BSEC
Hellenic Chairmanship

# 7th International Scientific Conference

# Energy and Climate Change

## *Towards Green Economy*

## PROCEEDINGS

organized by

Energy Policy and Development Centre (KEPA)

National and Kapodistrian University of Athens

**ISBN: 978-960-466-142-8**
**ISSN: 2241-7850-3**

# Contents

BSEC Hellenic Chairmanship

academic impact

# 7th International Scientific Conference on Energy and Climate Change

towards green economy

## AGENDA

| Day 1 | 10 October 2014 |
|---|---|
| 9:30 – 10:00 | Registration |
| 10:00 – 11:30 | **Session 1: Opening** |
| | **CHAIR**<br>Amb. Traian CHEBELEU<br>Deputy Secretary General BSEC-PERMIS<br>Prof. Edoardo CROCI<br>IEFE – Bocconi University, Italy<br>Prof. Dimitrios MAVRAKIS<br>Director of KEPA, National and Kapodistrian University of Athens, Hellas |
| | **SPEAKERS** |
| | Prof. Theodoros FORTSAKIS<br>Rector of the National and Kapodistrian University of Athens, Hellas |
| | Amb. Michail CHRISTIDIS<br>Coordinator of the Hellenic Chairmanship of BSEC, Hellenic Ministry of Foreign Affairs |
| | Amb. Traian CHEBELEU<br>Deputy Secretary General BSEC-PERMIS |
| | Mr. Mammad ZULFUGAROV<br>Secretary General, BSEC Business Counsil |
| | H.E. Mr. Lucian FATU<br>Ambassador of the Romanian Embassy in Hellenic Republic |
| | H.E. Mr. Kwang Heon DOH<br>Counselor of the South Korean Embassy in Hellenic Republic |
| | Prof. Dimitrios MAVRAKIS<br>Director of KEPA, National and Kapodistrian University of Athens, Hellas |
| 11:30 - 12:00 | Coffee break |

BSEC Hellenic Chairmanship

| 12:00 – 14:00 | **Session 2: Policies** |
|---|---|
| | **CHAIR**<br>Prof. Dejan IVEZIC<br>University of Belgrade, Serbia<br>Prof. Milton TYPAS<br>National and Kapodistrian University of Athens, Hellas |
| | **SPEAKERS** |
| | "Wind, Biomass and Solar Energy Resources in Egypt"<br>by Prof. Zeinab SAFAR - Cairo University, Egypt |
| | "Participatory Backcasting Approach in Energy Planning –An Experience from the City of Niš"<br>by Dr. Marija ŽIVKOVIC - University of Belgrade, Serbia |
| | "Policy Coordination for Green Bioeconomy – A Manifesto for Southern Europe"<br>by Prof. Emmanuel KOUKIOS - National Technical University of Athens, Hellas |
| | "Monitoring of the German Energiewende – institutional setting and scientific challenges"<br>by Mrs. Jeannette PABST - Federal Environment Agency, Germany |
| | "Scenarios for a Greenhouse Gas Neutral Society in Germany"<br>by Mr. Mark NOWAKOWSKI - Federal Environment Agency, Germany<br>"Short term assessment of the energy efficiency policy mixtures in the Black Sea Region"<br>by Dr. Popi KONIDARI and M.Sc. Anna FLESSA - Energy Policy and Development Centre – National and Kapodistrian University of Athens, Hellas |
| 20:30 | **Dinner** |

BSEC Hellenic Chairmanship

academic impact

## Day 2 | 9 October 2014

| | |
|---|---|
| 09:00 – 09:30 | Registration |
| **09:30 – 11:30** | **Session 3: Climate Change** |

**CHAIR**

Prof. Krzysztof WARMUZINSKI
Institute of Chemical Engineering, Polish Academy of Sciences, Poland

Prof. Evaggelos DIALYNAS
National and Kapodistrian University of Athens, Hellas

**SPEAKERS**

"The use of alkaline industrial waste in the capture of carbon dioxide"
by Prof. Krzysztof WARMUZINSKI - Institute of Chemical Engineering, Polish Academy of Sciences, Poland

"Energy Demand Analysis and Energy Saving Potentials in the Greek Road Transport Sector"
by Dr. Spyros KIARTZIS - HELLENIC PETROLEUM S.A., Hellas

"A review on climate change adaptation policies for the transportation sector"
by Mr. Iraklis STAMOS - Centre for Research and Technology Hellas, Hellenic Institute of Transport, Hellas

"The Norwegian support and subsidy policy of electric cars. Should it be adopted by other countries?"
by Professor Anders SKONHOFT - Norgegian University of Science and Technology, Norway

"Gas-To-Wire As A Way Of Bridging The Energy Gap In A Developing Country"
by Mr. Emeka OJIJIAGWO - University of Wolverhampton, United Kingdom

| | |
|---|---|
| **11:30 – 12:00** | **Coffee break** |
| **12:00 – 13:30** | **Session 4: Renewable Energy Sources** |

**CHAIR**

Prof. Chien Te FAN
National Tsing Hua University, Taiwan

Prof. Antonios CALOKERINOS
Vice Rector of the National and Kapodistrian University of Athens, Hellas

**SPEAKERS**

"Legal issues in Chinese international trade disputes on photovoltaic products --- On the perfection of green subsidies WTO rules"

BSEC Hellenic Chairmanship

academic impact

| | |
|---|---|
| | by Prof. Chien Te FAN - National Tsing Hua University, Taiwan |
| | "Impact of distributed generation on power system: case study"<br>by Dr. Astrit BARDHI - University Polytechnic of Tirana, Albania |
| | "Feed-in Tariff Reform in PV Sector: What's the Next Step?"<br>by Dr. Anton Ming-Zhi GAO - National Tsing Hua University, Taiwan |
| | "Horizon scanning for social sustainability in the bioenergy value chain"<br>by MBA Mrs. Elena FEDOROVA - Thule Institute, University of Oulu, Finland |
| 13:30 - 15:00 | Lunch break |
| **15:00 – 18:00** | **Session 4: Renewable Energy Sources** |
| | **CHAIR**<br>Prof. Haji MALIKOV<br>Geotechnological Problems of Oil, Gas and Chemistry (GPOGC) of the Azerbaijan State Oil Academy (ASOA), Azerbaijan<br>Prof. Katherine M. PAPPAS<br>National and Kapodistrian University of Athens, Hellas |
| | **SPEAKERS** |
| | "Validation and utilization of numerical weather model data in energy systems analysis, modelling and forecasting of decentralized renewable electricity production"<br>by Mr. Hans SCHERMEYER - Karlsruher Institute for Technology, Germany |
| | "Reforming Energy Subsidies for a Better Implementation of Renewable Energies in Tunisia"<br>by Mrs. Asma DHAKOUANI - Ecole Nationale d'Ingenieurs de Tunis, Tunisia |
| | "Biodiesel Production from Microalgal Systems: A Resource Based Feasibility and GHG Assessment"<br>by Mr. Lazaros KARAOGLANOGLOU, National Technical University of Athens, Hellas |
| | "Potentials of Biofuel Generation from Organic Waste: A Pilot project at a Composting Facility in Darmstadt, Germany"<br>by Dipl.-Ing. Jan KANNENGIESSER - Technical University of Darmstadt, Germany |
| | "Economic analysis of an offshore wind farm near Samothraki island"<br>by Dipl. Eng. E. I. KONSTANTINIDIS - Democritus University of Thrace - Department of Production Engineering and Management, Hellas |
| | "Recycled waste plastics composite: Possible construction material for wind turbine blades"<br>by Ms. Janet M. MWANIA - University of Nairobi, Kenya |
| | "Energy and Exergy Analysis Concepts: Modelling of Olkaria II Geothermal Power Plant in Kenya" |

BSEC Hellenic Chairmanship

by Mr. Nahshon NYAMBANE - University of Nairobi, Kenya

"Investigating the opportunities for wave energy in the Aegean Sea"
by Mr. George LAVIDAS - Institute for Energy Systems - University of Edinburgh, United Kingdom

"Risks and opportunities of Eucalyptus planting (Case study in the framework of the GIZ-German-Madagascan Environmental program)"
by Ms. Laura PRILL - University of Hamburg, Germany

| Day 3 | 10 October 2014 |
|---|---|
| 9:00 – 9:30 | Registration |
| 9:30 – 11:30 | **Session 5: Projects** |
| | **CHAIR**<br>Dr. Lulin RADULOV<br>BSREC, Bulgaria<br>Prof. Konstantinos KARAGIANNOPOULOS<br>National Technical University of Athens, Hellas |
| | **SPEAKERS** |
| | Mr. David J. LIPPEATT<br>Economic Councelor of the U.S. of America Embassy in Hellenic Republic |
| | "Cooperation between local and regional authorities for sustainable energy and climate - results of the European Coopenergy project"<br>by Edoardo CROCI - IEFE – Bocconi University, Italy |
| | "The IncoNet EaP project and Opportunities for Grants"<br>by Dr. George BONAS - IncoNet EaP, CeRISS, Hellas |
| | "Accelerating progress towards the Green Economy"<br>by Ms. Anastasia IOANNOU - University of Piraeus, Hellas |
| | "Belenos Activities in the field of green energy and its storage"<br>by Dr. Elli VARKARAKI - Belenos Clean Power Holding, Switzerland |
| | "CIRCLE- 2/ Adapt-Med "Is current decision making "adapted to internalize adaptation" into policy making? Project Presentation"<br>by Mrs. Theodora PARAMANA - National and Kapodistrian University of Athens, Hellas |
| | "European CCS Demonstration Project Network: Real life experiences towards a low carbon world"<br>by Mrs. Zoe KAPETAKI - Global CCS Institute, Belgium |
| 11:30 – 12:00 | **Coffee break** |

BSEC Hellenic Chairmanship

academic impact

| | |
|---|---|
| 12:00 – 13:30 | "European Gas Assessment (EU-Gas) model"<br>by Mr. Andreas KANDIROS - Epsilon International SA, Hellas |
| | "Case study in the framework of the Economics of Land Degradation Initiative on energy-wood plantations in northern Madagascar"<br>by Mr. Gernot GAUGER - University of Hamburg, Germany |
| | "Mobilizing and transferring knowledge on post-2012 climate policy"<br>by Ms. Anastasia IOANNOU - University of Piraeus, Hellas |
| | "SUNSHINE: Smart Urban Services for Higher Energy Efficiency"<br>by Mr. Andreas KANDIROS - Epsilon International SA, Hellas |
| | "SUstainability Policy and practice: An Executive Re-training program (SUPER)"<br>by Prof. Emmanuel KOUKIOS - National Technical University of Athens, Hellas |
| 13:30 – 15:00 | **Session 6: Round table** |
| | **CHAIR**<br>Prof. Dimitrios MAVRAKIS<br>Director of KEPA, National and Kapodistrian University of Athens – Hellas |
| | *Discussion on HORIZON2020 calls for 2015 and other international funding activities* |

## End of Conference

| | |
|---|---|
| **Conference Venue** | Kostis Palamas building<br>2nd Floor<br>Akadimias 48 and Sina str., Athens |
| **Organizer** | Energy Policy and Development Centre (KEPA)<br>National and Kapodistrian University of Athens<br>E-mail: epgsec@kepa.uoa.gr<br>Website: www.kepa.uoa.gr |

**Sponsors**

ΔΕΠΑ PUBLIC GAS CORPORATION S.A.

NATIONAL BANK OF GREECE

ΔΕΗ Public Power Corporation S.A.-Hellas Energy for everyone

PROMITHEAS NET

NKUA KEPA

6/6

## List of Participants

| A/A | Title | First Name | Last Name | Organization |
|---|---|---|---|---|
| 1 | Dr. | Astrit | Bardhi | Polytechnic University of Tirana, Albania |
| 2 | Dr. | George | Bonas | IncoNet EaP, CeRISS, Hellas |
| 3 | Prof. | Antony | Calokerinos | National and Kapodistrian University of Athens, Hellas |
| 4 | Amb. | Traian | Chebeleu | Black Sea Economic Cooperation-PERMIS |
| 5 | Amb. | Michail | Christidis | Hellenic Ministry of Foreign Affairs, Hellas |
| 6 | Mrs. | Athina | Christou | Public Power Corporation S.A, Hellas |
| 7 | Mr. | Eric | Cicora | U.S.A. Embassy in Hellenic Republic |
| 8 | Prof. | Edoardo | Croci | IEFE - Bocconi University, Italy |
| 9 | Prof. | Marc | De Clercq | Ghent University, Belgium |
| 10 | Mrs. | Asma | Dhakouani | Mediterranean Renewable Energies Center, Tunisia |
| 11 | Prof. | Evangelos | Dialynas | National Technical University of Athens, Hellas |
| 12 | Mr. | Kwang Heon | Doh | South Korean Embassy in Hellenic Republic |
| 13 | Prof. | Chien-Te | Fan | National Tsing Hua University, Taiwan |
| 14 | Amb. | Lucian | Fatu | Romanian Embassy in Hellenic Republic |
| 15 | Mrs. | Elena | Fedorova | University of Oulu, Finland |
| 16 | Mrs. | Anna | Flessa | National and Kapodistrian University of Athens Energy Policy and Development Centre (KEPA) |
| 17 | Mrs. | Tereza | Fokianou | FLOW Energy & Environmental Operation S.A., Hellas |
| 18 | Prof. | Theodoros | Fortsakis | National and Kapodistrian University of Athens, Hellas |
| 19 | Prof. | Anton Ming-Zhi | Gao | The Institute of Law for Science and Technology (ILST), National Tsing Hua University, Taiwan |
| 20 | Mr. | Gernot | Gauger | University of Hamburg, Germany |

| | | | | |
|---|---|---|---|---|
| 21 | Mrs. | Chrysa | Giannakoudi | IncoNet EaP, CeRISS, Hellas |
| 22 | Mrs. | Eleni | Gratsia | Ministry of Environment Energy & Climate Change, Hellas |
| 23 | Mrs. | Damla | Gumuskaya | Turkish Embassy in Hellenic Republid |
| 24 | Mr. | Odysseas | Iliopoulos | National Bank of Greece, Hellas |
| 25 | Ms. | Anastasia | Ioannou | University of Piraeus, Hellas |
| 26 | Mr. | Igor | Ivanchenko | Ukrainian Embassy in Hellenic Republic |
| 27 | Prof. | Dejan | Ivezic | University of Belgrade, Serbia |
| 28 | Mr. | Roger | Jorgensen | Norwegian Embassy in Hellenic Republic |
| 29 | Mr. | Jan | Kannengiesser | Technical University of Darmstadt, Germany |
| 30 | Mrs. | Zoe | Kapetaki | Global CCS Institute, Belgium |
| 31 | Prof. | Constantinos | Karagiannopoulos | National Technical University of Athens, Hellas |
| 32 | Mr. | Lazaros | Karaoglanoglou | National Technical University of Athens, Hellas |
| 33 | Mr. | Olim | Kasimov | Consulate General of Uzbekistan in Athens |
| 34 | Mr. | Yannis | Kechagiaras | IncoNet EaP, CeRISS, Hellas |
| 35 | Dr. | Spyros | Kiartzis | Hellenic Petroleum S.A., Hellas |
| 36 | Mr. | Dimitrios | Kliafas | National Bank of Greece, Hellas |
| 37 | Mrs. | Natalia | Klimenko-Rampias | National and Kapodistrian University of Athens Energy Policy and Development Centre (KEPA) |
| 38 | Dr. | Popi | Konidari | National and Kapodistrian University of Athens Energy Policy and Development Centre (KEPA) |
| 39 | Mr. | Emmanuel | Konstantinidis | Democritus University of Thrace, Hellas |
| 40 | Mr. | Konstantinos | Konstantopoulos | U.S.A. Embassy in Hellenic Republic |
| 41 | Prof. | Emmanuel | Koukios | National Technical University of Athens, Hellas |
| 42 | Mr. | Stamatis | Laskaris | Infrastructure Projects and Business Development Consultant (EM), Hellas |

| | | | | |
|---|---|---|---|---|
| 43 | Mr. | George | Lavidas | University of Edinburgh, United Kingdom |
| 44 | Mr. | David | Lippeatt | U.S.A. Embassy in Hellenic Republic |
| 45 | Mrs. | Valia | Magoula | TAIPEI representative in Hellenic Republic |
| 46 | Prof. | Haji | Malikov | Geotechnological Problems for Oil, Gas and Chemistry, Azerbaijan |
| 47 | Mr. | Emilios | Margaritis | Infrastructure Projects and Business Development Consultant (EM), Hellas |
| 48 | Ms. | Aliki-Nefeli | Mavraki | National and Kapodistrian University of Athens Energy Policy and Development Centre (KEPA) |
| 49 | Ms. | Eleni-Danai | Mavraki | National and Kapodistrian University of Athens Energy Policy and Development Centre (KEPA) |
| 50 | Prof. | Dimitrios | Mavrakis | National and Kapodistrian University of Athens Energy Policy and Development Centre (KEPA) |
| 51 | Mr. | Timo | Mrukwia | Technical University of Darmstadt, Germany |
| 52 | Ms. | Janet | Mwania | University of Nairobi, Kenya |
| 53 | Mr. | Wordy | Nicolas | U.S.A. Embassy in Hellenic Republic |
| 54 | Mr. | Mark | Nowakowski | Federal Environment Agency, Germany |
| 55 | Mr. | Nahshon | Nyambane | University of Nairobi, Kenya |
| 56 | Prof. | Katherine | Pappas | National and Kapodistrian University of Athens, Department of Biology |
| 57 | Mrs. | Theodora | Paramana | National and Kapodistrian University of Athens, Department of Geology and Geoenvironment |
| 58 | Mrs. | Jenny | Passari | National and Kapodistrian University of Athens Energy Policy and Development Centre (KEPA) |
| 59 | Mr. | Marios | Patsoules | European Energy Technology Institute (EETI), Hellas |
| 60 | Prof. | Serafim | Poulos | National and Kapodistrian University of Athens, Department of Geology and Geoenvironment |
| 61 | Mrs. | Laura | Prill | University of Hamburg, Germany |
| 62 | Mr. | Dmitry | Prokofiev | Russian Embassy in Hellenic Republic |
| 63 | Dr. | Lulin | Radulov | Black Sea Regional Energy Centre (BSREC), Bulgaria |
| 64 | Prof. | Zeinab | Safar | Cairo University, Egypt |
| 65 | Mr. | Hans | Schermeyer | Karlsruher Institute for Technology, Germany |

| | | | | |
|---|---|---|---|---|
| 66 | Amb. | Gil-Sou | Shin | South Korean Embassy in Hellenic Republic |
| 67 | Mrs. | Eleni | Sidiropoulou | Public Power Corporation S.A, Hellas |
| 68 | Prof. | Anders | Skonhoft | Norgegian University of Science and Technology, Norway |
| 69 | Mr. | Iraklis | Stamos | Centre for Research and Technology Hellas-HIT |
| 70 | Mrs. | Arakelian | Tatevik | Armenian Embassy in Hellenic Republic |
| 71 | Mrs. | Vasiliki | Tsadari | Public Power Corporation S.A, Hellas |
| 72 | Prof. | Milton A. | Typas | National and Kapodistrian University of Athens, Department of Biology |
| 73 | Dr. | Elli | Varkaraki | Belenos Clean Power Holding, France |
| 74 | Mrs. | Alexandra | Vasila | National and Kapodistrian University of Athens Energy Policy and Development Centre (KEPA) |
| 75 | Mr. | Konstantinos | Venetsanos | National Bank of Greece, Hellas |
| 76 | Mr. | Alfred | Wang | TAIPEI representative in Hellenic Republic |
| 77 | Prof. | Krzysztof | Warmuzinski | Institute of Chemical Engineerging, Poland |
| 78 | Dr. | Marija | Zivkovic | University of Belgrade, Serbia |
| 79 | Prof. | Essia | Znouda | Mediterranean Renewable Energies Center, Tunisia |
| 80 | Mr. | Mammad | Zulfugarov | BSEC Business Council, Turkey |

# Opening

# Opening speech by Prof. Theodoros FORTSAKIS

Rector of the National and Kapodistian University of Athens, Hellas

Excellencies, Ladies and Gentlemen and distinguished colleagues[i],

As the Rector of the National and Kapodistrian University of Athens, the oldest Greek university, I cordially welcome you to our premises on the occasion of the opening of the 7th 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 Hellenic Chairmanship in Office of the Black Sea Economic Cooperation Organization.

I take the opportunity to express my sincere gratitude to the Permanent Secretariat of the Black Sea Economic Cooperation Organization for the continuously expressed support to the efforts of our university 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.

In this context I would like to convey to you all my intention to transform our university to a *green paradigm* by taking concrete measures to shorten its carbon footprint. We are already in the process of introducing natural gas 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.

It is an ambitious target, taking into account the magnitude of our installations but we should not avoid undertaking the necessary measures that will finally allow us to become a green paradigm for our society. After all we constitute the first public institution that has built the first public bioclimatic and smart building in our country ten years ago, meaning the building of KEPA, and we can take advantage of the lessons learned from this experience.

As the Rector of this university, I would like to thank the Deputy Secretary General ambassador **Traian Chebeleu** and the Secretary General of the Business Council Mr. **Mammad Zulfugarov** of BSEC for their participation in this occasion and reassure them 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.

The European Union has released the biggest research and innovation program of the world, which is the Horizon 2020 and in the coming years with the additional support of the BSEC we are ready to develop and promote concrete proposals in a wide range of available programs among the EU member states, the associated countries and other countries worldwide on the basis of scientific excellence.

We have a huge potential, both in human resources and infrastructure in our schools and faculties and I am determined to take the advantage 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, to widen 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.

This year the conference brings together scientists from 16 countries from Europe, Central Asia, Asia – Pacific, Africa and America with the double aim to contribute to a high level scientific dialogue and to provide the ground for future cooperation on the basis of the Horizon 2020 and of the BSEC calls for proposals.

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

# Opening speech by Amb. Michail CHRISTIDIS

Coordinator of the Hellenic Chairmanship of BSEC, Hellenic Ministry of Foreign Affairs

Excellencies

Distinguished participants

On behalf of the Hellenic Chairmanship of BSEC, I have the pleasure to participate at this opening session of the 7th International Scientific Conference on Energy and Climate Change, organized by the PROMITHEAS Network coordinated by the Energy Policy and Development Centre (KEPA) of the National and Kapodistrian University of Athens.

The Conference takes place under the aegis of the Black Sea Economic Cooperation Organization and consists part of a multidimensional effort of the academic community of our region to promote regional cooperation on the crucial issues of Energy and Climate Change.

The Conference focuses this year on the efforts in our region to promote "Green Economy", an issue of global importance, especially in the context of the forthcoming Conferences of Parties (COP) in Lima this year and in Paris next year under the United Nations Framework Convention on Climate Change (UNFCCC).

It is important mentioning that the conference it is not only a scientific event, during which prestigious scientists meet to present their research outcomes but also a three days event where policy makers from ministries and agencies of BSEC and other countries are invited to participate and contribute presenting their national policies. In addition it is a forum where the market stakeholders can participate and take advantage of the knowledge and opportunities that are transferred and offered from this interaction between scientists, policy makers and market stakeholders. We have also noticed the effort to promote cooperation on the basis of the EU Horizon 2020 calls for proposals through the last day's organized brokerage event.

We are also aware of the existing problems in promoting this combined cooperation in the quite competitive and challenging area of green economy where the knowledge transfer and the capacity building on the emerging policy instruments will play a dominant role in the global efforts to confront Climate Change.

I am satisfied that the *"Green Energy Development Initiative"* that was included in the Ministerial Declaration of the Ministers on Energy who met at Nafplion, here in Greece, on 12 October 2010, during the Hellenic Chairmanship- in- Office is not only active but is flourishing, motivating and encouraging our societies to participate actively in the global efforts, to mitigate Climate Change.

I think that this is the right moment to express the appreciation of the Hellenic Chairmanship-in-office for the long lasting efforts of KEPA, especially of *Prof. Dimitrios Mavrakis* and the other academic institutions from BSEC countries to transfer knowledge to our governments and mobilize our societies on the crucial importance issues of Climate Change and the need for developing converging policies.

We fully support the efforts of PROMITHEAS network to establish resulting links of cooperation with the relevant communities of the European Union in the context of FP6, FP7 and now H2020 framework programmes of the European Union.

In this context it is worth mentioning the impact of PROMITHEAS – 4 project, financed by EU that aimed to transfer knowledge in our region on developing and evaluating mitigation-adaptation policy mixtures in most of our member states.

We have been kept informed in our ministerial meetings (Sofia, Nafplion, and Belgrade) and continuously in the relevant Working Groups of BSEC on this 3-year project and the offered opportunities for knowledge transfer and capacity building in the beneficiary countries.

I think that after three international and twelve national conferences that have been organized through PROMITHEAS-4 we have a better understanding of the state and the perspectives of Climate Change policies in our region and this allows me an optimistic approach concerning our efforts to develop regional converging low carbon policies.

In a period of global economic recession, green economy may be the triple answer to mitigate the climate change, to adapt our societies to the emerging severe atmospheric phenomena and finally to secure the present and future well being of our societies.

It is an effort that can not be successful if it is left only to international negotiations and agreements.

Political leaders should and have to conclude with binding legal agreements next year but our societies have to transfer them to the real economy and with no doubt we need the scientific community to add the necessary knowledge in this effort. We need the active and fast reaction of the market forces of our economies so as to adapt themselves to the new realities that are characterized by the new technologies and the innovative approaches.

With these thoughts allow me to congratulate the staff of KEPA and *Prof. Dimitrios Mavrakis* for their efforts to promote regional cooperation and indeed for the organization of this conference and finally to wish you every success in your works.

# Opening speech by Amb. Traian CHEBELEU

Deputy Secretary General BSEC-PERMIS

Dear Professor Mavrakis,
Distinguished Participants,

For a number of years, I have had the honour to represent the Black Sea Economic Cooperation Organization (BSEC) at the International Scientific Conferences on Energy and Climate Change, organized by *Promitheas* Network, directed by the Energy Policy and Development Centre (KEPA) and hosted by the National and Kapodistrian University of Athens.

We are indeed proud to offer the BSEC aegis to such a prestigious yearly event, as it was a small project supported by the Project Development Fund of BSEC which was at the origin of the *Promitheas* Network, which consists today of prestigious academic and research institutions from all the 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 from the European Union and with generous contributions of the Hellenic Government. The interest of our Organization in the follow-up of this project is confirmed by the fact that all the previous six *Promitheas* Scientific Conferences were held under the auspices of the successive BSEC Chairmanships-in-Office, currently the Hellenic BSEC Chairmanship-in-Office.

Since 2008, when it started, this conference has developed into one of the well established discussion fora in the BSEC Region for energy and climate change issues, that has gained a very much deserved prestige at international level, benefiting from the participation of scientists, researchers and policy makers from all over the world.

Over the years, these scientific conferences and, more generally, the activities of he Promitheas Network have made significant contributions to the knowledge transfer 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 its 12 Member States in these fields.

This year, the Conference focuses on “Green economy”, which is a major area of action of BSEC. In this regard, it is worth reminding that, in fact, it was under the previous BSEC Hellenic Chairmanship-in-Office, four years ago, when the Ministers of Energy of the BSEC Member States adopted in their meeting at Nafplion, Greece, on 12 October 2010, a Declaration concerning a *“Green Energy Development Initiative”* and have set up a Task Force with the aim to identify relevant issues within which regional cooperation can be most effective, and also to explore ways to promote green energy investments and innovative green energy projects. The Task Force started working in April 2012 and, *inter alia*, agreed on the creation of a Network between administrative bodies and/or centres and organizations mandated to promote renewable energy sources and energy efficiency measures and policies, as an important tool for exchanging information and for sharing know-how and good practices among the BSEC Member States.

This discussion regarding the creation of the Network have benefitted from a Working Paper which was elaborated by the Energy Policy and Development Centre (KEPA), in cooperation with BSEC PERMIS, in 2013. The participants agreed to continue discussion on the issue at the next meeting of the Task Force, which is going to take place on 3 November 2014, focusing on practical steps that need to be taken in order to start the functioning of the Network.

The Task Force has also started working on a Green Energy Strategy with the view to promoting renewable energy sources, clean technologies and energy efficiency, taking into account that the *BSEC Economic Agenda*, adopted by the Council of Ministers of Foreign Affairs of the BSEC

Member States and endorsed by the BSEC Summit in June 2012, on the occasion of the 20th anniversary of the Organization, envisages taking gradual steps to materialize the vision of transforming the BSEC Region into a model for clean energy by the year 2050.

In this context, a significant part of our efforts are focused on the development of the BSEC regional cooperation in Green Energy. We count very much on the professional advice and contribution of Professor Mavrakis and his team in these efforts. In fact, the activities of *Promitheas* Network and the series of International Scientific Conferences on "Energy and Climate Changes" have had significant contributions to bringing our Member States closer together and have provided valuable inputs to our activities in the framework of BSEC aimed at enhancing the regional cooperation in the fields of energy and environmental protection.

We need strengthening the interaction between the academic sector and energy stakeholders for an efficient cooperation in the BSEC framework in promoting green economy. Such interaction always produces ideas and concrete recommendations that we can use afterwards in our discussions within the BSEC Working Groups and materialize in action to be taken by our decision-making bodies.

