policies (Tuerk, A, 2013).

According to article 22 of the Council Regulation (EC) No 1085/2006 on the establishment of an instrument for pre-accession assistance (IPA), the Commission shall regularly evaluate the results and efficiency of policies and programmes with a view to improving future operations at policy level (ex-post evaluation). In addition, the MED Programme is expected to continuously improve its operation from lessons learnt from previous experiences. An evaluation plan for the period 2014-2020 should be submitted to the Commission prior to June 2016 (EC Regulation, 2013). Hence, the purpose of this paper is to analyse the effects of ETC in the promotion of RES and EE in IPA countries by considering the experience of the MED Programme. The added value of this research represents supplementary assessment input to the ETC intervention in non-EU member states within the specific contexts of RES and EE. Obtained results are expected to contribute to evaluation process to be carried out by the Commission (ex-post) as well as to input motivating improvements at both programme and project levels in future EU operations.

2. Methodological framework and data

The methodological approach of this work integrates three principal steps: (1) data gathering process, (2) desk research and analysis of results and (3) validation of obtained results. The assessment approach refers to the guide Evalsed (EC, 2013) by addressing thematic evaluation applied to RES and EE as well as generating additional data (e.g., survey analysis).

2.1 Data gathering process

Information of reference was obtained through programme guidance documents (e.g. Call for projects and terms of reference), websites of targeted projects, internal reporting documents used within monitoring process (e.g. activities reports, minutes) and deliverables (e.g. plans, studies, tools, publications). In some cases, the analysis considered draft versions of targeted documents as final versions were still in progress. Key bibliography as EU regulation, related initiatives, policy and scientific papers were also taken into account.

2.2 Desk research and analysis of results

This part was focused on screening the results delivered by IPA partners of Albania, B&H and Montenegro in the framework of the MED programme projects addressing totally or partially renewable energy and/or energy efficiency. Particular attention was paid to qualitative aspects linked to the typology of activities and results as well as to the ways in which IPA partners implemented activities oriented to increasing or stimulating the contributions from RES and EE in their territories. Several exchanges with stakeholders and one survey of reference integrating 12 questions were the central elements of this step.

The survey focused on 9 fields of analysis such as experience with IPA funding, continuation of activities after IPA grants, and synergies with transnational, national and subnational initiatives of reference.

The survey also integrated quantitative aspects linked to the effect of IPA partners' contributions throughout four variables of reference: (1) Number of reduced emissions of CO_2 (Ton equiv); (2) Installed power with renewable energy (MW); (3) Energy efficiency achieved (%); and (4) Investments triggered (€).

3. Analysis of results

The results of the analysis indicate that European Territorial Cooperation promoted by MED Programme has contributed positively to stimulate increase of actions in RES and EE in IPA countries. Table 2 summarises the main output at desk research step by identifying (a) general contributions obtained within cooperation dynamics established amongst partners (projects level) and (b) specific output facilitated by beneficiaries exclusively in their territories (IPA Partners).

Accordingly, IPA partners were benefited in a twofold way: on one hand, the project implementation itself contributed to increasing capacity building of beneficiaries in issues related to EU funding management, understanding and practicing territorial cooperation, exchanging knowledge and experiences with other partners and stakeholders (CEI, 2015), identifying and implementing good practices, developing joint approaches and methodologies, among others (Wolfgang k, 2014).

On the other hand, activities developed by IPA partners led to achievement of key results in their specific territories oriented to the fulfilment of the objectives established by the MED Programme (Terms of Reference) and by the specific projects of reference (as described in each project application form).

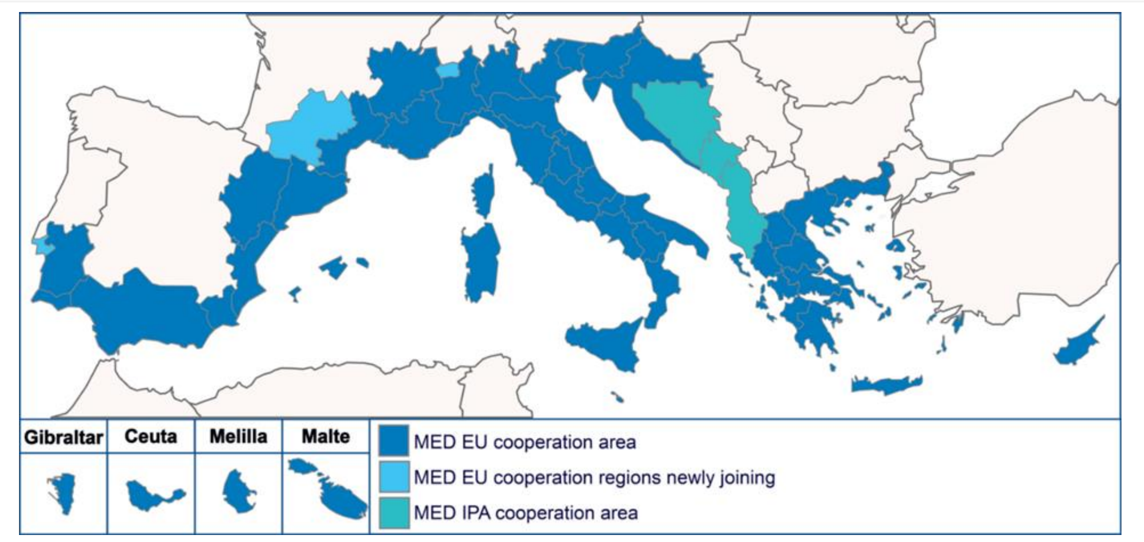

Figure 1: Cooperation Area of Interreg Med Programme for the period 2014-2020*
*MED EU Cooperation regions newly joining makes reference to the period 2014-2020

Table 1: Renewable energy objectives (framework of Energy Community Treaty).

Contracting party	Share of RES 2009	Target RES in 2020
Albania	31.2%	38%
Bosnia and Herzegovina	34%	40%
Montenegro	26.3%	33%

As these objectives are based on innovation measures applied to renewable energy and energy sector; IPA partners delivered, inter alia, local RES and EE roadmaps, guidance materials for energy management, energy audits, establishment of local working groups, provision of evidence for improving local, regional and national policies, sustainable energy action plans (SEAPs), state of the art and feasibility studies in related sectors, awareness raising campaign, training sessions and pilot activities (see, for instance, pilots of WIDER Project, 2015).

Projects co-financed by MED Programme normally follow a three-phase approach consisting of (1) diagnosis and strategies, (2) testing and demonstrative actions (3) transferability and capitalization (MED Programme, 2015). Accordingly, the analysed output of IPA partners is situated mostly in phases 1 and 2. In the first phase, IPA partners carried out activities and delivered output normally related to identifying initial parameters and/or benchmarks of the sector of reference (e.g. state of the art of renewable energy; criteria for green procurement). In the second phase, test activities and pilot actions were the most typical products. However, pilot approaches remain in many cases incomplete as monitoring elements and evaluation process were absent or not integrated. As for the third phase, little evidence of capitalisation strategies in IPA partners were found, and synergies with initiatives of reference were scarce.

A positive aspect observed in activities developed by IPA partners was the engagement of civil society through the "establishment of local groups". These nominated stakeholders' groups, integrating several perspectives of civil society, not only contributed to better address local strategies and enrich the quality of the results but also meant additional support to raise awareness on the benefits of renewable energy and energy efficiency in terms of environmental quality and economic growth.

3.1 Survey to stakeholders.

Aiming to count on the vision of IPA beneficiaries and validate collectively the observed results, the survey was addressed to a representative sample of partners (see details in methodological chapter), integrated 12 questions and focused on 9 different fields of analysis as follows:

3.1.1. Experience in management of IPA funding: About 30% of surveyed partners indicated that MED Programme and co-financed project of reference allowed them their first experience in IPA funding management. As for the remaining 70% of partners, IPA funding management experience oscillates between 2.5 (40%) to 6 years (30%). The main ETC programmes where these partners have acquired related experience were, in order of importance, South East Europe, IPA-Adriatic, Croatia-Montenegro CBC, Albania-Montenegro CBC and B&H-Serbia CBC.

3.1.2. Fields of intervention: Energy efficiency and renewable energy were the main fields of intervention by IPA partners in their respective projects of reference. Seventy percent of analysed partners identified EE as their principal field of intervention in their territories (primarily "cities"), with "buildings" being the main target of related activities. Concerning RES, 30% of partners focused their interventions notably on solar thermic, mini-hydro power, biomass, and wind technologies.

2.1.3. Typology of activities: IPA funding granted to surveyed partners was allocated to several types of activity according to working plans and projects' specific objectives. For 42% of partners, the most important activities were those oriented to obtaining a general picture of the area of intervention (e.g. mapping, analysis and feasibility studies). For 30% of partners, pilot activities and demonstration actions were identified as the categories covering a substantial part of working plans. The remaining 30% corresponds to training, dissemination and communication activities. Capitalisation activities were scarce being noticed in 10% of the sample.

Table 2: Summary of output delivered by MED Programme projects integrating IPA partners and addressing RES and EE in the period 2007-2013.

projects	***Main outputs from contributions at project and partner level***
GRASP www.grasp-med.eu Green pRocurement And Smart city suPport in the energy sector	Joint contributions by projects' partners (including IPA). Procurement System Analysis: Transnational Mapping and design of Common Operating Model Knowledge database on e-procurement and solutions implemented by public operators in the fields of renewable energy and energy efficiency Transnational networks. E-green procurement toolkit for supporting energy-efficient and renewable-based products and services Pilot actions (common methodology, implementation and assessment) Specific IPA partners' contributions **City Development Agency East Sarajevo-RAIS,** Bosnia-Herzegovina Establishment of Advisory Board and Evaluation Board Benefited 16 SMEs directly Regional and Comparative analysis Registration of 10 products into the database using GRASP-DBA tool GRASP seminar: Green procurement and energy efficiency technologies Promotional audiovisual material GRASP TV SPOT in local language **University of Vlora**, Albania Regional analysis and comparison report related to e-procurement in Albania Education materials and organization of theoretical training seminar in Tirana, Albania. Creation of the database for SMEs As coordinator of WP4: Development of modules of the GRASP application, DB platform (Module login, sign up, password reset, PA profile and SME profile template). Preparation of the specifications for the appropriate server configuration (toolkit)
ENERGEIA www.energeia-med.eu supporting entrepreneurship in the renewable energy sector.	Joint contributions by projects' partners (including IPA). Joint methodology for renewable energy sector mapping. Good practices in supporting entrepreneurships in the renewable energy sector. Regional collaborative plans Report on business support paths. Guide for pilot action implementations Specific IPA partners' contributions **SERDA Sarajevo Economic Region Development Agency,** Bosnia – Herzegovina. Regional Survey on the renewable sources in B&H, including a SWOT and a CAME analysis of sector. Establishment of working local involving policy makers at the Federal ministry of industry, energy and mining. Good practice selection indicating the first private company in B&H which is producing electricity from renewable energy sources "Intrade-energija". Pilot Actions focused on education of business support actors and business ideas or start-ups through workshops on topics as finance Actions to raise the awareness in the field of renewable energy, as well as on innovation, research and development, technology transfer strategies and business models.

REMIDA	Remidaproject	Private-public-people partnerships (PPPPs) for EE and RES.	• Joint contributions by projects' partners (including IPA). • Local EE and RES roadmap • Adhesion Support to the covenant of mayors in 9 municipalities • Sustainable energy action plans • Schemes of Private Public People Partnerships • operational/investment assessment analysis • Investment plan • handbook on case studies • Pilot actions • Specific IPA partners' contributions **Capital City Podgorica,** Montenegro • Constitution of local working group • Inputs for the definition of sustainable energy action plan Municipality Gračanica (including baseline emissions definition and calendar of activities) • Identification of best practice on energy efficiency and public-private-partnership in B&H • Awareness raising activities, e.g. Organization of the Open Day
WIDER	www.wider-project.eu	Innovation and Development in the Energy Sector focused on elderly	• Joint contributions by projects' partners (including IPA). • Joint measures to favour innovation for eco-smart housing for elderly • Pilot activities management and implementation (eco-innovation vouchers to SMEs) • Local workshops, road shows and innovation fairs • User feedback Report • Networking strategy/plan • Specific IPA partners' contributions **SERDA Sarajevo Economic Region Development Agency,** Bosnia - Herzegovina • organization of 5 scenario local workshops • Innovation vouchers to 7 Bosnian small and medium enterprises working on energy efficiency and a sustainable and holistic approach towards Silver economy, eco smart housing and active ageing of the elderly. (1) Bright home my home, (2) Senior Tourism (3) urban roof garden (4) Sustainable and independent (5) Termoprost (6) Homes certification (7) Epsimax • Co-organization of Transnational Capitalisation Event on 'Eco-Smart Housing for Elderly (hosted by Central Europe Initiative, Trieste)
E2STORMED	www.e2stormed.eu	Transitioning towards a more energy efficient urban water management	Joint contributions by projects' partners (including IPA). Regional Working Groups on Energy Efficiency Storm water management system Decision Support Tool on scenarios related to water storm management in terms of costs, benefits and CO2 emissions reductions Common approach for pilot activities on Greenroofs Specific IPA partners' contributions **Old Royal Capital Cetinje,** Montenegro Pilots on conventional drainage in historic centre and new development area (Gruda Donje polje) half consolidated urban area. water reuse benefits, runoff transport, flood protection, Building insulation. Inputs to urban planning process of Old Royal Capital Cetinje. Strategic action plan. Constitution of local Working Groups on Energy Efficiency

GREENPARTNERSHIPS www.greenpartnerships.eu Green partnerships- for greener cities and regions	Joint contributions by projects' partners (including IPA).
	Approaches definition for implementation of energy strategies
	Common model for comparison of existing implementation approaches
	Common list of obstacles in implementation of local energy strategies
	Transnational Expert Working Groups
	Database of existing models, best practices, methodologies and indicators on implementation of energy strategies
	Guide for efficient implementation of local energy strategies by forming local partnerships
	Specific IPA partners' contributions
	Agricultural University of Tirana, Albania.
	Pilot activity, School of Manza municipality, Albania. Use of biomass and municipality waste to produce energy for schools and kinder gardens including awareness raising and training courses.
	Establishment of local action group
	Awareness raising events (e.g. open days, workshops)
	International conference: Green Energy and Environmental Science in Albania
	Hydro Engineering Institute Sarajevo (HEIS), Bosnia-Herzegovina.
	Pilot activity, increasing energy efficiency in eco-schools and public administration buildings. Elementary School Vrhbosna and Gymnasium Dobrinja in Sarajevo.
	Feasibility study on creation and support fund for energy efficiency housing.
	Energy audit.
	Awareness raising campaigns in schools and public buildings administrations.
	Establishment of local action group
	Institute for Strategic Studies and Prognoses, Montenegro.
	Feasibility study on installation of hydro power plants in Montenegro.
	Pilot activity, connection of mini-hydropower plant Jezerstica to the energy network.
	Sustainable energy action plan.
	Establishment of local action group
	Awareness raising events (e.g. open days, workshops)

2.1.4. Typology of deliverables. Common products delivered by projects were mostly in form of reports, studies and publications. According to the obtained answers, the following deliverables were identified by IPA partners as the most important ones: Report on pilot activities (85% of partners), good practices identification and public consultation (71%), report on communication and benchmarking studies (57%), databases and reports on the state of the art (42%), tools and good practice implementation (28%). Additionally, 100% of surveyed partners indicated that these types of deliverable and associated activities were the most appropriate for the achievement of their expected objectives.

2.1.5. Project quantitative contribution. This analysis field was focused on four quantitative variables of reference: (1) Number of emissions of CO2 (Ton equiv); (2) Installed power with renewable energy (MW); (3) Energy efficiency achieved (%) and (4) Investments triggered (€). For the first two variables, 100% of screened structures did not provide any information. As for values related to energy efficiency achieved and investments triggered only two partners answered, indicating 30% and 2.539,55 € respectively. According to comments provided by partners, this absence of information can be a function of several reasons such as: project methodologies do not allow measurement and/or calculation; project stage is too early to allow obtaining the values; and lack of knowledge and skills to make calculations.

2.1.6. Perception on synergies with local, regional and national policies. IPA partners established synergies with similar initiatives and policies notably at national and regional level. Seventy-one percent of the sample perceived these national and regional synergies as "satisfactory" while 14% considered that they were "excellent". With regard to local policies, established synergies were perceived as "satisfactory" by 42%; "very good" by another 42%, and "excellent" by 16%. By contrast, the level of synergies established with transnational initiatives (e.g. other projects, initiatives for Balkan or Mediterranean regions) was limited to 28% of partners, i.e., those who integrate Horizon-2020 and United Nations projects in their activities.

*2.1.7. Public targets and number***.** Public target identified by partners was in most cases Small and Medium Enterprises (90% of sample). Other types of target corresponded to the public sector; within these, local authorities were addressed by 85% of partners, regional authorities (71%) and national authorities (42%). Also, partners focused on other specific key targets such as: consumers (71%), citizens (42%), students (42%), and technicians (42%).

Concerning the number of beneficiaries achieved by IPA partners in their specific territories, 85% of the sample estimates that project activities covered between 100-1000 beneficiaries, while the remaining 15% indicates that they achieved between 10.000 and 100.000 beneficiaries.

2.1.8. Continuation of activities after the end of IPA grants. Partners' strategies allow already the identification of ways to continue activities after the end of IPA grants. In 85% of cases, screened stakeholders see IPA funding through European territorial cooperation as the clearest way to assure continuation. From a thematic point of view, the core object of new ideas is identified in wind and solar sector (renewable energy) and public buildings and eco-smart housing (energy efficiency). Most partners will work on activities related to evolution from mapping towards investors' engagement, public procurement, capacity building mostly focused on public authorities and SMEs, implementation (e.g. urban plans, SEAPs and good practices), awareness raising, follow-up actions of pilot activities, as well as replicability.

2.1.9. Main Difficulties faced in project implementation. Financial difficulties derived from slow payment process and reimbursements of expenditures were identified by 42% of sample as main administrative obstacles. Payments in advance corresponding to 10% of partners' budget are perceived as insufficient. From a thematic point of view, IPA partners considered that most important difficulties lie in national regulations gaps and incompatibilities with EU regulation, acquis criteria achievement[127] and lack of knowledge, experience and skills of public targets.

3. Case Study: GRASP Project and Green Procurement in IPA Countries

An example of specific contributions is given by outlining the case of two IPA partners in project GRASP (Green pRocurement And Smart city suPport in the energy sector) that developed and tested a method for electronic Green Public Procurement (e-GPP). The two IPA partners were from Albania and B&H (GRASP, 2015).

3.1 Desk research and analysis of results. Analysis of research results indicated that, in Albania, all knew what eGPP is and were aware of their National legislation. All PAs use the National Public Procurement System but none uses Green Procurement Policies during tendering. Even though all of the questioned SMEs stated that they offer green products, most did not know the requirements of the products/services they are offering. Save time, save money, and gain flexibility are the main reasons for PAs to use eGPP. The main barriers that they face in the use of eGPP are the higher cost of green products/services; lack of information and useful tools; and insufficient demand for green products/services. The main reasons for SMEs not to participate in an eGPP are the lack of information, lack of interest, and the low probability of success.

For SMEs, the main barriers for participating in an eGPP are the insufficient demand and high cost for green products/services. Both PAs and SMEs stated that they would like to receive training on: the identification of specs for Green products/services; and Quality Management and manuals elaboration.

In B&H most questioned users (PAs and SMEs) knew, or at least had an overview of, what Green Public Procurement is. However, almost all were not aware of the National and Regional Regulation in GPP, and this is mostly due to lack of legislation, interest, information and education. Both SMEs and PAs knew what e-GPP is, but they did not know if a National Regulation on electronic Public Procurement

[127] Acquis is intended as the conditions and timing of the candidate's adoption, implementation and enforcement of all current EU rules.

exists in Bosnia-Herzegovina; nor did they know its content. Nevertheless, the PAs seemed to have a bit more knowledge on these matters compared to the SMEs.

Even though 10/16 questioned SMEs stated that they offer green products and services, only one was familiar with the requirements of the products/services he is offering, whereas the majority of the PAs (10/17) stated that it was not familiar with SMEs that offer green services/products.

The main reason that PAs are not using electronic public procurement lack of technical resources. This is followed by low perceived probability of success, and lack of interest.

Lack of legal experience and lack of information are the main reasons that none of the questioned SMEs has ever participated in an electronic format e-GPP.

Other important reasons are lack of necessary skills, lack of time, and lack of human resources. For both PAs and SMEs, the main reasons for participating in an electronic GPP are, saving time, saving money, and environmental commitment – all equally important.

The most important barriers identified by the SMEs in accessing GPP are: higher cost of green products or services, lack of information & useful tools on administration, long process of bureaucracy, and lack of coordination between regional and national PAs. For the PAs the main barrier for accessing GPP is the lack of information and useful tools on the Administration side; and then follow the lack of legal experience, and the higher cost of green products or services.

Regarding the training they would like to receive, the SMEs are more interested in GPP legal framework and manuals elaboration. Both SMEs and PAs would like to be trained on IT tools for Energy Efficiency.

Figure 2: Main Barriers faced by Public Administrations of Albania in the use of eGPP.

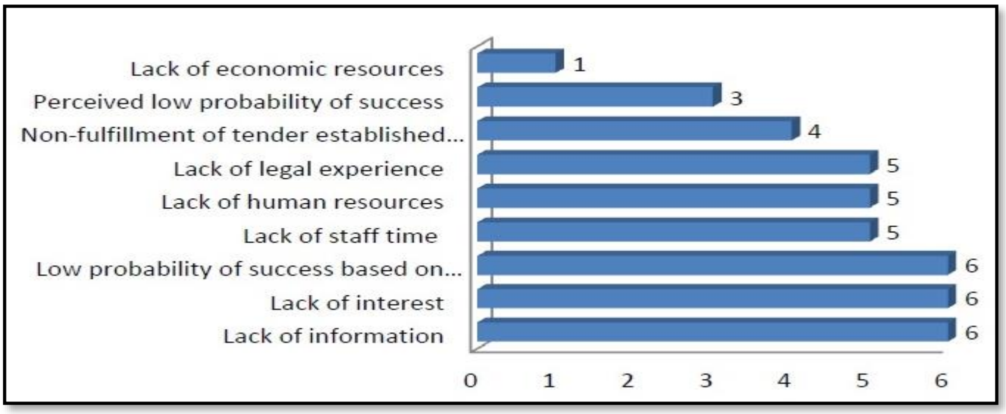

Figure 3: Main Barriers faced by SMEs of Albania in the use of eGPP.

Concerning the seminars about enterprises certificates, the SMEs are mainly interested in seminars about Environmental management systems, Eco design management, Eco-labeling and Energy management systems standards; whereas the PAs would like to attend seminars about Eco labeling, Environmental management systems, Eco design management, Energy management systems standards, and Carbon footprint. PAs show greater interest in receiving training compared to the SMEs.