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

# Opening speech by Mr. Mammad ZULFUGAROV

Secretary General, BSEC Business Council

Excellences,

Ladies and Gentleman,

At the outset, I would like to thank Promitheas.net and personally Prof. Mavrakis for organizing such a prestigious gathering and creating this opportunity that enables us to learn about the current scientific developments and research on Energy and Climate Change. I would also like to extend my sincerest compliments to BSEC Hellenic Chairmanship-in-Office and BSEC Green Energy Task Force for their kind contributions in the realization of this conference.

Organization of the Black Sea Economic Cooperation Business Council (BSEC Business Council), was established in 1992 by the representatives of the business communities of the twelve BSEC Member States to contribute to the efforts of their Governments to secure the greater integration of the Black Sea region into the world economy. BSEC Business Council is an international, non-governmental, non-profit organization. According to the Charter of the BSEC Organization, the BSEC Business Council is one of its four Related Bodies, forming its business pillar.

As the Organization representing the business communities in the 12 Member States, the BSEC Business Council aims to promote business cooperation and regional integration as a first step toward integration into the global business system. BSEC Business Council is determined to support and stimulate the development and strengthening of an international and regional collaboration mechanism to facilitate internationalization policies and set objectives towards shaping BSEC Region into a competent economic powerhouse in global economy.

BSEC Business Council offers a unique opportunity in a globalized world while importance of public-private partnership increases. The main objectives of the BSEC Business Council are to provide a platform for public-private partnership, lobbying and acting for the continuous improvement of the business and investment environment throughout the Black Sea Region by broadening cooperation with countries inside and outside of the region as well as by creating and strengthening cooperation with international organizations and financial institutions and to ensure the full-fledged participation in the global and regional initiatives. Therefore, BSEC Business Council facilitates, through trade conferences, business fora, fairs, exhibitions, sectoral meetings and etc, promotes regional and global trade, establishment of joint ventures and other strategic partnerships, the exchange of experiences and know-how, as well as other forms of cooperation among business people, thus contributing to the economic integration of the Region. The operation and activities of the BSEC Business Council are supported by both the business community and the governments aiming to secure the greater integration of the Black Sea region into the world economy.

In this context, I also would like to emphasize the role of BSEC Business Council in the Wider Black Sea Region, in terms of encouraging the green economy and energy efficiency.

The world economy today is no longer a simple sum of national economies and national markets but a global-universal system, in unity through relationships between subsystem and components. Its structure is extremely heterogeneous and contradictory. Challenging environment created by the free market conditions and the notion of internationalization will also lead business circles to adopt a more competitive business understanding in the home markets and encourage them to seek new challenges in international business. New trends in the global economy for greener solutions and energy efficiency is another issue for most of the emerging economies of the Black Sea Region as the environmentally friendly development of an economy and industrial infra-structure is not only a greener option but a vital choice for sustainability.

Across the globe, there is an increasing tendency towards energy efficiency and environmental protection. The new business understanding of the 21. Century evolves around environmental awareness. In this regard energy efficiency is more important in this new perspective. It is crucial to cut carbon emissions and continue to meet the targets set out in the Climate Change Act, which will allow us to afford growing energy demand in safer a way for the environment. Thus we may leave a more habitable World for our children, grandchildren and generations to come. Doing what is right for our planet, but doing what is right for our economy too.

Energy consumption is expected to grow by a third over the next two decades. The struggle for limited resources is a competition and it is the energy efficient that will be a more successful challenger.

Businesses that are protected from energy price volatility will be more secure in the business environment and can be most confident about the future. It is also same for consumers as well for countries that puts green energy before other priorities that will secure biggest share of jobs and sustainable growth in a global low carbon sector set to be worth around $4tr by 2015.

Sustainable energy sources, more efficient energy consumption, and our economies more resilient to energy price are vital for the growth and wealth that we need.

Businesses in Black Sea Region should seek to build on their position in the cleaner conventional energy, renewable energy, energy efficiency, water treatment equipment, solid waste treatment operations, mechanical and biological pre-treatment of waste, waste tire recovery, air quality and emissions monitoring equipment and environmental consulting services.

Public authorities have an important role to play in promoting our eco-industries. At regional and local level, we should continue to develop the right framework conditions and help provide specialist advice and finance facilities for SMEs. SMEs are often faced with market failures due to longer returns on investment and difficulty in penetrating well established markets.

I do believe this conference will serve to the highlighting the importance of green economy in the region and provide a common ground for participants to exchange their experiences in most challenging sectors of economy.

Wider Black Sea area shares a lot of economic and political incentives and this creates opportunities, even needs for stronger and more committed international cooperation.

In conclusion, I would like to emphasize the determination of International Secretariat of BSEC Business Council to further contribute to the strengthening of regional partnership for ensuring the sustainable development and prosperity of the Wider Black Sea Regions.

Thank you for your attention.

# Address by Romanian Ambassador Lucian FĂTU

Distinguished audience,

It is my privilege to address a short message to this conference and to thank the organizers for granting me the opportunity to do so. One year ago, almost to the day, I had a similar honour and I used it to highlight the main priorities of the Romanian Government in fostering the vital link between energy and climate change, between growth and environmental sustainability.

One year after, we address the same topics, we share the same goals, although a lot has changed in Greece, in Europe and worldwide, on the energy market and on the economic front. The Greek Chairmanship in Office of the BSEC provides a timely opportunity to look into the prospects of the *green economy*, but also beyond, as it brings together countries that are impacted, directly or indirectly, by the instability on the Northern shores of the Black Sea and by the looming wave of violent conflict south of Turkey. It is a test for the BSEC and a test for Europe. After a successful EU Presidency, I am confident Greece is fully capable of performing similarly in the BSEC. Ambassador Christidis is, in my opinion, the right man in the right place and at the right time.

Last night, while listening to Mr. Yannis Maniatis, Minister of Environment, Energy and Climate Change of the Hellenic Republic addressing the 2nd annual economic forum organized by the Hellenic Entrepreneurs Association, I realized once again the transnational relevance of the topics on our agenda today. According to Minister Maniatis, Greece needs a new *production model*, a *new social and business contract* that takes environment into account. The challenge he identified was: can we have progressive policies in a country that has been, during the last few years, committed to the conservative policies envisaged by its lenders? And I wondered if, in various forms, this is not a question we all face around the Black Sea and beyond. Proving this dilemma false can only be achieved through a production model that can create jobs and be economically profitable not just for those trading in carbon emission shares.

I would like to wish you all fruitful exchanges and productive networking.

Thank you.

# Opening Remarks by H.E. Gil-sou SHIN, Ambassador of the Republic of Korea in Athens

Distinguished Guests, Ladies and Gentlemen,

I believe that it is indeed highly meaningful for me to have this chance to attend the 7th International Scientific Conference on "Energy and Climate Change", which is oriented towards "Green Economy". This conference which brings together governments, scholars, businesses, and international organizations, has emerged as an excellent example of Global Public-Private Partnership.

Furthermore, constructive proposals and ideas could be put forward at this conference, thereby contributing to the shaping of the future for humankind.

Distinguished Guests,

Today, I would like to introduce policies of the Republic of Korea on how to respond the challenges we are facing.

Amongst the greatest challenges of our times are Climate change and resource depletion. Given this, it is only when we accord appropriate thought to environmental resilience that we can indeed achieve the resilient economies, societies, and institutions we discussed earlier today.

Yet policies for the strengthening of economic, social, and environmental resilience can lead not only to a synergy but indeed can also have potential negative effects or entail trade-offs among each other. Accordingly, they present the very challenging task for policy makers of drawing the "optimal policy mix".

In particular, for the shaping of environmentally resilient economies and societies there is a need not only for well-thought-out policies and a strong determination of governments, but also technological capacity in the private sector to make the realization of such policies possible. And there is a need also for consensus amongst the public with regard to such policies.

Distinguished Guests,

Seeking to achieve a virtuous circle between the environment and the economy, the Government of the Republic of Korea has set "green growth" as a top priority of the national development over the last five (5) years. In the policies we have sought to effectively reduce greenhouse gas emissions, strengthen capacity in adapting to climate change, and nurture green industries, and indeed green the entire value chain in our economy. And the Korean Government has invested the equivalent of "2 percent of GDP" to this end.

Such efforts have indeed borne fruit. We have institutionalized the pursuit of green growth; set reduction targets for greenhouse gas emissions and put in place systems for achieving those targets; and laid the foundation for future growth engines by investing in green technology.

As a part of such efforts, Korea has mainstreamed green growth as a task for all at both the international and the regional level, such as in the UN, OECD, G20, and ESCAP. We have endeavoured, in cooperation with like-minded countries, to spread understanding of and support for the values and benefits of green growth. In so doing, we have sought to make what may have been a rather grey word "growth" more vivid by painting it green.

In addition, we have continued to exert efforts to support developing countries in their efforts responding to climate change and making transition to a green economy. The establishment of the GGGI in 2012 and hosting of the GCF in Korea in 2013 are some instances of our efforts to support developing countries.

Distinguished Guests,

Moreover, we have also learned "valuable lessons" in the five years of the green growth policy. First of all, it might be said that the results have not been significant compared to the level of investment. It has also been said that the insufficient progress in terms of fostering a market-based ecosystem in the energy sector may be partly attributed to the supply-focused policy pursued by the government. It has resulted in a limited progress in encouraging business to participate voluntarily for achieving green growth. The failure to fully consider the needs of SMEs and socially vulnerable groups in the process of implementing green growth policy has also been said to have undermined the benefits of the policy.

Based on the lessons learned over the last five years, the Korean Government is establishing the second 'Five Year Plan for Green Growth', which will more actively embrace the concept of inclusive green growth, reflecting a balance of economic, environmental and social dimensions.

The key direction of the second Five Years Plan is to yield more tangible and substantial results by strategically selecting key areas and implementing these in a focused way, increasing the role of the market and private sector, and expanding green welfare for vulnerable groups of society.

Distinguished Guests,

I firmly believe that all the participants gathered here today will be pioneers in creating a green future.

It is my sincere hope that, with our heartfelt efforts, this conference will indeed yield highly fruitful results.

Thank you.

# Opening by Prof. Dimitrios MAVRAKIS

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

Excellencies,

Distinguished participants,

On September 23rd the Climate Leaders' Summit took place in the United Nations headquarters in the perspective of the forthcoming 21st Conference of Parties of the United Nations Framework Convention on Climate Change in December 2015 in Paris.

Unfortunately the results of this summit were disappointing taking into account the narrow window of opportunity for concrete and effective decisions.

Prominent leaders that took the floor have focused on generalities, presenting their national policies, achievements and perspectives but missed to contribute in developing the necessary momentum that will allow them next year to conclude with a legal binding agreement.

Twenty years after the Rio Summit the challenge of Climate Change still remains to be faced.

Years of dispute among developed and developing countries seem to conclude that a global effort should be undertaken to limit the increase of the atmospheric temperature to less than 2$^o$ C, in reference to the pre-industrial period.

Current trends in fundamentals show, according to United Nations reports that the world population is expected to increase from the current 7.2 to 9.6 billion till 2050 while at the same time world economy is expected to increase from the current $90 to $280 trillion.

According to the International Energy Agency these trends lead to the increase of energy demand by one-third up to 2035 with reference to the year 2010, with China and India accounting for 50% of the growth, and with fossil fuels keeping their dominant role in the fuel mixture.

In this perspective and following the current Baseline scenarios, the anthropogenic GHG emissions are estimated to increase the mean atmospheric temperature to the level of 3-6 even 7$^o$C till the end of 2100, according to successive reports of UNEP.

In addition the expected volume of $CO_2$ equivalent emissions will reach 56Gt$CO_2$eq by 2020 instead of the 44 Gt$CO_2$eq which is the target for the 2$^o$C pathway.

Even if the international pledges, undertaken in Copenhagen, are accomplished, emissions will be limited to 49Gt$CO_2$eq which provides a likely gap of 5Gt$CO_2$eq and this corresponds to GHG emissions of the transport sector of 2005.

We know that if we want to Mitigate Climate Change so as to enter the 2$^o$C pathway it is necessary to decrease the energy consumption from 170 kgoe/1000$ to 31kgoe/1000$ or in other terms to reduce our current production of emissions from 2.4 ton$CO_2$/1ton$_{oe}$ to 1.5 ton$CO_2$/1ton$_{oe}$

In this context the world political leaders have failed, so far, to create the necessary momentum for the next year's agreement.

The Kyoto protocol period has shown that regardless of how a country or a group of countries is determined to implement policies against Climate Change, those policies are insufficient to confront a global challenge. However the Kyoto period has created an amount of experience and knowledge on the characteristics of the political instruments that has to be developed for the efficient handling of the Climate Change.

The Framework for Various Approaches as it is defined, so far, allows a multiple approach for both developed and developing countries while the last ones in the context of the Nationally Appropriate Mitigation Actions, have the opportunity to participate in the global efforts through "tailor made" reliable national programs.

Nevertheless participation in the Framework for Various Approaches and taking advantage of the investment and international financing opportunities in the context of the Nationally Appropriate Mitigation Actions requires a certain level of knowledge and infrastructure that is missing from most of the developing and some of the developed countries.

Financing through the “prompt start” initiative of the World Bank, has contributed in knowledge transfer and capacity building on critical issues like the development of reliable data bases, monitoring, reporting and verifying procedures but the allocated funds proved to be quite insufficient in comparison to the global needs.

The Black Sea Trade and Development Bank could play an important role in this process if it could be convinced by the governments of BSEC to modify its relevant policies.

The Framework for Various Approaches in combination with the Nationally Appropriate Actions and the additional policy instruments for Reducing Emissions from Deforestation and Forest Degradation and for the Land Use, Land-Use Change and Forestry can provide an outline of policies capable to develop a global carbon market and the transformation to green economy.

Energy efficiency is recognized as one of the main pillars to mitigate the Climate Change and New Technologies are expected to play a key role in the coming years also. At this point I would like to underline the huge energy saving potential that exists in the countries of BSEC.

Our experience in developing mitigation pathways for twelve countries of our region, allows us the conclusion that in the context of the aforementioned policy instruments and with the appropriate financing for knowledge transfer and capacity building, countries with developing economies can proceed in developing converging national $2^o$ C pathways regardless of the present state of their mitigation policies.

Apart from the efforts to develop converging global climate change mitigation policies there is an increasing need for policies and measures capable to adapt our societies to the increased occurrence of the extreme atmospheric phenomena.

It is not the time to analyze this sector but social uneasiness created by the explosive mixture of increased population, crop destruction and damage of infrastructure, networks and buildings cannot only threaten the stability and the wellbeing perspectives of certain countries but may also lead to local or regional conflicts, a perspective that we tend to underestimate.

In KEPA, together with other scientific institutes from EU, Asia and Africa have concluded that in the forthcoming years it is necessary to provide the evidence base to policy makers that will allow them to develop their “triple win” $2^o$ C national pathways capable to converge with the relevant global efforts characterized by an optimum mixture of mitigation, adaptation and sustainable development policies.

We are aware of the argument that the cost of this “triple win” proposal is high for conventional economies but it is also true that the cost of not taking and implementing the necessary policies is estimated to be unbearable. If the already mentioned trends are going to be verified it has to be clear that the more we delay to act the higher the social and economic bill will be paid.

Excellencies, ladies and gentlemen

For more than ten years, as academic institution and as partners of PROMITHEAS network we participate in this effort to facilitate the development of the necessary knowledge base for the policy makers in our region and far beyond.

The same we plan to do during this annual Conference that is consisted of three parts allowing policy makers, scientist and market stakeholders to meet and have a constructive dialogue on how to contribute in the aforementioned global effort.

In this context and on behalf of my colleagues and the personnel of KEPA allow me to welcome and wish you a fruitful conference.

Thank you

# Policies

# Wind, Biomass and Solar Energy Resources in Egypt

**Mounir Wahba LABIB**
GHG Technical Advisor, EGYPT-Third National Communication (TNC) Project- UNDP, Egyptian Environmental Affairs Agency (EEAA) Misr Helwan Road Bldg. 30, Maadi, Cairo, Egypt

**Zeinab SAFAR***
Head of Mechanical Engineering Department, Cairo University, Egypt

**Wael Farag KESHK**
[3]Environmental Researcher, Mitigation & Clean Development Mechanism Department, Climate Change Central Department, Egyptian Environmental Affairs Agency (EEAA), Egypt

*E-mail: zeinabsafar@yahoo.com

**Abstract:** New and renewable energy resources in Egypt include solar, wind and biomass. Egyptian strategy for energy supply and use aims to increase the renewable energy share of the total energy demand to 20% by 2020 with contribution 12% from wind. Egypt is endowed with high potential of wind energy. The Wind Atlas indicates that there are large wind energy resource in the regions of the Western and Eastern Desert. There are some projects implemented in Zafarana along Red sea, but still insufficient to cover huge wind capacities in Egypt. Solar Atlas for Egypt indicates that Egypt lies among the Sun Belt countries with annual global solar insolation ranging from 1750 to 2680 kWh/m$^2$/year from North to South and annual direct normal solar irradiance ranging from 1970 to 3200 kWh/m$^2$ /year. Sunshine daily duration in this region is ranging from 9 - 11 hours. Biomass resources in Egypt that can be used for energy production are classified into Agricultural residues, Animal by-products, Agro industrial byproducts, Exotic plants, Oil crops, Municipal waste, and Sewage sludge. The total amount of biomass is about 60 million tons/y; they are still not well used as alternative fuel. This paper presents these activities in the country. Although there is a great potential for wind, solar & biomass resources in Egypt, they are not well used until now due to several barriers. These barriers include: market barriers institutional barriers and technical barriers. This paper presents these activities in the country.

## 1. Introduction

Renewable energy sources like wind, solar, geothermal, hydrogen and biomass play an important role in the world future. In line with the sustainable development, variety of programs worldwide has been initiated the future of a balanced global energy economy. The renewable energy sources include biomass, solar, geothermal, wind, hydrogen and waterfalls[1]. Sustainable energy is an important component of development planning, which is based on two main elements: using energy and its efficiency. An integral part of the energy sustainability is to minimize its negative impact on the environment[2]. Economic and social sustainable development is directly linked with the availability of adequate sources of energy, which ensure suitable living conditions. This requires the provision of a balanced mix of conventional and renewable energy resources, and reducing impacts of energy production and consumption on the surrounding environment and human health. The development of renewable energy technologies and systems and its entry to the commercial use have opened promising prospects for the potential to contribute significantly in providing part of the required energy for the process of development[3]. New and renewable energy resources in Egypt include mainly solar, wind and biomass. The Egyptian strategy for energy supply and use aims to increase sustainable sources of energy to meet the growing needs of economic growth and development for present and future generations, and to increase the renewable energy share of the total energy demand to 20% by 2020 with contribution 12% from wind[4]. The major barriers that face applying renewable energies in Egypt are technology and high cost.

## 2. National Energy Outlook

The primary energy sources of Egyptian energy sector are fossil fuel products liquid and natural gas. The energy consumption growth rate is ranging between 6-7% annually ,the projected consumption by year 2022 will be almost tripled for natural gas and will be one and half times for fossil fuel products. The overall consumption will be doubled**.** The electricity generation tends to be mainly driven by conventional technologies which include; 1) steam thermal power stations, 2) gas turbine and combined cycle, 3) off grid diesel engine generation, 4) hydropower plant, and 5) wind turbines. The hydropower resources are almost fully utilized 90% of available resources.

There is a small component of wind resources. In this context, the thermal power generation, including the first three technologies, represents about 84.4% whilst the hydropower represents about 14.8% and 0.8% is for wind technology**.** The electricity generation and fuel cin 2010 was 139000 GWhr [5].

## 3. National Strategy for Energy Supply and Use

The strategy was approved in February 2008, aims to increase the contribution of renewable energies by 20% of the total electricity generation by the year 2020. The share from the grid-connected wind power is 12% of the total electricity generation, and that represents about 7200 MW total capacities. Also, other renewable energy applications, led by hydropower and solar energy, will have a significant contribution. Such a plan gives room for private investments to play the major role in realizing this goal.

Efforts are being exerted in order to reach total capacities of 7200 MW and this will be achieved through two main paths[6]:

1- State-owned projects implemented by the New and Renewable Energy Authority (NREA) with total capacities of 2375 MW (represents 33% of total installed capacities). These projects will be financed through governmental agreements.

2- Private sector projects with total capacities of 4825 MW (represents 76% of total installed capacities). Policy of increasing the participation of private sector will include two phases:

   *Phase I:* Adopting Competitive Bids approach as the Egyptian Electricity Transmission Company will issue tenders internationally requesting private sector to supply power to build, own, operate wind farms and selling electricity for the company with price agreed upon between the company and the investor.

   *Phase II:* Application of Feed-in-tariff system, taking into consideration the prices and experience achieved in phase I. In May 2009, investors were invited to submit their prequalification documents for the first competitive bid for 250 MW wind farm. Through the few coming years, it is expected to launch some wind projects via competitive tenders.

The strategy stresses on adopting energy production policies for rationalizing and raising the efficiency of energy uses, including energy pricing structures in both the industrial and household sectors. These pricing structures aim at protecting limited-income groups from any unaffordable costs for their energy needs; and enhancing awareness for rationalizing energy utilization at homes, factories as well as other various services sites[7].
In addition to that, a National Energy Efficiency Strategy (NEES) in Egypt has been established aimed at creating a sustainable energy efficiency market through strategic partnerships between the public and private sectors[8].

Egypt is also hosting a regional center of excellence for renewable energy and energy efficiency in the Middle East and North Africa (RCREEE), which aims at supporting the formulation and dissemination of policies aiming at the promotion of renewable energies and energy efficiency, the development of new technologies in these fields[9].

## 4. Renewable Energies Opportunities in Egypt

New and renewable energy resources in Egypt include solar, wind, hydropower and biomass. The promising opportunities are in wind, solar and biomass energies.

Wind Energy

Egypt is endowed with high potential of wind energy. The Wind Atlas further indicates that there are large wind energy resource in the regions of the Western and Eastern Desert – in particular west and east of the Nile valley between 270 N and 290 N, are much higher than hitherto assumed. The mean wind speeds predicted are between 7 and 8 $ms^{-1}$ and the power densities range between 300 and 400 $Wm^{-2}$. The Wind Atlas for Egypt confirms the existence of a widespread and particularly high wind energy resource along the Gulf of Suez. With mean wind speeds and mean power densities of 7-10.5 $ms^{-1}$ and 350-900 $Wm^{-2}$, respectively, estimated for a height of 50 m over roughness class 1 (roughness length of 0.03 m), as presented in Figure 1[10].

*Wind Power Status in Egypt*
*Current projects*[6]

**A)** 5 MW Wind Farms in Hurghada, operates since 1993, it includes (42) wind turbines with different technologies, German, Danish, and American. Wind turbines have single, double and triple blades. The percentage of local manufacturing reached about 40% (blades, towers, mechanical and electrical works) and the capacity of wind turbines ranges between 100 to 300 kW.. The total production of the power plant in 2009/2010 reached around 7 GWh saving about 1.5 thousand tons of oil equivalents and reduces the emission of approximately 4000 tons of carbon dioxide.

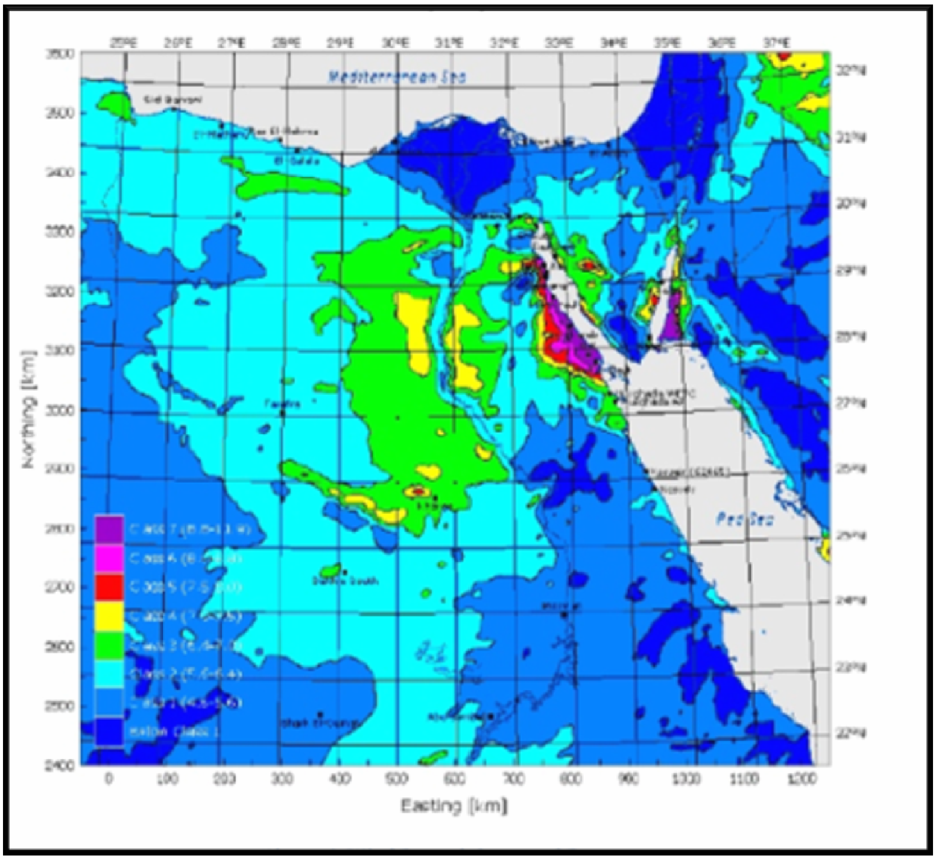



**Figure 1: Wind potentials around Egypt.**

B) 517 MW Wind Farm in Zafarana, This wind farm has been implemented in several stages (60, 80, 85, 80, 120 MW) starting in 2001and has been completed in August 2010 .

*Future Projects*[6]

New & Renewable Energy Authority is currently preparing to achieve wind projects with total capacities of 1120 MW. These projects will be implemented through governmental co-operation agreements according to the following:

**First: Projects with capacities of 540 MW under implementation and its financing procedures were completed:** 200 MW Wind plant in co-operation with KfW, European Investment Bank (EIB) and the European Union, 220 MW wind plant in co-operation with Japanese Agency for International co-operation (JICA) in the Gulf of El Zayt & 120 MW wind farm in co-operation with Spain in the Gulf of El-Zayt.

**Second: 580 MW wind farms are being financed:** Two wind farms with capacities of 180 MW in the Gulf of Suez where The government of Spain participate in 140 MW, 200 MW wind farm with Masder company Owned by Abu Dhabi government & 200 MW Wind farm project in co-operation with KfW, the French Development Agency (AFD) the European Investment Bank and the European Union.

**Third: 700 MW wind farm projects in West Nile are under Negotiation:** Also it is planned that the private sector shall implement wind projects with total capacities of 1370

Solar Energy[6]**:**

Solar Atlas for Egypt indicates that Egypt lies among the Sun Belt countries with annual global solar insolation ranging from 1750 to 2680 kWh/$m^2$/year from North to South and annual direct normal solar irradiance ranging from 2000 to 3200 kWh/$m^2$ /year. Sunshine duration in this region is ranging from 9 - 11 hours /day from North to South with very few cloudy days. Figure 2, presents Egypt annual average of global solar radiation[11].

*Solar Energy Status in Egypt*[3]

During the 1980s, the Ministry of Electricity and Energy imported 1000 solar flat plate water heaters with different capacities. They were installed in different places in order to initiate a market for solar water heaters and to increase the national awareness of the benefits and advantages of solar heaters uses.

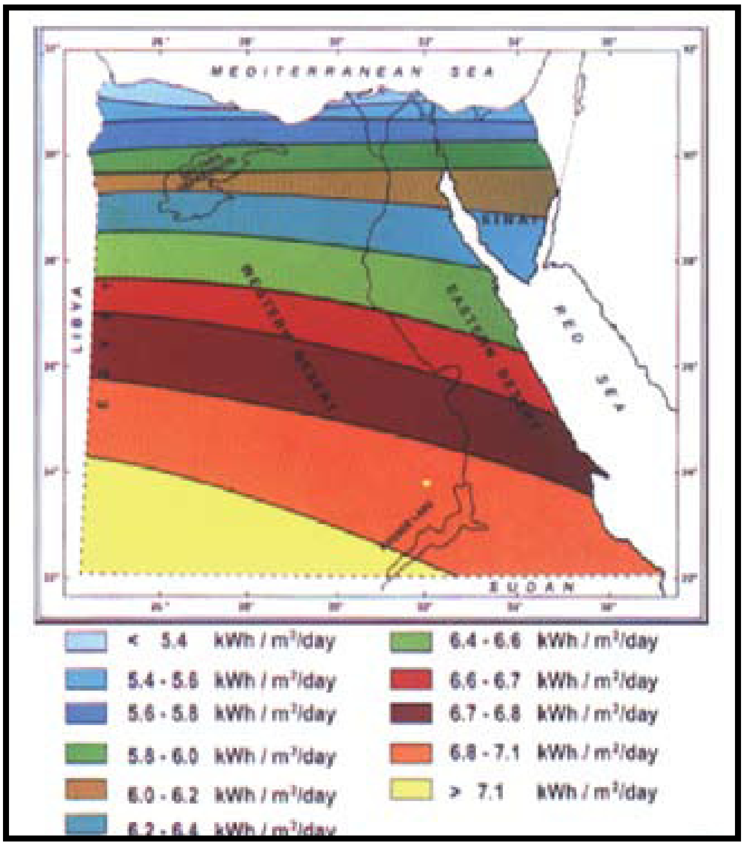



**Figure 2: Egypt Annual Average of Global Solar Radiation.**

At the same time, first private company for manufacturing of solar water heaters has been established, followed by establishment of local companies for manufacturing of solar water heaters reaching 10 companies so far, bringing the total of what has been manufactured and installed in Egypt until the year 2009 to about 400 thousand solar heater.