3.2 Validation of results. For validating research results, all GRASP partners piloted or tested the electronic Green Public Procurement tool developed by the project. Each partner selected a specific EE/RES category to test. The results were evaluated through the Life Cycle Cost (LCC) tool developed by GRASP. This tool was mainly designed to compare two similar products, i.e., one with a lowest up-front price, and the other with a sustainable lowest price (green product). The LCC tool also provides (a) the calculation of the absolute cost of a new product by analysing its lifetime cost, and (b) the valuation of a new substitute product, which is based on examining the savings produced by this product. Having completed the evaluation, the winning product can be compared to others, in order to select the best option based on LCC. The aim of this tool is to show that the misunderstanding that green products are more expensive is often false, especially in long-term projects.

In the case of the University of Vlora (ALB), an auction tender was tested with reserved procedures and the lowest price as the award criterion. The tender was carried out with the participation of five SMEs of the IT sector. Over the five year period, the environment-friendly product failed to save more money than the up-front lowest price alternative. However, it saved 0,124 tons of CO_2 compared to that alternative.

In the case of RAIS (B&H) the test-tender was an open procedure for the selection of facade works for the Administrative center of City of East Sarajevo, with the classical method compared to the GRASP method. The case has to do with a building retrofitting operation that uses multiple forms of energy source. Three different sources had to be taken into consideration: natural gas, fuel oil, and electricity. The overall cost is calculated as the sum of three different LCC sheets.

Table 3 describes the changes in the consumption of natural gas. Compared to the original building, the improved one obtains use of natural gas that is reduced by 50%. Beyond the energy saving that is due to the reduction of fuel consumption, the operation allows the reduction of CO_2 emissions. The fourth table shows the difference in electricity before and after building retrofitting. In this case the consumption of energy is higher in the improved building. The fifth table describes the use of fuel oil. Energy consumption for the improved building is zero, while prior to retrofitting the consumption was high (13764 l). The final assessment is based on the sum of the total LCC of all three different energy sources; it indicates that the environment-friendly option carries lower LCC but higher CO_2.

4. Conclusions

In the period 2007-2013, the MED Programme has contributed to increasing capacities of IPA partners engaged in projects of the programme 5th call. Analysed results have been achieved by exercising European Territorial Cooperation amongst Mediterranean partners with a direct effect on the stimulation of use and promotion of RES and EE in IPA territories.

Achieved results should be considered as interface of new interventions in same or similar thematic and targeted territories. Although project outputs are of varied nature they could be used individually or collectively to define starting points, references or baselines of future projects and initiatives.

Tables 3: Results of testing tool for multiple energy sources (natural gas, electricity and fuel oil).

Case: RAIS (natural gas)

	Lowest Price		Environment-friendly Price	
Price				
Price per product [Euro/product]	0,00	€	0,00	€
Lifetime [years]	1,00	y	25,00	y
Comparable number of replacements [n]	25,00	n	1,00	n
Total Cost [€]	0,00	€	0,00	€
Duration				
Lifetime [years]	25	y	25	y
Average yearly time usage [hours/year]	1.000	h/y	1.000	h/y
Total usage time [hours]	25000	h	25000	h
Number of purchases [n]	1	n	1	n
Total [hours]	25000	h	25000	h
Maintenance				
Number of years [years]	25	y	25	y
Units per year [work hour, kwp, page…]	0,00	n	0,00	n
Cost per unit [€]	0,00	€	0,00	€
Total [€]	0	€	0	€
Energy costs				
Price of energy [€/l]	0,57	€	0,57	€
Energy Consumption [KW or Watt e/t, m3 l...]	26741	W	10899	W
Lifetime energy consumption [kWh e/t, m3, l...]	668.534,50	kWh e/t	272.466,00	kWh e/t
Total energy costs [€]	383.070,27	€	156.123,02	€
Emissions				
Kg of CO2 per kWh, m3, l or kg	0,200	kg	0,200	kg
Total of CO2 avoided [ton]	0,000	t	79,214	t
Economic value of CO2 [€/ton]	7,02	€	7,02	€
Total economic value of avoided CO2 [€]	0,0	€	556,1	€
Total life cycle costs	**383.070,27**	**€**	**155.566,94**	**€**

Table 4: Results of testing tool for multiple energy sources (natural gas, electricity and fuel oil).

Case: RAIS (electricity)

	Lowest Price		Environment-friendly Price	
Price				
Price per product [Euro/product]	0,00	€	0,00	€
Lifetime [years]	25,00	y	25,00	y
Comparable number of replacements [n]	1,00	n	1,00	n
Total Cost [€]	0,00	€	0,00	€
Duration				
Lifetime [years]	25	y	25	y
Average yearly time usage [hours/year]	1.000	h/y	1.000	h/y
Total usage time [hours]	25000	h	25000	h
Number of purchases [n]	1	n	1	n
Total [hours]	25000	h	25000	h
Maintenance				
Number of years [years]	25	y	25	y
Units per year [work hour, kwp, page…]	0,00	n	0,00	n
Cost per unit [€]	0,00	€	0,00	€
Total [€]	0	€	0	€
Energy costs				
Price of energy [€/l]	0,04	€	0,04	€
Energy Consumption [KW or Watt e/t, m3 l...]	166146	W	300514	W
Lifetime energy consumption [kWh e/t, m3, l...]	4.153.650,75	kWh e/t	7.512.846,50	kWh e/t
Total energy costs [€]	147.039,24	€	265.954,77	€
Emissions				
Kg of CO2 per kWh, m3, l or kg	0,386	kg	0,386	kg
Total of CO2 avoided [ton]	0,000	t	-1296,895	t
Economic value of CO2 [€/ton]	7,02	€	7,02	€
Total economic value of avoided CO2 [€]	0,0	€	-9.104,2	€
Total life cycle costs	**147.039,24**	**€**	**275.058,97**	**€**

Table 5: Results of testing tool for multiple energy sources (natural gas, electricity and fuel oil).

Case RAIS (fuel oil)

	Lowest Price		Environment-friendly Price	
Price				
Price per product [Euro/product]	0,00	€	0,00	€
Lifetime [years]	25,00	y	25,00	y
Comparable number of replacements [n]	1,00	n	1,00	n
Total Cost [€]	0,00	€	0,00	€
Duration				
Lifetime [years]	25	y	25	y
Average yearly time usage [hours/year]	1.000	h/y	1.000	h/y
Total usage time [hours]	25000	h	25000	h
Number of purchases [n]	1	n	1	n
Total [hours]	25000	h	25000	h
Maintenance				
Number of years [years]	25	y	25	y
Units per year [work hour, kwp, page…]	0,00	n	0,00	n
Cost per unit [€]	0,00	€	0,00	€
Total [€]	0	€	0	€
Energy costs				
Price of energy [€/l]	1,04	€	1,04	€
Energy Consumption [KW or Watt e/t, m3 l...]	13764	W	0	W
Lifetime energy consumption [kWh e/t, m3, l...]	344.087,66	kWh e/t	0,00	kWh e/t
Total energy costs [€]	357.162,99	€	0,00	€
Emissions				
Kg of CO2 per kWh, m3, l or kg	0,275	kg	0,275	kg
Total of CO2 avoided [ton]	0,000	t	94,624	t
Economic value of CO2 [€/ton]	7,02	€	7,02	€
Total economic value of avoided CO2 [€]	0,0	€	664,3	€
Total life cycle costs	**357.162,99**	**€**	**-664,26**	**€**

The MED Programme, along with most ETC Programmes is placing high emphasis on capitalisation strategies addressed by projects and partners, which should be able to either improve what exists or create new and innovative solutions, based on acquired experiences. Accordingly, future IPA interventions should be more ambitious when addressing capitalisation in their daily activities.

Measurement of projects' impact in quantitative terms provides additional and more concrete elements for assessing related activities. Renewable Energy and Energy Efficiency interventions should integrate more extensively key indicators (e.g. renewable energy triggered), not only to allow better evaluation but also to follow specific objectives established by the Energy Treaty Community and Directive 2009/28/CE.

The case study of GRASP project provided evidence on green e-procurement applied to the RES and EE sectors. The experience reflects both the challenges and opportunities derived from integrating green practices in Public Administrations and SMEs of Albania and B&H. Obtained results suggest the potential of implemented tools to motivate changes and improve policies at subnational and national sector.

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Clean Coal Technologies

Establishment of a Policy and Legal Framework for Carbon Capture Storage (CCS) Technology Development in Taiwan: A Critical Review

by

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Abstract

Taiwan is a manufacturing powerhouse that produces high levels of carbon emissions. It is actively seeking to deploy carbon capture and storage (CCS) to reduce these high emission levels. Taiwan possesses potential storage sites both on and off the island. Therefore, the possibility of employing CCS as a tool to fight climate change is quite strong. This paper explores policies and legal regimes. In particular, it examines incentive mechanisms currently employed in developed countries (e.g., mechanisms employed in the European Union and in G8 member countries). This paper also offers insight into how Taiwan might implement a successful CCS program.

Keywords: Carbon capture and storage, CCS, IEA Model Regulatory Framework, storage, European CCS Directive of 2009.

1. Introduction

The Industrial Revolution, which was bolstered by fossil fuel combustion, led to many positive effects. However, it also caused large-scale environmental pollution. Carbon-based fuel emissions are generally considered one of the causes of climate change. Advocates believe that the devastating effects of climate change can be reversed by the adoption of mitigation practices. The IEA believes Carbon Capture and Storage (CCS) is a promising option that might produce approximately 22% of required carbon emission reductions [1]. The contribution of CCS and other technologies in emission reduction is illustrated in Figure 1.

Many developed nations have actively promoted the use of CCS to help meet their carbon targets and allow the continued use of coal in the energy mix. However, CCS is a high-cost option. It requires the use of incentives to encourage deployment. These incentives focus on the use of market-based mechanisms, favorable tax environments, and direct public funding to promote the use of CCS. Taiwan has one of the toughest energy situations of all industrialized countries (it imports 99.4% of its energy). Taiwan is a manufacturing powerhouse that produces high levels of carbon emissions. It is actively seeking to deploy CCS as a way to reduce these high levels. Taiwan possesses potential storage sites both on and off the island. Therefore, the possibility of Taiwan's use of CCS as a tool to fight climate change is quite strong. The potential rationales for its use include: (1) Coal will continue to be the most stable and cheapest energy source. It will continue to serve as feedstock for the refinery industry, as well as for electricity producers in Taiwan. (2) The commercialization of coal gasification by the use of CCS technology is the target of Taiwanese R&D investment. (3) The integration of intermittent electricity from renewable energy with CO_2 captured by CCS projects that produce chemicals will lead to a win-win status [2]. However, recently, the media appears to have turned against CCS development. Important local newspapers used headlines to warn about possible earthquakes and other deadly effects that might result from CCS development and storing CO2 underground [3]. Shocking images of dead people and cattle have also appeared. In fact, in 2006, similar news stories were published. At that time, the state-owned petroleum company, the CPC, intended to re-use existing oil wells and pipelines for enhanced oil recovery (EOR) and CCS purposes under the 2006 Mining Act. However, the draft plan was also published in the same newspaper and the plan was stopped [4]. In this author's preliminary opinion, one key factor is the fact that no regulatory regimes have been enacted to encourage local citizens' positive attitudes. This fact motivated this author to examine other relatively successful regimes' efforts to develop CCS.

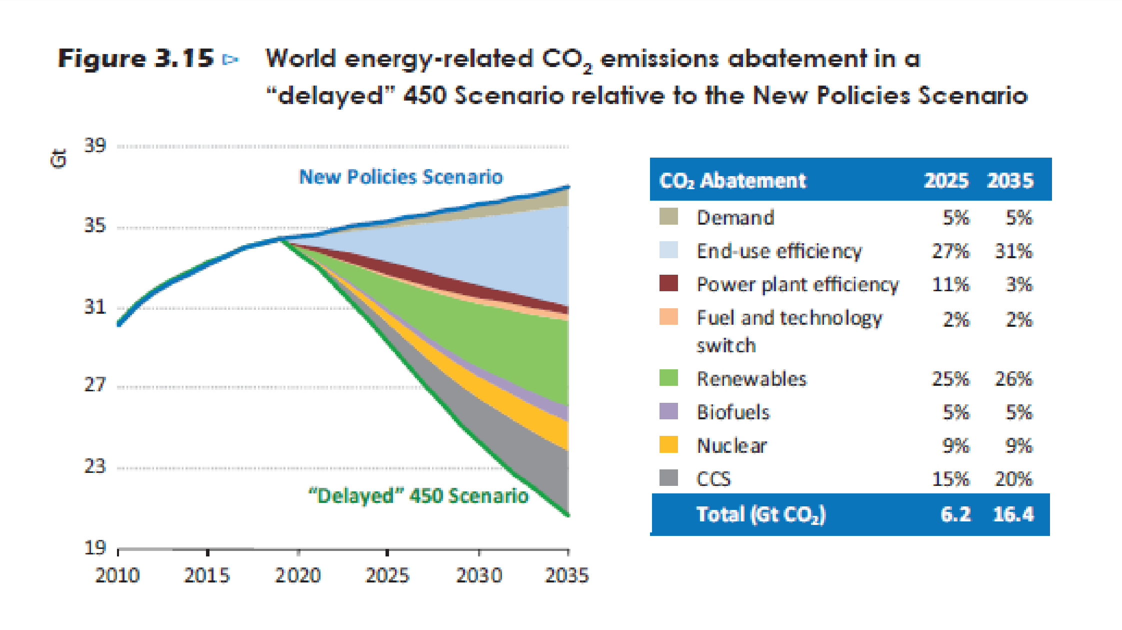

Figure 1: World Energy-related CO_2 Emissions Abatement Included in the 450 Scenario, Relative to the New Policies Scenario.

The main purposes of this article are to investigate the policy and legal framework of CCS in the literature, to identify the key elements of CCS, and to use Taiwan as a case study. Based on preliminary research, it appears that many CCS projects are being implemented around the world [5].

The overall frameworks used to create these CCS projects involve multiple successful elements, including *technology, R&D, competent authorities that draft good policies, laws (sufficient incentives and appropriate, rather than excessive, regulations), as well as the adequate implementation of small demonstrations.* In addition, the element of *public perceptions* has recently become a separate issue that is becoming more important under the promotional framework. Many recent studies have addressed this issue See for example, [6]. However, because of this article's page limits, the issue of public perceptions will be excluded from this article. This author will investigate into the lessons from related regime, particularly EU CCS Directive and IEA Model Regulatory Framework, apply in Taiwan, and provide analysis and solutions.

Finally, it is worth mentioning that this article is a condensed version of the multi-year research project report on CCS funded by the First phase National Energy Programme and conducted by the only legal team in Taiwan [7]. The main research methodology of this research is the comparative policy and law approach, which is quite unique for this journal. Yet, all of the lessons drawn from in this article are based on the real lessons learnt by the EU, the IEA, and other countries. These recommendations can play a role in persuading the government to reform its policy and legal framework. For instance, the proposal to exempt small-sized carbon storage pilot test projects from the rigid rule of environmental impact assessment was developed in 2013, and the deliberation on the formulation of strategic environmental assessment report, the discussion process in which this author is very involved, is currently under preparation. Thus, this latest development also shows how the lessons from early runners in the international community could be very helpful for latecomers like Taiwan. Hopefully, such a framework could also be beneficial for other developed countries wishing to develop CCS as their solution to climate change.

2. CCS and Technology R&DD

2.1. Main Lessons: From R&D to RD&D Funding

Globally, a significant amount of R&D funding has been spent on CCS. Much of this research funding has been provided by international organizations, the EU Framework Programme (FP), national governments, and private companies (Shell, Alstom, etc.) around the world. See for example, [8]. For instance, EU FP has long been supported to the development of CCS under the topic of "CO2 capture and storage technologies for zero emission power generation." [9].

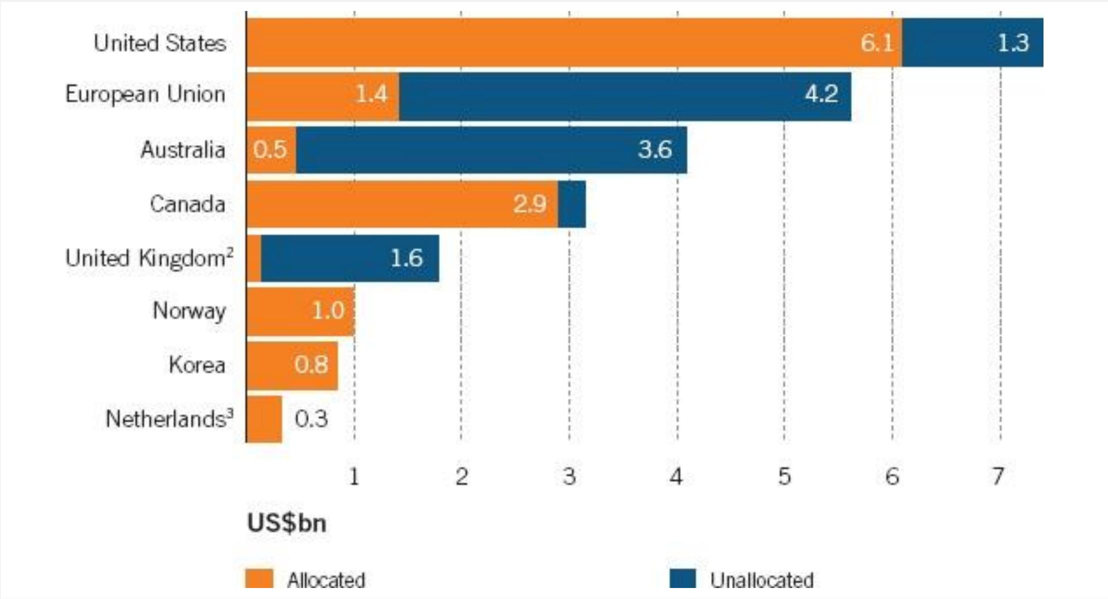

Figure 2: Main CCS Countries' Funding of Demonstrations.

As technology continues to mature, the focus shifted towards the deployment of demonstration projects. The trend has moved away from R&D (research and development) and toward RD&D (research, demonstration, and development) [10]. The recent demonstration funding performed by major CCS countries is illustrated in Figure 2.

2.2 R&D Funding in Taiwan

In Taiwan, funding for CCS R&D is provided by diverse sources, such as Tai-Power (a state-owned electricity company), CPC Corporation (a state-owned petroleum company), the National Science Council (NSC), which was renamed as the Ministry of Science and Technology recently, the National Energy Programme: Master Programme on Clean Coal, the Environmental Protection Administration (EPA), and the Bureau of Energy, Ministry of Economic Affairs (MOEABOE). CCS-related research is also being conducted by many universities, industries, and think tanks, such as the Industrial Technology Research Institute (ITRI), the Chung-Hua Institution for Economic Research (CIER), the Taiwan Institute of Economic Research (TIER), Institute for Nuclear Energy Research (INER), and Sinotech Consultants Inc. (Sinotech Inc.). Examples of projects include the Geological Survey and the Pilot Study of Carbon Storage, funded by Tai-Power, which was conducted by Sinotech Consultants between October 2011 and June 2013 [11]; ITRI's development of clean coal, carbon capture, and sequestration from February 2010 to December 2010, which was funded by MOEABOE [12]; INER's Strategic Planning for National Science and Technology Program-Energy (Nstpe) Clean Coal Master Project, which was funded by the NSC under the National Energy Program [13]. Research topics are not limited to technology. Other topics include economics, law, policy, strategy, public perceptions, and so on. For instance, among the published projects' titles are "The Recommendation Legal Framework of Developing Carbon Capture and Storage in Taiwan" [7], "CCS Technology Roadmap and Industry Development Strategy" [14], "Economics Review of CCS Development and Prospective" [15].

To provide a networking platform, two CCS-related Alliances were created in Taiwan: (1) the Ministry of Economic Affairs (MOEA) created the CCS R&D Alliance [16], and (2) the EPA created the CCS Strategy Alliance [17]. Therefore, it appears that R&D is not struggling in Taiwan.

However, in reality, Taiwan's technology R&D directions should be fine-tuned. An excessive number of R&D and feasibility studies have been conducted. The efforts of different projects conducted by the NSC, MOEA, and EPA have overlapped. Based on the aforementioned titles of the projects, a lot of attention has been paid to technological RD&D and economics research. Less attention has been paid to non-economics social science research. Perhaps this variance is related to the existence of too many technology and economics energy think tanks in Taiwan. Although a limited number of capture demonstration projects have been conducted, insufficient funds and a variety of regulatory barriers have prevented the performance of additional demonstrations and the drilling of carbon storage. To remedy this situation, the following factors should be addressed.

3. Appropriate, Coordinated, and Competent Authorities to Promote CCS

3.1. Main Lessons

To facilitate the development of CCS strategies, policies, and laws, it is important to examine bureaucratic issues. CCS applications are complex and comprehensive. With respect to bureaucracy, unavoidable *cross-ministerial and cross-department* issues exist that involve science, environmental, economics, mining (oil and gas), and climate authorities, and so on. For instance, in the Netherlands, the main authority in charge of developing and permitting carbon storage is the economics and mining authority (the Minister of Economic Affairs, Agriculture and Innovation), but spatial planning and pipeline issues are handled by the environmental authority (Minister of Infrastructure and Environment) [18]. In the UK, the environmental authority is in charge of environmental permission and environmental damage issues, while the energy policy authority (DECC) and the energy regulator (Ofgem) have responsibility for the incentives and RD&D of the CCS projects [19].

Yet, in spite of the inevitable structures of diverse authorities resulting from the division of different functions inside different governmental departments, the identification of a "main" authority is very important during the comparative process for this author. If we review practical development experiences, we will discover the experiences of a number of different competent authorities. For example, the Norwegian oil and petroleum authority maintains Sleipner gas field. Netherlands relies on its mining authority, the UK relies on its energy and climate authorities, and the US relies on its energy authority.

However, a common feature exists: A pluralistic and vague main authority should be avoided to prevent the issue of "everybody's business being nobody's business." It does not matter which type of authority formally addresses CCS issues. However, a one-stop shop or key authority must be developed that will maintain substantial authority and seriously address CCS matters. In the experience of the UK, for instance, the CCS incentives scheme and regulatory matters were driven by the ambition of the DECC [20].

3.2. Lessons for Taiwan

In Taiwan, the lack of a fully competent authority is also an issue. Although many authorities operate in the R&D arena, this is not the case with respect to detailed policy and regulatory issues. Currently, three main authorities manage the promotion of CCS R&D (i.e. EPA, MOEA, and NSC). Except for NSC's clear R&D duties, MOEA and EPA also expend significant amounts on R&D. Yet, they pay limited attention to their main task, which is the development of further *policies* or *legal* regimes. For example, a vacuum exists with respect to the EHS (environment, health, and safety) regulations. During a private meeting, the EPA stated that it did not believe any laws or ordinances should be drafted to accommodate CCS requirements. Yet, based on the experiences of the aforementioned countries, the revision of pre-existing regulations for the needs of CCS is very important. In the UK, for example, the Energy Acts of 2008 and 2011 were amended, and new regulations were proposed, such as the Storage of Carbon Dioxide (Licensing etc.) Regulations 2010.

In addition, the authority to provide sufficient incentives is also very important. The MOEA appears to be unable to provide sufficient funding to push CCS beyond R&D. This may explain why current practice favors the easy case of enhanced gas recovery (EGR) conducted by the CPC. It can be difficult to perform any new drilling because of the lack of incentives and regulations. The aforementioned impasse of June 2013 is also related to new drillings under a pilot test project. It is Tai-Power which is conducting the expenditure to carry out the pilot test. Yet, without further funding schemes from the government, it is unlikely to move ahead to larger-scale operations. Thus, such reliance on a state-owned energy company's funding to develop carbon storage is really unique if looking at the key developments in the UK and the Netherlands.