*Current Projects*[6]

A) Disseminating Solar Heaters Project in Hotels located in Red Sea and Sinai: The project is implemented with the co-operation between Egyptian Government, Italian Government and the United Nations Environment Program (UNEP).

B) Kuraymat 140 MW Integrated Solar Combined Cycle Power Plant: The project site at Kuraymat, which locates nearly 90 km South Cairo, has been selected because of: (1) High intensity direct solar radiation that reaches 2400 kWh /m2 / year. (2) An extended unified power grid and expanded natural gas pipelines. (3) Located near to the sources of water (the River Nile). (4) An uninhabited flat desert land. The project based on parabolic trough technology integrated with combined cycle power plant using natural gas as a fuel. The project is one of 3 similar projects are being implemented in Africa (Morocco, Algeria, Egypt), which mainly depending on integrating solar field with combined cycle. The capacity of the project is 140 MW including solar share of 20 MW.

C) Combined Cycle Island: The capacity is 120 MW. The cost of foreign portion is 17.43 Million Yen, equivalent of 174.8 Million Dollar (as soft loan from JICA) (0,75% interest + 10 years grace period + 30 years repayment period) + 281 Million L.E. financed through NREA. The cost of local portion is 281.86 Million L.E. financed through NREA. Gas Turbine and steam turbine was constructed. The first firing & operation of the turbine was completed and it is connected to the grid with 68 MW as maximum load. The water desalination plant was completed. The operation of steam turbine and Gas turbine has been started. The connection with the solar field tests and the performance are under preparation.

D) Photovoltaic Systems: In spite of being an expensive technology, Photovoltaic systems are considered the most appropriate energy application for rural and remote areas of small scattered loads which are faraway from national grid. The cost of PV systems' maintenance is limited while the PV life span is about 25 years. The total capacity of PV systems in Egypt is around 10 MW, for lighting, water pumping, wireless communications, cooling and commercial advertisements on highways.

E) Lighting villages using photovoltaic Systems: NREA signed a protocol for co-operation with the Italian Ministry of Environment, Land and Sea to electrify two remote settlements in Matrouh Governorate by PV systems. The project consists of: lighting of 100 houses and 40 street light units, 1 school and (3) mosques, and 2 medical clinic units. A contract between NREA and a Spanish company has been signed to implement the project in November 2009.

*Future Project*[6]

A) Solar Electricity Generation projects are considered one of the main aspects to increase the contribution renewable energies and the 5th year plan (2012 - 2017) includes: Solar thermal electricity generation plants, with total capacity of 100 MW & Photovoltaic plants with total capacity of 20 MW. Egypt proposed projects to be financed under the program of the Clean Technology Fund (CTF) to expand electricity generation projects from solar thermal concentrators.

B) EMPower Program, the objective of the project is reducing the cost of electricity generated by PV and CSP technologies, by increasing the global market demand for those technologies. This objective can be achieved by: “supporting utilities in countries around the world to help them to identify solar applications and to determine both, the potential demand and the cost of solar energy relative to other generation sources. 18 sites were visited by local and international experts to prepare a proposal for projects generating electricity from solar energy connected with different capacities starting from 1 MW for projects of PV and 50 MW of CSP.

C) Mediterranean Concentrating Solar Desalination (MED-CSD) Project. The partners of this project are institutes from North and South of the Mediterranean Sea, Egypt is represented by NREA. The Observatoire Méditerranéen de l'Energie (OME) acting as a coordinator for the project. The goal of this project is strengthen co-operation between institutions of research and development in this field in EU countries and their counterparts in Mediterranean countries, exchange experiences.

Biomass

For Biomass, the resources in Egypt that can be used for energy production are classified into the following categories: Agricultural residues (crop residues), Animal by-products (dung), Agro-industrial by-products (e.g. rice husk (the black cloud), bagasse),
Exotic plants (water hyacinth, reeds, etc), Oil crops (rape seed, Jatropha, etc.), other crops (elephant grass, etc.), Municipal waste which includes municipal solid wastes, Sewage sludge. The total amount of biomass is of the order of 60 million ton/y, which is equivalent to 20 million toe /y[10].

*Research Projects in the Field of Biomass*

A) **Developing a Complementary Mobile Briquetting System for Plant Residues, in co-operation with the Academy of Scientific Research and Technology:** The project aims to design and manufacture an integrated system for waste treatment such as cotton wastes, firewood and similar things, by transforming it into high-density, regular shape, easy transport and storage briquettes with the elimination of pests and pathogens. The project aims also to reduce the cost of storage, transport and handling of the waste, and to improve their properties as a fuel for domestic stoves instead of butane gas, or as a raw material used for the manufacture of improved feed and organic fertilizer, industrial soil and charcoal.

B) **Developing a Small Clean Carbonization System, in co-operation with US-Egypt Joint Science and Technology Board affiliated to the Academy of Scientific Research and Technology:** Within the framework agreement for scientific and technological co-operation between Egypt and the United States, NREA participates as an executive and technical body in the implementation of a research project to design and produce Clean Small Carbonization System to be used instead of conventional environmentally polluting systems. The concept of the project is to heat wastes and wood in an evacuated closed container to produce Gases, which will be sucked to a burning room of an oven for heating charcoal. The excess gases will be burnt outside the burning room.

Activities under Clean Development Mechanism (CDM) [12]:
In the context of addressing environmental issues and climate change phenomenon, Egypt signed Kyoto Protocol in 1997 and ratified it in 2005. According to Kyoto Protocol, the developed and industrialized countries that signed Annex 1 to the said Protocol are obliged to reduce their Green House Gases (GHGs) emissions by 5.2% from that of 1990, in the period from 2008-2012. Three mechanisms were identified to realize the

Protocol's goals: (1) Joint Implementation (JI), (2) Emissions Trade (ET), (3) Clean Development Mechanism (CDM). The third mechanism (CDM) is designed to allow co-operation between Annex 1 developed countries and developing countries through implementing projects financially supported by developed countries, in the developing countries provided that such projects contribute to both sustainable development in developing countries and GHG emission reductions. Such emission reductions will be sold to the developed countries hence be accredited to these countries in partial fulfillment of their emission reductions obligations.

**A)** Egyptian CDM Wind Power projects[12]:

a. **120 MW Wind Power Plant Project in co-operation with Japan:** The project has been registered in June 2007. The estimated annual electricity generation is about 452,016 MWh, hence saving about 103,060 TOE from fossil fuel and consequently, reducing about 248,609 TCO2eq.

b. **80 MW Wind Power Plant Project in co-operation with Germany:** The project has been registered in March 2010. The estimated annual electricity generation is about 300,000 MWh, hence saving about 68,400 TOE from fossil fuel and consequently, reducing about 171,500 TCO2eq.

c. **120 Wind Power Plant Project in co-operation with Denmark:** The project has been registered in September 2010; hence the approval is expected by the first half of 2010. The estimated annual electricity generation is about 399,456 MWh, hence saving about 91,076 TOE from fossil fuel and consequently, reducing about 224,723 $TCO_2eq$.

d. **85 MW Wind Power Plant Project in co-operation with Spain:** The project has been submitted and approval is anticipated around the fourth quarter of 2011. The estimated annual electricity generation is about 283,000 MWh, hence saving about 64,512 TOE from fossil fuel and consequently, reducing about 155,000 $TCO_2eq$.

**B)** Egyptian CDM Biomass Power projects[12]:

Emissions reduction through partial substitution of fossil fuels with renewable plantation biomass and biomass residues in CEMEX Assuit Cement Plant: The project has been registered in January 2011. The estimated annual emission reduction is 204,693 $TCO_2eq$.

**C)** Renewable Energy Program of Activities (PoAs)[19]:

In the context of clean development mechanism, Egypt shifted to more focus on program of activities that allow the possibility of implementing similar projects under the same program umbrella. These programs could be done at national, sub national, regional or global scale. Each program may include several renewable energy projects, e.g. wind, solar, hydro, etc.. according to the applied clean development mechanism methodologies within this program.

In that regard, Egypt has participated in 4 regional renewable energy program of activities as follows:

1. **The Programme for Grid Connected Renewable Energy in the Mediterranean Region** is a programme to promote renewable energy in North African and Middle Eastern countries. The idea of the PoA is to facilitate the development of green field energy projects connected to the national grids, deploying the following technologies: wind power, solar photovoltaic (PV), concentrated photovoltaic (CPV) and concentrated solar power (CSP). This is a regional PoA currently covering 7 countries of the Middle East and North Africa (MENA) region, namely: Algeria, Egypt, Jordan, Lebanon, Morocco, Mauritania and Tunisia. The PoA aims to facilitate carbon finance solutions for renewable energies in the region.

2. **Renewable Energy Programme of Activities in Middle East and North Africa.** The proposed PoA involves grid-connected renewable energy sources that will displace electricity generated by fossil fuel based power plants, resulting in the decrease of greenhouse gas emissions. The following renewable energy technologies are covered: Wind Power and Solar Power. The program diversifies sources of electricity generation that are necessary to meet a growing demand for energy and facilitates the transition away from fossil-fuel electricity generation

3. **Small-Scale Renewable Electricity Advancement Programme:** The objective of this PoA is to facilitate the development of renewable energy projects in the host countries, which currently face various technical, institutional & financial barriers for the commercial introduction of renewable energy supply by providing an additional stream of income in the form of revenues from CDM. Therefore the goal of the PoA is to: "Increase the in the host countries electricity production by renewable technologies for reduction of GHG emissions from conventional fossil fuel based power production".

4. **Renewable Power Advancement Programme:** The objective of this PoA is to facilitate the development of renewable energy projects in the host countries, which currently face various technical, institutional & financial barriers for the commercial introduction of renewable energy supply The following technologies for grid connected electricity production can be implemented under the PoA: Wind power, Solar PV, Solar thermal, Solar thermal with utilization of fossil fuel, Geothermal energy & Hydro power.

## 5. Results & Discussion

Although there is a great potential for wind, solar & biomass resources in Egypt, they are not well used until now due several barriers. These barriers include: market barriers (such as, small size of the market, limited access to international markets for modern Renewable Energy Technologies (RETs), limited involvement of the private sector[15]), institutional barriers (such as, unfavorable policies and regulatory mechanism for RE, no incentives for using RET such as tax cuts, etc, no compulsory feed in law and feed in tariff to encourage the private sector to invest, limited institutional capacity, R&D, demonstration and implementation projects[15]), technical barriers (such as lack of access to the technology/know how, inadequate operation and maintenance facilities and quality control on products, very little funds to promote R&D in RE technologies and invest in RE Components manufacturing and training[15]), financial barriers (such as, inadequate financing instruments for RE projects on both national and international levels), awareness and information or technological barriers[16].

## 6. Conclusions

Egypt has various opportunities for applying renewable energy technologies. Thus to achieve sustainability in Egypt's energy sector it is important to develop an overall national energy strategy that incorporates renewable sources and acts as an umbrella for the existing renewable energy plans. This strategy should be involved in the Egyptian development plan in all sectors, as this will help to overcome the existing barriers whether institutional, technical, financial, market, awareness and information or technological barriers. Under this strategy, research and development programs for making Egyptian manufacturing more effective and competitive regarding quality and price of RE products are essential. The research plan should focus on the following issues:

- Research and development work for each RET.
- Industrial research and development of components of RET and technical & financial Assistant for manufacturers.
- Human Resources development program and training for workers in the RET.
- Encourage private sector to invest in R & D for RE technologies.

## References

1. Global Renewable Energy Review, 2005.
2. Georgy.R.Y, "Energy Efficiency and Renewable Energy, Egypt - National study", Regional Activity Centre; March 2007.
3. Annual Report of the New and Renewable Energy Authority (NREA), www.nrea.gov.eg, (2008/2009).
4. NREA Home Page. See http://www.nrea.gov.eg/english1.html.
5. Central Agency for Public Mobilization and Statistics (CAPMAS), "Statistical YearBook of the Arab Republic of Egypt", www.capmas.gov.eg, June 2005.
6. Annual Report of the New and Renewable Energy Authority (NREA), www.nrea.gov.eg, (2009/2010).
7. Egypt's Second National Communication Report, March 2010.
8. United States Agency for International Development, Mission to Egypt, "Support to the Development of a National Energy Efficiency Strategy", December 2001.
9. RCREEE Home Page. See http://www.rcreee.org/index.aspx.
10. Saad. N., "Renewable Energy Potentials in Egypt", REMENA Master Program, 2010.
11. ERC – Final Report December 2006, "*Renewable Energy Sector in Egypt*" (Tender IMC/PS_217), Cairo, Egypt, 2006.
12. UNFCCC Home Page. See http://unfccc.int/cdm.
13. German Aerospace Center (DLR), "Concentrating Solar Power for the Mediterranean Region, MED CSP", 2005.
14. German Aerospace Center (DLR), Federal Ministry for the Environment, "TRANS Mediterranean Interconnection for Concentrating Solar Power", Germany, 2006.
15. Elsobki, M., "Regulatory Policies towards Renewable Energies in Egypt", 2nd International Conference on Scientific Research, Cairo University-Cairo, December 2005.

16. Desk Study Compiled by: Green Line Association, "Status and Potentials of Renewable Energy Technologies in Lebanon and the Region (Egypt, Jordan, Palestine, Syria)", February 2007.
17. NREA Egypt, UNEP Collaborating Centre on Energy & Environment, "Implementation of Renewable Energy Technologies – Opportunities and Barriers, Egypt Country Study", 2001.
18. Egyptian General Petroleum Corporation, Annual Reports, www.emp.gov.eg, (2002-2004).
19. Egyptian Designated National Authority, Annual Reports, www.eeaa.gov.eg

# Participatory Backcasting Approach in Energy Planning –An Experience from the City of Niš

**Dr. Marija ŽIVKOVIĆ [1]**
Assistant professor
**Prof. Dejan IVEZIĆ[1]**
Full professor
**M.Sc. Aleksandar MADŽAREVIĆ[1]**
Research Assistant
**M.Sc. Dimitrije MANIĆ [2]**
Research Assistant

[1] University of Belgrade-Faculty of Mining and Geology
Tel: +381113219158
Fax: +381113235539
e-mail: marija.zivkovic@rgf.bg.ac.rs
Address:Faculty of Mining and geology, Djusina 7, 11000 Belgrade, Serbia
[2] University of Belgrade-Faculty of Mechanical Engineering

**Abstract:** This paper presents in brief main steps and results from the first participatory backcasting project carried out in the Republic of Serbia. The aim of the project was implementation of multidisciplinary approach and involvement of policy makers and stakeholders in energy planning - in this case: planning the more sustainable heating system of the city of Nis. Participatory backcasting procedure was carried out through following phases: problem analyses, identification of stakeholders, interviewing, visioning, selecting criteria, selecting scenario, scenario testing against criteria and key uncertainties. Results from all main phases are presented and discussed.

## 1. Introduction

Exploring the possible futures, for planning and decision making, can be achieved with three classes of scenarios (Vergart and Quist, 2011). Each class of scenarios gives the answer to the different question:

1) What will happen? These scenarios are based on trends extrapolations. It is assumed that no major changes will occur, and that societies, technologies, and cultures will develop according to a continuous path from the past towards the future (business as usual scenarios).

2) What could happen? Usually a range of possible futures is exploring with this class of scenarios, due to uncertainty of influential parameters (exploratory; foresighting; strategic scenarios). In development of such scenarios assumptions of trends, expectations, cultural changes and other relevant variables are included.

3) What should happen*?* This class represents normative scenarios, which are used in backasting approach. Backcasting can be explained as "generating a desirable future, then looking backwards from that future to the present in order to strategize and to plan how it could be achieved" (Quist and Vergragt, 2006). In this approach desired and preferable future–end point is a starting point, and the analysis steps back in time to explore how it may be achieved.

Backcasting approaches are usually categorized as "path oriented", "target oriented" or "participatory" (Börjeson et al., 2006; Quist and Vergragt, 2006). Scenario literature recommends that scenarios should be developed in a participatory manner, in order to include a diversity of different perspectives (Rotmans et al., 2000). Also, participatory approach provides: enhanced legitimacy, specific knowledge, increased quality of outcomes, support for outcomes, learning and increased responsibility for implementation of outcomes.

To achieve sustainable system in future, new integrated approaches are required. The most important is that such approach that should combine (Quist et al., 2002):

- Involving a broad range of stakeholders and actors from different societal groups including government, companies, public interest groups and knowledge bodies, not only when defining the problem, but also when searching for solutions and conditions and developing visions.

- Incorporating not only the environmental component of sustainability, but also its economic and social components.
- Taking into account the demand side and the supply chain as related production and consumption system.

Backcasting has been used in many cases to explore goal-fulfilling or desirable futures for the climate change mitigation, for decreased energy use and decreased emissions of green house gases (Green and Vergragt, 2002). Pathway for climate-neutral Sweden was developed by integrated exploratory and normative approach (Milestrad et al., 2014). (Svenfelt et al., 2011) presented backcasting study focused on fulfillment of a Swedish target to decrease energy consumption in residential and commercial buildings by 50% by 2050 compared with the consumption in 1995, and identifying possible measures for achieving it. Scenarios and action plans for sustainable heating in Ireland developed by participatory backcasting study were presented at (Doyle and Davis, 2013). This approach is also implemented at local level in United Kingdom (Bale et al., 2012).

Participatory backcasting approach for strategic energy planning and decision making in Serbia is being implemented for the first time, for the heating system of the city of Nis. This paper presents main activities realized until now and the major results achieved.

## 2. Participatory backcasting project for the heating system of the city of Nis

With more than 260 thousand inhabitants, the city of Nis is the third largest city in the Republic of Serbia. It is located at the southeast of the country, in an area characterized with continental climate (warm summers and cold winters). The hating season lasts six months, average number of heating days per season is 179, while the number of degree days is 2613. Average temperature during heating season is 4,4°C (Todorovic, 2005).

For the analyses of the heating system a process based approach is adopted (Figure 1). This approach considers and analyzes both: the supply and demand side of process of the system and their interaction. A common approach is to break down a system or process into basic functional units (components, modules, process steps).

Concerning method implemented, the review of the literature show differences in methods that can be applied, ways of stakeholder involvement and number of steps (Quist et al, 2001),(Robinson, 1990). In general this approach consists of five main steps:

1. Strategic problem orientation;
2. Construction of sustainable future visions or scenarios;
3. Backcasting;
4. Elaboration, analysis and defining follow-up and agenda;
5. Embedding of results and generating follow-up and implementation.

Approach implemented for the heating system of the city of Nis, until now, in general follows the algorithm presented at figure 2.

Main steps that required participation of stakeholders (Figure 3) were: Interviews and participation in two creative workshops.

The first workshop, which took place in April 2014, included following activities:

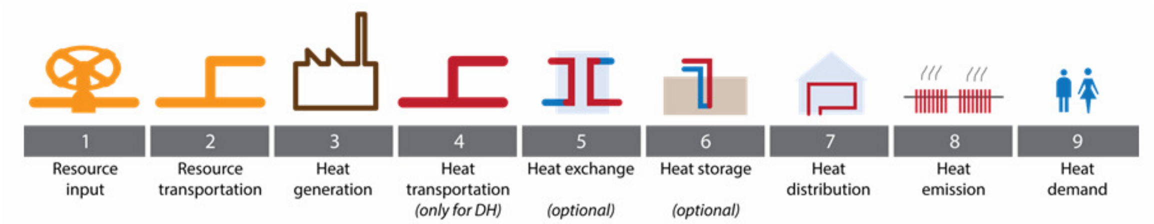



**Figure 1: Heating system interpretation according to process-based approach (Kordas et al., 2013).**

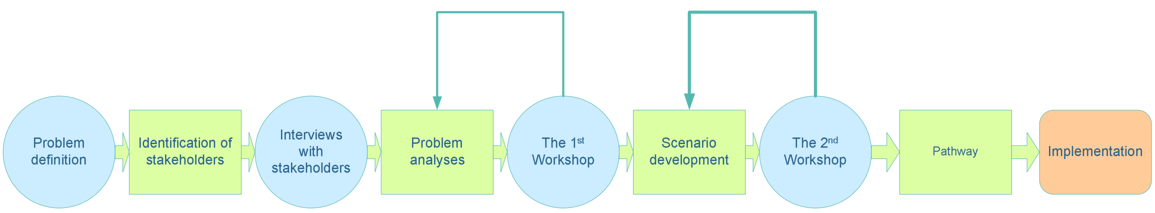



**Figure 2: Algorithm of the Participatory backcasting project for the heating system of the city of Nis.**

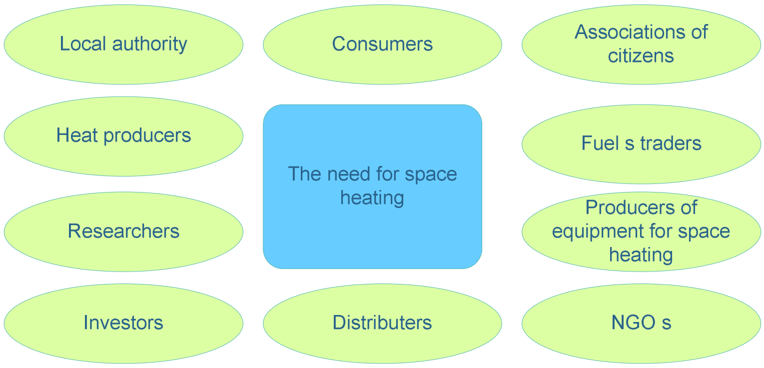



**Figure 3: The need for space heating and associated stakeholders.**

- Current state overview
- Problem analyses,
- Visioning (consensus among stakeholders)-qualitative description
- Criteria determination and ranking (consensus within groups)
- Inventory of drivers and their influence to the future system,
- Determination of key uncertainties,
- Stories of the future, by groups that consists from stakeholders with the same roles (for example: consumers, local authorities, producers, etc…)

During the second workshop (June 2014) following activities were finalized:

- Weighting of criteria,
- Selection of two key uncertainties,
- Scenarios testing against criteria,
- Robustness test,
- Scenario(s) selection,
- Pathway development.

An experience from this Project so far, confirms that this approach encourages broad participation of policy makers, producers, distributors, citizens in exploring possible future development pathways. Policy makers, representatives of local authorities and other stakeholders who are (or can be) directly involved in assessing possible futures, can help in shaping the future and reaching the target.

## 3. Major outcomes

*3.1. Problem orientation and current state overview- qualitative and quantitative characterization*

The first major step in implementing backcasting approach is description and elaboration of the current state which should consist of qualitative and quantitative characterization. Also, characterization of the present leads to the current indicators, important and useful for analyses, comparison and setting targets. For this activity various data sources were used: Publications of the Statistical office of the Republic of Serbia, Sustainable energy action plan for the city of Nis, interviews with stakeholders, data from the energy department of the city of Nis, papers, rapports, etc. The role of stakeholders in this phase is very important, since some of them have specific knowledge related to the analyzed problem.

The structure of fuels used for heating in household sector is presented at figure 4. The most used fuel is electricity, followed by firewood, and heat produced in district heating company. Low price per energy unit, compared to other energy sources, is the main reason for electricity consumption for heating. In practice it provides low level of comfort, since consumers use electrical heater(s) to heat only part of the apartment. Although it is renewable energy source with high share in consumption, firewood is used in inefficient traditional way mostly burned in wood stoves, causing high emission of carbon monoxide, nitrogen oxides, ash and particles. The usual practice when wood is used is heaing only the part of the apartment, similar as with electricity.

District heating company of the city of Nis is using dominantly natural gas which is the main fuel with share of 91%, while the remainder is extra heavy oil. As an example of stakeholders' feedback on fuel used in DH Company, advantages and disadvantages of current district heating system are pointed out.

Obtained result from the current state overview is also the end point of the pathway from the desirable future to the present.

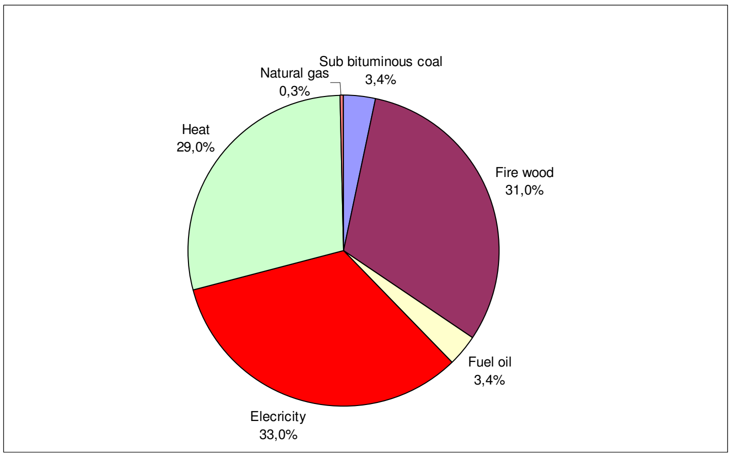



**Figure 3: Structure of final energy consumption for the heat demand in the household sector in 2010 (Sustainable Energy Action Plan for the City of Nis).**

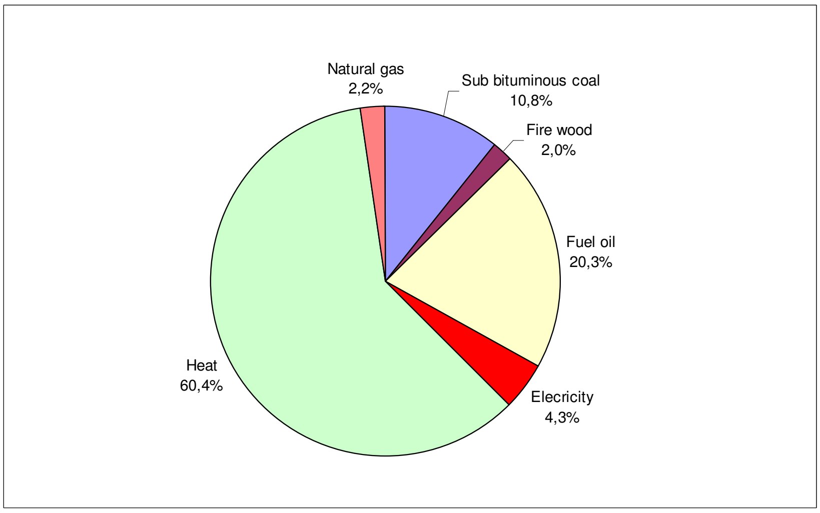



**Figure 4: Structure of final energy consumption for the heat demand in the public sector in 2010 (Sustainable Energy Action Plan for the City of Nis).**

**Table 1: Stakeholders feed back concerning fuel used in DH plant: (Interviews with stakeholders).**

| Advantages | Disadvantages |
|---|---|
| Environmentally friendly fuel usage in DH plant | Low security of supply |
| | High price per energy unit |
| | Imported fuel |
| | One supply route |

*3.1.1. Business as usual scenario-Visualization of possible future*

Before visioning, it is very useful to elaborate and present business as usual scenario, as the result from the model, if possible. Effect can be significant, since majority of stakeholders are not and does not need to be familiar with scenario development or long term energy planning. This step provides a descriptive answer to the question: "What will happen if the present practice and trends just continue?"

It is important to underline that future energy demand, supply structure and related emissions of pollutants are the result of present day policy decisions. It is more useful to work backwards to achieve a desired and defined objective, than to allow undesirable trends to continue.

*3.2. Visioning*

Visioning can be described as defining an attractive and clarifying sustainable future. It is important to mention that future visions in backcasting are not only analytical, but also social constructs. The idea is to stimulate processes open to different possible scenarios without big experts' involvement. The results of this stage of the project are description of the future (stories) from stakeholders groups and finally the vision statement achieved by consensus. Vision should be stated in positive context. For the case of the heating system of the city of Nis adopted vision statement is: "Affordable, comfortable and environmentally friendly heating in the city of Nis".

*3.3. Elaboration of criteria for the future system*

Criteria that will be used for the scenarios assessment are obtained as the result from the First workshop (Table 2). Stakehoders answerd the question: "What futre heating system should fulfil?"
During the Second workshop stakeholders reconsidered criteria with subcriteria and weighted them (Table 3). Obtained weights are used for scenarios assessment, and in the further phases of the project can be used for multi criteria decision making tools for a pathway selection.

*3.4. Scenario elaboration and assessment*

Scenarios proposed to stakeholders were descriptive and qualitative, developed as possible combination of parameters extracted from stakeholders descriptions of future (stories) and elaboration of week points of current system.

In the case of PB project in Nis to stakeholders were proposed scenarios with different combination of:

- Efficiency level of overall system,
- Share of renewable energy sources used for heating purposes,
- Level of system′s centralization,
- Level of nature based solutions implementation.

**Table 2: List of criteria with sub criteria.**

| Criteria | Sub criteria |
|---|---|
| Reliability and availability | Reliability |
| | Energy security |
| Affordability | For consumers |
| | For energy producers and/distributors |
| Environmental acceptance (environmentally friendly) | $CO_2$ emission<br>CO emission<br>NOx emission<br>SOx emission |
| Comfort | Thermal comfort |
| | Comfort of consumption (safety issues, need for fuel storage, cleaning…) |
| | Easy to operate (Possibility of adjust the temperature) |
| Energy efficiency | Efficiency of the production and distribution |
| | Efficiency of transformation |
| | Efficiency of consumption |

**Table 3: Criteria weights by stakeholders′ group.**

| CRITERIA | Group 1 | Group 2 | Group 3 |
|---|---|---|---|
| Reliability and availability | 0,35 | 0,30 | 0,30 |
| Affordability | 0,25 | 0,25 | 0,25 |
| Environmental acceptance (environmentally friendly) | 0,10 | 0,15 | 0,20 |
| Comfortable | 0,10 | 0,20 | 0,10 |
| Energy efficiency | 0,20 | 0,10 | 0,15 |

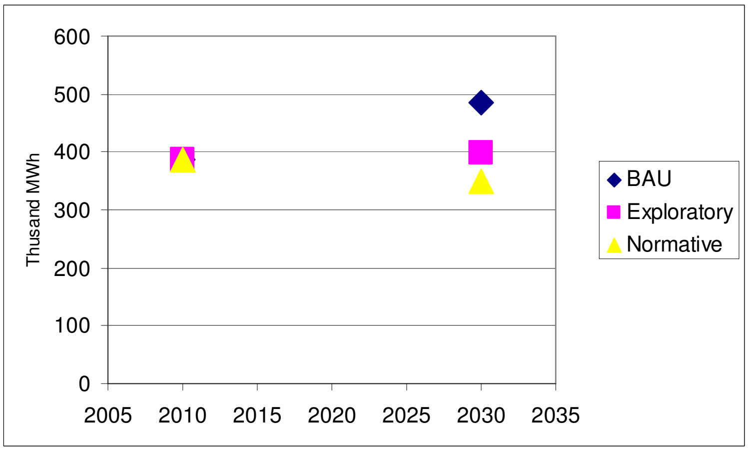



**Figure 5: Comparison of energy demand for heating in 2030, by scenario.**

For stakeholders learning it is very useful to elaborate and analyze at least one extreme scenario. Proposed scenarios were scored against criteria defined in the previous phase (Table 2 and 3.) of the project. Robustness test against two key uncertainties: Economic state of the country of and Political support, results with selection of not one but two proposed scenarios.

As the result from this phase scenario selected for further analyses is a combination those two scenarios which had the best scores against criteria and the best performance under key uncertainties. Practically it means that one type of solution is proposed to areas with single family houses, and the other to areas with multistory buildings. For areas with single family houses scenario that is selected is based on individual solutions with high share of renewable energy sources and high efficient buildings, while for multistory buildings is selected scenario that assumes further expansion of district heating network, introduction of renewable energy sources in centralized system and moderate buildings′ efficiency.

The target for energy consumption for heating established through participatory backcasting process as the result from exploratory scenario developed to explore effect of implementation of energy efficiency measures according to Energy Efficiency Action Plan and Energy Efficiency Law is more ambitious than target established through backcasting approach (Figure 5).

## 4. Conclusion

Exploring possible futures can be achieved by different classes of scenarios. Shift to normative scenarios, and application of participatory backcasting approach can contribute in reaching sustainable solution. This kind of approach for the purpose of energy planning is being implemented for the first time in Serbia. The need for participation of stakeholders is strong and the future vision can not be realized by limited stakeholders. However, despite the fact that stakeholders have the significant role in this approach, the role of experts should be also underlined. Also, experience from this project indicates the role of exploratory scenarios, especially elaboration of BAU scenario, and analyses for setting targets. Participatory backcasting contributes to stakeholders′ learning and better understanding of the whole process. The desirable future can be reached only if all stakeholders understand and take the part in implementing adopted strategy.

## References

Bale C.S.E., Foxon T.J., Hannon M.J. and Gale W.F., 2012. ″Strategic energy planning within local authorities in the UK: A study of the city of Leeds″, Energy Policy, Vol 48, p 242-251

Börjeson L., Höjer M., Dreborg K.H., Ekvall T., Finnveden G., 2006., ″Scenario types and techniques – towards a user's guide″, Futures, Vol 38, p 723–739

Doyle R., Davies A., 2013., ″Towards sustainable household consumption: exploring a practice oriented, participatory backcasting approach for sustainable home heating practices in Ireland″, Journal of Cleaner Production, Vol 48, p 260–271

Green K., Vergragt P., 2002., ″Towards sustainable households: a methodology for developing sustainable technological and social innovations″, Futures, Vol 34, p 381–400

Kordas O., Nikiforovich E., Pereverza K., Pasichny A., Spitsyna T., Quist J., 2013., ″Towards more sustainable heating and cooling systems in Ukraine: Participatory Backcasting in the city of Bila Tserkva″, 16th Conference of the European

Roundtable on Sustainable Consumption and Production (ERSCP) & 7th Conference of the Environmental Management for Sustainable Universities (EMSU), Istanbul, Turkey

Milestad R., Svenfelt A., Dreborg K.H., 2014., ″Developing integrated explorative and normative scenarios: The case of future land use in a climate-neutral Sweden″, Futures, Vol 60, p 59–71

Quist J., Knot M., Young W., Green K., Vergragt P., 2001., ″Strategies towards sustainable households using stakeholder workshops and scenarios″, International Journal of Sustainable Development, Vol 4, p 75–89

Quist J., Green K., Toth K.S., Young W., 2002., ″Stakeholder involvement and alliances for sustainable shopping, cooking and eating, in: T. Bruijn, A. Tukker (Eds.), Partnerships and Leadership: Building Alliances for a Sustainable Future″, Kluwer Academic Publishers, p 273–294

Quist J., Vergragt P., 2006., ″Past and future of backcasting: the shift to stakeholder participation and a proposal for a methodological framework″, Futures, Vol 38, p 1027–1045

Quist J., 2007., ″Backcasting for a Sustainable Future: the Impact After Ten Years″, Eburon, Delft NL

Sustainable Energy Action Plan for the City of Nis, 2013., available at: http://www.ni.rs/uploads/doc/uprave/ukdes/131212-ukdes-seap.pdf

Vergragt P. J., Quist J., 2011.,″Backcasting for sustainability: Introduction to the special issue″, Technological Forecasting and Social Change, Vol 78, Issue 5, p 747–755

Svenfelta A., Engströmb R., Svanea O., 2011., ″Decreasing energy use in buildings by 50% by 2050-A backcasting study using stakeholder groups″, Technological Forecasting and Social Change, Vol 78, Issue 5, p 785–796

Rotmans J., Kemp R., Asselt M.B.A., 2001., ″More evolution than revolution: transition management in public policy″, Foresight, Vol 3, p 15–31

Todorovic B., 2005., ″Heating facilities design″, Faculty of Mechanical Engineering, Belgrade (In Serbian)

Robinson J., 1990., ″Futures under glass: a recipe for people who hate to predict″, Futures, Vol 22, p 820–843

# Policy coordination for Green Bioeconomy – A manifesto for Southern Europe

**Prof. Emmanuel KOUKIOS**
National Technical University of Athens, Hellas

## Policy Coordination For Green Bioeconomy – A Manifesto for Southern Europe

*(The Manifesto of the European Mezzogiorno)*

**Emmanuel G. Koukios**
Head, Bioresource Technology Unit
National Technical University of Athens, GREECE

**Massimo Monteleone**
Coordinator, STAR*AgroEnergy Project
University of Foggia, ITALY

PROMITHEAS 2014 ATHENS

Università degli Studi di Foggia

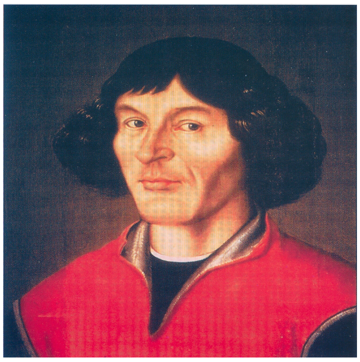
STAR AgroEnergy

Scientific & Technological Advancement In Research on Agro-Energy

Coordination and Support Action (Supporting)
FP7-REGPOT-2011-1

PROMITHEAS 2014 ATHENS

## "A Time of Change!"



## Wiki Definitions of Key Terms (1)

- MANIFESTO: "A published verbal declaration of the intentions, motives, or views of the issuer (…). It usually accepts a previously published opinion or public consensus and/or promotes a new idea with prescriptive notions for carrying out changes the author believes should be made"

PROMITHEAS 2014 ATHENS

## Wiki Definitions of Key Terms (2)

- MEZZOGIORNO: "The traditional term for the southern regions of Italy (…). It was sometimes associated with notions of poverty, illiteracy and crime: stereotypes of the South that often persist to this day. Sometimes it is referred to in order to generally highlight extreme disparities between regions within a country"

PROMITHEAS 2014 ATHENS

## The European Mezzogiorno

- From the western coast of Portugal to the eastern coast of Cyprus a spectre is spreading all over crisis-plagued Southern Europe: the spectre of following the wrong development model.
- Five EU Economies are directly concerned (W-to-E):
  - Portugal
  - Spain
  - Italy
  - Greece
  - Cyprus
- ALSO: Balkan, Mediterranean and other countries

PROMITHEAS 2014 ATHENS

## Focus on Sustainable Bioeconomy

- The term "bioeconomy" includes all industrial and economic sectors that produce, manage and otherwise exploit biological resources (and related services, supply or consumer industries), such as agriculture, food, fisheries, forestry etc.
- The term "bioeconomy" was first used in the short title of European Commission's FP7 Theme 2, "Food, Agriculture and Fisheries, and Biotechnology", i.e., *KBBE* or else the "Knowledge-Based BioEconomy"
- Bioeconomy is also included in the *Horizon 2020* research and innovation programme of the EU

PROMITHEAS 2014 ATHENS

## Bioeconomy in Europe (EC data)

| Bioeconomy Sector | Turnover (B Euro/yr) | Employment (millions) | Missing Info To be added |
|---|---|---|---|
| Agriculture | 210 | 15 | Aquaculture - Multipliers |
| Food | 800 | 4.1 | Imports - Mutlipliers |
| Forestry/Wood | 150 | 2.7 | Imports - Multipliers |
| Pulp/Paper | 400 | 0.3-4 | Imports - Mulipliers |
| Ind.Biotech. | 50 | ? | Green Chemistry/Biofuels |
| Totals | 1610 | 22.1 | (As above) |

MISSING INFO ON:

- Conventional sectors: aquaculture, HUMAN HEALTH
- Imports and exports of food, fibre and other biomass
- Emerging, knowledge-based sectors: "green chemistry"
- Added-value and rural multiplier coefficients
- Food & feed supplements, substitutes, additives, specialty
- Bio-wastes and residues
- More recent/better quality data from Member States

PROMITHEAS 2014 ATHENS

## 12+1 Reasons for Focusing on Green Bioeconomy as an EU Mezzogiorno Strategy

I. HIGH STAKES
II. CHANGE DYNAMICS
III. INNOVATION POTENTIAL
IV. ENVIRONMENTAL ASPECTS
V. CLIMATE CHANGE
VI. SUBSTITUTION
VII. SOCIO-ECONOMIC ASPECTS
VIII. QUALITY & SECURITY
IX. BUSINESS OPPORTUNITIES
X. POLICY COORDINATION
XI. EUROPEAN VALUE
XII. GLOBAL DEVELOPMENT
XIII. A SMART MOVE…

PROMITHEAS 2014 ATHENS

## Four Types of EU Bioeconomy (1)

| Type of System | Income Expectations | Innovation & Tech Level | Bioresource Management |
|---|---|---|---|
| *"Industrial North"* | Very High | High | Maximum Use |
| *"Green West"* | High | High | Best Practices |
| *"Rural South"* | Low | Low/Med | Best Practices |
| *"Emerging East"* | Very Low | Low | Maximum Use |

PROMITHEAS 2014 ATHENS

## Four Types of EU Bioeconomy (2)


PROMITHEAS 2014 ATHENS

## *THE TEN COMMANDMENTS:* 10 Theses for a New Development Model (1)

I. Recognize research and innovation as key development drivers
II. Give priority to product innovation for sustainable development
III. Get innovation power from the three "tsunamis": Info, Bio, Nano
IV. Couple technical innovation with required "soft" research actions
V. Focus national innovation strategies on "Green" (Sustainable) Bioeconomy targets

PROMITHEAS 2014 ATHENS

## *THE TEN COMMANDMENTS:*
## 10 Theses for a New Development Model (2)

VI. Consider a number of critical points for deployment of Southern European Bioeconomies

VII. Adopt new forms of research and innovation in Bioeconomy

VIII. Support new professional skills by novel education and training missions

IX. Learn to survive and navigate within a complex institutional and policy landscape

X. Plan for international and inter-regional cooperation on Green Bioeconomy themes

PROMITHEAS 2014 ATHENS

## II. All Innovation is not the Same!

- INNOVATION A: Process, Method, Protocol
  - In peripheral socio-economic value areas
  - Away from critical interfaces
  - Of cosmetic or status-related value
  - Useful in long-term change and public attitudes
- INNOVATION B: Product, Service, Function
  - In strategic sectors and fields
  - Bridging critical interfaces
  - Of vital structural and socio-economic value
  - Priority choice for immediate action

PROMITHEAS 2014 ATHENS

## III. The Low-to-Medium Tech Trap

- TECHNOLOGICAL HYBRIDISATION STRATEGY
  - «*Escaping from the Present*» through the side-door /backdoor - Synergies
  - Priority focus on High-Tech uptake and trends of convergence, e.g., ICT-BIO-NANO
  - High-Tech hybrids with conventional technologies generating national specialisations
  - Intelligent synthesis of sectors and fields, benefiting from fuzzy borders, internal breaks, penetrating emerging issues

PROMITHEAS 2014 ATHENS

## Biotech-driven Bioeconomy Hybrids

• GARDEN OF AMALTHIA: Food Industry, New Agriculture, Health, Quality of Life, Rural Development, Agro-Tourism, Agro-Biotech, ICT, ...

• HOUSE OF GAIA: Eco-Management, Green Industry, Renewable Energies, Industrial Biotech, Eco-Tourism, New Biomaterials, ICT, Nanotech, ...

• TEMPLE OF IASO: Health, Quality of Life, Culture, Urban Environment, Sustainable Transport, Knowledge -based Tourism, ICT, Health Biotech, Biomedical, Nano-applications, ...

PROMITHEAS 2014 ATHENS

## Linking the Information Society With the BioBased Economy

PROMITHEAS 2014 ATHENS

## IV. Couple Technical Innovation with Soft Aspects

- A VERY WIDE SPECTRUM: Economic, financial, legal, sociological, policy-related, cultural, cognitive, anthropological, psychological, historical, ethical, philosophical, epistemological, structural, strategic, and linked to other analysis and assessment methods
- THEIR REAL KEY ROLE: "Soft" aspects are in fact in the "core" of the innovation process, and their early activation is of the outmost importance for the success of the new development model.
- BEST PRACTICES: An example of a best-practice is systematic involvement of key stakeholders since the first stages of research
- SPECIAL TYPE OF TOOLS: "Strategic technological intelligence" studies can help us to identify critical non-technical elements and manage them properly

PROMITHEAS 2014 ATHENS

## VI. Main Critical Points for the Deployment of European Bioeconomies

*Based on recommendations by KBBE's Advisory Group*

1. Linking more closely KBBE research to that of the other related EU-funded RTD fields (environment, energy, and health);
2. Strengthening social and economic aspects within KBBE research;
3. Enhancing (eco)systems thinking, especially to improve understanding of complex bioeconomy phenomena, including sustainability issues;
4. Need for an interdisciplinary approach across the programme mainlines;
5. Focus on a small number of strategic research topics and aspects; major example bio-waste as a biomass resource;
6. More emphasis on the targeted development of appropriate tools, especially in fast growing fields like bio-informatics.
7. Mitigate Bioeconomy's fragmentation risks by a Great Vision

PROMITHEAS 2014 ATHENS

## Bio-Waste: A Critical Resource

**Bio-Waste on the KBBE Agenda?**


* *Slide taken from the AG8 presentation by Eckhart George.*

PROMITHEAS 2014 ATHENS

## A Challenge: Fragmentation vs. Integration – Managing Risks and the Role of Vision

PROMITHEAS 2014 ATHENS

## VII. Promoting Green Bioeconomy by Research

*The 7 "Golden Rules"*

0. An emerging space for vital innovation
1. Better understanding of complex phenomena involved
2. Planning and implementing knowledge-based actions
3. Environmental biotechnologies as a potential research flagship
4. Design of environmentally compatible solutions, drawing upon other novel RTD areas and approaches
5. Significant role in social and economic development, and key opportunity field for international cooperation
6. Responding to societal concerns, and assessing risks
7. Research to be accompanied by appropriate information, communication, dissemination and crisis-management components

PROMITHEAS 2014 ATHENS

## Bio-Greening – A Crossroads History

**THE BIO-PATH**

1962: Nobel Prize for DNA
1970s: Molecular Biology
1980s: Genetic Engineering
Genomes Mapping
1990s: Crises-like Phenomena
GMOs Public Debates
2000s: Biobased Development
Bio-Info-Nano Hybrids

**THE GREENING PATH**

1970: "Limits to Growth" Club of Rome Report
1970s: Oil Crises, Research on Renewable Energies
1987: "Our Common Future" Defining Sustainability Brundtland UN Report
1990s: Climate Change debate Kyoto Protocol, IPCC
2000s: Greening strategies Greening policies

PROMITHEAS 2014 ATHENS

## VIII. New Skill Needs for Green Bioeconomy

*The 7 "Golden Rules"*

0. STRATEGIC ISSUE - MULTI-PLAYER ACTIONS
1. RADICAL CHANGE: shift in socio-economic structures, cultures and lifestyles, knowledge modes, and organisation patterns
2. MUTUALLY TRANSFORMING PROCESSES: by learning and cognition
3. KNOWLEDGE: cognitive and affective elements
4. ALL CRITICAL FLOW SYSTEMS: molecular, energy, materials, information, financial, and human
5. TO DO (1): Introduce Greening skills through problem-oriented University curricula
6. TO DO (2): Add an extra layer to the existing professional education systems
7. TO DO (3): Use the KIC (Knowledge & Innovation Communities) concept as new instrument for change

PROMITHEAS 2014 ATHENS

## IX. Implementing Green Bioeconomy Within a Multi-Policy Environment (2)

**KBBE-Relevant EU Policies**

- Europe 2020
- ERA
- CAP, CFP
- Maritime
- Public Health
- Energy
- New Functional Biomaterials
- Environment
- Industrial Competitivity
- Regional Development
- International Development
- Crisis/Recovery Management

PROMITHEAS 2014 ATHENS

## IX. Implementing Green Bioeconomy Within a Multi-Policy Environment (2)

*Options for the Biobased policy component to safely cross the policy "Minefield":*

- *THE GORDIAN KNOT: Obtaining – through hard work, scientific excellence, and relevant political influences - the power necessary to develop into a new full policy for development cutting across the policy web.*
- *THE POWER OF FRIENDS: Forming a strategic alliance with a major policy areas - e.g., environmental, crisis management, agriculture - giving more power, but also the colour of its ally, e.g., green for the environment.*
- *HELP FROM THE SKY: Adopted by a powerful policy area, catalysing the horizontal inoculation of policies concerned with appropriate Bioeconomy elements, and promoting key synergistic actions, e.g., friendly regulations.*

PROMITHEAS 2014 ATHENS

## X. Inter-National/-Regional Cooperation (1): Open Bio-Systems – Closed Eco-Cycles

- Bioeconomic systems are usually open ones, communicating, trading and exchanging goods and services with each other
- This communication/exchange might involve any of their essential flows (molecular, cellular, energy, information, financial, and human)
- Self-sufficiency is normally an exception, usually caused by extreme conditions: wars, catastrophes, crises, political isolation
- In no case should the target of "sustainability" lead us to the wrong idea of closed, self-sufficient systems
- We advocate that interregional and international cooperation become key ingredients of the proposed new bioeconomic strategies
- We must distinguish this product and service openness from the green accounting of the closed cycles of nutrients, carbon, water and energy in rural and urban ecosystems

PROMITHEAS 2014 ATHENS

## X. Inter-National/-Regional Cooperation (2): New R&D Policy Shifts/Trends

GOALS & ISSUES:

- Bilateral → Multilateral
- Local → Regional
- Partner Networks → Synergies

TOOLS & APPROACHES:

- Episodes → Systems
- Open/Targeted projects → New Instruments
- Project-based → Programme-based

RESEARCH AGENDAS:

- Fragmented → Bioeconomy
- Joint R&D → Dissemination & Training
- Building upon successes → Forward looking

PROMITHEAS 2014 ATHENS

## Roadmap to the Future (1)

- "The regulators of the post-crisis world are doomed to fail in their efforts to make the global (…) system crisis -free. They can never know enough to manage such a complex system. They will only learn from the last crisis how to make the next one" (*N. Ferguson, 2012*)

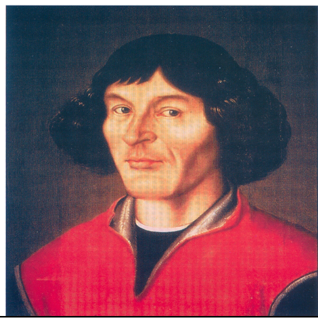
PROMITHEAS 2014 ATHENS

## Roadmap to the Future (2)

- Implementing sustainable bioeconomy will depend upon new agricultural practices, new industrial technologies, new business models, and new skill profiles. This task requires a sense of urgency to move forward timely, and mobilize human and other key resources of this procedure, a true REVOLUTION - *Let's get started!*

PROMITHEAS 2014 ATHENS

## "Aux Armes, Citoyens!"



# Scenarios for a Greenhouse Gas Neutral Society in Germany

**Mark NOWAKOWSKI**

Senior Scientific Officer

*Federal Environment Agency (Umweltbundesamt), Section I 2.2 "Energy Strategies and Scenarios"*

Tel: +49 340 2103 2283
Fax: +49 340 2104 2283
E-mail: mark.nowakowski@uba.de

Umweltbundesamt, Wörlitzer Platz 1, 06844 Dessau-Roßlau, Germany

**Abstract:** Germany and other industrial countries will have to reduce their greenhouse gas emissions tremendously by the year 2050 in order to keep global warming below 2° C. In order to support the implementation of the existing ambitious greenhouse gas reduction pledges of the government, the German Federal Environment Agency has – as a first step – analyzed three radically different "archetypal" scenarios for an electricity supply entirely based on renewable energy sources. These scenarios use different assumptions for both generation structures and the degree of interconnection. In the "Local Energy Autarky" scenario [1], small-scale decentralized energy systems use locally available renewable energy sources to satisfy their own power demand without being connected with each other or with outside suppliers. In the "Regions Network" scenario [2], electricity from renewable energy sources is exchanged throughout Germany and only a small part of the load is covered by electricity imports from neighboring countries. In the "International Large Scale" scenario [3], Germany's electricity supply is based on those potentials for renewable energy in Germany, Europe and its vicinity which can readily be tapped by large-scale technology projects. In this latter scenario, Germany imports much of its electricity demand via a well-developed intercontinental transmission grid. By this approach, it could be shown that a power supply based entirely on renewable energy for Germany is technically and ecologically feasible. In a second step, a scenario was developed considering all relevant greenhouse gas emission sources [4]. It could be shown that reductions of 95% compared to the level of 1990 and therefore greenhouse gas neutrality in Germany are technologically achievable by 2050. The use of storage technologies such as Power to Gas and Power to Liquid and thus the coupling of sectors will be an important pillar of such a system.

## 1. Introduction

Facing the threats that global warming brings, it has been widely recognized that anthropogenic greenhouse gas emissions need to be reduced to a great extent. With regard to regional and global consequences outlined by the IPCC, a maximum warming of 2° C compared to the pre-industrial age appears to be the limit for keeping the impacts of climate change within a tolerable range. In order to keep global warming within this limit, global greenhouse gas emissions must be cut by half by the middle of the century relating to the baseline year 1990. Due to their cumulated previous emissions, however, today's industrialized countries such as Germany must take their responsibility and reduce their $CO_2$ emissions by 80 to 95 percent by 2050.

The idea of a greenhouse gas neutral society is the motivation behind Germany's "Energiewende" or "energy transition". In fact, this process started some decades ago with the market introduction of renewable energy technologies (e.g. feed-in tariffs) as well as initiatives to increase energy efficiency. A strong public movement against nuclear power led to the first nuclear energy phase-out act which was passed in 2002. After the Fukushima Daiichi nuclear disaster, in 2011 both the federal government's and the parliament's consensual decision on the "Energiewende" foresees Germany phasing out nuclear energy completely by 2022 while significantly increasing renewable energy's share as well as energy efficiency in coming decades. The recent "Energiewende" program formulated a long-term perspective for a transformation of the whole energy system until 2050 and gave milestones along the way towards a carbon-neutral, renewables-based, and sustainable energy supply. In the long run, there will not be any alternative to that change, not only because of the obvious threats posed by nuclear energy (such as further accidents, the nuclear waste problem, ecological devastation in those countries where uranium is mined, or terrorist attacks), but above all for climate protection reasons.

In Germany, the electricity generation sector accounts for 40 percent of all energy-related emissions. Hence, it has the potential to make a major contribution to the desired emission reductions. With nuclear power no longer at hand as of 2022, and the crucial role which a reliable energy supply plays for a highly developed industrialized country such as Germany, the electricity sector appears as a key factor on the way towards a greenhouse gas neutral society.

## 2. Electricity from 100% renewable energy sources: three “archetypal” scenarios

As a first step, the Federal Environment Agency (Umweltbundesamt, UBA) has developed a set of three radically different scenarios for a future renewables-based power generation. The scope was to analyze the feasibility of Germany switching to an electricity supply based entirely on renewable sources by 2050 under technical and ecological aspects. The three studies differ in the assumptions regarding both generation structures and the degree of interconnection between individual regions in Germany and between Germany and other countries within a pan-European network.

In the “Local Energy Autarky” scenario, small-scale decentralized energy systems use locally available renewable energy sources to satisfy their own power demand without being connected with each other or with outside suppliers, i.e. without electricity imports.

In the “Regions Network” scenario, the electricity generated from renewable sources is exchanged throughout Germany and only a small share of the load is covered by electricity imports from neighboring countries.

The “International Large Scale” scenario looks at a possible future where Germany’s electricity supply is based on all renewable energy potentials in Germany, Europe and its vicinity which can readily be tapped by large-scale technology projects and storage power plants. In this latter scenario, Germany imports a significant share of its electricity demand via a well-developed intercontinental transmission grid.

These three “archetypal” scenarios represent extreme points of a solution space for a renewable electricity supply in Germany by 2050. This approach was chosen to demonstrate that there is not but one technically and ecologically feasible path towards attaining this goal but a whole range of viable alternatives. A real-life future energy supply system for Germany will most likely include characteristics of all three scenarios, however, depending on political and social priorities. Thus, the benefits of all variants may be combined in an efficient way.

## 3. “Local Energy Autarky” Scenario

The “Local Energy Autarky” scenario looks at energy structures on a rather small scale. The scope is restricted to decentralized energy systems such as provincial towns and city quarters which aim at satisfying their own power demand without being connected with each other or with outside suppliers, i.e. without electricity imports. Relying only on locally available renewable energy sources (i.e. solar and wind power as the availability of hydro or geothermal power is a rather exceptional case in Germany) to cover the electricity demand makes electricity storage a necessity within the simulation model. Biomass from energy crops was not considered in all of the scenarios, mainly because of competition for arable land and expected negative impacts on water, soil, biodiversity and wildlife. The model itself consists of different modules representing electricity demand (e.g. for households, commerce and industry), power generation of different renewable technologies, and meteorological data for four consecutive years, such as solar irradiation, wind speed, and outside temperatures. Various basic assumptions were made with regard to future developments such as energy efficiency.

The simulations were not applied to the whole of Germany but exemplarily to a rural community with a low population density and a city quarter with both a high population and building density. In a sensitivity analysis, each one of these settlement structures was modelled with and without trade/industry and at a location in northern as well as in southern Germany. Those locations are representative of the different meteorological conditions affecting the power generation from renewable sources such as wind and solar. Several variations were applied to the system, e.g. with regard to the share of electricity powered private vehicles or the installed generation capacities per technology.

The simulation results show that for this scenario the electricity demand of private households plus the demand for a complete shift to private e-mobility can be covered by the assumed locally available potentials for photovoltaics and wind energy, but only for the rural community and with an immense amount of storage capacity required. Due to significantly higher wind potentials in the North than in the South, the location in south Germany requires additional effort concerning the installed capacity for both electricity generation and storage. With the given assumptions and restrictions for this study, however, it is not possible at all to establish a self-sufficient electricity supply for the city quarter as in this case there are usually no locations available to put up wind turbines within the city borders. If the electricity demand for commerce and industry statistically corresponding to the number of inhabitants is taken into account, the rural community also fails at self-sufficiency.