Thus, how to distribute the work among multiple departments inside government could determine the success of a CCS policy and its legal regime in a country. Facing potential conflict between the incentive authority and the EHS regulatory authority, which authority should be principally in charge of developing CCS in Taiwan? Based on the international experience, we can opt for either an economics or a climate/environmental authority choice. Having learnt the lessons of the international experience, this article urges that the EPA should take the lead in formulating CCS regulations and adopt the primary role. There are several reasons for justifying such a statement. Firstly, the EPA is the main climate authority, and there is a close relationship between the adoption of CCS and emission reduction. Secondly, if Taiwan were to choose the Mining Act to deal with the regulation of CCS, the EPA would be the new competent authority following the government's reorganization. Thirdly, the EPA is also responsible for potential environmental pollution and the EIA resulted from the development of CCS. Fourthly, six types of greenhouse gas, including CO2, are designated as air pollutants by the EPA's regulations [21] Thus, the funding scheme to reduce GHG gases could be used to reduce CO2 by CCS as well. The EPA could also design a further incentive scheme under the Air Pollution Act. Finally, the most important reasons relates to the political will of the EPA to oversee CCS matters. The new minister of the EPA is a professor who specializes in geosciences [22]. In 2013, as the professor of National Taiwan University, he wrote a newspaper editorial giving strong support for CCS and correcting the untrue claims made by a newspaper [23]. For these reasons, the EPA seems to be in a better position to promote and regulate CCS than the MOEA in Taiwan.

4. Policy Supports for CCS

4.1. Main Lessons

CCS also involves cross-policy matters that can be integrated into multiple policies, such as energy, climate, industrial, science, technology, marine, economic, and so on. For example, in the EU, a wide range of policies has been instituted to support CCS development. Other countries that promote CCS also maintain similar policy structures, such as members of the Carbon Sequestration Leadership Forum (CSLF). This article will summarize the key policies of the EU in Table 1. More analysis will be presented in Section 4.3.

4.2. Lessons for Taiwan

In Taiwan, a policy structure similar to the ones in Table 1 can be also identified. Table 2 will provide an overview of the role of CCS in related policy papers.

4.3. Analysis

Table 1 and Table 2 look quite similar at first glance. However, if we compare these policy elements with the policy elements of EU and other CCS countries, it appears that Taiwan's current policies may become policy barriers.

The first important element relates to legal binding emission reduction targets that support CCS development. For instance, the emission reduction target and other targets of EU's 2020 20-20-20 vision depend on a certain type of emission reduction environment and determine the distribution of work between CCS and renewable energy.

Table 1: CCS-related policies in the EU.

Type of policy	Policy documents
1. Energy policy	● A strategy for competitive, sustainable and secure energy [24] ● European Energy Programme for Recovery [25] ● Energy Security and Solidarity Action Plan [26] ● An Energy Policy for Europe [27] ● Green Paper: A European strategy for sustainable, competitive and secure energy [28]
2. Research & innovation policies	● Demonstration of the capture and storage of CO2 [29] ● Strategic Energy Technology Plan (SET Plan) [30] ● Seventh Framework Programme (2007 to 2013) [31]
3. Climate policies	● SET-Plan for the development of low carbon technologies [32] ● Sustainable power generation from fossil fuels [33]

Table 2: CCS Related policy in Taiwan.

Type of policy	Policy documents
1. Science and technology	● General Direction of Low Carbon Environment: White Paper of Science and Technology R&D in Taiwan (2011–2014) [34] ● Specific: NSC Energy Programme: Clean Coal Master Programme; MOEA: Energy R&D White Paper 2007 [35]
2. Industrial policy	● MOEA, White Paper on Energy Technology and Industry 2014 [36] ● MOEA: White Paper on Energy Technology and Industry of 2012 [37] ● White Paper on Energy Technology and Industry 2010 [38]
3. Energy policy	● MOEA: 2008 Sustainable Energy Policy Framework [39] ● Conclusion report of 2009 National Energy Conference [40] ● 2012 Energy Development Framework [41]
4. Climate and energy policy package	● 2010 National Emission Reduction and Energy Conservation Programme (Master Plan on Energy Conservation and Emission Reduction 2010) by Carbon Emission Reduction and Energy Saving Commission, The Executive Yuan [42]

(source: compiled by this author)

However, in Taiwan, no legal embedded emission reduction targets have been determined. This made the government unwilling to include CCS in concrete energy policies. The government only includes CCS in abstract R&D policies. CCS was expected to come into play only after 2020. For instance, under the 2010 National Emission Reduction and Energy Conservation Programme, CCS was included in Landmark Programme VII, rather than in Landmark Programme II. This means CCS is merely considered a "tech," rather than a viable option under Landmark Program II: Low Carbon Energy System prior to 2020. Thus, Taiwan should set legal binding emission reduction targets and then consider CCS an energy policy option, rather than an R&D policy.

The second important element in this policy involves the "quantitative" demonstration targets for carbon storage. For instance, in EU's the Future of Carbon Capture and Storage in Europe, "the European Council's decision back in 2007 to support up to 12 large-scale demonstration projects by 2015." [43]. However, in Taiwan, the policy adopts a primarily "qualitative" approach that fails to mention a quantitative CCS target.All of the policy documents in Table 2 use empty wording to introduce the concept of CCS in Taiwan. For instance, the recent 2012 policy document provides that "with a view to reducing the carbon emission from coal, the introduction of clean coal technology may be considered at an appropriate time" [41]. A similar policy statement can be found in the important 2010 climate policy document: "the development of CCS technology to facilitate the carbon emission reduction [42]. No quantitative target has been mentioned in Taiwan.

5. Legal Regime for CCS

Currently, many countries have developed legal regimes for CCS development. See for example, [44]. The most structural of these policies are the EU CCS Directive and the IEA Model Regulatory Framework. [45], [46]. Thus, this article will also base its analysis on these two main documents, as well as on other supplementary documents to provide appropriate recommendations for Taiwan.

5.1. Incentives to Promote CCS

5.1.1. Main Lessons

Based on a review of the IEA Model Regulatory Framework and the EU CCS Directive, it is apparent that the design of legal incentives should embrace two elements: (1) Technology Development Cycle thinking and (2) Life cycle support thinking. The former hopes to extend the development stage beyond R&D. The latter focuses on upfront CCS costs, as well as on the operational and closure costs of carbon storage.

To accommodate the needs of these two directions, the IEA proposes six regimes to promote CCS. They include (1) carbon taxes, (2) cap and trade, (3) project-based mechanisms, (4) Feed-in Tariffs, (5) Emission performance standards, and (6) CCS Technology Mandate) [46]. Under the EU regime, the EU CCS Directive provides three key elements to encourage the CCS development: (1) Capture Ready Obligations, (2) R&D Exemptions (This directive shall not apply to geological storage of CO2, with a total intended storage below 100 kilotonnes, undertaken for research, development, or testing of new products and processes), and (3) exemptions from environmental laws (e.g. waste directives, waste transportation, waste shipping, and so on) [45]. In addition, to provide further funding for CCS demonstrations, funding will be made available under NER 300, FP7, FP8, or the European Energy Programme for Recovery (EEPR), and so on.

5.1.2. Lessons for Taiwan

Currently, funding is solely available for *preliminary, feasible, and small pilot test research*. Funding sources include the Energy Research and Development Fund under the Energy Management Act, the Petroleum Fund under the Petroleum Management Act, and the National R&D Budget.

The weakness of this regime is apparent. It lacks "Life Cycle Incentives" and "Technology Cycle Incentives" (R&D → Small demonstration → Large demonstration → Commercialization). Because of the lack of "Investment (or demonstration) Subsidies," funding is only available for small pilot tests. According to an interview with Sinotech Inc. and Tai-Power, funding is insufficient for medium- to large-scale demonstration sites, not to mention the absence of "luxuries," such as feed-in tariffs or other direct support schemes to encourage further large scale CCS applications.

5.1.2.1. Recommendation: Technology cycle Aspect

Based on lessons learned from the EU and the IEA, and considering Taiwan's non-electricity liberalization environment, this article provides the following recommendations. The main players of CCS are defined as Tai-Power, CPC, Private IPPs, and energy intensive industries (e.g. cement, steel, and so on). The incentives to be provided during different technology cycle stages include the following. The rationale will be provided later.

Table 3: Recommendation for Taiwan's Incentive Scheme.

Technology cycle phases	Provided to:	Measures
Small demonstrations	Tai-Power, CPC, private IPPs, and energy intensive industries (cement, steel, and so on)	● Enact "CCS Demonstration Subsidy Ordinances" (similar to geothermal and offshore wind) ● Tendering: the above-mentioned subsidy can be allocated via the tendering process [applies to all] ● Provide tax incentives
	[existing or new IPPs	● Provide long-term power purchase agreements (PPA) for existing or new IPPs willing to perform CCS demonstrations
Large demonstrations	Tai-Power, CPC, private IPPs, and energy intensive industries (cement, steel, and so on)	● Enact "CCS Demonstration Subsidy Ordinances" (similar to geothermal and offshore wind) ● Provide low-interest loans and guarantee ordinances for CCS [applies to all] ● Offer tax incentives [applies to all]
	[Tai-Power, IPPs]	● Enact emission performance standards [Tai-Power, IPPs] ● Develop technology mandates for new power plants: CCS-Ready
Commercialization and large-scale applications	Tai-Power, CPC, private IPPs, and energy intensive industries (cement, steel, and so on)	● Offer tax incentives [applies to all] ● Provide low-interest loans and guarantee ordinances for CCS. [applies to all]
	[IPP, Tai-power]	● Provide RPS (renewable portfolio standards), or tendering, FIP, fixed FIT for IPP, Tai-power
	[energy intensive industries: cement, steel, and so on]	● Offer net metering for energy intensive industries: cement, steel, and so on

Based on a review of the literature, there is a comprehensive incentives scheme provided by the Zero Emission Platform [47]. The multiple tools, including tax credits, loans, investment subsidies, feed-in tariffs, tendering, certificate systems, etc., are recommended for different technology deployment stages.

To apply such an approach in Taiwan, in terms of the technology cycle, there would need to be more R&DD activities at the small demonstration phase. So far, in the field of carbon storage, only one drilling project by Tai-Power and one EGR by CPC are in place. It seems the provision of investment subsidies and funding from the government by a subsidy ordinance would be very useful for removing the financial barriers, with a view to increase the small demonstrations. The distribution of the related funding could also follow the EU NER 300's tendering approach. Finally, the tendering process for new independent power plants (IPPs) should integrate those fossil fuel power plants with small-scale capture facilities. A special purchase rate to secure the investment security of such projects could be recommended as well.

At the large-scale demonstration stage, the incentives scheme should be reinforced. Again, in applying the ZEP's recommendation in Taiwan, there may be both a lax and a relatively strict approach. The former approach borrows the technology mandate idea from the EU CCS Directive in developing a carbon capture technology mandate for new power plants. Yet, a relatively more aggressive approach would be to apply emission performance standards for all fossil fuel power plants. Under such regulations, all fossil fuel power plants belonging to Tai-Power and IPPs might be forced to use capture technology.

If CCS technology is maturing, then the incentive regime to promote CCS could be similar to those promoting renewable electricity. Thus, the incentives focusing on electricity generation, such as feed-in tariffs, tendering, renewable portfolio standards, and net-metering, could be adopted at this stage. Compared with large or small demonstration stages, the main difference is the tendency toward investment subsidies/grants. At this stage, investment subsidies are weak and have been replaced by more electricity generation-oriented incentive schemes.

5.1.2.2. Recommendation: Life-cycle Aspect

Another aspect of recommendations could focus on the life-cycle development of CCS.

Firstly, a demonstration/investment subsidy ordinance scheme to provide subsidies for carbon capture, transportation pipelines, and carbon storage plays a key role in such life-cycle incentive ideas, while at the same time, a tax credit and low-interest loan guarantee scheme are recommended as well. Secondly, for carbon storage, special attention has to be paid to the preparatory stage and the risk of developing carbon storage. The exploration risk of finding a suitable site or the associated financial burden could be resolved by exploration subsidies or exploration loans. Thirdly, for carbon capture installations, an electricity generation-oriented incentive scheme should be considered. The weaker net-metering scheme or RPS and the more favorable scheme of long-term PPAs or feed-in tariffs could be considered. Finally, for carbon transportation pipelines, extra incentives would also be important.

5.2. Regulations of CCS

5.2.1. Main Lessons

Based on a preliminary review of regulatory regimes employed in different jurisdictions, it appears that concerns are quite similar. Firstly, some consideration should be given to CCS installation chains, including carbon capture, transportation pipelines, shipping, and carbon storage. Secondly, particular attention should be paid to current less-regulated regimes in relation to carbon storage. A life cycle that includes carbon storage regulations should be introduced. Therefore, this article will focus on the development of a life cycle regime for carbon storage, as the existing legal regime is relative capable of dealing with capture and transportation facilities.

Life cycle concepts differed slightly between the IEA and the EU. (Figure 3) However, they can be compared. This article will also provide a comparison table of legal texts. Based on the IEA Model Regulatory Framework and the EU CCS Directive, a summary of five similarities between the EU and IEA carbon storage regulatory regimes is listed below.

1. Seamless “Permission” (or notification).
2. Seamless “Plan” of Storage Operators.
3. Seamless “Distribution of Duties” between Authority and Operators.
4. Seamless “Distribution of Liability” between Authority and Operators.
5. Seamless Distribution of “Monitoring” Duties Between Authority and Operators.

The regulatory regimes are quite similar. The relationship between IEA and EU regulatory regime can be summarized as Table 1. Of all the regulations, the environmental concerns dealt with by related environmental regulations play a relatively big role. In the UK’s experience, a lot of regulations have been revised, such as the Energy Act 2008 (Consequential Modifications) (Offshore Environmental Protection) Order 2010, the Energy Act 2008 (Consequential Modifications) (Offshore Environmental Protection) Order 2010, the Environmental Damage (Prevention and Remediation) Regulations 2009, and the Environmental Liability (Scotland) Amendment Regulations 2011. When drawing up environmental regulations, the *environment impact assessment* regime plays the key role.

The considerations of the EIA in related regulation revisions (Storage of Carbon Dioxide (Amendment of the Energy Act 2008 etc.) Regulations 2011) is adopted. Additionally, the UK even conducted the world’s first strategic environmental assessment for a framework for the development of clean coal. See, for example, DECC [48]. The UK’s experience also shows how important environmental concerns are during the process of formulating regulations for development of CCS technology.

5.2.2 *Lessons for Taiwan*

5.2.2.1. Overall Regulation Issues

Currently, a regulatory vacuum exists for carbon storage in Taiwan. In addition, there limited life cycle regulatory thinking exists. These attitudes may be related to the perception that carbon storage is solely an R&D activity, rather than a viable energy policy option. Hence, it is believed that regulation is not required. Yet, as shown in the aforementioned headline news for 25 June, this perception must change because small pilot tests require legal intervention to provide green lights. This reflects the need for regulatory intervention.

According to a preliminary analysis performed by a government study, many types of legislation may be related to CSS development, including planning laws, pollution (air, water, waste) laws, Environmental Impact Assessment (EIA) laws, SEA(strategic environmental assessment) Laws, public participation laws, information disclosure laws, disaster acts, and so on [7].

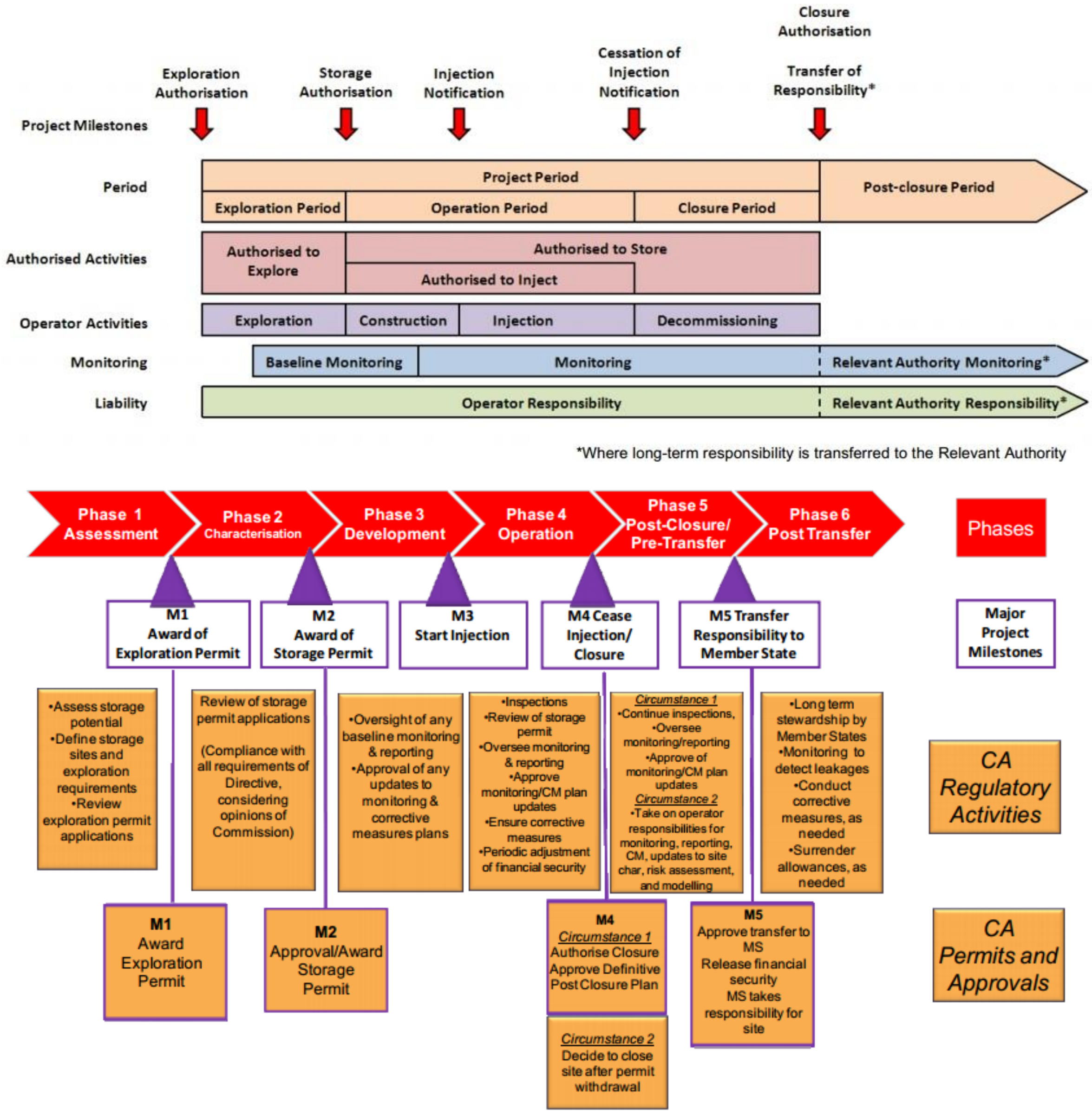

Figure 3: A Comparative Life-Cycle Regulation of Carbon Storage under the IEA Model Regulatory Framework and EU CCS Directive.

Several questions might be related to the development of CCS. For instance, under the pollution laws, the following questions are relevant [7].
Is CO_2 considered as waste under the Waste Management Act?
2. Is CO_2 (may affect water PH values) considered a pollutant under the *Water Act*?
3. Should Taiwan imitate Japan and regulate CCS under the *Marine Pollution Act*?
4. Should Taiwan imitate the US and regulate CCS under the *Ground Water and Soil Protection Act*?

Similarly, other questions relate to the ways EIA laws integrate CCS concerns. For example, should we include RD&D exemptions from EIA in EIA laws? Should we draft EIA thresholds for capture installations, CO_2 pipelines, or carbon storage?

5.2.2.2. The Core Law for Development of Further Regulations

Moreover, based on successful lessons, we can determine the requirements of a "core law" (either an existing law, or a new law) to address CCS development. For example, the Netherlands employs the Mining Act (Mijnbouwwet ("Mining Act") ("Act of 6 June 2011 Amending the Mining Act"). In contrast, in Germany, a new law concerning CCS demonstration is passed in 2012 [49].

Table 4: A Comparative Table on Seamless Regulations of the IEA Model Regulatory Framework and EU CCS Directive.

			IEA modeling framework	EU CCS directive
Permission	Exploration permit		6.3	5
		Site selection	6.4	4
	Storage permit		6.5	6～9
	Injection permit		6.5(5)	9III
	Closure or transfer of responsibility permit		6.10	17 and 18
Plan	Monitoring Plan Emergency Response Plan Human Health and Environmental Safety Plan Closure Plan Post-Closure Plan		6.5	Art. 13, 16, 17, 18.
Distribution of Duties	Authority	Inspection	6.6	15
		Monitoring	6.7	13
		corrective measures and remediation measures	6.8	16
	Operator	corrective measures and remediation measures	6.8	16
		regular reporting duty	6.7(4)	14
		duty during closure period	6.10(1)(a)(i)	17II
Distribution of Liability	project period	Operator	6.9	Art. 18
	post closure period	State (financial liability: from the operator)	6.11、6.12	Art 18-20
		Operators	6.10(1)(a)(i)	Art.17(2), 18(7)
Distribution of "Monitoring" Duty	Project Period: operators and the State		6.7(3)	13
	post-closure Period: State		6.11(2)(b)	18(1)

Based on these lessons, this article identified that the most closely related legal regime that exemplifies life cycle thinking is the *Mining Act*. There is a lot of similarity between the Mining Act and the *five seamless* elements of the IEA and the EU, even though a few regulatory items are missing. The relationship between this Act and IEA/EU's life cycle thinking is provided in Table 5. Except for the similarities that exist between the Mining Act and carbon storage concerns, the advantage of employing the Mining Act approach in Taiwan is related to the fact that it can be difficult to pass new energy laws in Taiwan's legislative reality (which, in turn, makes it more difficult to enact new CCS Laws).

In addition, it might be simple to include carbon storage in the Mining Act: The Executive Yuan can use its authority under Article 3I (61) of the Mining Act and designate CO_2 as a type of mining resource. In this way, it would be possible to avoid the unwillingness of both the EPA and MOEA to regulate carbon storage because Executive Yuan (equivalent to Cabinet Office) possesses higher authority.

5.2.2.3. The Regulatory Challenges Ahead

However, several challenges must be faced in the future. Firstly, based on Table 1 above, it is apparent that the current Mining Act fails to address all regulations related to "closure" and the post-closure period for carbon storage. Thus, additional small revisions in the form of administrative ordinances are required. However, because the future Mining Act will be subject to the EPA's authority, the EPA's unwillingness to accommodate CCS requirements might challenge the development and realization of this type of life cycle regulatory thinking.

Secondly, challenges continue to affect new drilling under the Mining Act approach. This approach provides additional regulatory certainty to EOR (i.e. reuse of existing oil wells and storage spaces in existing near-exhausted wells-EHR and other EOR purposes under the Mining Act).

Mining Act "red tape" should not be required. However, with respect to new drillings, the Mining Act requires local governments' permission. Based on the current political atmosphere, this looks very unlikely. For example, the designation of CO_2 mining zones requires that developers obtain almost-impossible and politically sensitive "water and soil" permissions from local governments prior to obtaining Mining Zone approvals from the Central government.

Thirdly, in Taiwan's special situation, EIA is heavily used and sometimes "abused" by environmental NGOs to kill many development projects (e.g. scientific parks, recreational hotels, wind parks, and so on). Currently, no EIA exemptions have been determined for CCS RD&D projects. Pilot and CCS demonstrations and experimental projects may face opposition from environmental NGOs.

In fact, according to the EIA Ordinance, exemptions from EIA are provided for RD&D and pilot tests of geothermal and oceanic energy. If we consider the similar or lesser environmental risks and effects of carbon storage, in comparison with geothermal, similar RD&D exemptions are strongly recommended by this author. However, this would then require the revision of "Ordinances" by the EPA. However, as noted above, the EPA believes that no laws require changes. In addition, the EPA believes no additional regulations required to accommodate the needs of CCS. Therefore, further efforts are required to remedy this bureaucratic issue.

Recently there is some light on this issue. Facing pressure from the news on 25 June 2013, EPA began to revise The Ordinance on Mandatory EIA Projects, and provide 10 kilo tone EIA exemption for RD&D of carbon storage [50].

Table 5: The Relationship between Taiwan Mining Act and IEA/EU Seamless Regulatory Framework.

Regulatory measures			
1. Seamless "Permission" (or. notification)	Exploration permit		Articles of Mining Acts
		Site selection	12, 15(1)
	→storage permit		13、17、18、26、43、58
	→injection permit		20
	→closure permit (liability transfer)		37、38 Art.18 of Mining Safety Act
Seamless "Plan" for Storage Operators	Monitor plan Corrective measures plan H&S emergency response plan		15(2)、49 Art.10, 13 of Mining Safety Act
	Closure Plan Post closure plan		48
3. Seamless "Distribution of Duties" between Authority and Operators			
Authority	Inspection		63
	Monitor		Art.34, 57 of Mining Safety Act
	Corrective measures and remediation measures		Art.37 of Mining Safety Act
Operator	corrective measures and remediation measures)		15(2), 49
	Report duty		59、60
4. Seamless Distribution of Liability between Authority and Operators			
Project period	Operator		49
Post closure period	The State (financial duty: operator)		???
	Operator (exceptional)		48
5. Seamless Distribution of "Monitoring" Duties Between Authority and Operators			
Project period	Operators and the State		15(2), Art.27 of Mining Safety Act
Post closure period	The State		???
Other regulations in EU CCS Directive			
The composition of co2 stream		?	
Information disclosure		?	
EIA, risk assessment		15(2), 43(3) Art. 11(1) of The Ordinance on Mandatory EIA Projects.	

Actually, this author found out this 10 kilo tonne R&D exemption from CCS directive two and half year ago. The idea was discussed in inside meeting for numerous times. Yet, the EPA seems to be unwilling to revise for the needs of carbon storage. It should thank to the media pressure to give birth to this RD&D exemption. Yet, such RD&D exemptions after the controversial events of 25 June 2013 make it difficult to discuss the issue in a rational manner.

Thus, such an exemption regime has not been integrated into the EIA Ordinance so far. Even so, this also proves how important the issue of an EIA exemption regime during the development of CCS technology.

Finally, to coordinate CCS development among authorities, policies, incentives and regulations, significant amounts of hard work and political will be required. Would the creation of a legal regime help resolve this difficult task? From the UK's lessons on SEA of CCS and also other lessons of SEA on offshore wind, including Denmark, Belgium [51], Spain [52], Norway [53], Scotland [54] and Ireland [55], SEA might play a key role. SEAs could include full consideration of licensing issues.

This may benefit countries in which legislation is piecemeal and has been distributed across numerous public departments. Thus, SEAs might save time and bureaucratic efforts and, ultimately, strengthen investors' trust in this new technology. In addition, SEAs can be used to inform developers of the availability of economically viable, environmental friendly socially acceptable sites [56]. All of these factors might suit the needs of controversial CCS matters because Taiwan has already introduced EIA and SEA schemes in its Environmental Impact Assessment Act. The application of SEAs in CCS activities would only require a simple revision to the Administrative Ordinance on the List of Must-SEA Policies, Plans, and Programmes. As part of this author's recommendation, the EPA has begun to consider the possibility of development of the SEA for CCS in a voluntary manner since last year. The formulation of the draft report will be handled by the aforementioned energy think tank, the ITRI, and the Graduate School of Environmental Engineering at the National Taiwan University. This author will play a role as the only legal scholar to integrate his knowledge of European-style CCS SEA with the Taiwanese case (Gao, Anton Ming-Zhi, "The Application of European SEA Directive in the Carbon Capture and Storage (CCS) Decision Makings: the Issue of Screening," 17(6) European Energy and Environmental Law Review 341-370 (2008)).

6. Conclusion

The facilitation of one novel technology from laboratory R&D to demonstration/large-scale applications requires technology development, as well as the development of a large architecture that includes bureaucracy, policies, and legal frameworks. CCS is not exempt from this process. Based on successful or relatively successful lessons learned from efforts performed in "democratic" "rule of law" countries, the author determined that no such frameworks were helpful in the deployment of this novel technology. No frameworks were able to alleviate public citizens' concerns. Yet, the evidence reveals that relatively large numbers of demonstration projects are being implemented in these countries.

However, CCS development, particularly onshore storage, has recently been faced with significant amounts of global controversy and opposition because of the public's lack of acceptance and lack of support; see for example, [43]. Does this imply that all this hard work has been performed in vain and no method can be used to fight against "Pure Environmentalism" and NIMBYism? The answer may not be so dire. In these mature and "rule-of-law" regimes, it might still be possible to persuade the public to accept this technology. For example, after a dedicated information and engagement campaign was conducted in Spain, an EEPR-supported project successfully overcame public opposition. Similarly, positive development of offshore storage has occurred in the UK, the Netherlands, and Italy [43]. These successful projects may prove that games played with rules might survive better than games played without rules.

The purpose of this article is to provide an overview of the rules of the game around the world and to identify a policy and legal framework for the successful deployment of CCS. There are five key findings:

Firstly, in spite of a lot of RD&D efforts in Taiwan (see Section 2), the research results face difficulties in being put into practice. The main reason is due to the lack of an aggressive authority and a related policy and legal regime to facilitate the deployment of CCS. This also reflects the fact that study results from social scientists like this author are not sufficient to persuade government to make more efforts. Rather, governments focus more on and emphasize the science and technology aspects of research. Yet, without a good policy and law, science and technology developments are hampered.

Secondly, in terms of a competent authority, Taiwan is currently facing the issue of overlapping R&D efforts from multiple ministers while the role of further policy and legal regimes is being ignored. The main likely authority in Taiwan would be either the MOEA or the EPA. Borrowing the lessons from other countries, such as the UK, and taking into account Taiwan's unique situation, it is recommended that the EPA should play a greater role in the near future.

Thirdly, Taiwan's CCS policy looks similar to those in Western countries. Yet, on taking a closer look, two weaknesses emerge: (1) The role of CCS is still not considered as a mature technology. Thus, CCS would be only a possible option under an energy R&D policy, instead of a viable solution under an energy or climate policy; (2) there is a lack of a quantitative target for the development of CCS demonstration sites.

Fourthly, there is a legal vacuum in CCS discussions, despite of a lot of legal recommendations provided by this author and face-to-face discussions with the former Minister of the EPA. Neither the incentive nor the regulatory regime are well developed. Hopefully, with the recent inauguration of a new Minister of the EPA, the requisite legal framework will be improved. During private meetings, this author also found out that the progression of an SEA could shade some light on the further development of a legal regime.

Of course, the events that occur behind the scenes rely on the importance of "political will" to use CCS technology to combat climate change and to develop CCS industries so they can become the next stars of export technology. Thus, the technological strength of CCS, as well as the strength of related technology (e.g. mines, oil, gas, and so on) will affect the willingness of each country and politician to promote this type of technology. However, this situation remains a "chicken or the egg first" type of situation. How can Taiwan, as a latecomer in the use of this technology, catch up? Perhaps, the development of this type of framework should become both a priority and a solution!

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Large-scale laboratory study on the CO_2 removal from flue gas in a hybrid adsorptive-membrane installation

by

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Abstract

A hybrid adsorptive-membrane process, developed in our laboratory, is one of the attractive methods of carbon dixiode removal from flue gas streams. Stage one of the process includes a four-column PSA (pressure swing adsorption) unit, whereas stage two is a membrane module. In this paper experimental results are presented concerning the removal of CO_2 from ternary $CO_2/N_2/O_2$ mixtures in a large-scale laboratory hybrid installation processing 5 to 10 m^3(STP)/h of dry feed gas. Extensive experiments performed over a wide range of the operating parameters have shown the possibility to increase CO_2 content from 12 vol.% to over 95 vol.%, with a recovery of 100%. It is also found that the key parameter which has a strong direct effect on the performance of the two separation sections is the flowrate of the enriched gas fed into the PSA unit during purge. Generally, an increase in this flow favourably influences the operation of the whole hybrid system provided there is no CO_2 breakthrough into the purified gas. The experiments do not yield a clear-cut answer concerning the effect of the hybrid configuration upon the energy consumption. Although the value obtained in our experiments (4.1 MJ per kilogram of CO_2 captured) was higher than the numbers reported elsewhere, rough calculations done for a large-scale pilot installation (1000 m^3(STP)/h) show that the energy expenditure can be decreased to 1.66 MJ/kg (CO_2), and thus to a level lower than that in a number of single- and two-stage adsorption systems.

Keywords: flue gas, CO_2 abatement, hybrid process, pressure swing adsorption, membrane separation

1. Introduction

The EU Directive 2009/31/WE concerning geological storage of carbon dioxide (the so-called CCS Directive) provided a strong incentive for the development and implementation of technologies for capturing CO_2 from various flue gas streams, especially those generated by the power industry. The separation of CO_2 from gaseous mixtures can be realized using well-known techniques, such as adsorption and membrane permeation (Metz et al., 2005). However, due to the low CO_2 concentrations in the flue gas (usually well below 20 vol.%), a reasonably high purity and recovery of this gas (above 90 vol.%) can only be obtained using staged adsorptive or membrane separations (Tanczyk et al., 2010, Zhao et al., 2008, Chou and Chen, 2004, Na et al., 2001). In two-stage systems, the high recovery is achieved by minimizing CO_2 concentration in the purified stream leaving the first stage and recycling the CO_2 remaining after the second stage to the inlet of stage one.

The hybrid process is an extension of two-stage adsorptive or membrane separations which, while combining the advantages of the two, mitigates the negative characteristics of these processes, namely, high energy consumption in the case of pressure swing adsorption (PSA) and considerable capital cost of membrane systems. Based on a theoretical analysis of air separation Akinlabi et al., 2007 show that in hybrid membrane-adsorptive or adsorptive-membrane systems the energy consumption can indeed be lowered compared with purely adsorptive or membrane installations.

Warmuzinski et al., 2013a propose a hybrid configuration in which the first stage includes a four-column PSA installation and the second stage is a membrane module equipped with polymeric capillary membranes. In such a system the feed gas does not require compression prior to entering the installation; moreover, the enriched stream before the membrane module is free of most of the ballast and, with CO_2 concentrations exceeding 20 vol.%, it becomes possible to lower the compression level. Extensive numerical simulations presented elsewhere (Warmuzinski et al., 2013b) for the system proposed reveal that it is indeed possible to raise CO_2 content from around 13 vol.% to over 97 vol.%, with a virtually complete recovery (100%).

In the present study experimental results are reported for the removal of CO_2 from flue gas in a large-scale laboratory hybrid installation. These results fully corroborate all the quantitative conclusions resulting from the comprehensive numerical calculations (Warmuzinski et al., 2013b).

2. Hybrid installation

The hybrid installation is shown schematically in Fig. 1. The dry feed gas (a mixture containing nitrogen, oxygen and 12-13 vol.% of CO_2) is introduced into the PSA section at a pressure of ~1.1 bar and with a flow rate of 5-10 m^3 (STP)/h. The PSA section yields two gas streams. The stream enriched in CO_2 is collected at the bottom of adsorbers (A1, A2, A3 and A4) via a vacuum pump (P2) and stored in a tank (ZB2). A fraction of the enriched gas is recycled to the PSA section during the cocurrent purge steps; the remainder is compressed and directed into a buffer tank (ZB4) through which the gas is supplied to a membrane module (MB). The other stream that leaves the PSA section is the purified gas, i.e., a mixture of nitrogen and oxygen collected from the top of the four adsorbers during cocurrent feed, depressurization from 1.1 bar to 1 bar and purge with the CO_2-enriched stream.

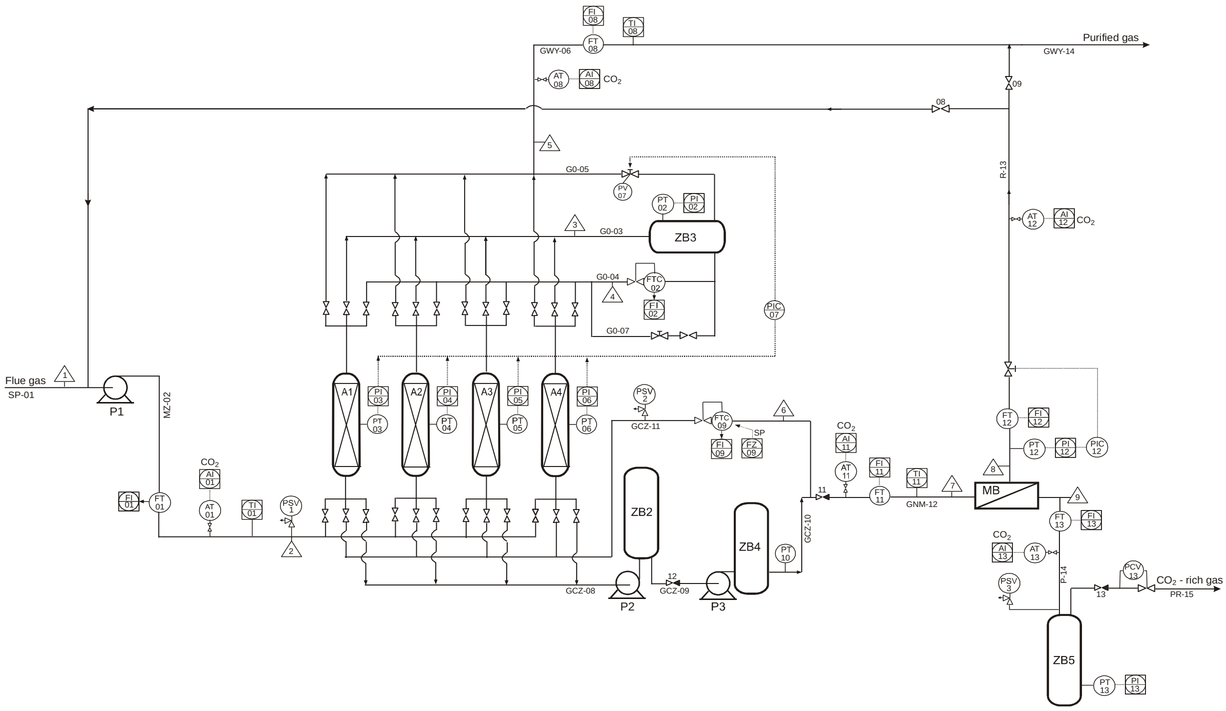

Figure 1: Hybrid installation for the CO_2 capture from flue gases (A1-A4 – adsorbers, AT – gas composition, MB – membrane module, PT – pressure, P1 – blower, P2 – vacuum pump, P3 – compressor, TI – temperature, FT – gas flow rate, ZB2 – enriched gas tank, ZB3 – purified gas tank, ZB4 – buffer tank, ZB5 – CO_2 tank)

A part of the purified gas stored in ZB3 is fed into the columns in which the countercurrent steps are realized (i.e. regeneration under a reduced pressure of around 0.15-0.2 bar and pressurization to 1.1 bar). The enriched gas supplied to the membrane section is split into two streams: the permeate (the principal product of the process), recovered at the atmospheric pressure and containing roughly over 90 vol.% of CO_2, and the retentate, collected at an elevated pressure of 2.95-4.38 bar (this stream contains 20 – 60 vol.% of CO_2 and, upon depressurization, is recycled to the inlet of a blower (P1)). The adsorbers have a diameter of 200 mm and are packed with a zeolite molecular sieve 13X; the height of the packing is 1.5 m.

The PSA cycle studied includes the steps of feed with the flue gas, cocurrent depressurization, purge with the CO_2-enriched stream, countercurrent depressurization, vacuum regeneration with the purified gas and pressurization with the purified gas. The details of the cycle have been presented elsewhere (Warmuzinski et al., 2015).

3. Experiments

The objective of the experimental studies was, on the one hand, to generate data necessary to validate the preliminary assumptions of the hybrid process (Warmuzinski et al., 2013a, Warmuzinski et al., 2013b) and, on the other, to generate data necessary to validate a model of the hybrid process and to provide a sound basis for the scale-up of the installation and its further optimization.

Before the individual measurement series were started, the beds were thoroughly regenerated for about three days at a low pressure and simultaneously purged with dry air supplied at the top of the columns. To enhance the regeneration the bottom sections of the columns were heated to about 70ºC using electrical tapes. The regeneration was stopped when no CO_2 could be detected chromatographically in the bottom gas stream.

Following the regeneration, the values of the principal operating parameters for the PSA unit were set. These included the duration of the whole cycle (with the individual steps of equal length), feed flow rate and composition, the flow rate of the purified gas in the regeneration step and the flow rate of the enriched gas during purge with this stream. Next, the feed pressure for the membrane module was set and the process was carried out until a cyclic steady state was reached (this usually took around 24-30 hours).

Fig. 2 shows the parameters of the enriched gas, while Fig. 3 shows the parameters of the CO_2-rich stream at the outlet from the hybrid installation as functions of the duration of PSA steps. Net flow rate in Fig.2 means a difference between an average flow rate of the enriched gas provided by PSA unit and an inlet flow rate of the enriched gas during purge step in PSA unit. Extending step duration in PSA unit by almost 30% (Fig. 2) at constant flow rates of the feed (10 m^3(STP)/h), regenerating stream (1.03 m^3(STP)/h) and the purge gas (~5.5 m^3(STP)/h) leads, on the one hand, to a rise in CO_2 content in the enriched stream (from 65 to 80 vol.%), and to a considerable drop in the net yield of the enriched gas leaving PSA section on the other. For the longest duration of the step (135 s) the breakthrough of CO_2 into the purified stream could be observed (in excess of 3 vol.%). As it can be seen in Fig. 3, CO_2 purity exceeds 95 vol.%. From the other side the duration of a PSA cycle only slightly affects the purity and the yield of the CO_2-rich product.

In Fig. 4 the concentrations of carbon dioxide in principal process streams are shown as a function of the enriched gas flowrate during purge, for the duration of PSA step of 105 s and the flowrates of PSA feed and purified gas during regeneration of, respectively, 7.5 and 1.03 m^3(STP)/h.

With an increase in the flowrate of the enriched purge stream by some 45%, CO_2 content in this stream also increases markedly (from 52.1 to 66.5 vol.%). The concentrations of CO_2 in both permeate and retentate streams also rise, although to a much lesser degree (from 91.8 to 94.4 vol.% and from 34.7 to 38 vol.%, respectively).

An effect of the flowrate of the purified gas during regeneration for the flowrates of the gas entering PSA unit and that of the enriched stream during purge of, respectively, 7.5 and 6.3 m^3 (STP)/h is shown in Fig. 5.

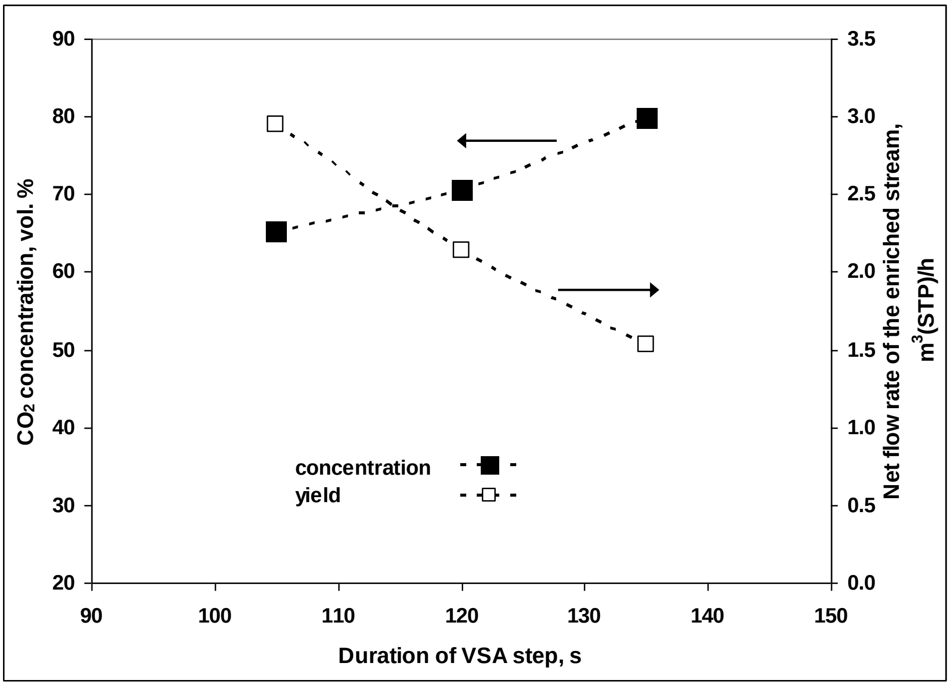

Figure 2: Parameters of the enriched stream leaving the PSA unit vs. duration of PSA steps. Flow rates: 10 m^3(STP)/h (feed), 1.03 m^3(STP)/h (regenerating stream), ~5.5 m^3(STP)/h (purge gas).

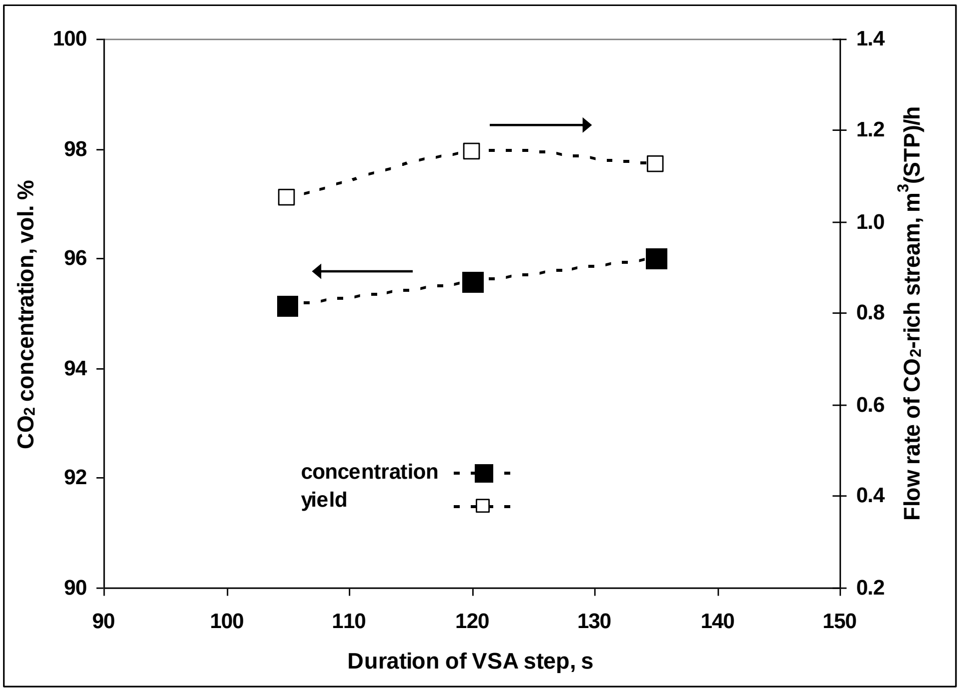

Figure 3: Parameters of the CO_2-rich product vs. duration of PSA steps. Flow rates: 10 m^3(STP)/h (feed), 1.03 m^3(STP)/h (regenerating stream), ~5.5 m^3(STP)/h (purge gas).