Thus, the concept sketched in the “Local Energy Autarky” scenario may be a feasible option in particular cases under favorable circumstances (e.g. local availability of geothermal and/or hydro power, no industrial activities etc.). According to the findings in this study, however, it presents no viable alternative for a 100 percent renewables-based electricity supply, at least not for the whole of Germany. On the other hand, there are enough regions in the world with very low population densities yet high renewable power potentials where successfully operating energy transmission grids exist only in central areas – if any. In such cases, a local autarky approach as described here – or similar “island solutions” – may be both a feasible and economical option in order to make electricity available to remote areas lacking an overlaying energy infrastructure.

## 4. “Regions Network” Scenario

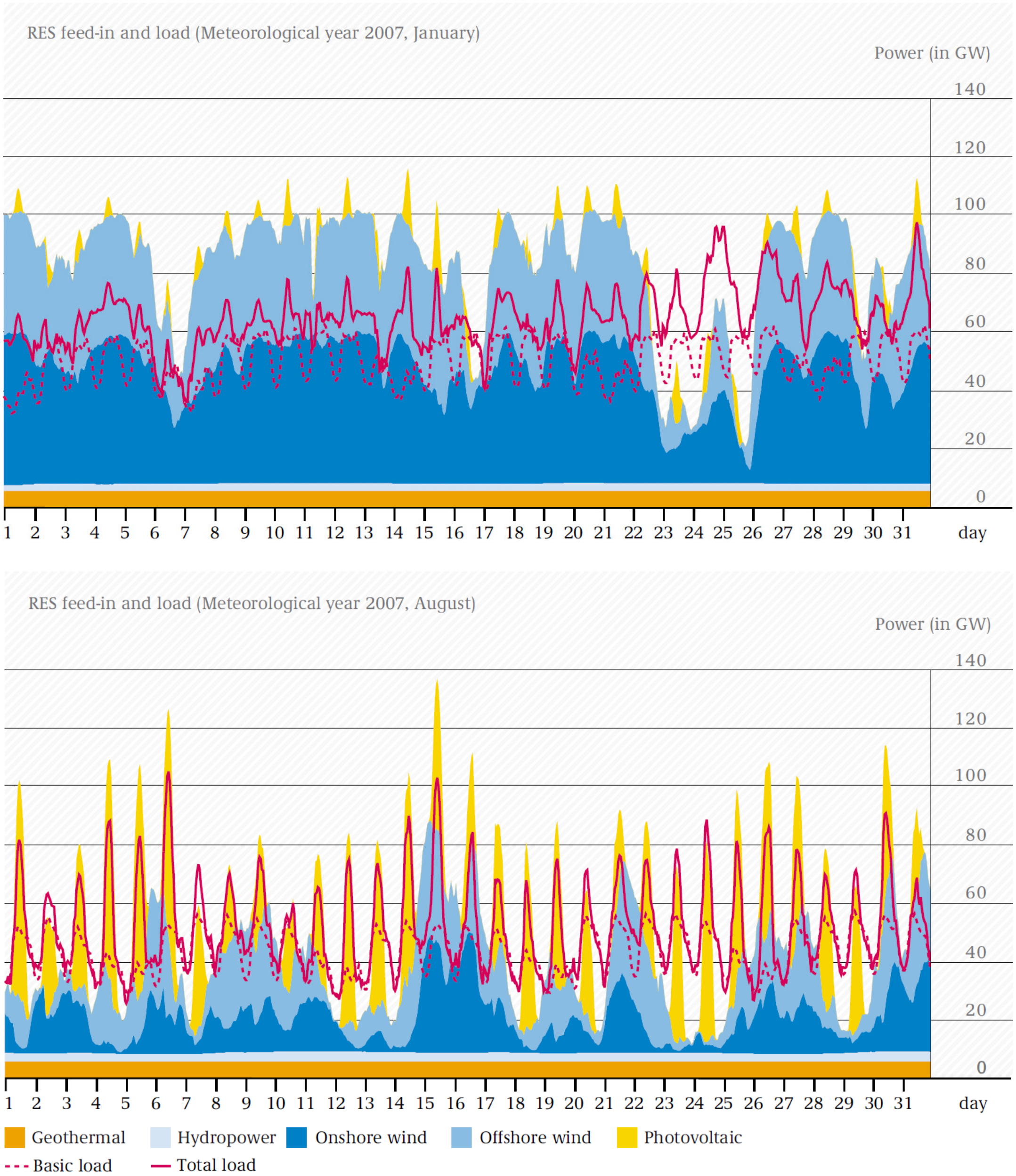
The “Regions Network” scenario follows a different approach. Herein, the renewable electricity generation and the demand in 2050 are modelled for all Germany. It is assumed that all German regions make extensive use of their renewable energy potentials. A well-developed national electricity transmission grid ensures large-scale balancing across the various regions. Moreover, the introduction of large-scale electricity storage and the tapping of demand side management potentials make a substantial contribution to the balancing of load and generation. Efficient energy use in all sectors compensates for the rise in consumption caused by moderate economic growth, increased e-mobility, and the use of heat pumps. Imports of renewable electricity from neighboring countries cover less than five percent of the annual demand and are not necessary to attain supply security.

The simulations show that under the given assumptions for 2050 the power requirement can be covered at any moment at today’s level of supply security and in an ecologically compatible way. Fluctuations in renewable energy feed-in can be offset and sufficient balancing power can be provided at the same time. Technology leaps are not assumed in this scenario – these outcomes are achievable with today’s best available technologies. The potentials identified throughout Germany are sufficient to even cover the considerable additional power demand from e-mobility, the wide use of heat pumps for heating and hot water provision, and air conditioning. The total PV potentials that were identified for Germany are around 275 GW. For the model calculations an installed PV capacity of 120 $GW_{peak}$ was assumed for Germany in 2050. At present, we see installations of around 30 $GW_{peak}$. The wind potentials are enormous, too, which was confirmed by a recent UBA study [5]. Still, an installed capacity of 60 GW onshore and 45 GW offshore is sufficient to meet the demand assumed in this scenario. Further potentials for hydro and geothermal power as well as the use of waste biomass add to this composing a reliable system of diverse renewable electricity sources.

It could be shown that an electricity supply system based completely on renewable energy sources as simulated in the “Regions Network” scenario does not compromise supply security. Nor does it increase the dependency on energy imports. However, essential prerequisites are a significant increase in reserve capacities for electricity generation and storage, the exploitation of the large potential for load management as well as expanding and modifying existing infrastructure to facilitate this as well as electricity transport, including an ambitious expansion of the grid. The political decisions needed to make such a development happen must be taken in the years to come. The study devotes a separate chapter to corresponding policy recommendations.

Figure 1 shows the simulation results for the feed-in from renewable energy sources against the load in the 2050 “Regions Network” scenario for two different seasons. On the top chart (Figure 1 (a)) we see a typical situation for a winter month with a major share of wind power while photovoltaic does not contribute substantially to cover the load. In combination with geothermal and hydro power the wind feed-in even exceeds the load at many times thus charging the storage facilities. Between days 23 and 26 there is no sufficient feed-in to meet the load, however, which means that stored energy is being utilized. The bottom chart of figure 1 (Figure 1 (b)) reflects a typical summer supply situation with a significant feed-in of photovoltaic electricity generation and a clearly lower input from both onshore and offshore wind. While the photovoltaic midday spikes go together well with the load peaks (as a result of load management), storage capacities need to be tapped during night hours when the load is higher than the supply. The crucial part of storing away excess electric energy becomes obvious here. Short-term storage facilities such as pump storage power plants can balance out deviations between feed-in and load for one to several days. Similarly, demand side management functions as virtual short-term storage by time-shifting the load instead of the generation. Long-term storage systems such as chemical energy binding can balance feed-in fluctuations for any time period from days to years. Currently, the benefits of electrolysis and methanation in particular are subject to further investigations.

The basic concept of the so-called “Power to Gas” process is the transformation of renewable electricity which is not directly used within the




power system into hydrogen through the electrolysis of water.

**Figure 1: Examples of feed-in from renewable energy sources in the year 2050 for the Regions Network scenario, based on the meteorological year 2007 (a) January, (b) August (source: [2]).**

Further catalytic processes can generate methane and other hydrocarbons from hydrogen. Methane for its part may be stored in existing underground spaces, so-called cavern and pore storage facilities. Later, this methane may be reconverted on demand in combined heat and power plants, gas turbines, or combined cycle power plants. Chemical storage thus allows for innovative load and generation management. It limits the need for additional generation capacities and reduces stress on the transmission grid, e.g. when methane is transported through the existing natural gas grid instead. Therefore chemical storage helps to integrate large amounts of electricity from renewable energy sources into the energy system. Beyond that, both methane and hydrogen could be used in the chemical industry or as alternatives to fossil fuels in the heating and transport sectors.

With respect to the results of both the “Local Energy Autarky” and the “Regions Network” scenarios it can be concluded that besides a local renewable generation the national electricity transport network is an important component for achieving a 100 percent renewable energy supply in Germany. On the one hand, the large-scale balancing between fluctuating renewable energy feed-in and load can be beneficial. On the other hand potentials will have to be tapped where they exist. Regions with excess potential and a comparatively low demand such as North Germany with its high wind potentials will have to cater to regions with a shortfall such as the industrial centers of electricity consumption in southern and western Germany.

## 5. "International Large Scale" Scenario

As the previous two scenarios have shown, the larger the control volume becomes the easier it gets to balance out the fluctuating generation of wind and solar power. For the "International Large Scale" scenario a meta-analysis of available studies was done. The central research question was whether and to which extent a wider electricity network reaching across Germany's borders could be beneficial in terms of the optimal use of renewable energy, the large-scale balancing between the fluctuating renewable energy feed-in and load, and the need for storage. This third "archetypal" scenario features the highest share of electricity imports into Germany ranging between 10 and 20 percent. Germany's and Europe's electricity supply is based here on all renewable energy and storage potentials in Germany, Europe and its vicinity (such as the Middle East and North African regions) which can readily be tapped through large-scale technology projects (e.g. solar thermal energy from North Africa, geothermal energy from southern Europe and Turkey, pump storage power plants in Scandinavia, or wind power from the British Isles). A well-developed intercontinental transmission grid connects generation centers with the centers of electricity consumption, allowing fluctuations of renewable electricity in feed-in to be balanced out on a Europe-wide scale.

The analysis of the examined scenario studies does not identify any characteristics of the described electricity systems that are principally infeasible in terms of supply security and from a technological or ecological point of view. The advantages and disadvantages of renewables-based electricity systems with large shares of net imports in relation to renewables-based electricity systems with no or little net imports are discussed in the meta-study. The most important benefit of a strategy relying on net imports may be that considerably less electricity storage capacity is needed compared to a largely self-sufficient electricity supply. This advantage is particularly relevant because the technological and economic feasibility of building considerable amounts of new storage capacity within Germany is in question. On the other hand, one of the most important drawbacks of a strategy relying to a great extent on net electricity imports is the higher technical, financial, and political-administrative complexity of developing a cross-border infrastructure as well as power plants abroad.

In the meantime, other reputable institutions have also examined the feasibility of an electricity supply entirely based on renewable sources and published relevant studies. For example, the publication "Pathways Towards a 100% Renewable Electricity System" [6] by the German Advisory Council on the Environment SRU or "The Energy Report" [7] by the World Wide Fund For Nature WWF present scenarios which show how a 100% renewables-based electricity supply could be realized. The core findings are consistent with the results presented here and show that such a system can provide sufficient power at any time of year. Other relevant studies are: "Long-Term Integration of Renewable Energy Sources into the European Energy System" [8] by LTI-Research Group, or "Energy Rich Japan: A Vision for the Future" [9] by Lehmann et al.

## 6. Germany 2050: a greenhouse gas neutral country

With the studies presented so far, it could be shown that an electricity supply entirely based on renewable sources in Germany by 2050 is technically and ecologically feasible and that there are degrees of freedom with respect to potential pathways towards such a future depending on the chosen framework. This can only be one of several steps, however, if Germany seriously aims at reductions in its greenhouse gas emissions of up to 95 percent by 2050. On the way to a greenhouse gas neutral society, considering all relevant greenhouse gas emitting sectors becomes indispensable. In addition to the complete energy supply, including heating and transport, this also means emissions from industry, waste disposal, agriculture and forestry as well as changes in land use.

In an interdisciplinary approach, UBA has therefore developed a scenario for a greenhouse gas neutral Germany with per-capita emissions of just one metric ton of $CO_{2eq}$ in 2050. The scope was to demonstrate that greenhouse gas neutrality is technically achievable and to initiate a timely discussion on possible solution spaces for a greenhouse gas neutral Germany and greenhouse gas neutral industrial countries in general. It becomes obvious that along with the electricity sector, particularly the heat and transport sectors must become completely $CO_2$ neutral, as well, as others such as agriculture and certain industrial processes cannot eliminate all their emissions.

As for the previous scenarios, general assumptions for 2050 include:

- Market penetration of today's best available technology. No technology leaps or new inventions are necessary to meet the target, but further development of current technology is expected.

- Continuity of current lifestyle, behavioral and consumption patterns although changes herein would be favorable but cannot be forced or predicted
- A slight drop in population numbers from 82.5 million in 2005 to approximately 72.2 million
- Germany will still be an exporting industrial country with an average annual growth of 0.7 percent of its gross domestic product.

In order to satisfy the energy demand of the heat and transport sectors in a greenhouse gas neutral manner, the large-scale introduction of the above-mentioned “Power to Gas” technology is the key component of our scenario. The thus generated hydrogen can be used directly substituting fossil resources in industrial processes. Or it may be converted to methane via “Power to Gas” and liquid hydrocarbons via “Power to Liquid”, respectively. This allows for easy storage within the existing natural gas system plus beneficial coupling of the different sectors. The stored methane is a versatile material which can be either reconverted into electricity on demand or used as fuel for both heating and transport or as a basis for further chemical processes.

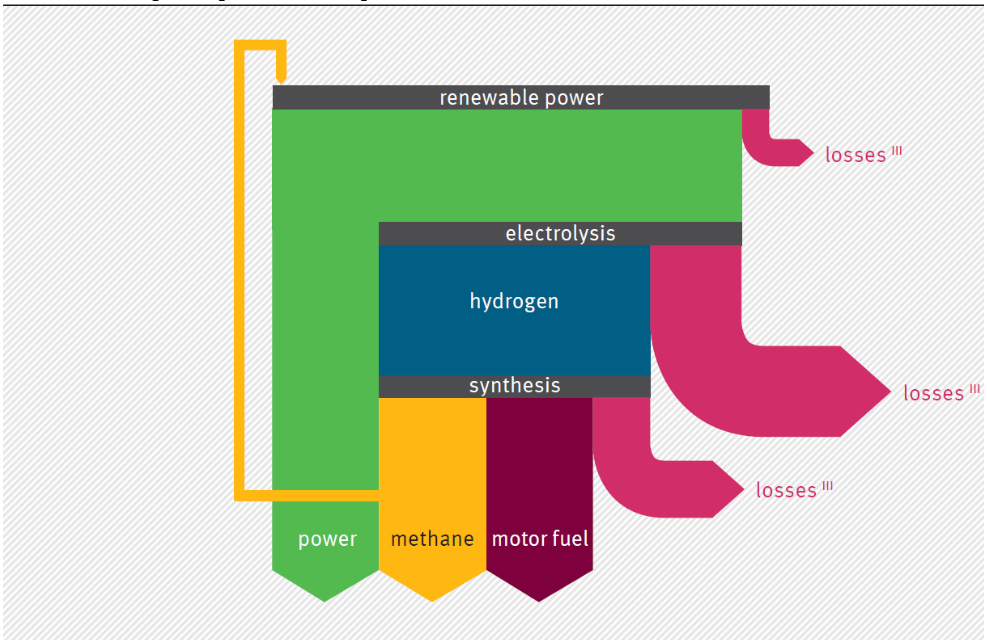
Figure 2 shows a schematic of the energy flow in the scenario “UBA THGND 2050”. Herein, final energy is predominantly provided by renewable power. The figure does not show further losses during transfer when importing renewable gas and fuel. Hydrogen does not figure as a final energy carrier in our scenario which would open up further options, though.

On the one hand we assume a final energy demand for Germany in 2050 which is reduced by 50 percent compared to the numbers of 2010. On the other hand the coupling of the other energy sectors with the electricity sector via “Power to Gas” implies a steep rise in electricity consumption. The net energy to be generated amounts to approximately 3,000 TWh/a, predominantly produced by wind and PV installations, depending on domestic and global capacity. Hydropower and geothermal installations contribute a smaller share to the general power supply. Although Germany has the necessary technical potential to generate the whole power demand, we assume that a good proportion of the renewable power will probably be generated outside Germany, by ecological as well as economic reasons.

While the sector coupling through “Power to Gas” can help to reduce greenhouse gas emissions within the energy sector significantly, other sectors need different measures in order to accomplish substantial contributions.

Among others, these include:

- Avoidance and displacement of traffic;
- Fundamental changes to many industrial production processes and adaption of technology in the correspondent installations in order to use renewably generated energy carriers;




I Including demand for renewable inputs for the chemical industry.
II Representations of energy flows are proportional to the energy flows required.
III Including line losses, losses from reconverting methane into power and losses from converting biomass into power

**Figure 2: Qualitative representation of the energy flow in the scenario “UBA THGND 2050” I, II (source: [4]).**

- Collection of landfill gas (mainly methane) and subsequent biological oxidation plus the expansion of separate organic waste collection schemes;
- Combining technical efficiency measures in the agricultural sector, the modification of production methods therein, and limitations on animal-rearing.

## 7. Conclusions

The studies presented in this paper show that not only Germany's electricity sector could reach greenhouse gas neutrality by 2050. Moreover, emissions from the whole energy sector including heating and transport could fall to near zero while other sectors could substantially reduce their emissions, too. The UBA-scenario for a greenhouse gas neutral Germany shows that the final energy demand could be reduced by 50 percent compared to 2010 through contributions of all sectors. This is only achievable, however, if comprehensive action is taken with respect to the whole system and energy efficiency in particular. Many questions remain unaddressed by this first attempt to initiate an inevitable discussion. Among others, these include an economic cost-benefit analysis of the outlined development, the economic and regulatory framework that would encourage the necessary changes, resource and environmental impact aspects of the presumed technologies, the employment of yet alternative technologies, and the weight of displacement of emissions abroad.

Yet, the value of the studies is obvious: If global warming is to be kept within tolerable limits, not only Germany but all industrialized nations and finally the whole world must reconsider the generation and use of energy as well as further measures to reduce greenhouse gas emissions. A serious and scientifically based discussion about this process cannot be commenced early enough.

## References

[1] Peter S. *Modellierung einer vollständig auf erneuerbaren Energien basierenden Stromerzeugung im Jahr 2050 in autarken, dezentralen Strukturen.* Dessau-Roßlau: Umweltbundesamt; 2013.

(Available in German only. English press release and download: http://www.uba.de/en/press/pressinformation/decentralised-renewable-energy-supply-is-ok-self)

[2] Klaus T et al. *Energieziel 2050: 100% Strom aus erneuerbaren Quellen.* Dessau-Roßlau: Umweltbundesamt; 2010. (English short version download: http://www.uba.de/sites/default/files/medien/publikation/add/3997-0.pdf)

[3] Samadi S et al. *Vollständig auf erneuerbaren Energien basierende Stromversorgung Deutschlands im Jahr 2050 auf Basis in Europa großtechnisch leicht erschließbarer Potentiale – Analyse und Bewertung anhand von Studien.* Dessau-Roßlau: Umweltbundesamt; 2014. (Available in German only. Download: http://www.uba.de/publikationen/vollstaendig-auf-erneuerbaren-energien-basierende)

[4] Werner K, Nissler D (eds.). *Germany 2050: A Greenhouse Gas Neutral Country.* Dessau-Roßlau: Umweltbundesamt; 2013.

(Available in German only. English version in press. Download: http://www.uba.de/publikationen/treibhausgasneutrales-deutschland-im-jahr-2050-0)

[5] Lütkehus I et al. *Potenzial der Windenergie an Land. Studie zur Ermittlung des bundesweiten Flächen- und Leistungspotenzials der Windenergienutzung an Land.* Dessau-Roßlau: Umweltbundesamt; 2013. (Available in German only. Download: http://www.uba.de/sites/default/files/medien/378/publikationen/potenzial_der_windenergie.pdf)

[6] German Advisory Council on the Environment (SRU). *Pathways Towards a 100% Renewable Electricity System.* Berlin: SRU; 2011.

[7] Singer S, editor. *The Energy Report: 100% Renewable Energy by 2050.* Gland: WWF; 2011.

[8] The LTI-Research Group, editor. *Long-Term Integration of Renewable Energy Sources into the European Energy System.* Heidelberg: Physica-Verlag; 1998.

[9] Lehmann H et al. *Energy Rich Japan: A Vision for the Future.* Aachen: ISUSI; 2003.

# Short-term assessment of the energy efficiency policy mixtures in the Black Sea region

**Dr. Popi KONIDARI**[1]

Head of Climate Change Policy Unit of the Energy Policy and Development Centre (KEPA)

**Mrs. Anna FLESSA, MSc.**

Fellow Researcher of the Energy Policy and Development Centre (KEPA)

**Mrs. Eleni-Danai MAVRAKI, MSc.**

Fellow Researcher of the Energy Policy and Development Centre (KEPA)

**Abstract:** Energy Efficiency is concerned as one of the main pillars of the efforts to mitigate climate change. The emerging economies of the Black Sea region demonstrate a sufficient potential to increase their energy efficiency with relatively low cost. This paper examines the short term effectiveness of the currently implemented policy mixtures for energy efficiency in ten emerging economies of the Black Sea region (Albania, Armenia, Azerbaijan, Bulgaria, Moldova, Romania, Russia, Turkey, Serbia and Ukraine) with the use of the LEAP model and the multi-criteria evaluation method AMS. The short term assessment of these ten energy efficiency policy mixtures under the same methodology (database, key drivers, assumptions, criteria-tree) allows to conclude on: i) which policy mixtures are effective in reaching the national targets of energy savings within the time period 2018-2023; ii) the strengths and the weaknesses of each one of these policy mixtures and iii) the level of heterogeneity in efforts for this group of countries.

## 1. Introduction

Energy demand is driven by population and income growth (BP, 2013). Projections for world population estimate that by year 2020 it will be at 8.1 billion people, while the global Gross Domestic Product (GDP) in 2020 is expected to be roughly the same with that of the 2011 level (World Energy Council, 2013). The Total Primary Energy Suppy (TPES) is projected to grow from 14092Mtoe in 2011 to 17208Mtoe in 2020 (World Energy Council, 2013). If these trends continue then world primary energy consumption is projected to grow by 1.6% p.a. from 2011 to 2030, adding 36% to global consumption by 2030 (BP, 2013).

One of the most effective ways of reducing energy consumption is the adoption of procedures and technologies that lead to energy savings (EC, 2007). If developing countries could raise their energy productivity[1], then they could slow the growth of their energy demand by more than half over the next decade which would result to 25% lower energy demand in 2020 (Diana Farrell and Jaana Remes, 2009).

This paper aims to examine the currently implemented policy mixtures for the promotion of Energy Efficiency (EE) in ten emerging economies (Albania, Armenia, Azerbaijan, Bulgaria, Moldova, Romania, Russia, Turkey, Serbia and Ukraine) and provide an insight on their implementation and its obstacles. These countries were selected since they were the case studies for mitigation/adaptation policy portfolios for the EU FP7 funded program PROMITHEAS-4. The next session concerns the policy mixtures of these eleven emerging economies. The third session is devoted to the two research tools that are used for this paper. The forth session refers to the evaluation of the policy mixtures. The last session is for discussion and conclusions.

## 2. Policy mixtures for the promotion of EE

Four of these countries (Albania, Moldova, Serbia and Ukraine) are members of the Energy Community (EnC), two are observers to the EnC[2] (Armenia, Turkey) and two are EU member States (Bulgaria, Romania). Azerbaijan and Russia do not belong in any of the aforementioned groups, but with the other countries are members of the organization Black Sea Economic Cooperation (BSEC).

The policy mixtures for EE in these eleven countries have the objectives/targets that are presented in Table 1. Each country has a different policy mixture to support EE. The whole set of

[1] EE can be measured with energy intensity or energy productivity. Energy productivity is the ratio of real GDP per primary energy input (http://wupperinst.org/uploads/tx_wupperinst/energy_efficiency_definition.pdf)

[2] http://www.energy-community.org/portal/page/portal/ENC_HOME/MEMBERS

Policy Instruments (PIs) that these ten countries use until 31.12.2010- along with the relative rules and influencing mechanisms – is included in Table 2. For the monitoring, supervision and implementation of these policy instruments each country has established a list of pertinent authorities.

*Albania:* Former Ministry of Economy, Trade and Energy[3], now Ministry of Energy and Industry; National Agency of Natural Resources[4]; Albanian Energy Regulator[5]; Albanian Power Corporation[6].

*Armenia:* Ministry of Energy and Natural Resources[7]; Ministry of Nature Protection[8]; Armenia Renewable Resources and Energy Efficiency Fund[9].

*Azerbaijan:* Ministry of Industry and Energy.

*Bulgaria:* "Sustainable Energy Development Agency", under the Ministry of Economy, Energy and Tourism; Directorate "Energy strategies and policies for sustainable energy development" within the Ministry of Economy, Energy, and Tourism which is specifically dedicated to RES and EE policies and Bulgarian Energy Efficiency and Renewable Sources Fund[10].

*Moldova:* Ministry of Economy and Trade[11]; Ministry of Environment[12]; ANRE[13].

*Romania:* Ministry of Economy, Trade and Business Environment[14;] Ministry of Environment and Forests[15]; Romanian Energy Regulatory Authority[16].

*Russia:* Ministry of Energy[17]; Ministry of Finance18; the Ministry of Economic Development[19]; The Ministry of Regional Development[20]; Sberbank[21]; the Russian [Federal] Energy Agency (REA)[22] within the Ministry of Energy; two energy commissions: i) the Commission on Fuel and Energy Complex, ii) the Commission on modernization and technological development of the Russian economy.

*Serbia:* There is no relevant implementation network.

*Turkey:* Coordination Board on Climate Change[23]; Climate Change Department of the Ministry of Environment and Urbanization[24]; Ministry of Energy and Natural Resources[25].

*Ukraine:* Ministry of Energy and Coal Industry of Ukraine[26]; the Ministry of Ecology and Natural Resources of Ukraine[27]; State Agency for Energy Efficiency and Energy Conservation (SAEEEC)[28] (former National Agency for Efficient Use of Energy Resources) and State Environmental Investment Agency of Ukraine (NEIA)[29].

## 3. LEAP model

The Long range Energy Alternatives Planning System (LEAP), developed by SEI's U.S. Center, is an integrated modeling software tool, widely used for energy policy analysis and climate change mitigation assessment (SEI, 2012b). It allows to: i) track energy consumption, production and resource extraction in all sectors of an economy; ii) account for both energy sector and non-energy sector Greenhouse Gas (GHG) emission sources and sinks iii) analyze emissions of local and regional air pollutants, making it well-suited to studies of the climate co-benefits of local air pollution reduction. LEAP can serve as a historical database demonstrating the evolution of an energy system and a forward-looking, scenario-based tool (SEI, 2012b).

*Use of LEAP*

A common approach was adopted for all ten countries. For each one, a LEAP dataset was prepared, representing the energy system of the country along with historical data (current accounts for the time period 1990-2010) obtained from official national and international sources.