It is evident from Fig. 5 that even considerable rise (over twofold) in the flow rate of the purified gas during regeneration produces only minor decrease in the content of CO_2 in principal process streams. In almost all of the cases presented in Figs 2-5 a hybrid installation ensures 100% CO_2 recovery. Only in the case of the longest cycle step length (135s) CO_2 recovery was smaller than 100%. The low capacity of the system leads to a relatively high energy penalty per kilogram of CO_2 captured. In the best case (10 m^3 (STP)/h) the energy consumption was 4.1 MJ/kg (CO_2), and was thus higher by 30 – 100% than in other experimental installations. Low yields have a detrimental effect on the efficiency of the pumps

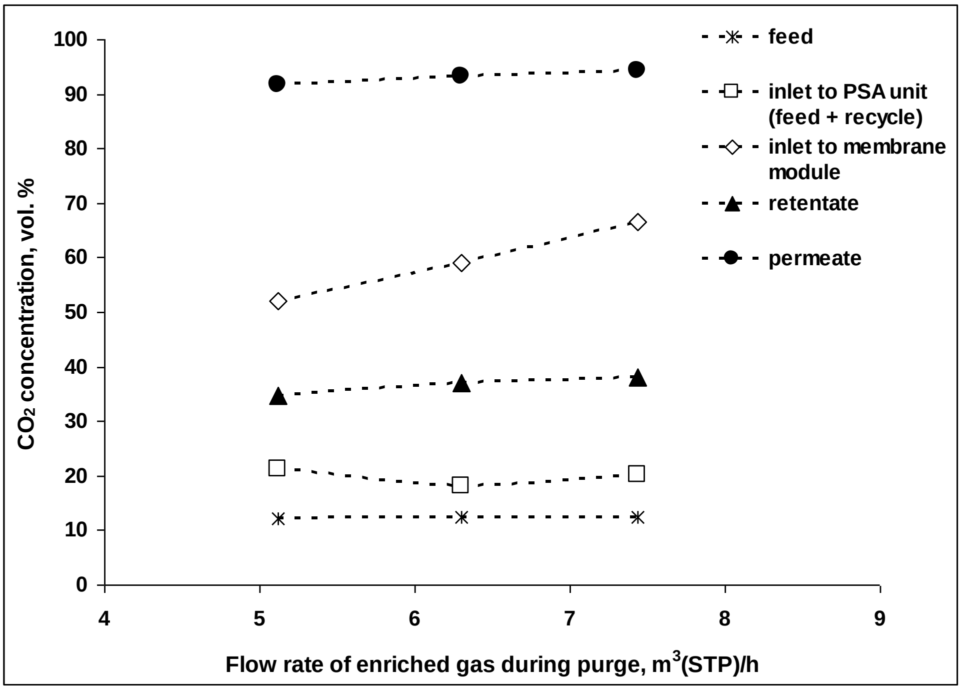

Figure 4: CO_2 content in key process streams vs. inlet flow rate of the enriched gas during purge. Flow rates: 7.5 m^3(STP)/h (feed), 1.03 m^3(STP)/h (regenerating stream). Duration of PSA step: 105 s.

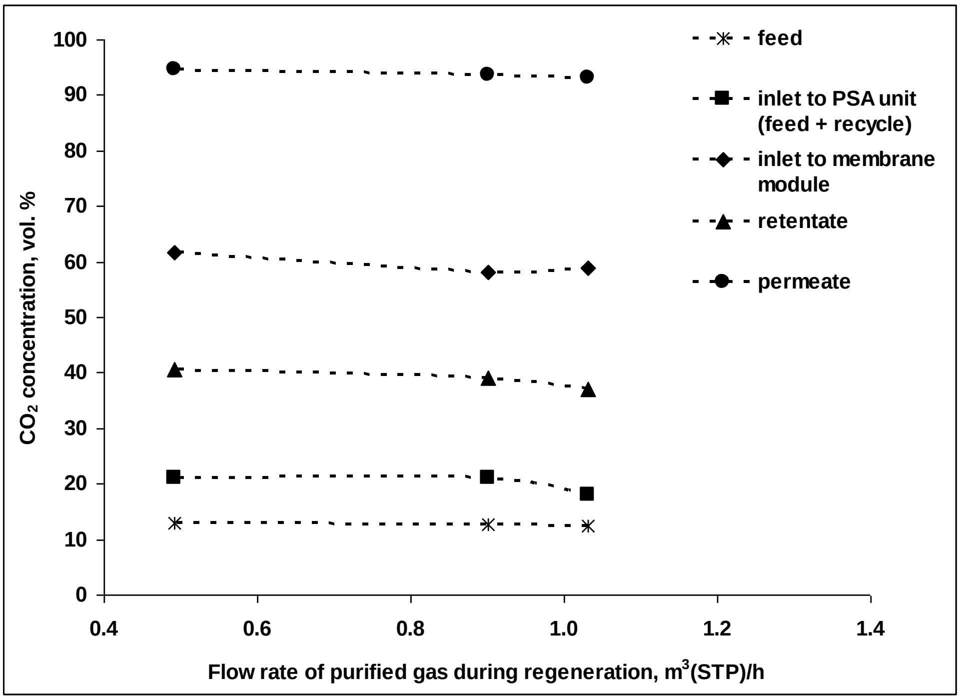

Figure 5: CO_2 content in key process streams vs. inlet flow rate of the purified gas during regeneration. Flow rates: 7.5 m^3(STP)/h (feed), 6.3 m^3(STP)/h (purge gas). Duration of PSA step: 105 s.

Therefore, in our study the amount of energy has been estimated that would be consumed in a hybrid installation of a capacity larger by two orders of magnitude, i.e. 1000 m^3(STP)/h. The values obtained for such an installation were between 2.0 MJ/kg (CO_2) (for the system shown in Fig. 1) and 1.66 MJ/kg (CO_2) (if the only stream compressed is the portion of enriched gas introduced into the membrane module).

4. Conclusions

In this study experimental data from an installation combining pressure swing adsorption and membrane separation have been presented. In the four-column PSA section fed with a dry $CO_2/O_2/N_2$ mixture two gas streams were produced continuously, namely the purified gas and the gas enriched in CO_2. The latter stream, with a flowrate equal to, in the most favourable cases, 20 – 30% of that of the feed was compressed and further enriched in a commercial membrane module.

Extensive experiments performed over a wide range of the operating parameters have consistently shown the possibility to increase CO_2 content from the initial 12 vol.% to over 95 vol.%, with a recovery of 100%. The experiments fully corroborate the preliminary theoretical conclusions (Warmuzinski et al., 2013a, Warmuzinski et al., 2013b) and reveal the potential of such a technique for efficiently removing carbon dioxide from flue gas streams. Although the scale of the process (5-10 m^3 (STP)/h of the feed gas) was small compared with real-life situations, the study has provided a wealth of data that show the principal directions in which further studies should proceed.

The present study does not yield a clear-cut answer concerning the effect of employing a hybrid configuration upon the energy consumption. Although the value obtained in our experiments (4.1 MJ per kilogram of CO_2 captured) was higher than the numbers reported elsewhere, rough calculations done for a large-scale installation show that the energy expenditure can be decreased to 1.66 MJ/kg (CO_2), and thus to a level lower than that in a number of one- and two-stage adsorption systems. Decreasing the energy penalty in adsorptive-membrane hybrid installations seems therefore feasible, although rigorous multiparameter optimization of a large-scale process would have to be performed to firmly support this presumption.

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Warmuzinski K., Tanczyk M., Jaschik M., 2015. “Experimental study on the capture of CO_2 from flue gas using adsorption combined with membrane separation”. International Journal of Greenhouse Gas Control 37, p. 182-190.

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Pilot study on the CO_2 removal from flue gas in amine-based plant at Tauron's power plants

by

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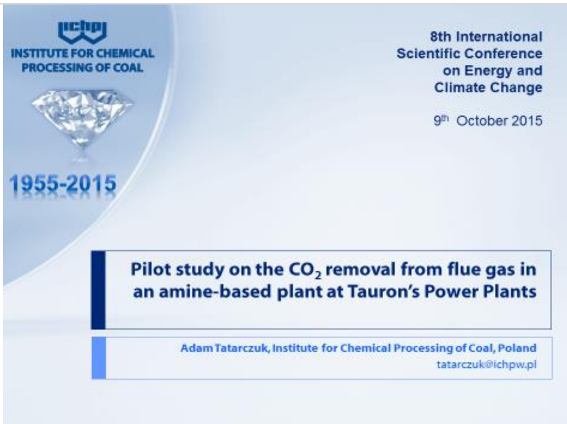
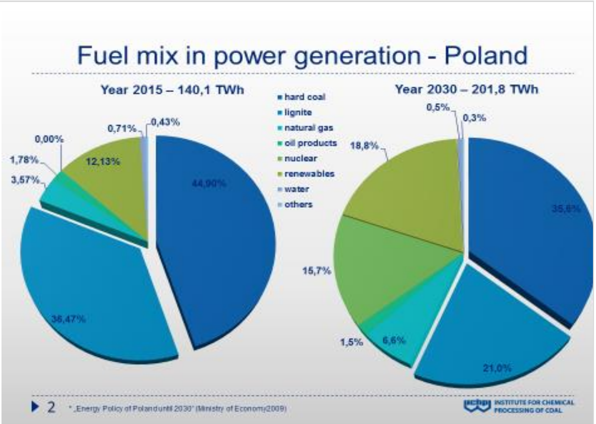
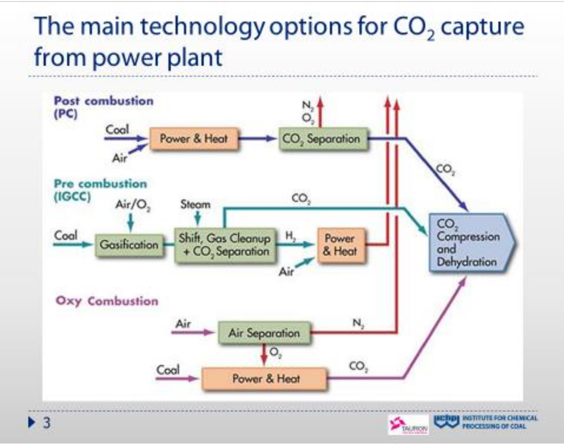
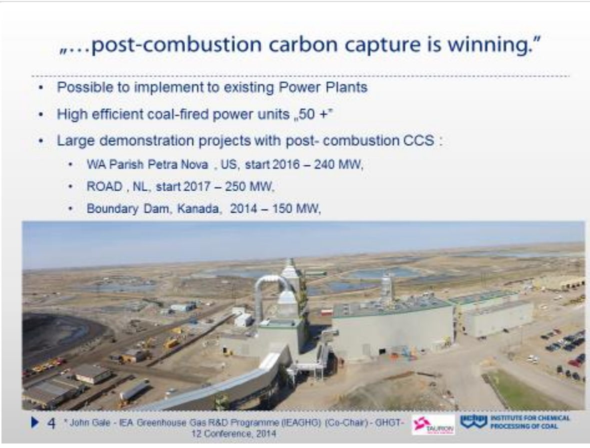
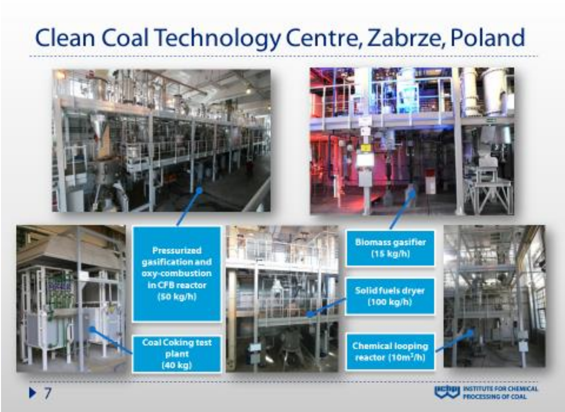
Institute for Chemical Processing of Coal, Poland

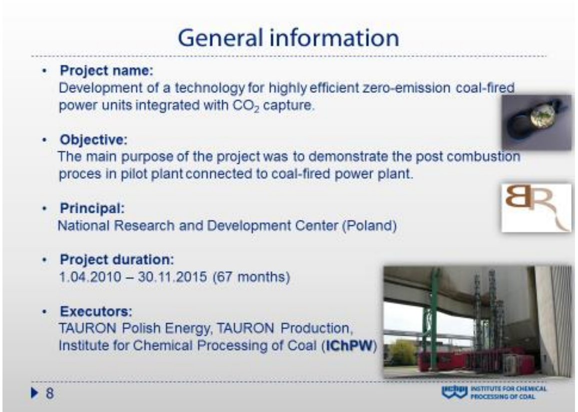


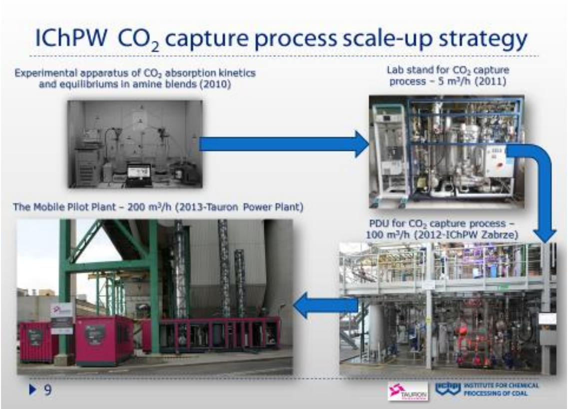






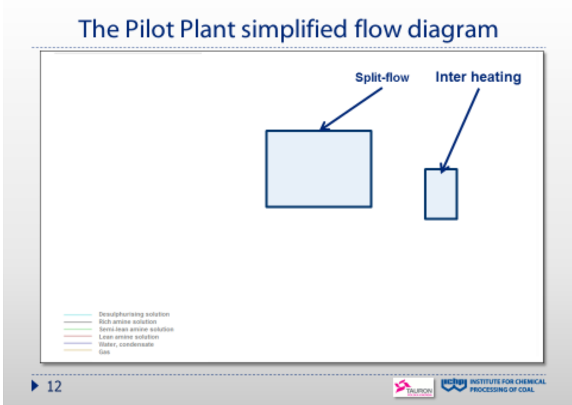

Clean Coal Technology Centre, Zabrze, Poland
Pressurized gasification and oxy-combustion in CFB reactor (50 kg/h)
Coal Coking test plant (40 kg)
Biomass gasifier (15 kg/h)
Solid fuels dryer (100 kg/h)
Chemical looping reactor (10m³/h)
7


General information
Project name:
Development of a technology for highly efficient zero-emission coal-fired power units integrated with CO2 capture.
Objective:
The main purpose of the project was to demonstrate the post combustion proces in pilot plant connected to coal-fired power plant.
Principal:
National Research and Development Center (Poland)
Project duration:
1.04.2010 – 30.11.2015 (67 months)
Executors:
TAURON Polish Energy, TAURON Production, Institute for Chemical Processing of Coal (IChPW)
8


IChPW CO2 capture process scale-up strategy
Experimental apparatus of CO2 absorption kinetics and equilibriums in amine blends (2010)
Lab stand for CO2 capture process – 5 m³/h (2011)
The Mobile Pilot Plant – 200 m³/h (2013-Tauron Power Plant)
PDU for CO2 capture process – 100 m³/h (2012-IChPW Zabrze)
9


Pilot plant deployment - Jaworzno Power Plant – 04.2014
10

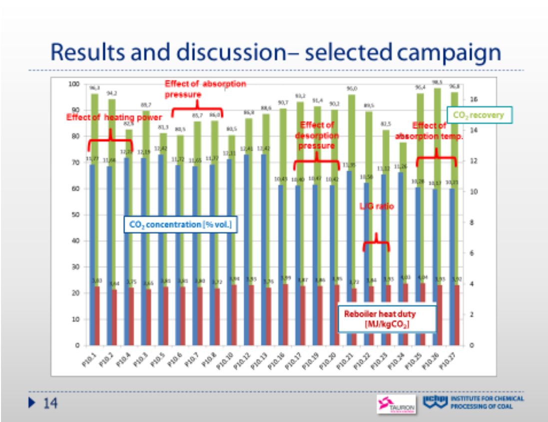

The Pilot Plant commissioning–05.2014 Jaworzno Power Plant (TAURON)
Column diameter:
Column height:
Number of devices:
Measurements:
Solvent:
Solvent stream:
Gas stream:
Tested gas:
11

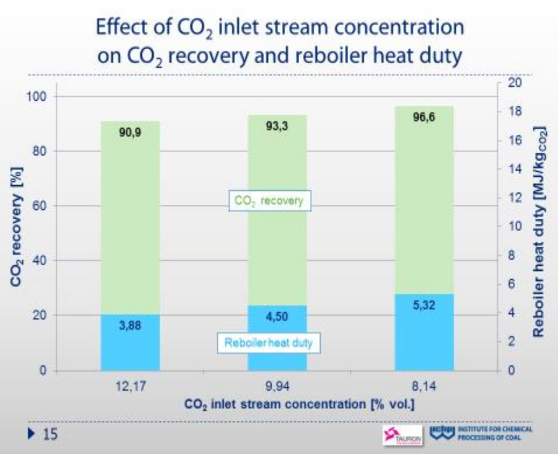

The Pilot Plant simplified flow diagram
Split-flow
Inter heating
12

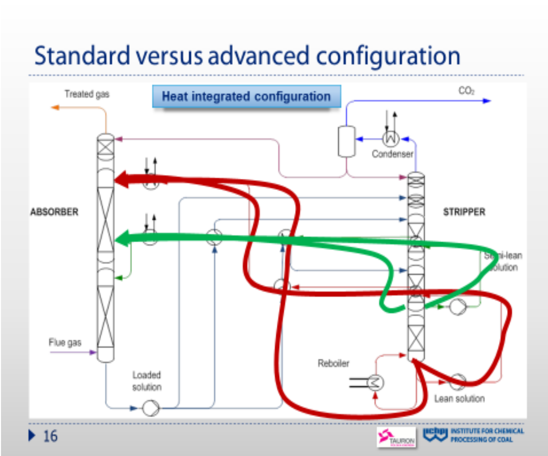
Results and discussion
Nomenclature

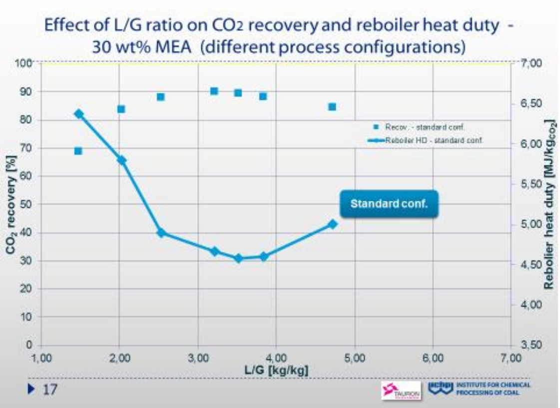
Parameter	Description	Unit
CO_2 recovery	Amount of CO_2 captured divided by amount of CO_2 in flue gas Typical values: 80 – 90	%
Reboiler heat duty	Energy delivered to the process divided by amount of CO_2 captured (gross values- with heat losses) Typical values: 3 – 5	$\frac{MJ}{kg_{CO_2}}$