3 http://www.mete.gov.al/
4 http://www.akbn.gov.al/index.php?&lng=en
5 http://www.ere.gov.al/index.php?lang=2
6 http://www.kesh.al/content.aspx?id=18
7 http://www.minenergy.am/
8 http://www.mnp.am/?p=80
9 http://r2e2.am/en/
10 http://www.bgeef.com/display.aspx
11 http://www.mec.gov.md/
12 http://www.mediu.gov.md/index.php/en/
13 http://www.anre.md/index.php?vers=3
14 http://www.minind.ro/
15 www.mmediu.ro/
16 www.anre.ro
17 http://minenergo.gov.ru/aboutminen/leaders/
18 http://www.minfin.ru/en/
19 http://www.economy.gov.ru/wps/wcm/connect/economylib4/en/home/about/
20 http://www.minregion.ru/
21 http://sberbank.ru/en/corporatecustomers/carbonfinance/
22 http://www.energohelp.net/articles/all-law/
23 http://iklim.cob.gov.tr/iklim/AnaSayfa/IDKK.aspx?sflang=en
24 http://iklim.cob.gov.tr/iklim/AnaSayfa/IDKK.aspx?sflang=en
25 http://www.enerji.gov.tr/index.php?dil=en&sf=webpages&b=yayinlar_raporlar_EN&bn=550&hn=&id=40721
26 http://mpe.kmu.gov.ua
27 http://www.menr.gov.ua/
28 http://saee.gov.ua/en/
29 http://www.seia.gov.ua

**Table 1: Objectives for EE.**

| Country | Target - Explanation | LEAP historical data (total final energy consumption in Mtoe for the respective period | LEAP expected total final energy consumption in Mtoe for respective year | Change based on LEAP outcomes (%) | Difference with target (%) |
|---|---|---|---|---|---|
| Albania | 9% reduction in year 2018 compared to the average of the total final energy consumption for the five year period 2004-2008[30] | 3.15 | 3.69 | +16 | -25.00 |
| Armenia | Reductions in 2020 per sector compared to the average of final energy consumption for the period 2008-2010 (23% - residential/household sector; 41,6% - industrial sector ; 17,1% - transport sector; 14,6% - Public and commercial services and 3,5% - agricultural sector) Average 19.96% | 1.83 | 2.46 | +34.45 | -54.41 |
| Azerbaijan | No official quantitative target – only qualitative | 7.65 (2008-2010) | 8.52 (2020) | +11.43 | -11.43 |
| Bulgaria | 9% reduction of the energy consumption for the period 2008-2016, compared to the average final energy consumption for the period 2001-2005 | 7.44 | 9.93 (2016) | +33.42 | -42.42 |
| Moldova | 20% reduction by 2020 of total primary energy consumption compared to 2009 | 1.868 | 1.989 | +6.48 | -26.47 |
| Romania | 19% reduction of the 2020 primary energy consumption (amount of 10Mtoe) compared to projections for that year. Final energy consumption for 2020 should be 30320Ktoe and primary energy consumption 42990Ktoe | - | 32.27 | -24.93 | +5.94 |
| Russia | 40% reduction by year 2020 of the energy intensity of GDP[31] compared to the 2007 level. | 442.7 (0.395Mtoe/Beuro) | 622.5 (0.431 Mtoe/Beuro) | +9.18 | -49.18 |
| Serbia | 9% reduction of the final energy consumption in 2018 compared to that of year 2008 | 9.912 | 13.45 | +35.69 | -44.69 |
| Turkey | 20% reduction of the primary energy intensity by 2023 compared to the amount in 2008; intermediate target of 10% up to 2015; (energy consumed per GDP) | 79.9 (0.173Mtoe/Beuro) | 98.6 (0.170Mtoe/Beuro-2015)<br>136.5 (0.166Mtoe/Beuro-2023) | -1.58, -3.8 | -16.19<br>(2023) |
| Ukraine | energy saving targets of 30-50% in various timeframes, to 2015 and to 2030[32] - Reduction of the energy consumption in the public sector at least by 20% of the 2009 level by 2014 | 77.2 (2008-2010) | 109.1 | +41.32 | -41.32 |

[30] http://www.energy-community.org/pls/portal/docs/1138177.PDF
[31] energy consumed per unit of GDP (UNDP, 2009)
[32] http://saee.gov.ua/documents/Ukraine_EE_2013_ENG.pdf

**Table 2: Policy instruments and their rules – influencing mechanisms for the ten examined countries.**

| | Countries | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Albania | Armenia | Azerbaijan | Bulgaria | Moldova | Romania | Russia | Serbia | Turkey | Ukraine |
| *Policy instruments* | | | | | | | | | | |
| Energy audits | X | | | X | | X | X | | | |
| Energy efficiency standards | X | X | | | | | X | | X | |
| Metering of energy consumption | X | | | | | | | | | |
| Energy building code | X | | | | | X | | | X | |
| Energy labeling of appliances | X | | | X | | X | X | | | |
| Voluntary certification | | X | | | | | | | | |
| Emission limits/technological standards | | | X | | | | X | | | |
| Dissemination policy instruments | | | | | X | | X | | X | |
| Energy service contracts | | | | | | | X | | | |
| Energy certificates | | | | X | X | X | | | X | |
| Emission trading schemes (JI, CDM, GIS, voluntary carbon market) | | | X | X | X | X | X | | X | X |
| *Rules – influencing mechanisms* | | | | | | | | | | |
| Tax exemptions/rebates | X | | X | X | | | | | | |
| Investment aid (Grants, soft loans, Subsidies) | X | | | X | | X | X | | | |

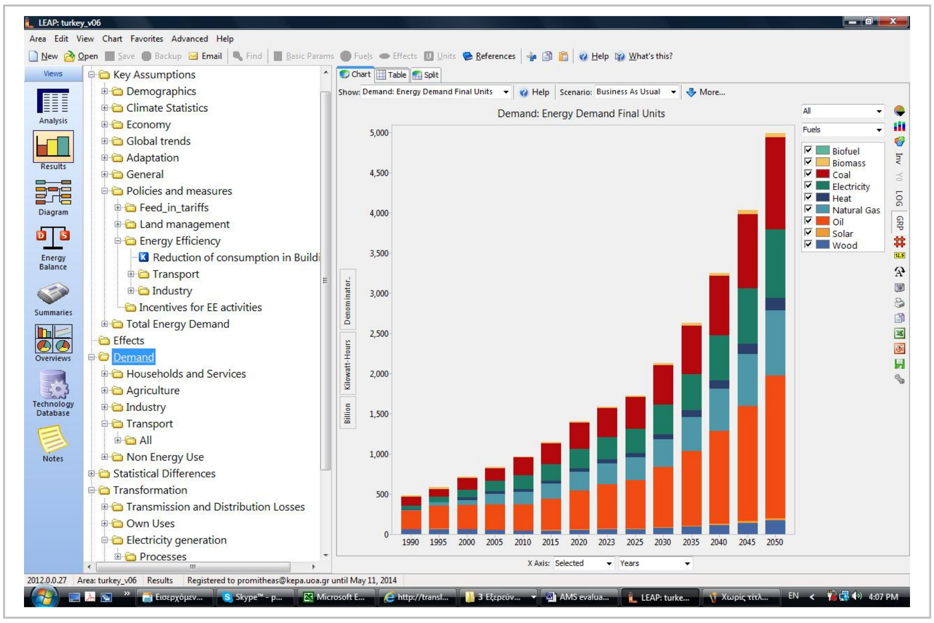


**Figure 1: LEAP interface.**

The key assumptions for the evolution of the most important drivers were determined. More specifically, the time evolution for: i) population was based on the projections of the Department of Economic and Social Affairs of the United Nations (UN, 2011); ii) National real GDP on the projections of the International Monetary Fund (IMF) (IMF, 2012). Depending on the availability of historical data the growth of the variable "Final energy intensity" or "Total energy" of an economic national sector was dependent to the growth of the "GDP real". The use of GDP real over GDP nominal was preferred for removing the effect of inflation and being able to compare the outcomes among all countries. The fuel share for each sector remained as it was since this analysis focuses on the currently implemented policy mixtures only for EE.

## 4. AMS method

Each policy mixture will be assessed for its performance under the criteria/sub-criteria of the AMS method which is the combination of three standard multi-criteria methods: the Analytical Hierarchy Process (AHP), the Multi-Attribute Utility Theory (MAUT) and the Simple Multi-Attribute Ranking Technique (SMART) (Konidari and Mavrakis, 2007; 2006). The AHP procedure provides values for the weight coefficients of criteria /subcriteria, while the other two - MAUT/SMART - provide normalized grades for the performance of PIs or PMs under the selected criteria/subcriteria. The MAUT procedure is applied when the user of the method has available and credible data under the same sub-criterion for all the evaluated PIs/PMs, while the SMART procedure when - due to the absence of data - grades are based on user's judgement and/or experts' opinion. AMS consists of four basic steps: 1) creation of criteria-tree; 2) determination of weight coefficients for criteria/sub-criteria; 3) grading for the performance of the PI/PM under a criterion/sub-criterion; 4) collection of the previously produced grades and formation of the aggregate grade for each evaluated PI/PM. Consistency and robustness tests are performed within the relevant steps.

For the first step the criteria-tree is that of previous applications (Figure 1) (Konidari and Mavrakis, 2007; 2006).

1. Environmental performance: overall environmental contribution of the PI/PM towards the goal. Assessment under this criterion is based on the sub-criteria:

   a) *Direct contribution to reduction of GHG emissions* - synthesis and magnitude of GHG emissions reductions directly referred to and attributed only to the PI/PM;

   b) *Indirect environmental effects* - ancillary outcomes attributed only to the PI/PM.

2. *Political acceptability*: attitude of all involved entities towards the PI. Assessment is facilitated through its sub-criteria:

   *a) Cost effectiveness* - property of the PI/PM to achieve the goal under the perspective of a financial burden acceptable and affordable by the involved entities (target groups);

   b) *Dynamic cost efficiency* - property of the PI/PM to create, offer or allow compliance options that support research projects, incremental and radical pioneer technologies and techniques, and institutional or organizational innovations leading to GHG emission reductions and lessening the impacts of climate change impacts;

c) *Competitiveness* - capacity of the entity to compete, under the particular PI/PM, via price, products or services with other entities and maintain or even increase the magnitude of specific indicators describing its financial performance;

d) *Equity* - fairness of the PI/PM in distributing emission rights, compliance costs and benefits among entities (countries/sectors) for accomplishing GHG emission reductions and handling climate change impacts.

e) *Flexibility* - the property of the PI/PM to offer a range of compliance options and measures that entities are allowed to use in achieving reductions under a time frame adjusted according to their priorities;

f) *Stringency for non-compliance and non-participation* - level of rigidity determined by provisions of the PI/PM towards emitters that failed to comply or did not participate to its implementation.

3. *Feasibility of implementation (or enforcement):* aggregate applicability of the PI/PM linked with national infrastructural (institutions and human resources) and legal framework. Assessment is based on:

   a) *Implementation network capacity* - ability of all national competent parties to design, support and ensure the implementation of the PI/PM.

   *b) Administrative feasibility* - aggregate work exerted by the regulatory implementation network during the enforcement of the PI/PM;

   c) *Financial feasibility* - property of the PI to be implemented with low overall costs by the pertinent regulatory authorities.

For the second step, the values for the weight coefficients of the aforementioned criteria/sub-criteria are those calculated in previous work (Konidari and Mavrakis, 2007). The consistency test was also performed for these values with very good results (Konidari and Mavrakis, 2007).

The third step will be presented analytically in the following session. For the fourth step a grade (commonly measured performance) - determined in third step - of the assessed PI/PM for a certain sub-criterion is multiplied with the respective weight coefficient of the sub-criterion. All products (concerning all sub-criteria) are added and form the grade of the criterion that is supported by these sub-criteria. The sum of these products is the grade of the PI/PM under the criterion. This criterion grade is multiplied with the respective weight coefficient of the criterion. All new products are added and form the final grade, which expresses the effectiveness of the evaluated PI/PM. Calculations will be done with the software ClimAMS, which is developed to facilitate work with AMS.

### *Evaluation*

All ten policy mixtures are evaluated against the described criteria and their respective sub-criteria.

### ***Criterion 1: Environmental performance***

*Direct Contribution to GHG emissions:* The outcomes of the LEAP model are used for evaluating the performance of the policy mixtures under this sub-criterion. The policy mixture that has achieved the highest reduction in energy consumption so as to reach the set national EE target is the one that contributes more to the reduction of GHG emissions. The calculations and the results are presented in Table 1.

*Indirect environmental effects:* the total amount of the total environmental effects is provided by LEAP outcomes (Table 3).

## ***Criterion 2: Political acceptability***

*Cost efficiency:* Based on the work performed in PROMITHEAS-4, an index was developed so as to understand the benefit-cost gains that the implementation of a PI has on the target groups. The classification of the marginal abatement costs for certain technologies promoted under certain PIs was used to specify this index. For each of these eleven countries a mean Cost efficiency index is calculated depending on the implemented PIs (Table 4).

*Dynamic cost efficiency*
Albania: EE technologies are not promoted. Although building standards exist, compliance with these regulations is low (about 8%) (Energy Charter Secretariat, 2013). Also, commercial banks have no experience in financing EE projects that could contribute in the penetration of such technologies (UNECE, 2010).

Armenia: The main barriers for the promotion of innovative EE technologies are: i) Low natural gas tariff that does not motivate smaller gas consumers for energy savings (Armenia Renewable Resources and Energy Efficiency Fund, 2008). ii) reluctance of apartment owners to invest in EE approaches and technologies.

**Table 3: Amount of emissions (carbon monoxide, sulfur dioxide, nitrogen oxides).**

| Country | Reference year | Target year 2020 | Difference |
|---|---|---|---|
| | in $MtCO_2eq$ | | % |
| Albania | 0.392 (2004-2008) | 0.448 (2018) | +14.52 |
| Armenia | 0.106 (2008-2010) | 0.177 | +65.9 |
| Azerbaijan | 0.734 (2008-2010) | 0.758 | +30.2 |
| Bulgaria | 1.152 (2001-2005) | 1.569 (2016) | +36.15 |
| Moldova | 0.0225 (2009) | 0.0222 | -1.33 |
| Romania | 0.43 (2009) | 0.50 | +16.2 |
| Russia | 3.7 (2007) | 5.1 | +37.8 |
| Serbia | 0.078 | 0.177 | +126.9 |
| Turkey | 10.8 (2008) | 18.6 (2023) | +72.2 |
| Ukraine | (2008-2010) 3.6 | 5.0 | +38.88 |

**Table 4: Cost efficiency of the policy mixtures.**

| Country | CEI indexes for each PI of the mixture | CEI index (Psedo monetary unit/$tCO_2$) |
|---|---|---|
| Albania | -5.75-1.5-0.75-2.5 | -2.625 |
| Armenia | 0 | 0 |
| Azerbaijan | -1.75-0.25-0.25 | -0.75 |
| Bulgaria | -5.75-0.75-2.5-0.5-0.75 | -2.05 |
| Moldova | -0.75-0.5 | -0.625 |
| Romania | -1.5-0.25-5.75-2.5-0.5 | -2.1 |
| Russia | -5.75-2.5-0.25-0.75-0.5+0.5 | -1.541 |
| Serbia | 0 | 0 |
| Turkey | -1.5-5.75-2.5+0.5-0.25+0.5-0.5 | -1.357 |
| Ukraine | -0.5 | -0.5 |

**Table 5: Equity measurement.**

| Country | Target groups for EE | Ratio of participation | Index |
|---|---|---|---|
| Albania | 1 sector out of six – Households (Buildings) | 1/6 | 0.166 |
| Armenia | Households | 1/6 | 0.166 |
| Azerbaijan | Transport - Energy | 2/6 | 0.333 |
| Bulgaria | Households-Industry - Energy | 3/6 | 0.5 |
| Moldova | Energy | 1/6 | 0.166 |
| Romania | Households-Transport-Industry-Waste management-Energy | 5/6 | 0.833 |
| Russia | Households, Transport, Energy, Industry | 4/6 | 0.666 |
| Serbia | 0 | 0 | 0 |
| Turkey | Households, Transport, Energy, Industry | 4/6 | 0.666 |
| Ukraine | Households-Energy | 2/6 | 0.333 |

iii) Armenian energy utility regulation (as in many countries) encourages energy companies to: a) sell as much as they can for recovering their fixed costs, and b) invest in new production capacity, rather than in measures to reduce load (Armenia Renewable Resources and Energy Efficiency Fund, 2008).

Azerbaijan: There is no information regarding the promotion of research on such technologies (existing PIs or planned ones were not available). No official studies about the potential of the country in EE were available, implying the lack of such studies capable of supporting research.

Bulgaria: Innovations are not directly encouraged. Reseach and development of such technologies are not supported (Energy Efficiency Watch, 2013). Modernization with EE technologies is a necessity for the service and industry sector (Energy Efficiency Watch, 2013).

Moldova: EE technologies and procedures are still not used (Schmieder U., 2012). The government subsidises energy prices for socially vulnerable groups, therefore up to a certain consumption of electricity or natural gas prices are below economically sustainable levels (Schmieder U., 2012). The residential sector currently absorbs more than 40% of the total energy consumption, and EE and RES projects are scarce (East Invest, 2011).

Romania: The country recognizes the need for a Reseach – Development - Innovation effort complementary to the direction of action "Increased energy efficiency and sustainable development of the energy systems" included in the National Strategic Reference Framework 2007-2013 (Government of Romania, 2006).

Russia: The main problems for the EE implementation are linked with the lack of (Pacific Northwest – National Laboratory, 2012; UNDP, 2009; European Commission, 2009): i) motivation; ii) knowledge and information; iii) funding and long-term investments; and iv) organization and coordination. The country has low rates of technological adoption (137th in the world) (World Economic Forum, 2013). Research on EE is supported by Two Federal Targeted Programs, the "Research and Development in Priority Areas of Science and Technology Complex of Russia 2007-2012" and "National Technological Basis for the period 2007-2011" (Asia Pacific Energy Research Centre, 2012; Ministry of Energy of the RF, 2013[33]). There are private research institutes and organisations engaged in research on improving EE in various sectors of the Russian economy (Asia Pacific Energy Research Centre, 2012). However, R&D for new technologies is still lacking (FAO, 2012b).

Serbia: In 2010, the government adopted the Scientific and technological development strategy of the country for the period 2011 - 2014 (Official Gazette of the RS No. 13/10) (Stojiljkovic D. et al., 2012). The Strategy refers to seven national Research and Development priorities among which is energy and EE (Stojiljkovic D. et al., 2012).

Turkey: Although there is a high level of awareness about EE of appliances, the purchasing in-efficient home appliances is not at the same level (Ministry of Energy and Natural Resources, 2012). There are currently 70 new buildings in the private sector awarded with green building certificates, but there is no green building practice in public buildings yet (Energy Charter Secretariat, 2013). Arcelik S.A. is the only Turkish company among the top 1.000 allocating resources to R&D (Arcelik S.A., 2014).

Ukraine: The potential for energy savings is large, especially in the industry and residential sectors, but remains largely untapped and insufficiently addressed (Energy Charter Secretariat, 2013; IEA, 2012). Many power plants are working far beyond their technical life and at low efficiency levels (IEA, 2012). Support for R&D is low and insufficiently focused, resulting in efforts and resources being spread inefficiently. One of the priority focus areas for innovation activity for 2012-2016 is recommended to be EE (UNECE, 2013). As in the case of Armenia there is need for the progressive and predictable removal of subsidies for gas, coal and electricity consumers and reallocation of budget resources towards EE support measures (IEA, 2012).

[33] http://minenergo.gov.ru/activity/vie/

*Grades: Albania – 4, Armenia – 4, Azerbaijan – 3, Bulgaria – 5, Moldova – 4, Romania – 5, Russia - 6, Serbia – 5, Turkey – 7, Ukraine – 4.*

*Competitiveness*

*Albania:* Foreign investors are discouraged to proceed with EE projects due to complex authorization procedures, non-transparent regulations, inefficient bureaucracy and corruption, lack of a regulatory framework, weak and/or very restricted support mechanism/incentives, absence of public funding for such projects and initiatives (UNECE, 2010; USAID, 2009). As for attracting investors through CDM projects, the country does not offer opportunities. More attention is paid to RES projects than in EE (Hido M. E., 2012).

*Armenia:* Armenian industries have a unique opportunity to improve their international competitiveness by proceeding with EE investments (Armenia Renewable Resources and Energy Efficiency Fund, 2008). But from the other hand they do not exploit this advantage due to the usage of inefficient technologies (Armenia Renewable Resources and Energy Efficiency Fund, 2008). If Armenian industries fail to invest in EE they may face the possibility to terminate their functions under new tariff increases (Armenia Renewable Resources and Energy Efficiency Fund, 2008).

*Azerbaijan:* One more challenge for the government is to be successful in attracting investments in the non-oil economy and furthermore to RES and EE investments (EBRD, 2010). The government is interested in developing the country's EE and RE potential also through the CDM framework. Investment in CDM projects seems to be attractive[34] (BMU, 2008).

[34] the web-sit of "East-Invest provides information of indicative CDM projects (http://www.east-invest.eu/en/Investment-Promotion/Azerbaijan-2/AZ-alternative-energy)

Bulgaria: The country has one of the lowest business costs in Europe which facilitates EE investments, but so far, major foreign investors in the energy sector invested in the energy distribution network (InvestBulgaria Agency, 2011). The policy mixture for EE is expected to enhance the Bulgarian competitiveness, according to the Energy Strategy (Energy Charter Secretariat, 2008). Foreign investors are discouraged due to the lack of source diversification in the energy sector, the unliberalized market coupled with extremely inefficient governance of state energy assets and non-competitive public procurement approach (Center for the study of democracy, 2013).

Moldova: Although legislation related to investment policy is up to standard and refers to national treatment of foreign investors, the latter still face heavy restrictions in specific areas such as the acquisition of agricultural land (OECD, 2011). However, without defined priorities for CDM projects and more incentives foreign private investors are not encouraged.

Romania: The government offers a number of investment incentives to attract FDI, including real estate tax exemptions, preferential tax deductions for the purchase of new technology and R&D centers (KPMG, 2013). New investments and job creation are supported by grants coming from national and EU sources (KPMG, 2013). The current EE policy mixture does not provide investors with a long term vision (Romanian Association for the promotion of energy efficiency, 2013).

Russia: There are opportunities for foreign investors in investments for EE technologies, but they are not so attractive compared to other countries (Ernest & Young, 2012). Two more reasons that affect the competitiveness of the country in "green investments" are (UNECE, 2010): i) the delay in the complete privatization and liberalization process in the Russian energy sector and ii) the strong state influences in the strategic decisions of market operators that limit often the foreign investors to a role of minority shareholders, with no influence on the corporate governance of the companies (UNECE, 2010).

Serbia: Due to the lack of an EE policy mixture the country does not attract investments for EE procedures and technologies.

Turkey: The Turkish industry needs to adapt to the increasing global competition, improve its own competitiveness and maintain its high-growth areas (Republic of Turkey – Ministry of Industry and Trade, 2010). For the achievement of these objectives the Ministry of Energy and Natural Resources, the Energy Market Regulatory Authority (EPDK) and other relevant organizations intensified efforts so that energy/climate change policies do not become a barrier for the industrial development (Republic of Turkey – Ministry of Industry and Trade, 2010). The Arcelik A.Ş. company - started its business in 1955 on the Turkish market has become a market leader in many European countries, known also for its high EE standards in this sector. Turkey is among the R&D locations for cooling appliances such as Germany and China (Thomas, Klaus, 2013).

Ukraine: Considering the country's stage of economic development, the market attractiveness and current assets, the OECD identified the EE sector as one of the sectors that could attract foreign investors and improve the Ukrainian sectoral competitiveness (UNECE, 2013; IEA, 2012). The introduction of incentives so as to increase the demand for ESCO services along with a network of auditors for implementing measures indicated by energy audits would probably contribute to the development of the market for EE measures more efficiently than the penalty system (UNECE, 2010). On the other hand, Ukraine is one of the most active countries in the JI market, accounting for over 40% of global ERUs in June 2012 (Energy Charter Secretariat, 2013). Ukraine participates in international emission trading through the Green Investment Scheme (GIS), using the revenue from emissions trading for funding mostly small-scale EE projects in public buildings and landfill gas recovery for energy use (Energy Charter Secretariat, 2013).

*Grades: Albania – 3, Armenia – 3, Azerbaijan – 3, Bulgaria – 3, Moldova – 4, Romania – 4, Russia - 4, Serbia – 1, Turkey – 7, Ukraine – 7.*

*Equity:* For equity the ratio of sectoral participation is used. It is considered that the larger the ratio is the fairer is the scenario in sharing the burden among the sectors. Households, Industry, Energy, Transport, Agriculture, Waste management (Table 5).

*Flexibility*

Albania: From Table 2, only two flexibility mechanisms are in force.

Armenia: There are no targeted subsidies for energy and heating needs under the perspective of EE and RES goals, that could assist the: i) low affordability/lack of initial investment resources of households regarding energy/energy efficiency because of low incomes, high poverty level and insufficiency of state social welfares (no) (UNDP/GEF, 2012; Energy Charter Protocol on Energy Efficiency and Related Environmental Aspects PEEREA, 2005); (ii) slow rate of realization of EE and energy saving on demand side due to lack of awareness, promotion mechanisms and appropriate managing structures (UNDP/GEF, 2012). The range of incentives is restricted, but this can be justified due to the inadequate legislative framework.

Azerbaijan: There are limited incentives (tax exemptions) and only for the transport sector.

Bulgaria: The minor availability of obligations offers the greatest flexibility. There are several flexible influencing mechanisms (i.e. different levels of performance standards for boilers, lighting, appliances, etc.) and several economic incentives.

Romania: Investment aids offer flexibility (Table 2).

Russia: Significant tax incentives for the support of energy-saving technologies were introduced with Law "on Energy Saving and on Increasing Energy Efficiency" approved in November 2009 (UNECE, 2010). These tax incentives include: i) investment tax credits up to 30% for companies investing in energy efficiency and energy saving technologies; ii) accelerated depreciation of assets belonging to the category of objects with high energy efficiency or classified in top energy efficiency classes and iii) partial compensation of interests on loans granted by Russian banks for investing in energy savings and increased EE technologies (UNECE, 2010).

Moldova, Serbia, Turkey and Ukraine do not have rules-influencing mechanisms that could offer flexibility.

*Grades: Albania – 3, Armenia – 1, Azerbaijan – 2, Bulgaria – 3, Moldova – 1, Romania – 3, Russia - 3, Serbia – 1, Turkey – 1, Ukraine – 1.*

*Stringency for non-compliance:* The level of stringency is determined by sanctions, penalties and other rules-influencing mechanisms for transgressors. Almost all of these studies eleven emerging economies do not have rules-influencing mechanisms for non-compliance. The two EU Member States (Bulgaria, Romania) have monitoring procedures and the obligation to take additional measures for complying with the EU obligations. For Ukraine there are penalties collected from companies that are not functioning energy efficiently (UNECE, 2010). No other information is available for this sub-criterion.

*Grades: Albania – 1, Armenia – 1, Azerbaijan – 1, Bulgaria – 5, Moldova – 1, Romania – 5, Russia - 1, Serbia – 1, Turkey – 1, Ukraine – 2.*

### *Criterion 3: Feasibility of implementation*

*Implementation network capacity*

Albania: There is no formally mandated agency delegated to develop and implement the national and sectoral EE policies and programmes (Energy Charter Secretariat, 2013). The published documents of certain national entities (such as AKBN, ERE) for EE are limited, with no essential and updated information. For the Albanian Energy Regulator the last annual report is of 2012.[35] The web-sites are not user friendly and the limited information is not directly accessible. EE issues were the responsibility of the former Ministry of Economy, Trade and Energy[36],[37], but now the new Ministry of Energy and Industry[38] has a special "Department of Resources Energy Efficiency and Renewable Energy[39]". The new web-site does not have an English version or relevant publications. Training was provided to auditors in the field of EE of buildings (European Commission, 2013).

Armenia: There is lack of sufficient information, skills and data regarding EE investments that are economically and financially viable (Armenia Renewable Resources and Energy Efficiency Fund, 2008). Although the national Program provides a solid foundation for estimating the national EE potential it lacks detailed estimates about improving EE in two largest energy consuming sectors: transport and heating in buildings (Armenia Renewable Resources and Energy Efficiency Fund, 2008). There is a recognized need of establishing EE agencies that would help to coordinate various donor-sponsored and government programmes and policies on EE (European Parliament, 2013).

Azerbaijan: There is no entity specifically for EE issues in the country. Only a few non-governmental organizations are engaged in EE development. There are no complete studies about the national EE potential. EE potentials have been analyzed in several studies, mainly from international organizations, such as IFC or EBRD (Allplan, 2013).

Bulgaria: In the field of EE and renewable energy, the existing capacity of the implementation network can be considered as very good. Training for energy assessors and auditors is offered by six University centres (Energy Efficiency Watch, 2013). Local energy agencies could also play an effective role in EE implementation but need assistance for the commercialization of their services and further coordination of their efforts (Energy Charter Secretariat, 2008).

[35] http://www.ere.gov.al/mat.php?idr=184&idm=243&lang=2
[36] http://www.mete.gov.al/error.php?idr=2&lang=2
[37] http://www.mete.gov.al/error.php?idr=535&lang=2
[38] http://www.energjia.gov.al/
[39] http://www.energjia.gov.al/al/ministria/drejtorite

Moldova: The current policy mixture has a poor performance under the capacity of the relevant implementation network. The relevant reports are not updated. The web-sites are not user friendly and the information is not directly accessible. In most of them there is no English version to facilitate foreign researchers. Users need to devote time is searching for the necessary information. At the web site of the Energy Efficiency Agency[40] there are no publications or relevant information.

Romania: Institutions such as the Buildings Performance Institute Europe (BPIE) provide information about EE issues in Romania. Lack of skilled workers or low levels of training in the use of new technologies designed for EE and RES (BPIE, 2014). The web-site of the Romanian Sustainable Energy Finance Facility[41] has an English version, but no publications for results about EE. The web-site of the Romanian Regulatory Authority[42] has a session for EE, but the part about reports is empty for both versions, Romanian and English.

Russia: The development of analysis work and assessments for supporting the awareness of customers and for providing a quantitative background for the identification of attractive EE and RES projects is restricted due to the partial absence of databases with consumption data on public and residential buildings (UNECE, 2010). Even if a new Law had included the establishment of such databases, long time is needed until these databases become statistically significant, since usually there are no past data to refer to (UNECE, 2010). Also, established on line databases are not updated or do not provide the necessary information.

A number of Coordination Councils[43] (such as energy service organisations and associations, energy producer and end-user economic entities) for the implementation and coordination at different levels of energy saving and EE policies are established in Russian regions and municipalities (Asia Pacific Energy Research Centre, 2012). Some indicative entities are the Center for Energy Efficiency (CENEF), Center for Energy Policy, AcademEnergoServis, Institute for Energy Policy, RusDem, ESCO Negawatt, Rus Esco, 3E, Energo Servis, etc. (Asia Pacific Energy Research Centre, 2012). Also, the Russian Green Building Council (RuGBC)[44] is activated for green building construction (Pacific Northwest – National Laboratory, 2012). The web-site has English version, but no available publications. Due to the weaknesses of the current implementation network there is still incomplete metering of energy consumption on final customers, which are billed not on actual consumption but on living surface or other similar norms (UNECE, 2010).

Serbia: There is no entity specifically for EE issues. The Energy Agency[45] of the Republic of Serbia has on its web-site a session for RES, but not for EE.

Turkey: Since 1981 the studies on EE and increasing usage of RES in the end use are carried out by General Directorate of Electrical Power Resources Survey and Development Administration (EIE) being bound to the Ministry of Energy and Natural Resources[46]. In 2007, an Energy Efficiency Coordination Board was established to carry out EE studies within all relevant organizations all over the country, monitor its results and coordinate efforts (EEA, 2011). Despite all these statements, there are very limited reports on EE for Turkey, most in Turkish language (AllPlan, 2013). There are no available web-sites for any of these entities so as to get information.

Ukraine: The State Agency on Energy Efficiency and Energy Saving of Ukraine is the main institution for EE in the country (European Parliament, 2013). The English version of its web site does not have information (publications and activity>EE are under construction). The limited demand for ESCO services shows that awareness and understanding of the benefits of EE projects is not very widespread (UNECE, 2010). Awareness regarding business opportunities in the financing of EE projects is limited on the part of commercial banks because most activities were financed by state funds or by international assistance programmes (UNECE, 2010). Another disadvantage of this implementation network is the strong lack of transparency regarding the amount of financing and the allocation criteria for the State Fund for Energy Conservation (UNECE, 2010).

*Grades: Albania – 2, Armenia – 3, Azerbaijan – 2, Bulgaria – 6, Moldova – 1, Romania – 3, Russia - 3, Serbia – 1, Turkey – 4, Ukraine – 2.*

*Administrative feasibility*

Albania: Because of not having a formally mandated EE agency different ministries and

[40] http://aee.md/en/energy-efficiency/description-4 and http://aee.md/en/

[41] https://www.seff.ro/downloads/9/page.html

[42] http://www.anre.ro/en/

[43] The "Coordinating Council for Energy Saving and Energy Efficiency, Relations with Business and Regions" was established in September, 2008 (Presidential Decree No. 889, issued on 4.06.2008 and RF Ministry of Energy act (No. 75 of 15.09.2008). It was intended to work out EE policy, to coordinate activities of federal and regional governments and business institutions in pursuing energy saving state policy and EE improvement (European Commission/AESA Consortium, 2009).

[44] http://www.rugbc.org/en

[45] http://www.aers.rs/Index.asp?l=2

[46] http://www.enr-network.org/GDRE.html

organizations are involved in a number of activities (Energy Charter Secretariat, 2013). Very often the activities between these different stakeholders are not coordinated (Energy Charter Secretariat, 2013). Although the government has adopted a National EE Action Plan for 2011-2018, a legal framework and an inter-institutional distribution of responsibility for its implementation have not yet been established (EBRD, 2013).The Law on EE has still not been adopted while the implementation of the national EE action plan encounters lack of political commitment, administrative capacity and financial resources (European Commission, 2013; Zajmi Rajmonda, 2013; EBRD, 2013). The preparation of the second national EE action plan is delayed (European Commission, 2013).

Armenia: The pertinent governmental authorities for EE policy issues have delayed in implementing the necessary legislative framework for these issues (Armenia Renewable Resources and Energy Efficiency Fund, 2008; Energy Charter Protocol on Energy Efficiency and Related Environmental Aspects PEEREA, 2005). Although EE standards exist, only few were implemented (Armenia Renewable Resources and Energy Efficiency Fund, 2008). Furthermore, apart from programs sponsored World Bank, EBRD and USAID, only few governmental EE initiatives exist demonstrating administrative coordination and readiness problems (Armenia Renewable Resources and Energy Efficiency Fund, 2008). Also, despite the fact that the budgeting laws permit to public administration bodies to reallocate energy savings, they were not adequately flexible to proceed with sufficient incentives for such issues (Armenia Renewable Resources and Energy Efficiency Fund, 2008).

Azerbaijan: No progress in establishing a legal framework for EE and its respective implementation entities (AllPlan, 2013). There were delays with the implementation of the EE policy instruments.

Bulgaria: There is still work for creating a low carbon economy framework for the country (BTI 2014). There is lack of an overall strategy for the EE in the residential sector so as to provide a combination of legislation, funding programmes and information measures - all were considered to currently be insufficient (Energy Efficiency Watch, 2012).

Moldova: The country will receive assistance from EBRD for the development of a regulatory framework on EE of buildings aligned with European Directive on Energy Performance of Buildings. Also, EBRDl assist with the preparation of a dedicated Law on EE of Buildings and on amending Housing Codes to unlock residential sector for sustainable energy financing (EBRD, 2010).

Romania: There are a number of ministries with overlapping responsibilities for buildings, with a lack of correlation between them and their respective departmental regulations and laws (BPIE, 2014). There is lack of staff capacity in the public sector and changes in the institutional framework are considered as a challenge (Energy Efficiency Watch, 2012). On the other hand, relevant EU legislation was transposed, providing a legislative framework and some funding mechanisms are available (Energy Efficiency Watch, 2012).

Russia: There was a lack of: i) a clear policy framework for the substantial support of EE and RES; ii) clear responsibilities for policy implementation and monitoring of progress and this clearly constituted a significant legal and institutional barrier (UNECE, 2010). The currently implemented policy mixture is not characterized by administrative feasibility due to problems that emerged each time that a new policy instrument was implemented.

Serbia: There is not an effective regulatory framework designed to increase EE and advance the use of alternative sources (Jefferson Institute, 2009). Little progress is quoted for RES and EE, because the Energy Law is partly in line with the RES Directive (European Commission, 2012). Serbia has not yet adopted the planned framework law on rational use of energy.

Turkey: Enhancement of inter-ministerial coordination is needed, in particular in the fields of energy, environment, transport, housing and industry (Energy Charter Secretariat, 2014).

Ukraine: Further strengthening of administrative capacity at all levels of the country and coordination between the authorities requires particular attention (CEC, 2009). The legal framework for the energy sector in general and particularly that referring to EE and RES is complex and partly fragmented, partly outdated (UNECE, 2010).

*Grades: Albania – 2, Armenia – 2, Azerbaijan – 1, Bulgaria – 4, Moldova – 1, Romania – 4, Russia - 3, Serbia – 1, Turkey – 2, Ukraine – 2.*

*Financial feasibility*

Albania: The National EE Action Plan plan was approved by the Albanian Government in September 2011. In order to support the implementation of the NEEAP, a budget needs to be made available (Energy Charter Secretariat, 2013). In total, for all sectors analyzed the amount of value from public funds to be invested for EE measures is estimated as 6,687,000€ (Energy Charter Secretariat, 2013). EBRD through its updated "Strategy for Albania" will: i) assist the Albanian Power Corporation (KESH) so as to improve its financially viability and stability, by providing long-term loans for the safety, maintenance and upgrading of its generation utilities as well as for a possible restructuring of its operations (EBRD, 2012); ii) continue to implement the WeBSEFF/WeBSEDFF frameworks for the financing of RES and EE projects by extending support to private concessionaires and companies implementing energy savings (EBRD, 2012).

Armenia: There is not adequate governmental funding (Energy Charter Protocol on Energy Efficiency and Related Environmental Aspects PEEREA, 2005). On the other hand the country established cooperation with international entities that support EE projects. These entities are: i) European Bank for Reconstruction and Development (EBRD) which in its document "Strategy for Armenia" refers to its intention to continue supporting creditworthy RES and EE projects (EBRD, 2009). ii) International Finance Corporation (IFC) (member of the World Bank Group) which operates the Armenia Sustainable Energy Finance Project[47] . iii) World Bank whose Board of Executive Directors approved on March 27, 2012 a 1,82 million USD grant from the Global Environment Facility (GEF) Trust Fund for the EE Project for Armenia[48].

Azerbaijan: There is a 14 million EURO budget support programme aiming to assist the Azeri Ministry of Energy in developing a legislative and regulatory framework for RES and EE (EC, 2012). Simultaneously, EBRD intends to continue supporting Azerbaijan's infrastructure development with emphasis on the power sector and EE investments (EBRD, 2010).

Bulgaria: Public bodies have access to several EU funds, such as EU Structural and Cohesion Funds and IEE projects (notably Concerted Actions) to design and implement EE policies. Bulgarian Energy Efficiency Fund (BEEF) provides EE loans on a commercial lending basis, partial credit guarantees and portfolio guarantees to ESCOs. The Fund financed or guaranteed about 160 projects valued at over US$80 million by 2011. Around 54% of loans were provided to municipalities and the rest to corporate and other clients (such as hospitals and universities). Support for EE is financed mainly under OP Regional Development (Operation 1.2 Residential Policy form Priority Axis 1) with an indicative budget of EUR 40 million. So far the OP has been focused on EE in public buildings (schools and municipalities). All the residential housing measures are still to be initiated. They will include EE renovation and construction, insulation, heating systems (incl. gas) and use of RES (Center for the Study of Democracy, 2013).

Moldova: The country has limited financial sources to implement the current policy mixture. EE has been improving slowly over the past 10 years, due to support from a range of development partners, but it still requires important investments to reach regional levels (World Bank, 2014).

Romania: Funding EE measures in the country is important since there are very limited financial resources in the public sector, for investing in EE and measures, legislation and action plans can not be implemented due to lack of budgets (Energy Efficiency Watch, 2012). In the residential sector, some available financial programmes include tax reductions and financial support for the renovation of multi-family buildings (Energy Efficiency Watch, 2012).

Russia: The absence of any tariff components to cover environmental externalities leads to diminished awareness of the value of natural resources on behalf of the Russian customers and implies the absence of a potential financial mechanism for EE projects (UNECE, 2010). Financial incentives for EE in industry are provided by international institutions apart from governmental incentives. Such institutions are: i) EBRD: It launched a 300 million EUR framework facility, the Russian Sustainable Energy and Carbon Finance Facility (RSECF), after the approval of the EBRD Board of Directors in May 2009[49]. ii) International Finance Corporation (IFC) (member of the World Bank Group): It operates the Russia Sustainable Energy Finance Programme (RSEFP)[50] since 2005. iii) The Nordic Environment Finance Corporation (NEFCO)[51].

Serbia: The Government has international and national sources of financing (Republic of Serbia, 2013): i) the German Development Bank (KfW): KfW Entwicklungsbank and the Serbian Government (rehabilitation program of District Heating Systems in Serbia) (Embassy of Denmark in Belgrade, 2010); ii) Fund Green for Growth

---

[47] http://www.ifc.org/wps/wcm/connect/region__ext_content/regions/europe+middle+east+and+north+africa/ifc+in+europe+and+central+asia/regional+priorities/climate+change/armenia+sustainable+energy+finance+project_

[48] http://www.worldbank.org/en/news/press-release/2012/03/27/global-environment-facility-supports-energy-efficiency-investments-in-public-facilities-of-armenia

[49] http://www.ebrd.com/pages/project/psd/2009/37857.shtml

[50] http://www.ifc.org/wps/wcm/connect/regprojects_ext_content/ifc_external_corporate_site/rsefp_home/overviewenglish/home

[51] http://www.nefco.org/introduction/this_is_nefco

(funds for financing small and medium enterprises for EE and RES projects (Republic of Serbia, 2013)); iii) Italian Credit Facility (procurement of equipment, technologies and spare parts for small and medium enterprises (Republic of Serbia, 2013)); iv) European Investment Bank - financing projects of small and medium enterprises (up to 100% of the project value) and infrastructure projects launched by local authorities in the field of energy and environmental protection (Republic of Serbia, 2013); v) EBRD supports financially the promotion of EE and RES projects. Local sources of EE financing: i) Fund for Development of the Republic of Serbia (Official Gazette of the Republic of Serbia 88/2010); ii) Fund for Development of Autonomous Province of Vojvodina. Also, the first annual programme for financing EE projects in the public sector was adopted in March 2012, with a budget of € 13 million (European Commission, 2012).

Turkey: EBRD plans to promote through its investments, favourable market conditions for the development of EE instruments across economic sectors and RES (EBRD, 2012). The country has limited incentives for the existing policy instruments.

Ukraine: Budgets/ funds for EE measures/ investments have been inadequate (Ministry of Strategy and Finance, the Republic of Korea, 2010). In 2005-2006 the Government allocated approximately 800 million UAH (equivalent to 160 million USD) including local budgets, to implement measures envisaged by the Comprehensive State Programme of Energy Saving (CSPES) of Ukraine and the Programme of State Support of Development of Alternative and Renewable Energy Sources and Small Hydropower and Thermal Power (UNECE, 2010). However, the Comprehensive State Program of Energy Saving was 60% underfunded (Ministry of Strategy and Finance, the Republic of Korea, 2010). In 2010, actually only an amount of 9,9 billion UAH (about 2,1 billion USD) was allocated for implementing the CSPES EE program planned by the NERC (Ministry of Strategy and Finance, the Republic of Korea, 2010). Ukraine intends to invest 30 billion USD or 6 billion USD (about 3,3% of GDP in 2008) per year, over the time period 2009-2014 for energy saving measures (Ministry of Strategy and Finance, the Republic of Korea, 2010). 25% of these investments will be financed by the state budget using revenues from emissions trading, surcharges on thermal power plants, funds financed by industries and foreign investments (Ministry of Strategy and Finance, the Republic of Korea, 2010). In early 2008, the Government established the State Energy Conservation Fund as a budgetary fund for financing EE improvements (UNECE, 2010). The revenues of the fund come from penalties collected from companies that are not using energy efficiently (UNECE, 2010).

The international financial resources for implementing the Ukrainian EE policy are from: i) BSTDB (BSTDB, 2011); ii) World Bank through the Energy Efficiency Project, (200 million US$, approved by the Board in May 2011) (World Bank, 2012b); iii) EBRD with a total amount of EBRD investments approximately one billion USD, with 20-30% of this amount allocated for EE projects (UNECE, 2010); iv) Neighbourhood Investment Facility (NIF) (under the European Neighbourhood and Partnership Instrument) (CEC, 2009); v) United States Agency for International Development (USAID) approved financing (one million USD) for the implementation of EE projects in the industrial sector.

*Grades: Albania – 3, Armenia – 3, Azerbaijan – 3, Bulgaria – 7, Moldova – 3, Romania – 4, Russia - 3, Serbia – 1, Turkey – 2, Ukraine – 2.*

**AMS outcomes**

The outcomes are presented in Table 6.

## 5. Conclusions

The outcomes of AMS show that the most effective EE policy mixture is that of Romania, while the one with the lowest performance is that of Serbia since it has not yet been developed. The Romanian EE policy mixture had better performance in two of the three criteria, in environmental performance and political acceptability.

Romania is closer to fulfil its EE target, followed by Azerbaijan that has no quantitative EE target, but will restrict its energy consumption more than the other countries of the region. Armenia has the lowest performance in achieving the set EE target.

Under the criterion of political acceptability, three countries demonstrate close performance, Romania, Albania and Bulgaria. This is due to two factors, cost efficiency and equity. The combination of policy instruments in these three countries is more cost efficient compared to that of the others. In Romania almost all economic sectors are under policy instruments for EE.

Under the third criterion, feasibility of implementation, Bulgaria had the most effective performance, due to a more efficient implementation network and to the financial feasibility of its policy mixture. It is followed by Romania.

**Table 6: Results of the AMS method.**

| **Criteria** | **Countries** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Albania** | **Armenia** | **Azerbaijan** | **Bulgaria** | **Moldova** | **Romania** | **Russia** | **Serbia** | **Turkey** | **Ukraine** |
| Direct contribution to GHG emission reductions (0,833) | 40.594 | 0.00 | 59.325 | 16.550 | 38.565 | 83.300 | 7.219 | 13.416 | 52.754 | 18.068 |
| Indirect environmental effects (0,167) | 14.636 | 7.944 | 12.594 | 11.819 | 16.700 | 14.417 | 11.604 | 0.00 | 7.124 | 11.463 |
| **Environmental performance (0,168) - A** | **55.230** | **7.944** | **71.918** | **28.368** | **55.265** | **97.717** | **18.823** | **13.416** | **59.878** | **29.531** |
| Cost efficiency (0,473) | 47.300 | 0.000 | 13.514 | 36.939 | 11.262 | 37.840 | 27.767 | 0.000 | 24.452 | 9.010 |
| Dynamic cost efficiency (0,182) | 1.140 | 1.140 | 0.731 | 1.820 | 1.140 | 1.820 | 2.883 | 1.820 | 4.568 | 1.140 |
| Competitiveness (0,085) | 0.394 | 0.394 | 0.394 | 0.394 | 0.614 | 0.614 | 0.614 | 0.155 | 2.462 | 2.462 |
| Equity (0,175) | 3.487 | 3.487 | 6.996 | 10.504 | 3.487 | 17.500 | 13.992 | 0.000 | 13.992 | 6.996 |
| Flexibility (0,050) | 0.758 | 0.299 | 0.474 | 0.758 | 0.299 | 0.758 | 0.758 | 0.299 | 0.299 | 0.299 |
| Stringency for non-compliance (0,034) | 0.160 | 0.160 | 0.160 | 1.012 | 0.160 | 1.012 | 0.160 | 0.160 | 0.160 | 0.255 |
| **Political acceptability (0,738) - B** | **53.239** | **5.480** | **22.270** | **51.427** | **16.962** | **59.544** | **46.174** | **2.434** | **45.933** | **20.161** |
| Implementation network capacity (0,309) | 4.661 | 2.767 | 1.732 | 10.910 | 1.090 | 2.767 | 2.767 | 1.090 | 4.313 | 1.732 |
| Administrative feasibility (0,581) | 1.732 | 4.661 | 2.934 | 11.605 | 2.934 | 11.605 | 7.446 | 2.934 | 4.661 | 4.661 |
| Financial feasibility (0,110) | 0.761 | 0.761 | 0.761 | 4.755 | 0.761 | 1.186 | 0.761 | 0.300 | 0.476 | 0.476 |
| **Feasibility of implementation (0,094) - C** | **7.154** | **9.189** | **5.427** | **27.270** | **4.785** | **15.559** | **10.974** | **4.324** | **9.450** | **6.869** |
| **Total (A+B+C)** | **49.242** | **6.149** | **29.028** | **45.283** | **22.252** | **61.823** | **38.271** | **4.457** | **44.846** | **20.485** |

There seems to be a high heterogeneity among these ten countries of the Black Sea region in the effectiveness of EE policy mixtures. Romania has a clear leading position compared to the other ones, despite the poor performance in dynamic effectiveness, competitiveness and flexibility. The second group of countries ie Albania, Bulgaria and Turkey show a similar overall performance. The Russian EE policy mixture is in the middle position of this ranking. Azerbaijan, Moldova and Ukraine show similar overall performance due to political acceptability and feasibility of implementation. Particularly for the third criterion they need to overcome the inadequate implementation network capacity and the need to secure the necessary financial resources that could boost EE investments in the country. The last group includes Armenia and Serbia that have the lowest performance.

The difference between the countries will be hardly overcome since Romania and Bulgaria and Romania that scored higher will intensify their efforts in the future as EU Member States and will probably improve the performance of their policy mixtures. Serbia as a new EU Member State has to handle more obstacles so as to incorporate the relevant EU Directives and establish the necessary institutes that will facilitate the implementation of an EE policy mixture. Moldova and Ukraine as Energy Community members have undertaken specific obligations, but financial resources are their main problem for an effective EE policy mixture.

## References

Allplan, 2013. Energy Efficiency Finance - Task 1 Energy Efficiency Potential - Country Report: AZERBAIJAN. Prepared for OeEB by Allplan GmbH in cooperation with Frankfurt School and Local PartnersVienna, October 2013. At: http://www.oe-eb.at/en/osn/DownloadCenter/projects/Energy-Efficiency-Finance-Azerbaijan.pdf

Arcelik S.A., 2014. Coorporate overview 2014. At: http://www.arcelikas.com/userfiles/file/medya/arcelikas_corporate_overwiev.pdf

BP, 2013. BP Energy Outlook 2030 – January 2013. Available at: http://www.bp.com/content/dam/bp/pdf/statistical-review/BP_World_Energy_Outlook_booklet_2013.pdf

Buildings Performance Institute Europe (BPIE), 2014. Renovating Romania – A strategy for the energy renovation of Romania's Building stock. At: http://bpie.eu/uploads/lib/document/attachment/39/Renovating_Romania_EN_Final.pdf

Center for the study of democracy, 2013. The Bulgarian Economy: Competitiveness 2013. Policy Brief No. 39, June 2013. At: http://www.google.com/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=26&cad=rja&uact=8&ved=0CEIQFjAFOBQ&url=http%3A%2F%2Fwww.csd.bg%2FfileSrc.php%3Fid%3D21435&ei=GkEoVNf6ItO8ggTs14LQDg&usg=AFQjCNH2cn60T2LZUgAqdqRcCp30bx4uAA&bvm=bv.76247554,d.eXY

Diana Farrell and Jaana Remes, 2009. The McKinsey Quartely – Economic studies – February 2009. Promoting energy efficiency in the developing world-Developing economies have a huge opportunity to strengthen their economic prospects by boosting their energy productivity. Available at: http://www.globalurban.org/McKinsey%20Global%20Institute%20Report%20on%20Promoting%20Energy%20Efficiency%20in%20the%20Developing%20World.pdf

East Invest, 2011. Moldova Investment Guidebook – Moldova at a glance – Strategic Sectors & Business Opportunities. Under the responsibility of Chamber of Commerce and Industry of the Republic of Moldova. At: http://www.chamber.md/invest/images/files/MoldovaInvestmentGuidebook.pdf

EBRD, 2013. Commercial Laws of Albania, January 2013 – An assessment by the EBRD. At: http://www.ebrd.com/downloads/sector/legal/albania.pdf

EBRD, 2012. Strategy for Turkey. At: http://www.ebrd.com/downloads/country/strategy/turkey.pdf

EBRD, 2010. Strategy for Moldova 2010-2013. At: http://www.google.com/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=64&cad=rja&uact=8&ved=0CC8QFjADODw&url=http%3A%2F%2Fwww.enpi-info.eu%2Flibrary%2Fsites%2Fdefault%2Ffiles%2Fattachments%2Fmoldova.pdf&ei=fVoxVI7SEsfnaLWYgugI&usg=AFQjCNFll6gjdpzI6AuV3936xB-t6_J3KA&bvm=bv.76802529,d.d2s

Energy Charter Secretariat, 2013. In Depth Review of the Energy Efficiency Policy of Albania. At: http://www.encharter.org/fileadmin/user_upload/Publications/Albania_EE_2013_ENG.pdf

Energy Charter Secretariat, 2013. In Depth Review of the Energy Efficiency Policy of the Republic of Turkey. At: http://www.encharter.org/fileadmin/user_upload/Publications/Turkey_EE_2014_ENG.pdf

Energy Charter Secretariat, 2013. In Depth Review of the Energy Efficiency Policy of Ukraine. At: http://www.encharter.org/fileadmin/user_upload/Publications/Ukraine_EE_2013_ENG.pdf

Energy Charter Secretariat, 2008. In-Depth Review of Energy Efficiency Policies and Programmes – Bulgaria 2008. At: http://www.encharter.org/fileadmin/user_upload/Publications/Bulgaria_EE_2008_ENG.pdf

Energy Charter Secretariat, 2014. http://www.encharter.org/fileadmin/user_upload/Publications/Turkey_EE_2014_ENG.pdf

Energy Efficiency Watch, 2013. Energy Efficiency in Europe – Assessment of Energy Efficiency Action Plans and Policies in EU Member States 2013 – Country Report Bulgaria. Supported by Intelligent Energy Europe. At: http://www.energy-efficiency-watch.org/fileadmin/eew_documents/Documents/EEW2/Bulgaria.pdf

Energy Efficiency Watch, 2013. Energy Efficiency in Europe – Assessment of Energy Efficiency Action Plans and Policies in EU Member States 2013 – Country Report Romania. Supported by Intelligent Energy Europe. At: http://www.energy-efficiency-watch.org/fileadmin/eew_documents/Documents/EEW2/Romania.pdf

Energy Efficiency Watch, 2012. At: http://www.energy-efficiency-watch.org/fileadmin/eew_documents/EEW2/EEW_Survey_Report.pdf

European Commission, 2013. Commission Staff Working Document – Albania 2013 Progress report – Accompanying the document Communication from the Commission to the European Parliament and the Council – Enlargement Strategy and main Challenges 2013 -2014, COM(2013) 700 final – Brussels 16.10.2013, SWD(2013) 414 final. At: http://ec.europa.eu/enlargement/pdf/key_documents/2013/package/al_rapport_2013.pdf

European Commission – Directorate General for Energy and Transport, 2007. 2020 Vision – Saving our energy. At: http://ec.europa.eu/energy/action_plan_energy_efficiency/doc/2007_eeap_en.pdf

European Parliament- Directorate – General for external policies – Policy Department, 2013. Workshop Eastern Partnership prospects on Energy Efficiency and Renewable Energy. Available at: http://www.iris-france.org/docs/kfm_docs/docs/observatoire-pol-etrangere-europe/expo-afetat-2013-433708en.pdf

Government of Romania, Ministry of Education and Research – National Authority for Scientific Research, 2006. National Research, Development and Innovation Strategey, 2007-2013. At: http://www.euraxess.gov.ro/strategy_EN.pdf

Hido M. Edmond, 2012. Resource Efficiency Gains and Green Growth Perspectives in Albania. Study by Friedrich Ebert Stiftung. At: http://library.fes.de/pdf-files/id-moe/09455.pdf

InvestBulgaria Agency, 2011. Bulgaria – Investment climate and business opportunities. At: http://bulgarico.com/wp-content/uploads/2011/02/Bulgaria-The-Right-EU-Location.pdf

Konidari P. and Mavrakis D., 2007. A multi-criteria evaluation method for climate change mitigation policy instruments. Energy Policy 35, pp. 6235-6257.

KPMG, 2013. Developing a Market Entry Strategy for Romania. At: http://www.kpmg.com/RO/en/IssuesAndInsights/ArticlesPublications/news/Documents/developing-market-entry-2014-EN.pdf

Ministry of Energy and Natural Resources, General Directorate of Renewable Energy, Directorate of Energy Efficiency, 2012. Market transformation of energy efficient appliances in Turkey. At: http://www.tr.undp.org/content/dam/turkey/docs/projectdocuments/EnvSust/UNDP-TR-%20EVUDP%20ENG%20(1)_baskiyagiden.pdf

PROMITHEAS-4, Knowledge transfer and research needs for preparing mitigation/adaptation policy portfolios (2011-2013), available at: http://www.promitheasnet.kepa.uoa.gr/Promitheas4/

Romanian Association for the promotion of energy efficiency, 2013. Energy efficiency in Romania- White book. At: http://arpee.org.ro/wp-content/uploads/2014/04/Cartea-Alba-english.pdf

Schmieder Uta, 2012. Resource efficiency gains and Green Growth perspectives in Moldova. Study by Friedrich Ebert Stiftung. At: http://library.fes.de/pdf-files/id-moe/09410.pdf

UNECE, 2013. Azerbaijan national case study for promoting EE investment - An analysis of the Policy Reform Impact on Sustainable Energy Use in Buildings. At: http://www.unece.org/fileadmin/DAM/energy/se/pdfs/gee21/projects/cs/CS_Azerbaijan.pdf

United Nations Economic Commission for Europe, 2013. Innovation Performance Review – Ukraine. At: http://www.st-gateukr.eu/_media/Innovation_Persormance_Review_UKR_2013.pdf

World Bank, 2014. World Bank Group – Moldova Partnership- Country Program Snapshot, April 2014 http://www.worldbank.org/content/dam/Worldbank/document/Moldova-Snapshot.pdf.