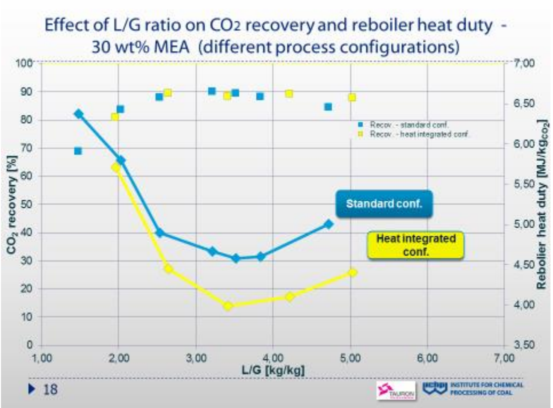
13

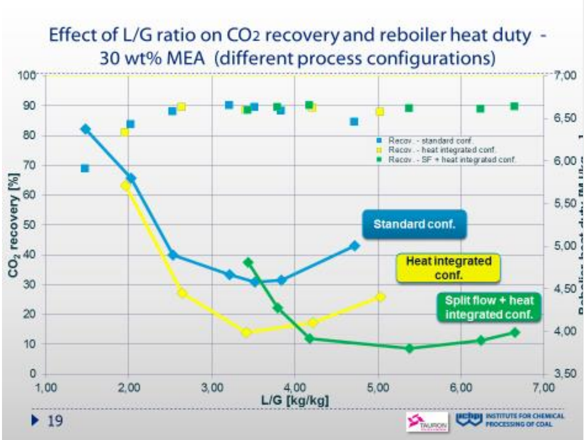


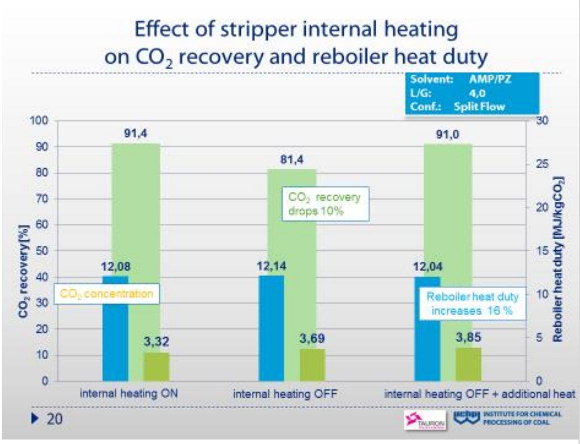


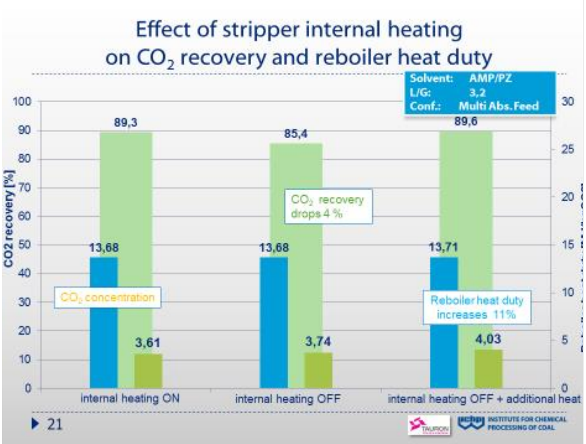


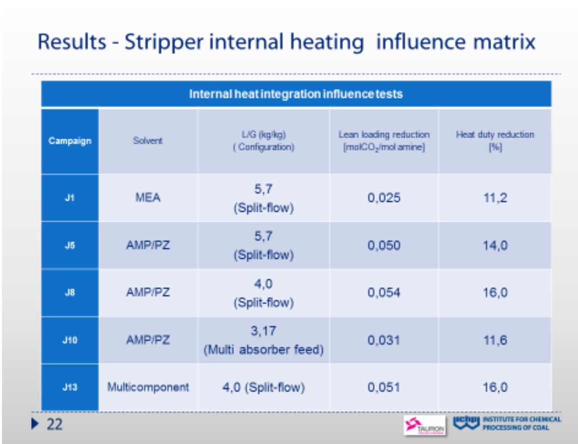






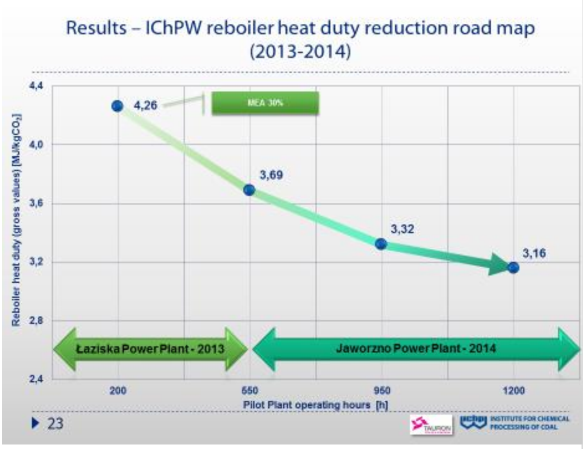


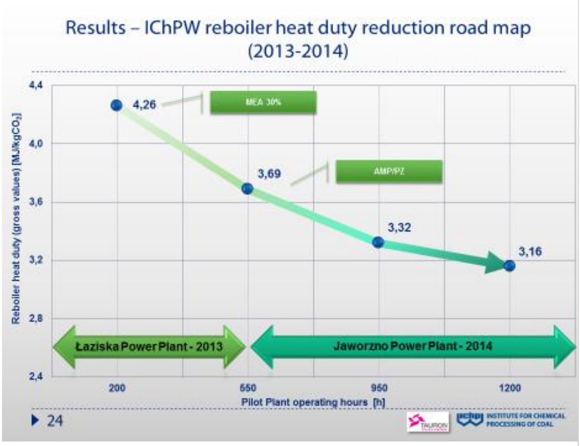


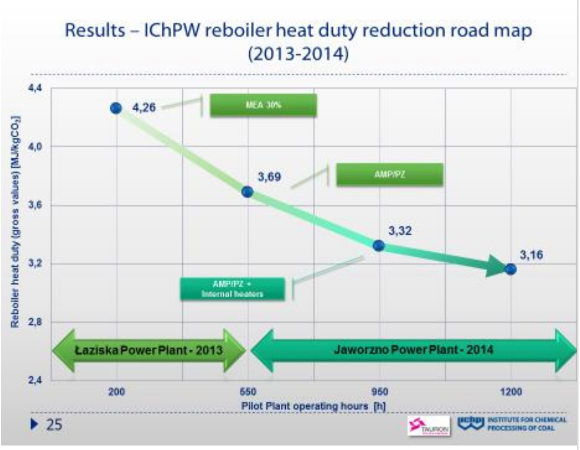

Results - Stripper internal heating influence matrix

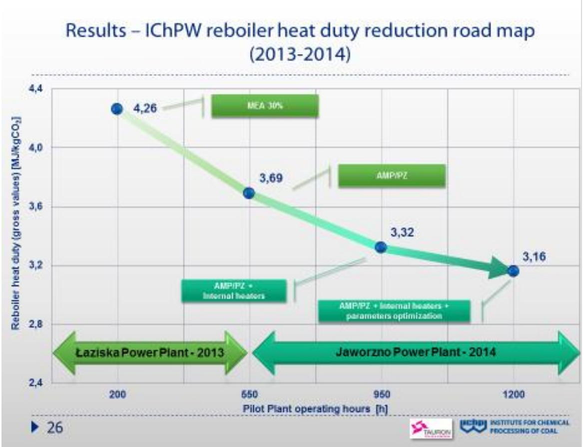
Internal heat integration influence tests

Campaign	Solvent	L/G (kg/kg) (Configuration)	Lean loading reduction [molCO_2/mol amine]	Heat duty reduction [%]
J1	MEA	5,7 (Split-flow)	0,025	11,2
J5	AMP/PZ	5,7 (Split-flow)	0,050	14,0
J8	AMP/PZ	4,0 (Split-flow)	0,054	16,0
J10	AMP/PZ	3,17 (Multi absorber feed)	0,031	11,6
J13	Multicomponent	4,0 (Split-flow)	0,051	16,0






Results – IChPW reboiler heat duty reduction road map (2013-2014)
Reboiler heat duty (gross values) [MJ/kgCO2]
4,4
4,0
3,6
3,2
2,8
2,4
4,26
MEA 30%
3,69
AMP/PZ
3,32
3,16
AMP/PZ + Internal heaters
Łaziska Power Plant - 2013
Jaworzno Power Plant - 2014
200
550
950
1200
Pilot Plant operating hours [h]
25
INSTITUTE FOR CHEMICAL PROCESSING OF COAL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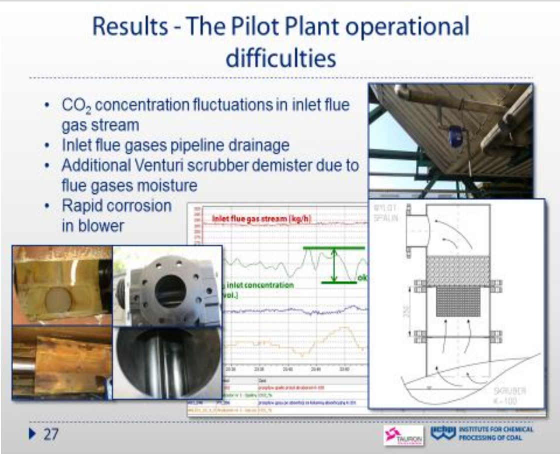
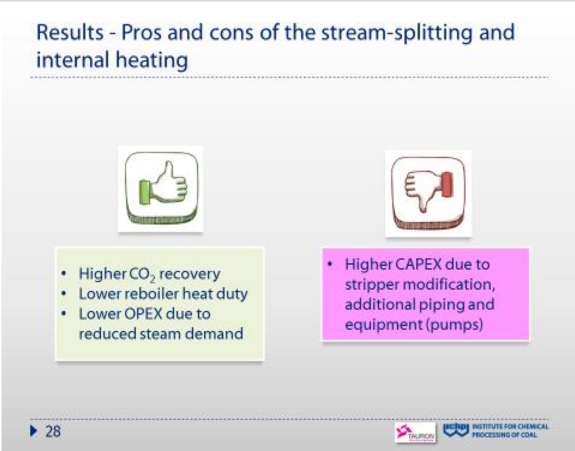
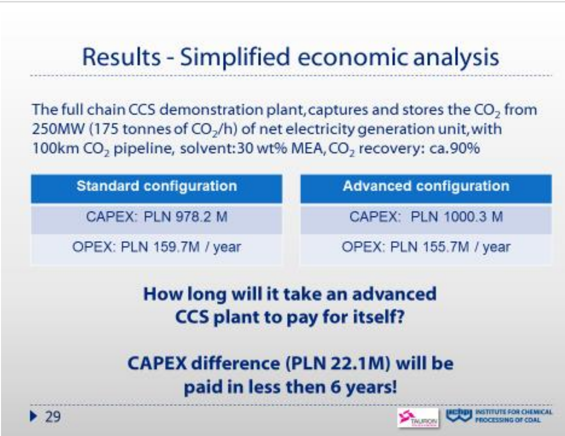
3,2
2,8
2,4
4,26
MEA 30%
3,69
AMP/PZ
3,32
3,16
AMP/PZ + Internal heaters
AMP/PZ + Internal heaters + parameters optimization
Łaziska Power Plant - 2013
Jaworzno Power Plant - 2014
200
550
950
1200
Pilot Plant operating hours [h]
26
INSTITUTE FOR CHEMICAL PROCESSING OF COAL


Results - The Pilot Plant operational difficulties
• CO2 concentration fluctuations in inlet flue gas stream
• Inlet flue gases pipeline drainage
• Additional Venturi scrubber demister due to flue gases moisture
• Rapid corrosion in blower
Inlet flue gas stream [kg/h]
Inlet concentration vol.]
SKRUBER
27
INSTITUTE FOR CHEMICAL PROCESSING OF COAL


Results - Pros and cons of the stream-splitting and internal heating
• Higher CO2 recovery
• Lower reboiler heat duty
• Lower OPEX due to reduced steam demand
• Higher CAPEX due to stripper modification, additional piping and equipment (pumps)
28
INSTITUTE FOR CHEMICAL PROCESSING OF COAL


Results - Simplified economic analysis
The full chain CCS demonstration plant, captures and stores the CO2 from 250MW (175 tonnes of CO2/h) of net electricity generation unit, with 100km CO2 pipeline, solvent: 30 wt% MEA, CO2 recovery: ca. 90%
Standard configuration
CAPEX: PLN 978.2 M
OPEX: PLN 159.7M / year
Advanced configuration
CAPEX: PLN 1000.3 M
OPEX: PLN 155.7M / year
How long will it take an advanced CCS plant to pay for itself?
CAPEX difference (PLN 22.1M) will be paid in less then 6 years!
29
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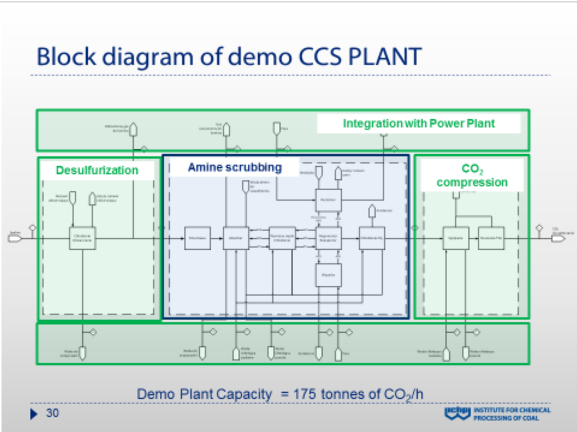
Block diagram of demo CCS PLANT
Integration with Power Plant
Desulfurization
Amine scrubbing
CO2 compression
Demo Plant Capacity = 175 tonnes of CO2/h
30
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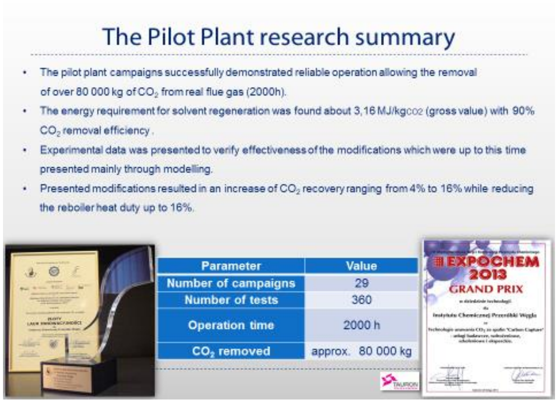
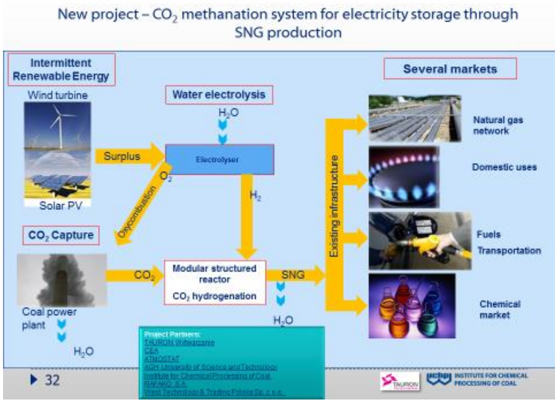

The Pilot Plant research summary
The pilot plant campaigns successfully demonstrated reliable operation allowing the removal of over 80 000 kg of CO_2 from real flue gas (2000h).
The energy requirement for solvent regeneration was found about 3,16 MJ/kg$_{CO2}$ (gross value) with 90% CO_2 removal efficiency .
Experimental data was presented to verify effectiveness of the modifications which were up to this time presented mainly through modelling.
Presented modifications resulted in an increase of CO_2 recovery ranging from 4% to 16% while reducing the reboiler heat duty up to 16%.
Parameter | Value
Number of campaigns | 29
Number of tests | 360
Operation time | 2000 h
CO_2 removed | approx. 80 000 kg
EXPOCHEM 2013
GRAND PRIX


New project – CO_2 methanation system for electricity storage through SNG production
Intermittent Renewable Energy
Wind turbine
Solar PV
Surplus
Water electrolysis
H_2O
Electrolyser
O_2
Oxycombustion
H_2
CO_2 Capture
Coal power plant
H_2O
CO_2
Modular structured reactor
CO_2 hydrogenation
SNG
H_2O
Existing infrastructure
Several markets
Natural gas network
Domestic uses
Fuels Transportation
Chemical market
Project Partners:
TAURON Wytwarzanie
CEA
ATMOSTAT
AGH University of Science and Technology
Institute for Chemical Processing of Coal
RAFAKO S.A.
Wind Technology & Trading Polska Sp. z o.o.
32
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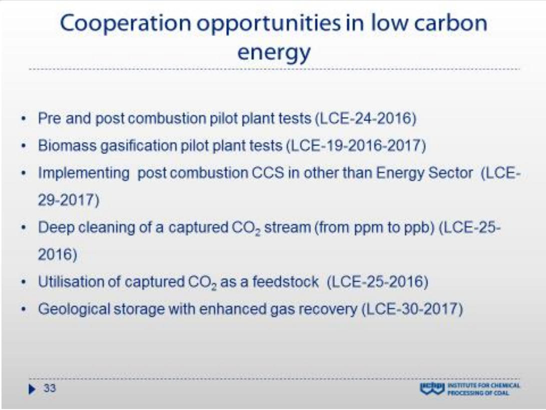
Cooperation opportunities in low carbon energy
Pre and post combustion pilot plant tests (LCE-24-2016)
Biomass gasification pilot plant tests (LCE-19-2016-2017)
Implementing post combustion CCS in other than Energy Sector (LCE-29-2017)
Deep cleaning of a captured CO_2 stream (from ppm to ppb) (LCE-25-2016)
Utilisation of captured CO_2 as a feedstock (LCE-25-2016)
Geological storage with enhanced gas recovery (LCE-30-2017)
33
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STRATEGIC RESEARCH PROGRAM – ADVANCED TECHNOLOGIES FOR ENERGY GENERATION
TASK No. 1 – „Advanced technologies for energy generation: Development of a technology for highly efficient zero-emission coal-fired power units integrated with CO_2 capture"
Project co-financed by the National Centre of Research and Development in the framework of Contract SP/E/1/67484/10, dated 05 May 2010r.
Research team:
dr inż. Aleksander Sobolewski
dr inż. Krzysztof Dreszer
mgr inż. Józef Popowicz
dr inż. Lucyna Więcław Solny
mgr inż. Adam Tatarczuk
mgr inż. Marcin Stec
mgr inż. Tomasz Szczypiński
mgr inż. Piotr Kolon
mgr inż. Dariusz Śpiewak
mgr inż. Tomasz Spietz
mgr inż. Aleksander Krótki
mgr inż. Andrzej Wilk
Industrial partners team:
dr inż. Stanisław Tokarski – TAURON Polska Energia SA
mgr inż. Janusz Tchórz – TAURON Wytwarzanie SA
mgr inż. Sławomir Dziaduła – TAURON Wytwarzanie SA
inż. Stanisław Gruszka – TAURON Wytwarzanie SA
mgr inż. Jerzy Janikowski– TAURON Polska Energia SA
mgr inż. Janusz Zdeb – TAURON Wytwarzanie SA
TAURON
POLSKA ENERGIA
Project manager:
dr hab. inż. Marek Ściążko, prof. nadzw.
E-mail: office@ichpw.pl
Internet: www.ichpw.zabrze.pl
34
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STRATEGIC RESEARCH PROGRAM – ADVANCED TECHNOLOGIES FOR ENERGY GENERATION
TASK No. 1 – „Advanced technologies for energy generation: Development of a technology for highly efficient zero-emission coal-fired power units integrated with CO_2 capture"
Project co-financed by the National Centre of Research and Development in the framework of Contract SP/E/1/67484/10, dated 05 May 2010r.
We invite you to take a virtual tour of the Clean Coal Technology Centre:
http://ichpw.wkraj.pl/#/65563/0
and to watch the movie about the Institute:
http://koala.ichpw.zabrze.pl/video/Institute_for_Chemical_Processing_of_Coal.mp4
35
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Tauron's Pilot Plant - That's one small step for [an] engineer, one giant leap for Poles.
Thank you for attention
36
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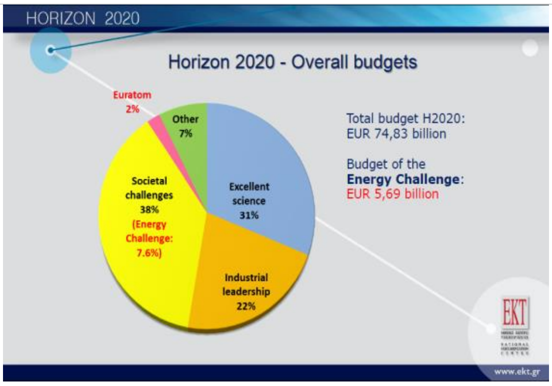
Programmes and Projects

Funding opportunities under Horizon 2020 – Secure, Clean and Efficient Energy

by

Christiana SIABEKOU

National Documentation Centre, Hellas


HORIZON 2020
Horizon 2020 - Overall budgets
Euratom 2%
Other 7%
Societal challenges 38% (Energy Challenge: 7.6%)
Excellent science 31%
Industrial leadership 22%
Total budget H2020: EUR 74,83 billion
Budget of the Energy Challenge: EUR 5,69 billion
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HORIZON 2020
PRIORITY 1 : Excellent Science
Why:
▪ World class science is the foundation of tomorrow's technologies, jobs and wellbeing
▪ Europe needs to develop, attract and retain research talent
▪ Researchers need access to the best infrastructures
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HORIZON 2020
Excellent Science:
Funding (€ million, 2014-2020)
European Research Council (ERC)
Frontier research by the best individual teams
13 095
Future and Emerging Technologies
Collaborative research to open new fields of innovation
2 696
Marie Skłodowska-Curie actions (MSCA)
Opportunities for training and career development
6 162
Research infrastructures (including e-infrastructure)
Ensuring access to world-class facilities
2 488
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HORIZON 2020
PRIORITY 2 : Industrial Leadership
Why:
▪ Strategic investments in key technologies (e.g. advanced manufacturing, micro-electronics) underpin innovation across existing and emerging sectors
▪ Europe needs to attract more private investment in research and innovation
▪ Europe needs more innovative small and medium-sized enterprises (SMEs) to create growth and jobs
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HORIZON 2020
Industrial leadership:
Funding (€ million, 2014-2020)
Leadership in enabling and industrial technologies (LEITs)
(ICT, nanotechnologies, materials, biotechnology, manufacturing, space)
13 557
Access to risk finance
Leveraging private finance and venture capital for research and innovation
2 842
Innovation in SMEs
Fostering all forms of innovation in all types of SMEs
616 + complemented by expected 20% of budget of societal challenges + LEITs
& 'Access to risk finance' with strong SME focus
EKT
www.ekt.gr


HORIZON 2020
PRIORITY 3 : Societal Challenges
Why:
▪ Concerns of citizens and society/EU policy objectives (climate, environment, energy, transport, etc) cannot be achieved without innovation
▪ Breakthrough solutions come from multi-disciplinary collaborations, including social sciences & humanities
▪ Promising solutions need to be tested, demonstrated and scaled up
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HORIZON 2020

Societal Challenges: Funding (€ million, 2014-2020)

Health, demographic change and wellbeing	**7 472**
Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the Bioeconomy	**3 851**
Secure, clean and efficient energy *	**5 690**
Smart, green and integrated transport	**6 339**
Climate action, environment, resource efficiency and raw materials	**3 081**
Inclusive, innovative and reflective societies	**1 310**
Secure societies	**1 695**
Science with and for society	*462*
Spreading excellence and widening participation	*816*

*Additional funding for nuclear safety and security from the Euratom Treaty activities (2014-2018)

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HORIZON 2020

Type of actions

- Research and Innovation Actions (RIA)
- Innovation Actions (IA)
- Coordination and Support Actions (CSA)
- Other actions: ERC, Marie Sklodowska-Curie, SME Instrument, Fast track to innovation

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HORIZON 2020

Type of actions

- **RIA**: funding for research projects tackling clearly defined challenges, which can lead to the development of new knowledge or a new technology
- **IA**: funding is more focused on closer-to-the-market activities. For example, prototyping, testing, demonstrating, piloting, scaling-up etc. if they aim at producing new or improved products or services
- **CSA**: funding covers the coordination and networking of research and innovation projects, programmes and policies.

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HORIZON 2020

Rules for Participation (1/2)

1. **A single set of rules**:
   - Adapted for the whole research and innovation cycle
   - Covering all research programmes and funding bodies
   - Aligned to the Financial Regulation, coherent with other new EU Programmes
2. **One project – one funding rate**:
   - Maximum of 100% of the total eligible costs (except for innovation actions, where a 70% maximum will apply for profit making entities)
   - Indirect eligible costs: a flat rate of 25% of direct eligible costs
3. **Simple evaluation criteria**:
   - Excellence – Impact – Implementation (Excellence only, for the ERC)
4. **New forms of funding aimed at innovation**:
   - pre-commercial procurement, inducement prizes, dedicated loan and equity instruments

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HORIZON 2020

Rules for Participation (2/2)

5. **International participation**: facilitated but better protecting EU
6. **Simpler rules for grants**: broader acceptance of participants accounting practices for direct costs, flat rate for indirect costs, no time-sheets for personnel working full time on a project, possibility of output-based grants
7. **Fewer, better targeted controls and audits**:
   - Lowest possible level of requirements for submission of audit certificates without undermining sound financial management
   - Audit strategy focused on risk and fraud prevention
8. **Improved rules on intellectual property**:
   - Balance between legal security and flexibility
   - Tailor-made IPR provisions for new forms of funding
   - A new emphasis on open access to research publications

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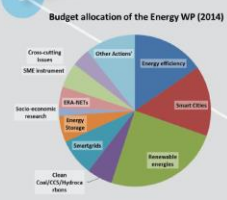
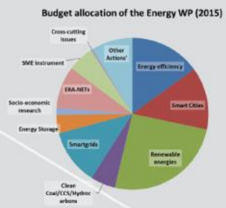


Total budget for 2014: **607 million**

\+ Contribution to JTI Fuel Cells and Hydrogen in 2014: **60 million**



Total budget for 2015: **647 million**

\+ Contribution to JTI Fuel Cells and Hydrogen in 2014: **70.5 million**

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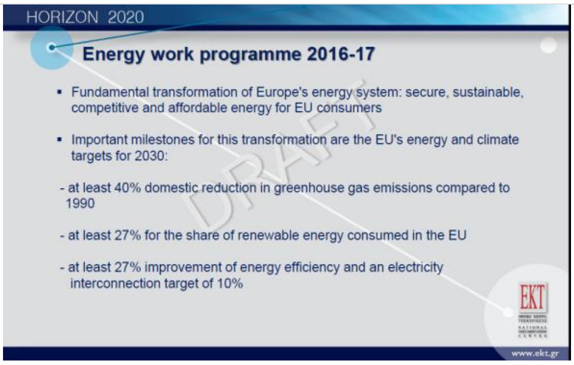
HORIZON 2020
Energy work programme 2016-17
Fundamental transformation of Europe's energy system: secure, sustainable, competitive and affordable energy for EU consumers
Important milestones for this transformation are the EU's energy and climate targets for 2030:
- at least 40% domestic reduction in greenhouse gas emissions compared to 1990
- at least 27% for the share of renewable energy consumed in the EU
- at least 27% improvement of energy efficiency and an electricity interconnection target of 10%
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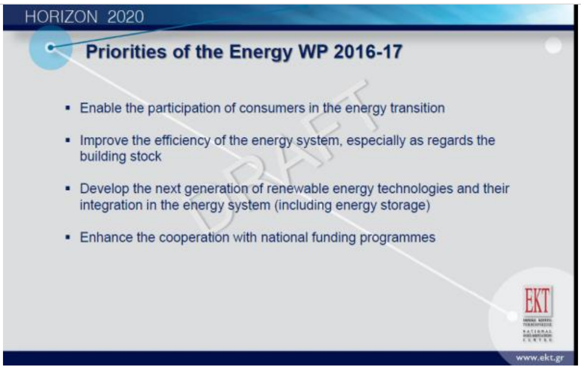
HORIZON 2020
Priorities of the Energy WP 2016-17
Enable the participation of consumers in the energy transition
Improve the efficiency of the energy system, especially as regards the building stock
Develop the next generation of renewable energy technologies and their integration in the energy system (including energy storage)
Enhance the cooperation with national funding programmes
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HORIZON 2020
The 2016-2017 calls of the Energy Challenge
Energy Efficiency (EE)
Heating and Cooling
Engaging consumers
Buildings
Industry, services and Products
Innovative financing
Competitive low-carbon energy Technologies (LCE)
Energy system (grids, storage)
Renewable energies
Decarbonising fossil fuels
Socio-economic research
European Research Area in energy
Smart Cities and Communities (SCC)
Light-house demonstration projects
SME instrument (SIE)
Call budgets (in Mio €)
Call 2016 2017
EE 93 101
LCE 352,66 367,62
SCC 60 71,50
SME 46 50
EKT
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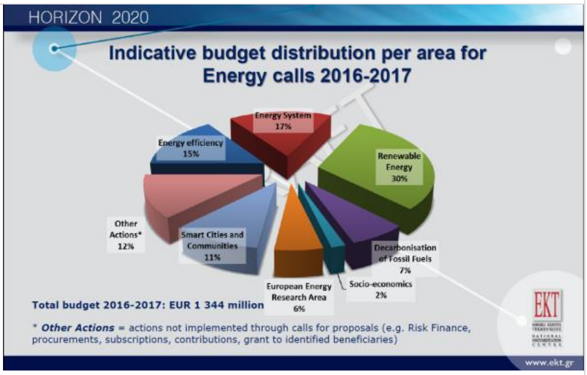
HORIZON 2020
Indicative budget distribution per area for Energy calls 2016-2017
Energy System 17%
Energy efficiency 15%
Renewable Energy 30%
Other Actions* 12%
Smart Cities and Communities 11%
Decarbonisation of Fossil Fuels 7%
European Energy Research Area 6%
Socio-economics 2%
Total budget 2016-2017: EUR 1 344 million
* Other Actions = actions not implemented through calls for proposals (e.g. Risk Finance, procurements, subscriptions, contributions, grant to identified beneficiaries)
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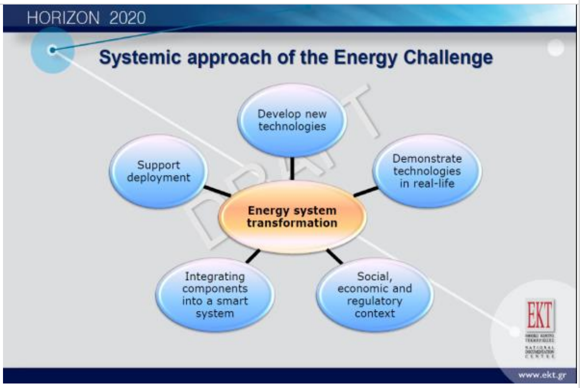
HORIZON 2020
Systemic approach of the Energy Challenge
Develop new technologies
Support deployment
Demonstrate technologies in real-life
Energy system transformation
Integrating components into a smart system
Social, economic and regulatory context
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HORIZON 2020
ENERGY CHALLENGE (2016-2017)
Low Carbon Energy
Smart Cities & Communities
Energy Efficiency
SMEs and Fast Track to Innovation
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HORIZON 2020
Heating and cooling
Innovative Financing
Call Energy Efficiency
Engaging consumer
Industry, services and products
Buildings
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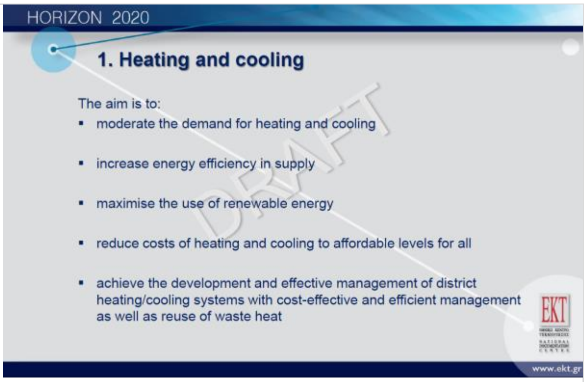
HORIZON 2020
1. Heating and cooling
The aim is to:
▪ moderate the demand for heating and cooling
▪ increase energy efficiency in supply
▪ maximise the use of renewable energy
▪ reduce costs of heating and cooling to affordable levels for all
▪ achieve the development and effective management of district heating/cooling systems with cost-effective and efficient management as well as reuse of waste heat
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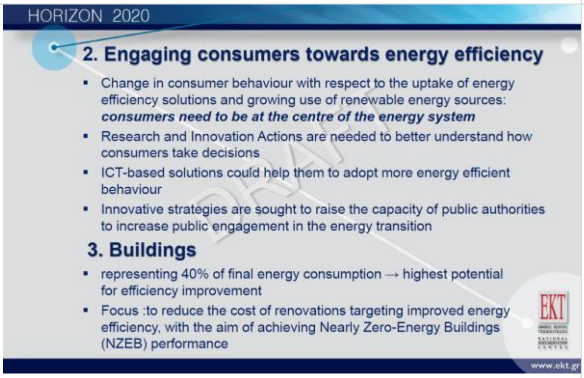
HORIZON 2020
2. Engaging consumers towards energy efficiency
▪ Change in consumer behaviour with respect to the uptake of energy efficiency solutions and growing use of renewable energy sources: consumers need to be at the centre of the energy system
▪ Research and Innovation Actions are needed to better understand how consumers take decisions
▪ ICT-based solutions could help them to adopt more energy efficient behaviour
▪ Innovative strategies are sought to raise the capacity of public authorities to increase public engagement in the energy transition
3. Buildings
▪ representing 40% of final energy consumption → highest potential for efficiency improvement
▪ Focus :to reduce the cost of renovations targeting improved energy efficiency, with the aim of achieving Nearly Zero-Energy Buildings (NZEB) performance
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HORIZON 2020
4. Industry, products and services
▪ Improve the energy efficiency of products, production processes and technologies in support of the competitiveness of EU industry and services
▪ Main focus on: manufacturing processes, energy recovery, energy audits and energy management systems, re-use of industrial waste, optimisation of the value chain and industrial symbiosis
5. Innovative financing for energy efficiency
▪ Focus: development of innovative financing mechanisms, investment instruments and schemes for energy efficiency that allow the demonstration and uptake of business cases related to energy savings, and kick-starting a large scale market for energy efficiency finance
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HORIZON 2020
ENERGY CHALLENGE (2016-2017)
Low Carbon Energy
Smart Cities & Communities
Energy Efficiency
SMEs and Fast Track to Innovation
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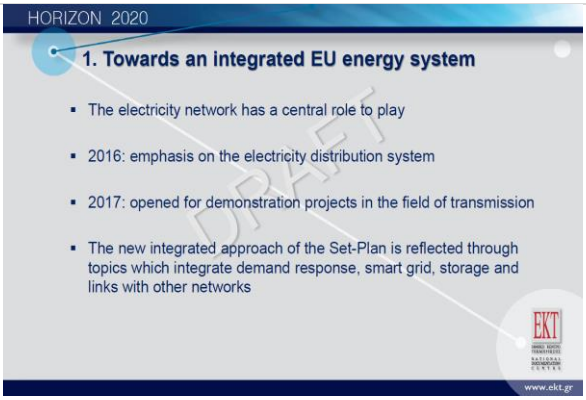
HORIZON 2020
Integrated EU energy system
Cross-cutting issues
Renewable energy technologies
Call Competitive Low Carbon Energy
European Research Area in Energy
Decarbonisation of Fossil Fuels
Social, economic and human aspects
DRAFT


HORIZON 2020
1. Towards an integrated EU energy system
The electricity network has a central role to play
2016: emphasis on the electricity distribution system
2017: opened for demonstration projects in the field of transmission
The new integrated approach of the Set-Plan is reflected through topics which integrate demand response, smart grid, storage and links with other networks
DRAFT
EKT
www.ekt.gr


HORIZON 2020
Integrated EU energy system
Renewable energy technologies
Decarbonisation of Fossil Fuels
Social, economic and human aspects
European Research Area in Energy
Cross-cutting issues
Call Competitive Low Carbon Energy
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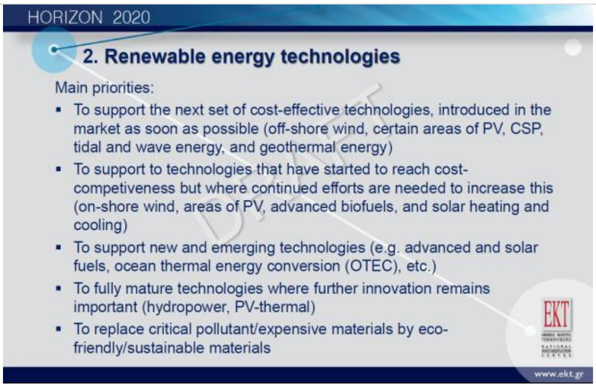
HORIZON 2020
2. Renewable energy technologies
Main priorities:
To support the next set of cost-effective technologies, introduced in the market as soon as possible (off-shore wind, certain areas of PV, CSP, tidal and wave energy, and geothermal energy)
To support to technologies that have started to reach cost-competitiveness but where continued efforts are needed to increase this (on-shore wind, areas of PV, advanced biofuels, and solar heating and cooling)
To support new and emerging technologies (e.g. advanced and solar fuels, ocean thermal energy conversion (OTEC), etc.)
To fully mature technologies where further innovation remains important (hydropower, PV-thermal)
To replace critical pollutant/expensive materials by eco-friendly/sustainable materials
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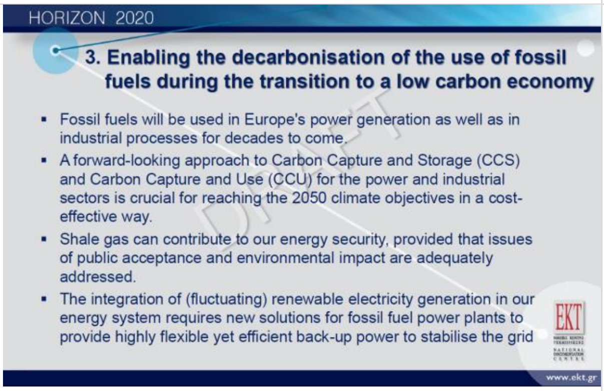
HORIZON 2020
3. Enabling the decarbonisation of the use of fossil fuels during the transition to a low carbon economy
Fossil fuels will be used in Europe's power generation as well as in industrial processes for decades to come
A forward-looking approach to Carbon Capture and Storage (CCS) and Carbon Capture and Use (CCU) for the power and industrial sectors is crucial for reaching the 2050 climate objectives in a cost-effective way.
Shale gas can contribute to our energy security, provided that issues of public acceptance and environmental impact are adequately addressed.
The integration of (fluctuating) renewable electricity generation in our energy system requires new solutions for fossil fuel power plants to provide highly flexible yet efficient back-up power to stabilise the grid
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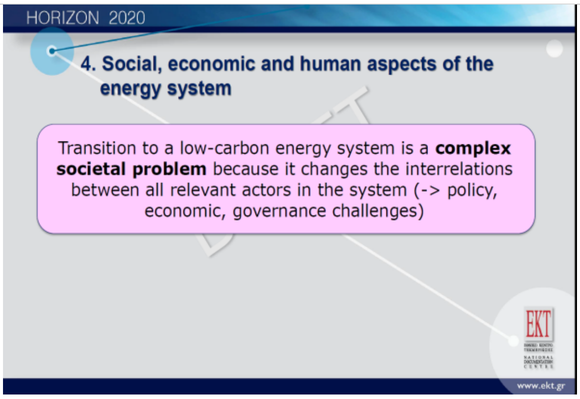
HORIZON 2020
4. Social, economic and human aspects of the energy system
Transition to a low-carbon energy system is a **complex societal problem** because it changes the interrelations between all relevant actors in the system (-> policy, economic, governance challenges)
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HORIZON 2020
5. Supporting the development of a European research area in the field of energy
Encourage coordination of national and EU efforts to increase effectiveness and efficiency;
Pool resources and create critical mass to address challenges that no country can tackle alone;
European Research Area
Towards an Energy Union
Align efforts to develop a European Research Area in energy and to create the Energy Union, one of the political priorities of the Juncker Commission;
The new Integrated SET Plan provides the strategic framework for setting priorities and for discussing implementation;
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HORIZON 2020
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Social, economic and human aspects
European Research Area in Energy
Cross-cutting issues
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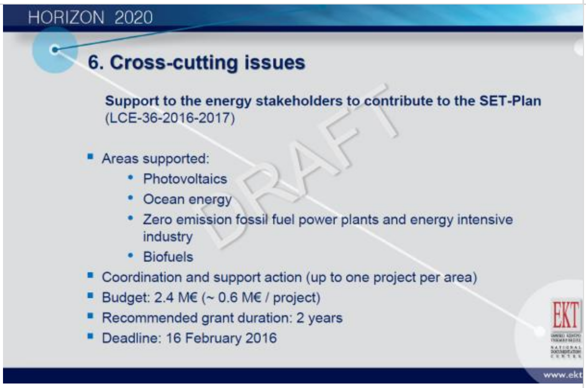
HORIZON 2020
6. Cross-cutting issues
Support to the energy stakeholders to contribute to the SET-Plan (LCE-36-2016-2017)
Areas supported:
Photovoltaics
Ocean energy
Zero emission fossil fuel power plants and energy intensive industry
Biofuels
Coordination and support action (up to one project per area)
Budget: 2.4 M€ (~ 0.6 M€ / project)
Recommended grant duration: 2 years
Deadline: 16 February 2016
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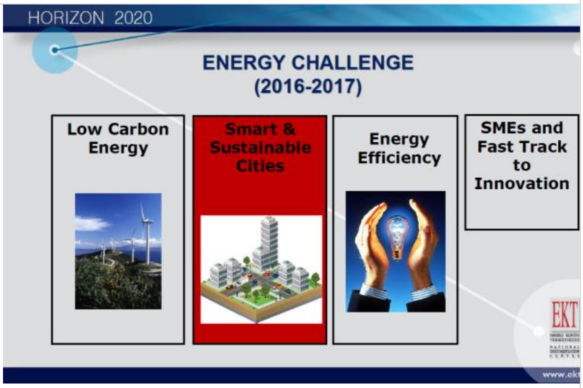
HORIZON 2020
ENERGY CHALLENGE (2016-2017)
Low Carbon Energy
Smart & Sustainable Cities
Energy Efficiency
SMEs and Fast Track to Innovation
EKT


HORIZON 2020
➢ Improving quality of live, competitiveness and sustainability
➢ Exporting European knowledge in a strong growth market estimated globally at €1.3 trillion in 2020
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HORIZON 2020
Topic SCC-1-2016-2017:
Sustainable, cost-effective and replicable district-scale solutions at the intersection of energy and transport enabled by ICT
Intelligent, user-driven and demand-oriented city infrastructure and services
Continuation of the 'Lighthouse project' approach
Integrating smart buildings, smart grids, energy storage, electric vehicles, smart charging infrastructures and the latest generation of ICT platforms based on open specifications
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HORIZON 2020
ENERGY CHALLENGE
(2016-2017)
Low Carbon Energy
Smart Cities & Communities
Energy Efficiency
SMEs and Fast Track to Innovation
EKT
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HORIZON 2020
SMEs & Fast Track to Innovation for energy
1. SME Instrument: stimulating the innovation potential of SMEs for a low carbon and efficient energy system
▪ Phase 1: feasibility study/Phase 2: innovation project/Phase 3: commercialisation phase
▪ Continuously open call
2. Fast Track to Innovation – Pilot
▪ Covering all fields across LEITs (Leadership in enabling and industrial technologies) and Societal Challenges
▪ Maximum of 5 partners/maximum €3 M per project
▪ Continuously open call/Time to grant not exceeding 6 months
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EKT: National Infrastructure for Research & Innovation
National Information System for Research and Technology
Interoperable e-infrastructure for open access to scientific content & services
http://www.epset.gr
metrics
Metrics (www.ekt.gr/metrics):
Assigned by national authorities to provide RDI indicators to Eurostat
(additional publications on bilbiometrics)
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HORIZON 2020
EKT – National Contact Point (NCP) for Horizon 2020
Excellence Science
• European Research Council (ERC)
• Future & Emerging Technologies (FET)
• "Marie Skłodowska-Curie Actions"
• Research Infrastructures
Industrial Leadership
• Access to finance
• Information & Communication Technologies (ICT)
www.ekt.gr/horizon2020
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HORIZON 2020
EKT – National Contact Point (NCP) for Horizon 2020
Societal Challenges
• Health, Demographic Change & Wellbeing
• Secure, clean and efficient energy
• Inclusive, innovative and reflective societies
• Science with and for society
&
Euratom
www.ekt.gr/horizon2020
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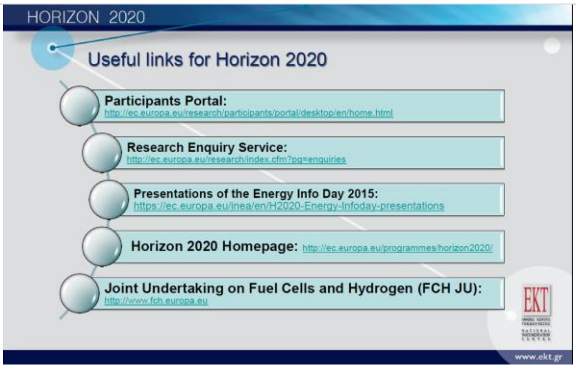
HORIZON 2020
Digital services to research & business community
▪ Information on Research & Innovation in Greece and abroad
▪ Access to Funding: information, trainings, pre-screening of proposals
▪ International Collaboration: partner search support, networking
▪ Exploitation of results: business coaching, technology audits, partnership agreements for technology transfer, venture capitals
▪ Open Access to research results: national OpenAIRE node, repositories, e-journals, policy support
▪ Intellectual Property Rights: helpdesk, signposting
▪ Metrics for scientific-based research policies: Eurostat indicators, bibliometrics, intelligence reports per field
Research & Innovation for growth and competitiveness!


HORIZON 2020
Enterprise Europe Network - Hellas
▪ The Enterprise Europe Network is the largest network of integrated business support
▪ Its scope is:
• To boost competitiveness in enterprises (especially SMEs)
• To support the development of the less-favoured regions in the country
• To promote and facilitate innovation in enterprises as well as in research organisations
• To strengthen the links between research, business, finance
• To foster economic and environmentally sustainable growth and employment
• To enhance European interaction in business, technological, economic & political terms
enterprise europe network
www.ekt.gr


HORIZON 2020
Enterprise Europe Network
More than 600 partner organisations in 63 countries
www.ekt.gr


HORIZON 2020
How do I find a new market abroad?
How do I get European funding?
I need a business partner in another country…
How can I sell my innovative ideas and technology?
What does this EU law mean for my business?
www.ekt.gr


HORIZON 2020
Useful links for Horizon 2020
Participants Portal:
http://ec.europa.eu/research/participants/portal/desktop/en/home.html
Research Enquiry Service:
http://ec.europa.eu/research/index.cfm?pg=enquiries
Presentations of the Energy Info Day 2015:
https://ec.europa.eu/inea/en/H2020-Energy-Infoday-presentations
Horizon 2020 Homepage: http://ec.europa.eu/programmes/horizon2020/
Joint Undertaking on Fuel Cells and Hydrogen (FCH JU):
http://www.fch.europa.eu
www.ekt.gr


HORIZON 2020
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www.ekt.gr
www.enterprise-hellas.gr

ENERGY EFFICIENCY

HERON

AT A GLANCE

Title: HERON (no 649690) – A forward-looking socio-economic research on Energy Efficiency in EU countries

Funding mechanism: HOPIZON 2020, Research & Innovation Action,

Total Budget: €958,750.00

EC Contribution: 100%

Duration: 26 months

Start Date: 1 May 2015

Consortium: eight (8) partners from seven (7) European countries and one (1) candidate country

Project Coordinator: UoA – KEPA (HELLAS)

Project Web Site: www.heron-project.eu

Key Words: energy efficiency, socio-economic research, innovation, building & transport sectors, end-users behaviour, barriers

THE CHALLENGE

Energy efficiency is considered as the most clean and effective "fuel" in the combat against Climate Change and compromises one of the pillars of the submitted to UNFCC Intended National Determined Contributions (INDC) by EU.

Understanding the behavioral obstacles of end-users that hinder the implementation of effective policies defines the challenge that HERON undertakes to investigate for the benefit of EU countries.

THE AIM

The HERON aims to facilitate policy makers of multi-level governance and market stakeholders in EU, to develop and implement effective energy efficiency policies in the sectors of building and transport, incorporating the end-users behavior.

THE INNOVATIVE ELEMENT

Non-economic and non-market elements, such as social, educational and cultural, will be incorporated with economic and technological elements into energy scenarios development and modeling reflecting the end-user behavior towards energy efficiency in building and transport sectors.

THE POLICY DIALOGUE

A well-structured policy dialogue with national market stakeholders and policy makers at various levels of governance at eight countries will conclude with an EU level conference in Brussels.

THE BENEFITS

The outcomes of the project will empower policy makers and market players by providing them with an innovative policy tool allowing them to select and implement the most effective policy instruments for energy efficiency in building and transport sector incorporating the end-users behavior.

THE PROJECT OBJECTIVES

1. The impact of socio-economic and institutional factors on implementing energy efficiency policies and measures.
2. The development of energy efficient pathways to the horizon 2030 and beyond taking into account the socio-economic drivers and the updated energy efficiency measures:
3. The contribution to improving energy modeling by incorporating social, educational and cultural factors so as to reflect the end-user behavior
4. The establishment of communication channels between researchers, decision makers of different governance levels and social and market stakeholders
5. Dissemination of the project's outcomes

THE WORK PACKAGES

1. Mapping of energy efficiency policy instruments and available technologies in buildings and transport
2. Mapping and assessment of social, economic, cultural and educational barriers in buildings and transport
3. Developing an innovate integrated framework to incorporate main drivers and barriers into scenario analysis
4. Forward-looking scenario analysis, focusing on macroeconomic and microeconomic impacts of energy efficiency policy options
5. Policy recommendations through multi-criteria evaluation and feedback mechanisms with policy makers and market stakeholders
6. Dissemination and Communication
7. Management

FIND US

On Twitter @HERON_project

PROJECT PARTNERS	
NATIONAL AND KAPODISTRIAN UNIVERSITY (UOA-KEPA) - COORDINATOR	GR (Greece)
UNIVERSITA COMMERCIALE LUIGI BOCCONI (UB)	IT (Italy)
SDRUZHENIE CHERNOMORSKI IZSLEDOVATELSKI ENERGIEN TSENTAR (BSERC)	BG (Bulgaria)
OXFORD BROOKES UNIVERSITY (OBU)	UK (United Kingdom)
UNIVERSITEIT ANTWERPEN (UA)	BE (Belgium)
WUPPERTAL INSTITUTE FOR CLIMATE, ENVIRONMENT AND ENERGY (WI)	DE (Germany)
UNIVERSITY OF BELGRADE - FACULTY OF MINING AND GEOLOGY (UB-FMG)	RS (Serbia)
ESTONIAN INSTITUTE FOR SUSTAINABLE DEVELOPMENT, STOCKHOLM ENVIRONMENT INSTITUTE TALLINN CENTRE (SEI T)	EE (Estonia)

Infrared Thermography

by

Michalis PERAKIS

Wedling & NDT Institute, Hellas

INFRARED THERMOGRAPHY

OPTIMIZATION OF POWER PLANTS AND THERMAL LOSS MANAGEMENT

Mr. Nikolaos K. KARPATHAKIS
Dipl. Mech. Eng., MSc, MBA

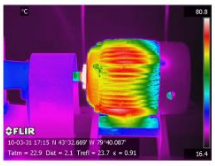
What exactly is Thermography?

It is a technique that 'visualizes' thermal patterns

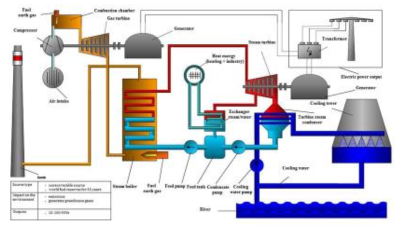
Thermography belongs in condition monitoring techniques together with the ones bellow:

- Vibration Analysis and diagnostics
- Lubricant analysis
- Airborne Ultrasound
- Ultrasound Inspection in solids (thickness measurement etc)

...A typical thermographic image



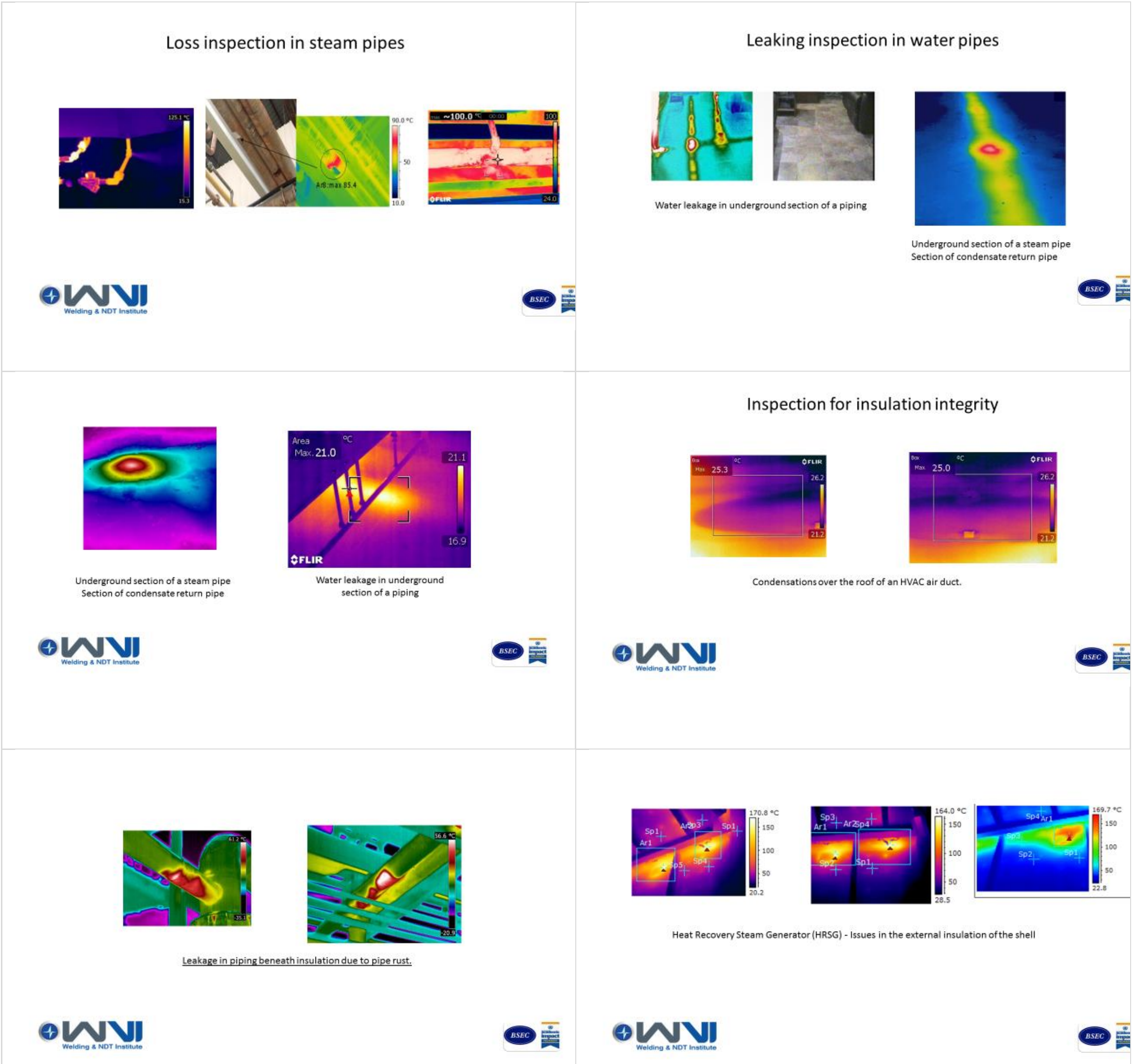
Power Plant Overview – CCPP Logic diagram

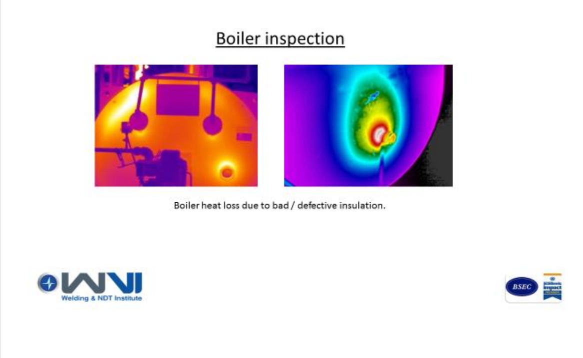


Thermography contribution in the optimization of power plants and thermal loss management.

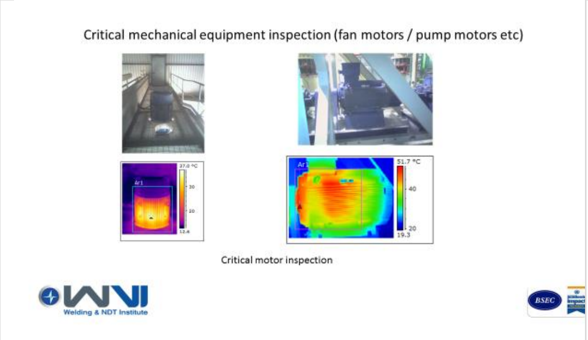
Thermography contributes in the optimization of thermal loss in power plants in the following manner

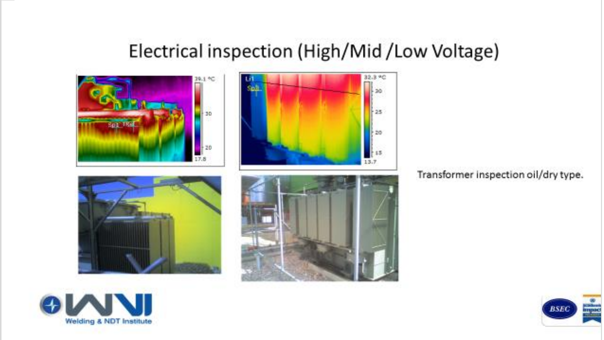
- Loss inspection in steam pipes
- Leaking inspection in water pipes
- Inspection for insulation integrity
- Boiler inspection
- Natural gas pipe leaking inspection
- Critical mechanical equipment inspection (fan motors / pump motors etc)
- Electrical inspection (High/Mid /Low Voltage)
- And many more (...)

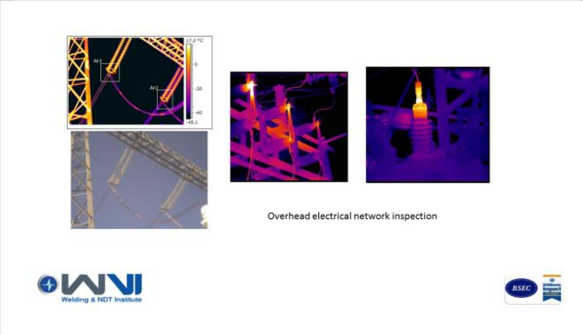

Loss inspection in steam pipes
Leaking inspection in water pipes
Water leakage in underground section of a piping
Underground section of a steam pipe
Section of condensate return pipe
Underground section of a steam pipe
Section of condensate return pipe
Water leakage in underground
section of a piping
Inspection for insulation integrity
Condensations over the roof of an HVAC air duct.
Leakage in piping beneath insulation due to pipe rust.
Heat Recovery Steam Generator (HRSG) - Issues in the external insulation of the shell
Welding & NDT Institute

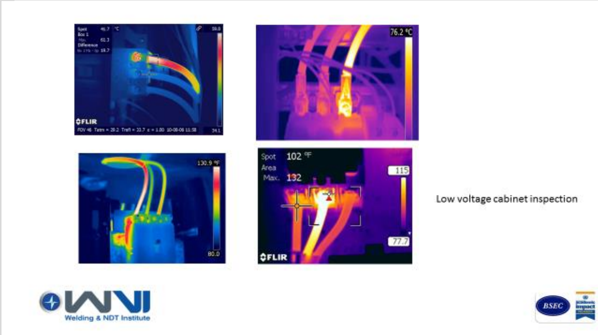

Boiler inspection
Boiler heat loss due to bad / defective insulation.
Welding & NDT Institute
BSEC

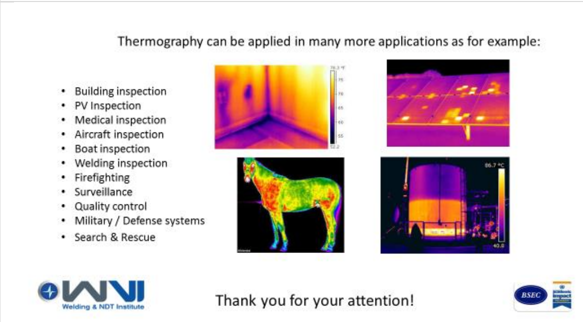

Natural gas pipe leaking inspection
Welding & NDT Institute
BSEC


Critical mechanical equipment inspection (fan motors / pump motors etc)
Critical motor inspection
Welding & NDT Institute
BSEC


Electrical inspection (High/Mid /Low Voltage)
Transformer inspection oil/dry type.
Welding & NDT Institute
BSEC


Overhead electrical network inspection
Welding & NDT Institute
BSEC

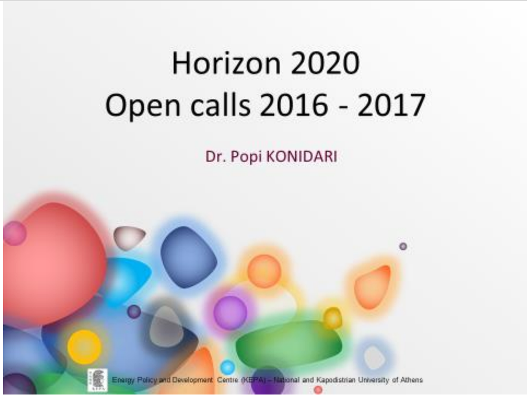

76.2 °C
FLIR
Low voltage cabinet inspection
Welding & NDT Institute
BSEC

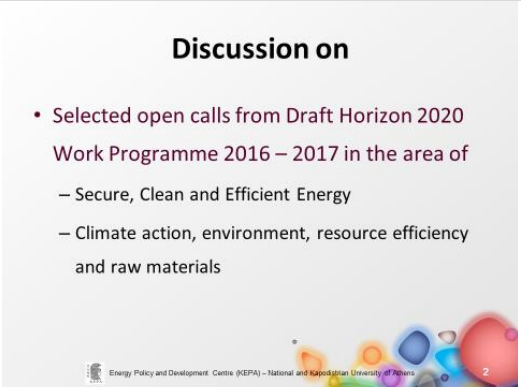

Thermography can be applied in many more applications as for example:
• Building inspection
• PV Inspection
• Medical inspection
• Aircraft inspection
• Boat inspection
• Welding inspection
• Firefighting
• Surveillance
• Quality control
• Military / Defense systems
• Search & Rescue
Thank you for your attention!
Welding & NDT Institute
BSEC

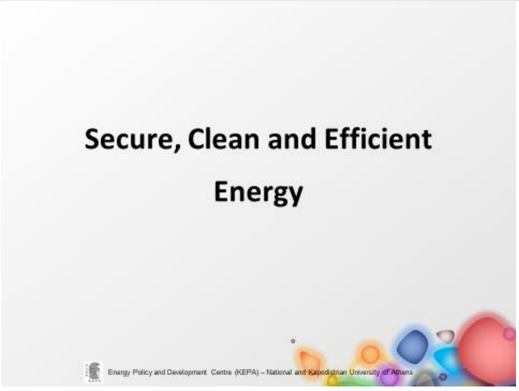
Horizon 2020 – Open calls 2016-2017

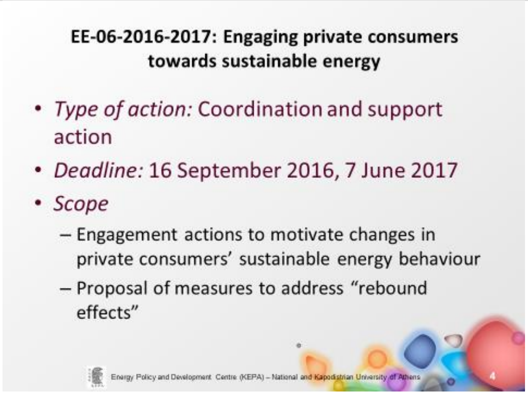
by

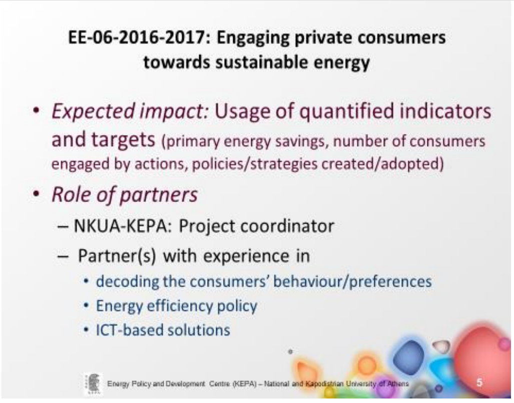
Dr. Popi KONIDARI

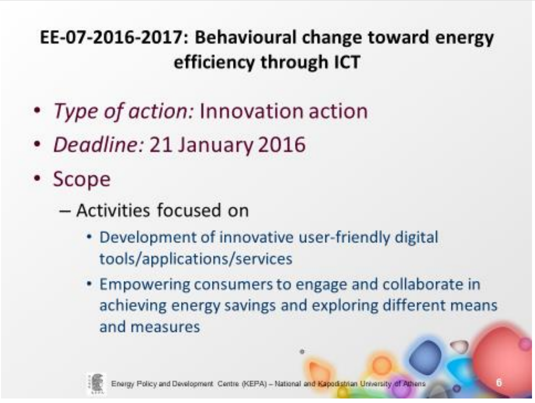


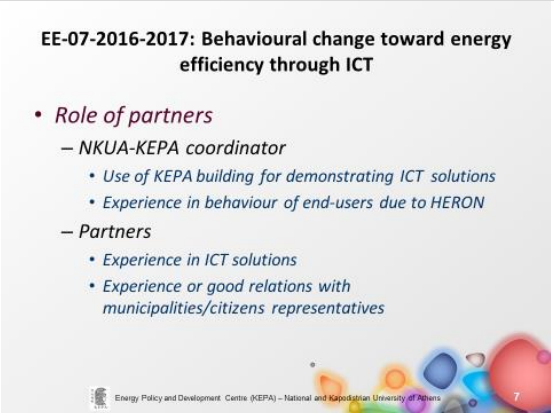











EE-07-2016-2017: Behavioural change toward energy efficiency through ICT
• Role of partners
– NKUA-KEPA coordinator
• Use of KEPA building for demonstrating ICT solutions
• Experience in behaviour of end-users due to HERON
– Partners
• Experience in ICT solutions
• Experience or good relations with municipalities/citizens representatives
Energy Policy and Development Centre (KEPA) – National and Kapodistrian University of Athens
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EE-08-2016: Socio-economic research on consumer's behaviour related to energy efficiency
• Type of action: Research and Innovation
• Deadline: 21 January 2016
• Scope
– Advance knowledge on how
• EE investment decisions are made by different consumer groups
• EE policies have impact on financial and non-financial barriers
– Investigate differentiation between possible EE investments due to different factors
Energy Policy and Development Centre (KEPA) – National and Kapodistrian University of Athens
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EE-08-2016: Socio-economic research on consumer's behaviour related to energy efficiency
• Role of partners
– NKUA-KEPA as coordinator
– Partners with
• Knowledge in forming questionnaires
• Conducting large scale surveys
• Knowledge on macro- and micro-economic models
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EE-09-2016-2017: Engaging and activating public authorities
• Type of action: Coordination and support action
• Deadline: 16 September 2016, 7 June 2017
• Scope
A. Actions aiming at engaging public authorities
B. Peer to peer learning for public authorities – step up public authorities' capacity to help deliver the energy transition
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EE-09-2016-2017: Engaging and activating public authorities
• Role of partners
– NKUA-KEPA – project coordinator or partner
– Partner experienced with
• Activities of covenant of Mayors
• Techno-economic analysis of EE technologies
• Organizing seminars on energy and climate policy issues
• Dissemination in wide scale
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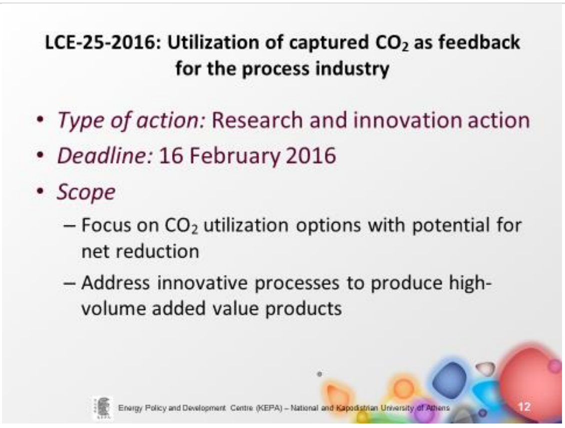
LCE-25-2016: Utilization of captured CO_2 as feedback for the process industry
• Type of action: Research and innovation action
• Deadline: 16 February 2016
• Scope
– Focus on CO_2 utilization options with potential for net reduction
– Address innovative processes to produce high-volume added value products
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LCE-25-2016: Utilization of captured CO_2 as feedback for the process industry
• Role of partners
– NKUA-KEPA simple partner
– Partner active in utilisation of captured CO_2
– Partner with experience in LCA studies
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LCE – 32- 2016: European Platform for energy-related Social Sciences and Humanities
• Type of action: Research and innovation action
• Deadline: 5 April 2016
• Scope
– Address specific research and innovation needs in energy field
– Integrate and build upon already existing networks and initiatives
Socio-economic Sciences and the Humanities (SSH) contribute to an in-depth, shared understanding of the complex and interrelated socio-economic challenges facing Europe and the rest of the world. Social sciences and humanities deal with knowing (data, statistics, indicators), explaining (tools, definitions, methods), understanding (context, causes, mechanisms), forward looking (modelling, foresight, scenarios) and recommending (from knowledge to policy).
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LCE – 32- 2016: European Platform for energy-related Social Sciences and Humanities
• Role of partners
– Partner experienced with
• Networking
• Creation and establishment of platform
• Multidisciplinary orientation
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Climate action, environment, resource efficiency and raw materials
Energy Policy and Development Centre (KEPA) – National and Kapodistrian University of Athens


SC5-03-2016: Climate services market research
• Type of action: Research and Innovation action
• Deadline: 8 March 2016
• Scope
– a. Defining the European and international climate service market characteristics and foresight into market growth
– b. Climate services market barriers and enabling conditions
Common element: grow the climate service market by developing best practices and recommendations
Energy Policy and Development Centre (KEPA) – National and Kapodistrian University of Athens
17


SC5-03-2016: Climate services market research
• Role of partners
– NKUA-KEPA as coordinator
– Partners with experience in Covenant of Mayors
– Partners apart from researchers, policy makers and market stakeholders
• Ministries
• Organizations
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SC5-06-2016: Pathways towards the decarbonization and resilience of the European economy in the timeframe 2030-2050 and beyond
• Type of action: Research and innovation action
• Deadline: 8 March 2016
• Scope
– b. Assessment of the global mitigation efforts in the perspective of the long-term climate goal (2016)
• Profile of partners
– NKUA-KEPA as coordinator
– Partners with experience in climate change policy and particularly in UNFCCC negotiations
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SC5-07-2017: Coordinating and supporting research and innovation on the decarbonization of the EU economy
• Type of action: Coordination and support action
• Deadline: 7 March 2017
• Scope
– Create a network of leading and relevant projects in the field of EU decarbonization
• Profile of partners
– Partners experienced with
• Networking
• Scenario analysis and modeling
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Thank you
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