World Energy Council, 2013. World Energy Resources – 2013 Survey. ISBN: 978 0 946121298. Available at: http://www.worldenergy.org/wp-content/uploads/2013/09/Complete_WER_2013_Survey.pdf

Zajmi Rajmonda, 2013. Energy Efficiency in Albania, Status of transposition, Implementation, The way forward. At: http://www.env-net.org/wp-content/uploads/2013/06/CoPlan_Energy-Efficiency_Report-RZajmi_July-2013.pdf

# Climate Change

# The use of alkaline industrial waste in the capture of carbon dioxide

**Dr. Jolanta JASCHIK[1]**

**Dr. Manfred JASCHIK**

**Prof. Krzysztof WARMUZINSKI**

[1] *Contact details of the corresponding author*

Tel: +48 32 231 0811
Fax: +48 32 231 0318
e-mail: jjaschik@iich.gliwice.pl

Address: Polish Academy of Sciences, Institute of Chemical Engineering. ul. Baltycka 5, 44-100 Gliwice, Poland

**Abstract:** The fixation of $CO_2$ in the form of inorganic carbonates, also known as mineral carbonation, is an interesting option for the removal of carbon dioxide from various gas streams. The captured $CO_2$ is reacted with metal-oxide bearing materials, usually naturally occurring minerals. The alkaline industrial waste, such as fly ash from coal-fired power stations and waste from flue gas desulphurisation plants, can also be considered as a source of calcium or magnesium. In the present study the solubility of fly ash generated by a Polish power station equipped with lignite fluidized-bed boilers was analysed. The principal objective of the study was to assess the potential of the fly ash from lignite fluidized bed combustion as a reactant in the process of mineral carbonation. The relevant experiments were done in a laboratory 1 $dm^3$ reactor equipped with a heating jacket and a stirrer. The rate of dissolution was measured at various temperatures (20–80ºC), waste-to-solvent ratios (1:100–1:10) and stirrer speeds (300–1100 $min^{-1}$). The results obtained clearly show that the fly ash studied can be employed in the mineral carbonation of $CO_2$.

Keywords: mineral carbonation, $CO_2$ capture and storage, industrial waste, fly ash, dissolution

## 1. Introduction

The process of mineral carbonation is regarded as one of a number of options for the capture of $CO_2$ (Metz et al., 2005, Huijgen et al., 2005, Huijgen et al., 2003). The carbonation employs a reaction of $CO_2$ with metal oxides (usually those of Ca and Mg). Following the reaction, geologically stable and environmentally neutral carbonates are formed which may then be stored. Natural sources of alkaline oxides include minerals containing the silicates of calcium, magnesium, potassium and sodium, such as wollastonite, serpentine and talc. Advantages of the carbonation process include safe and permanent immobilization of $CO_2$ and the possibility to further utilize the product thus obtained (e.g. as a construction material). Major drawbacks result from slow kinetics, considerable amounts of minerals required and high cost. The high cost of the process is still prohibitive in terms of large-scale applications, due to the costly sorbent preparation (grinding, thermal processing) and the necessity to compress $CO_2$.

The simplest approach to mineral carbonation would be to react gaseous $CO_2$ with metal-oxide bearing phase. Unfortunately, such direct gas-solid reactions are too slow to be practical, and thus require the extraction of the metal from the solid. This can be done by suspending the solid material in an aqueous solution and letting it dissolve and release metal ions. The dissolution may be the rate-limiting step for the overall carbonation process and thus requires careful analysis.

One of the ways to lower the cost of the carbonation process is the use of alkaline industrial waste, such as fly and bottom ashes, concrete waste and slag. The waste commonly occurs in the pulverized form and thus does not require additional mechanical processing. The calcium and/or magnesium oxides are usually unbounded and their release to the solution is much faster than in the case of natural minerals. The industrial waste does not have to be mined and, moreover, a relevant installation can be placed close to a waste source, thus lowering the overall cost. This cost is reduced even further by the fact that the fly ash does not necessitate any thermal processing.

The process of neutralizing $CO_2$ with industrial waste like cement waste and blast-furnace slag has been presented in the literature (Stolaroff et al., 2005), with costs estimated at around 8 US dollars per tonne of $CO_2$. This value is considerably lower than the costs for the sequestration based on natural minerals, estimated by the Intergovernmental Panel on Climate Change (IPCC) at 50-100 US dollars per tonne (Metz et al., 2005). The comparison of costs for different methods for $CO_2$ storage is presented in Table 1.

**Table 1: Costs of storage per tonne of $CO_2$ avoided.**

| | |
|---|---|
| Geological storage | 0.5 – 8 $ / t $CO_2$ |
| Ocean storage | 5 – 30 $ / t $CO_2$ |
| Mineral carbonation: | |
| natural minerals | 50 – 100 $ / t $CO_2$ |
| cement, concrete | 22 -35 $ / t $CO_2$ |
| residue* steel slag, concrete waste | 8 $ / t $CO_2$ |

* Huijgen et al., 2005a

The possibilities for using industrial waste to capture $CO_2$ in Poland have been described in (Uliasz et al., 2008, Uliasz et al., 2006). However, the analysis of the carbonation process requires not only the knowledge of the chemical composition of the waste, but also its properties, the rate of dissolution included. The determination of the optimum operating conditions for the process for a given type of waste, and especially, of the optimum dissolution parameters, may lead to a practically viable technology for the permanent binding of $CO_2$.

In an earlier paper (Jaschik et al., 2013) the possibilities for utilizing ashe from pulverized hard coal fired boilers (both with and without desulphurisation products), in the capture of carbon dioxide were analyzed. The dissolution of this ashe in water and organic solvents was studied.

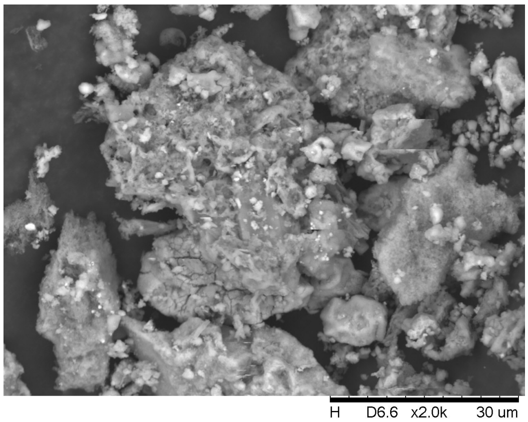
The present paper deals with the kinetics of dissolution of the fly ashe from lignite fluidized bed combustion. The principal objective of the study was to assess the potential of the fly ash as a reactant in the process of mineral carbonation.

## 2. Materials and experimental methods

The fly ashes studied in the present work were collected from the lignite fluidized bed combustion at a Polish power plant. The main characteristics of the ashes are presented in Table 2. The chemical composition and phase composition of the solid ash were determined using Thermo iCAP 6500 Duo ICP Spectrometer (Thermo Fisher Scientific) and Empyrean X-ray Diffractometer (PANalytical), respectively. The particle size distribution was measured by Mastersizer 2000 laser particle size analyser (Malvern Instruments), using 2-propanol as a dispersant. BET surface area as well as total and micropore volumes were determined using ASAP 2020 physisorption analyzer (Micromeritics).

The characteristic structure of ash particles is shown in Figure 1. The particles of ash from fluidized bed boilers (Figure 1a) have irregular shape, porous and uneven surface, while particles originating from conventional pulverized coal fired boilers (Figure 1b) have regular spherical shape and smooth surface, caused by the formation of glassy phase.

a




b

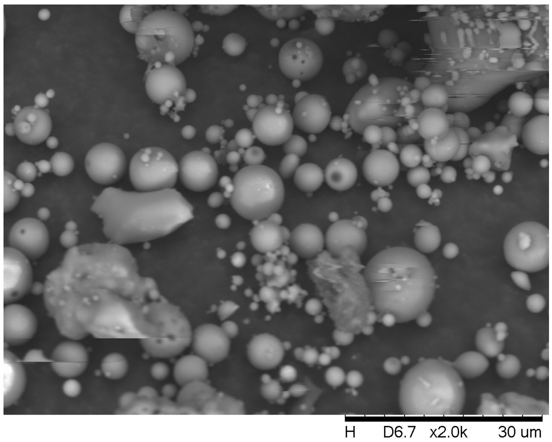



**Figure 1. SEM images of ashes: a - fluidized bed combustion, b – pulverized hard coal fired boilers; magnification – 2000x.**

Experimental studies concerning kinetics of the dissolution of fly ash were done in a laboratory installation that included a periodic reactor with a heating jacket of a capacity of 1 $dm^3$. The reactor is made of borosilicate glass (QVF/Normag), and has a draft tube with 4 baffles and a propeller mixer. A schematic diagram of the experimental setup is shown in Figure 2.

Suspensions of ash with water of a given solid-to- liquid mass ratio were mixed in the reactor at fixed temperature and stirrer speed. During the single experimental run samples of the suspension (around 20 ml each) were withdrawn using a pump.

**Table 2: Main characteristics of fluidized ash studied.**

| **Chemical composition, wt. %** | | | | |
|---|---|---|---|---|
| $SiO_2$ | CaO | MgO | $Al_2O_3$ | $Fe_2O_3$ |
| 27.0 | 29.1 | 2.02 | 20.2 | 4.54 |
| $Na_2O$ | $K_2O$ | $SO_3$ | $P_2O_5$ | $TiO_2$ |
| 1.27 | 1.01 | 8.75 | 0.2 | 1.68 |
| **Phase composition, wt. %** | | | | |
| $SiO_2$ | $CaSO_4$ | CaO | $Ca(OH)_2$ | $CaCO_3$ |
| 1.9 | 12.4 | 12.0 | 0.2 | 6.4 |
| $\alpha$-$Fe_2O_3$ | $NaAlSi_3O_8$ | rozenite | jarosite | amorph. |
| 1.6 | 1.5 | 0.6 | 0.4 | 63.0 |
| **Particle size distribution, µm** | | | | |
| $D_{0.1}$ | $D_{0.5}$ | $D_{0.9}$ | D[3,2] | D[4,3] |
| 5.61 | 32.86 | 130.71 | 11.81 | 62.31 |
| **Surface and porosity** | | | | |
| BET, $m^2/g$ | micropore area, $m^2/g$ | total pore volume, $mm^3/g$ | micropore volume, $mm^3/g$ | average pore size, nm |
| 6.664 | 0.588 | 3.71 | 0.026 | 14.24 |

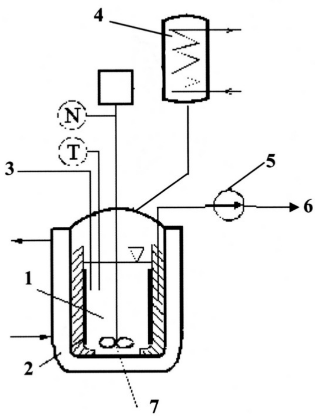



**Figure 2: Schematic diagram of the experimental setup: 1 – reactor, 2 – heating jacket, 3 – inlet of solution and solid phase, 4 – cooler, 5 – peristaltic pump, 6 – sample withdrawal, 7 – mixer, T – temperature control, N – mixer speed control.**

The suspension was immediately filtered, then the concentrations of $Ca^{+2}$, $Mg^{+2}$ and $SO_4^{-2}$ ions were determined in the filtrate by complexometric titration using EDTA ($Ca^{+2}$, $Mg^{+2}$) and by spectrophotometer DR2800 using Hach Lange cuvette tests ($Mg^{+2}$, $SO_4^{-2}$). These concentrations made it possible to determine the extraction degree of calcium and magnesium (defined as the ratio of an ion concentration in the solution to a hypothetical maximum concentration after complete dissolution of the fly ash).

Both the temperature of the suspension and mixer speed were controlled during the experiments. The reactor was equipped with a cooler to prevent solvent losses due to evaporation. The dissolution was carried out for about 4.5 hours. At the end of an individual measurement the reactor was emptied and its contents filtered and weighed to determine the weight of the remaining solid phase and the filtrate.

The dissolution rate in water was measured over a range of temperatures (10-80°C), for the weight ratio of the fly ash to the solvent varied between 1:100 and 1:10 and for a stirrer speed of 300 to 1,100 $min^{-1}$.

### 3. Results and discussion

The studies reveal that the content of $Ca^{+2}$ and $SO_4^{-2}$ ions in the filtrate obtained after the dissolution of ash is almost independent of the stirrer velocity (Figure 3a, 3b), decreases with temperature (Figure 4a, 4b) and increases with the rise in the ash-to-solvent ratio (Figure 5a, 5b), until it reaches the saturation level at a ratio of 1:20. A further increase of this ratio does not produce any increase in the $Ca^{+2}$ and $SO_4^{-2}$ content, as the state of saturation has already been attained. Simultaneously, the extraction degree of calcium drops with an increase in the ash-to-solvent ratio from around 64 % (at a ratio of 1:100) to 10.5 % for a ratio of 1:10 (both for 20°C). The extraction degree of sulphate drops in the same cases from around 69.5 % (1:100) to 16.7 % (at a ratio of 1:10). It is also found that in all the cases analysed the equilibrium concerning the ions of $Ca^{+2}$ was established after some 30 minutes, whereas for the dissolution of calcium sulphate the time necessary to reach the equilibrium was as long as 2 hours. As can be seen, the dissolution of calcium sulphate is slower than that of calcium oxide, but after 4.5 hours of dissolution the final degree of extraction of sulphate ions is larger than that for calcium ions.

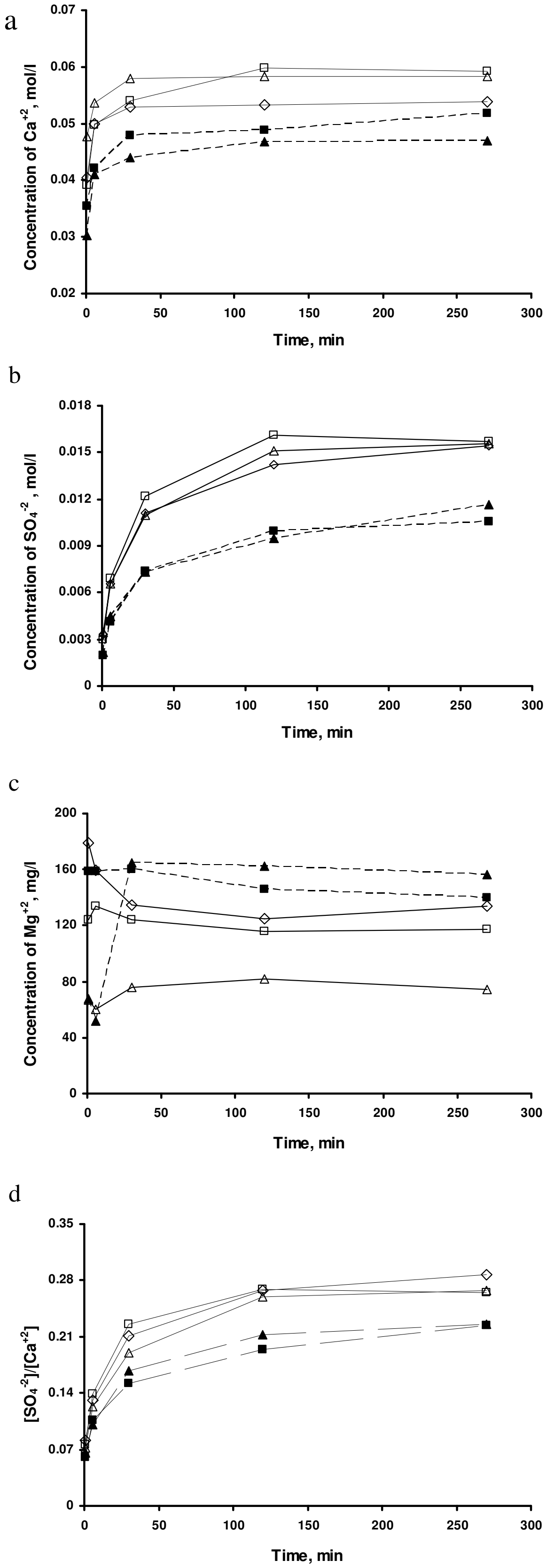



**Figure 3. The effect of stirrer speed on the concentration of $Ca^{+2}$ (a), $SO_4^{-2}$ (b) and $Mg^{+2}$ (c) and on the ratio of $SO_4^{-2}$ to $Ca^{+2}$ (d); temperature = 20°, ash-to-water ratio = 1:50 (▲■), 1:20 (□◊Δ), stirrer speed: ■□ – 300, ▲Δ - 600, ◊ - 1100 $min^{-1}$.**

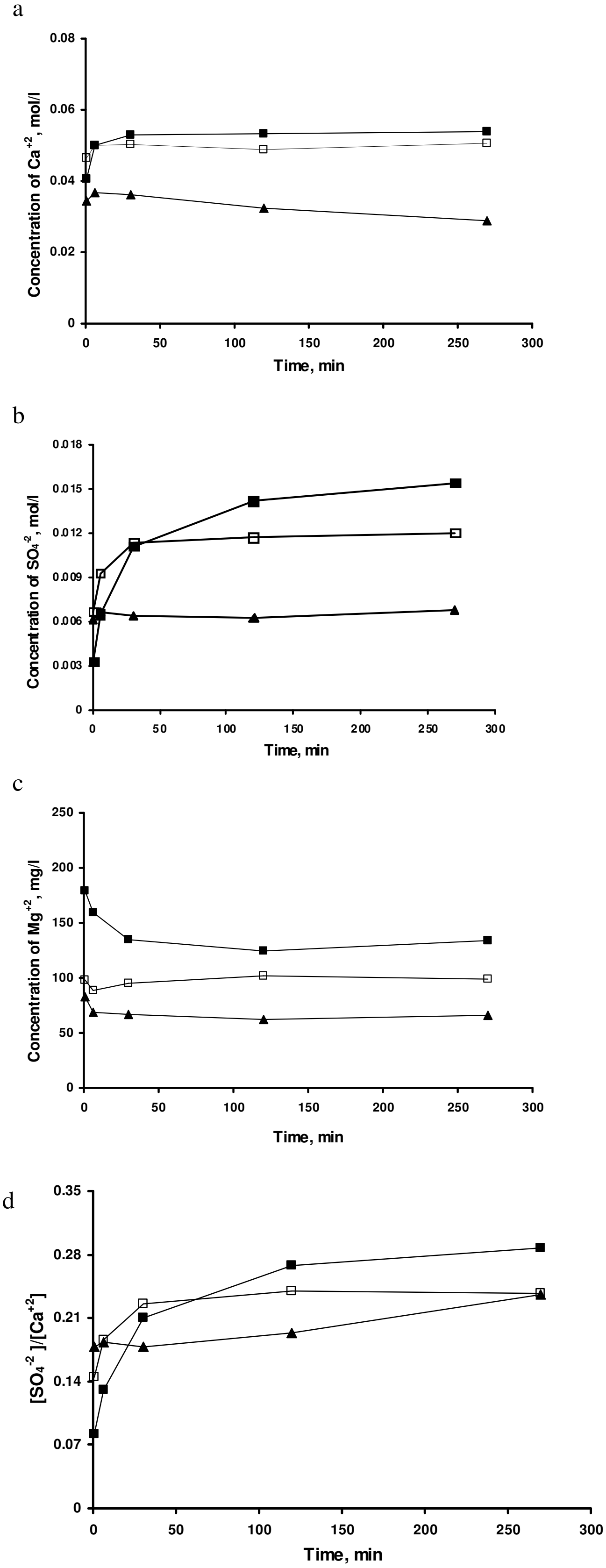



**Figure 4. The effect of temperature on the concentration of $Ca^{+2}$ (a), $SO_4^{-2}$ (b) and $Mg^{+2}$ (c) and on the ratio of $SO_4^{-2}$ to $Ca^{+2}$ concentrations (d); stirrer speed = 600 $min^{-1}$, ash-to-water ratio = 1:20; ■ - 20°C, □ - 40°C, ▲ - 80°C.**

Consequently, the proportion of active calcium ions (i.e. those originating from free CaO and $Ca(OH)_2$) in the total amount of the ions of calcium released into the solution decreases during the process. This proportion also decreases with an increase in the ash-to-solvent ratio.

The concentration of magnesium ions drops with a rise in temperature (Figure 4c) and/or stirrer velocity (Figure 3c). However, the content of magnesium oxide in the fly ash from fluidized bed boilers is relatively low and, as can be seen from the analysis of phase composition (Table 2), magnesium is present solely as a component of the vitreous phase. Furthermore, the amount of magnesium released into the solution is probably too low to have any measurable impact on the process of carbonation.

In all the cases studied the pH of the solutions obtained after 4.5 hours of dissolution was about 12.5. However, after one minute the pH of filtrate was at least 12. It is thus obvious that from the first minutes of the dissolution the leachates obtained were highly alkaline.

If the mineral carbonation is realized by an aqueous direct scheme, the extraction of reactive components from the ash and the precipitation of carbonates take place simultaneously in the same reactor (Huijgen et al., 2005). When the ash studied is used in the carbonation process, the sulphate ions will be present in the suspension. These ions, alongside the carbonate ions (created in the reaction of $H_2O$ with $CO_2$) will produce insoluble layers of $CaSO_4$ and $CaCO_3$, which will probably coat the surface of ash particles thus preventing further dissolution of calcium oxide, as it was observed in the experiments reported elsewhere (Uibu et al., 2009, Huijgen et al., 2005). Therefore the content of sulphate and carbonate ions in the liquid phase has to be closely monitored, as they lead to the formation of insoluble layers on the surface of particles and thereby strongly inhibit the dissolution. Moreover, the coating of the precipitated solids building on the ash particles makes recycling of unconverted feedstock impossible.

If the mineral carbonation is realized by the aqueous indirect scheme, the extraction of reactive components from ash and the precipitation of carbonates take place in two separate steps. When the ash studied is used in an indirect process, the alkaline solution containing mainly calcium and sulphate ions will be obtained after the first step and directed to the next reactor.

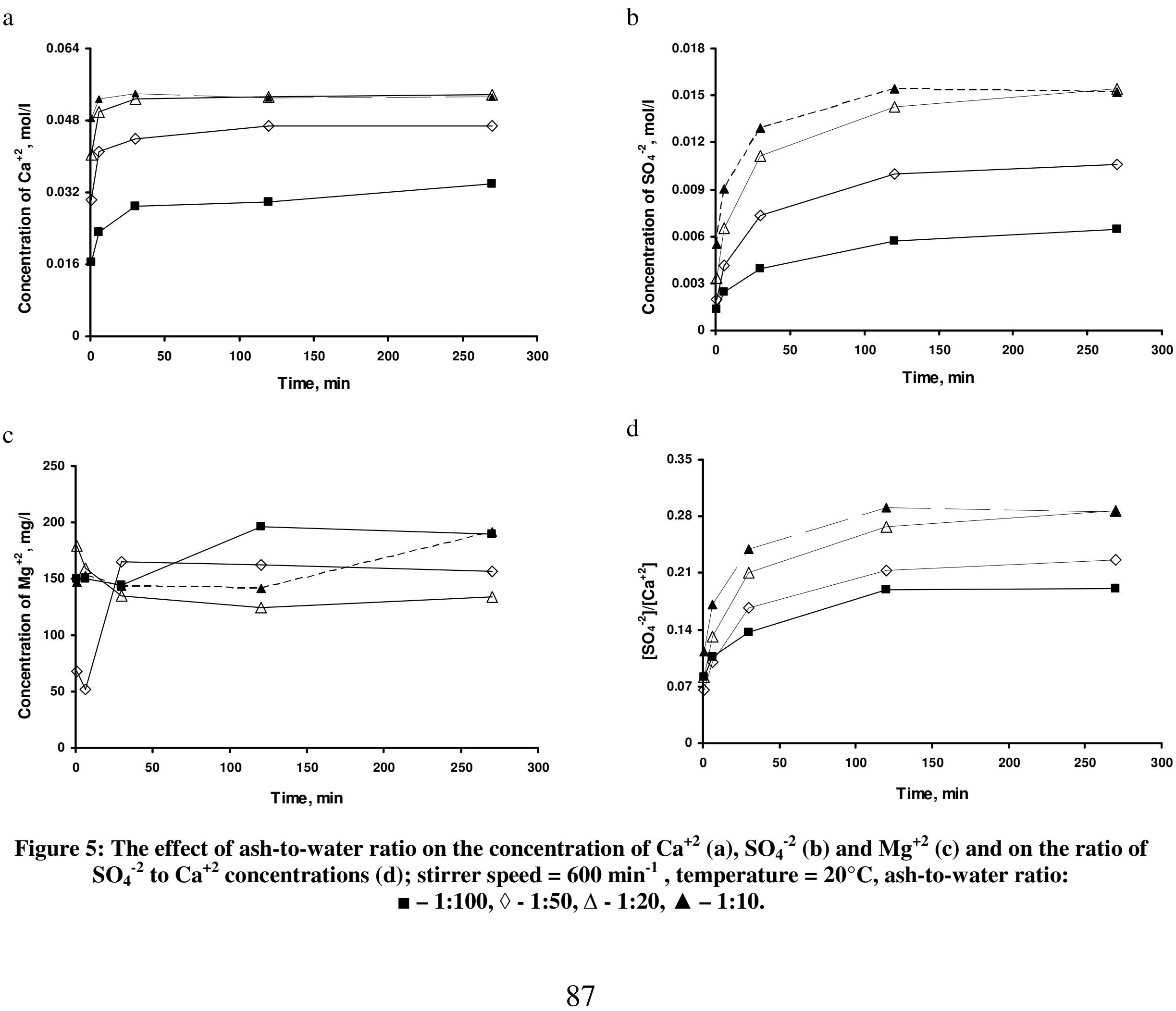



**Figure 5: The effect of ash-to-water ratio on the concentration of $Ca^{+2}$ (a), $SO_4^{-2}$ (b) and $Mg^{+2}$ (c) and on the ratio of $SO_4^{-2}$ to $Ca^{+2}$ concentrations (d); stirrer speed = 600 $min^{-1}$ , temperature = 20°C, ash-to-water ratio: ■ – 1:100, ◊ - 1:50, ∆ - 1:20, ▲ – 1:10.**

However, in this case the sulphate ions, while not hindering the dissolution of ash, will affect the precipitation of calcite (Huijgen et al., 2005a). This approach is thus advantageous and is proposed for the future study of carbonation process using ash from lignite fluidized bed combustion.

## 4. Conclusions

The results obtained clearly show that the fly ash studied can be employed in the mineral carbonation of $CO_2$. The high content of calcium oxide and the considerable proportion of the reactive form of CaO compared with the total calcium content lead, over a short period of time, to a solution saturated with calcium ions. The solution, despite the presence of considerable amounts of calcium sulphate in the fly ash, still remains alkaline (pH of about 12.5). Therefore, the next step of carbonation with the presence of carbon dioxide should occur with relatively high yield.

## References

Huijgen, W.J.J., Comans, R.N.J., 2003. “Carbon dioxide sequestration by mineral carbonation. Literature Review”. Report ECN-C-03-016, Energy research Centre of the Netherlands, Petten, The Netherlands.

Huijgen, W.J.J., Comans, R.N.J., 2005. “Carbon dioxide sequestration by mineral carbonation. Literature Review Update 2003-2004”. Report ECN-C-05-022, Energy research Centre of the Netherlands, Petten, The Netherlands.

Huijgen, W.J.J., Comans, R.N.J., 2005a. “Mineral $CO_2$ sequestration by carbonation of industrial residues. Literature overview and selection of residue”. Report ECN-C-05-074, Energy research Centre of the Netherlands, Petten, The Netherlands.

Jaschik, J., Warmuzinski, K., Jaschik, M., 2013.“The use of alkaline industrial waste in the sequestration of carbon dioxide“. Proceedings of the XXI National Conference on Chemical and Process Engineering, Kolobrzeg. Available only in Polish.

Metz, B., Davidson, O., de Coninck, H., Loos, M., Meyer, L. (Eds.), 2005. “IPCC Special Report on Carbon Dioxide Capture and Storage”. First Ed., Cambridge University Press, Cambridge.

Stolaroff J.K., Lowry G.V., Keith D.W., 2005. “Using CaO- and MgO-rich industrial waste streams for carbon sequestration”. Energy Conversion and Management, Issue 46, p. 687-699.

Uibu M., Kuusik R., 2009. “Mineral trapping of $CO_2$ via oil shale ash aqueous carbonation: controlling mechanism of process rate and development of continuous-flow reactor system”. Oil Shale, Issue 28, No 1, p. 40-58

Uliasz-Bochenczyk A., Mokrzycki E., Mazurkiewicz M., Piotrowski Z., 2006. “Utilization of carbon dioxide in fly ash and water mixture”. Trans IChemeE, Part A, Chem. Eng. Res. Design, Issue 84(A9), p. 843-846

Uliasz-Bochenczyk A., Mokrzycki E., Piotrowski Z., Pomykala R., 2008. “Estimation of $CO_2$ sequestration potential via mineral carbonation in fly ash from lignite combustion in Poland”. Physics Procedia, GHGT-9.

# Energy Demand Analysis and Energy Saving Potentials in the Greek Road Transport Sector

**Christos BITOS**
International Hellenic University, MSc student

**Dr. Spyros KIARTZIS**[1]
Hellenic Petroleum SA

[1] *Contact details of corresponding author*
Tel: +30 2310 750599
Fax: +30 2310 750250
E-mail: skiartzis@helpe.gr
Address: Hellenic Petroleum SA, Thessaloniki Industrial Complex, 54110, Thessaloniki, Greece

**Abstract:** The Greek road transport sector is simulated in this paper in order to analyze the current status of energy demands and pollutant emissions for a variety of future scenarios and policies. A forecasting transport model has been developed using the Long-Range Energy Alternatives Planning System (LEAP) software. The LEAP model is used to estimate total energy demands and the associated emissions for the base year 2010 and extrapolated till 2035 for future scenarios and predictions. Base lines of the energy consumption and $CO_2$ equivalent emissions of the road transport sector in a business-as-usual (BAU) scenario are estimated employing a vehicle stock-turnover modeling approach. Apart from the business-as-usual scenario, the model is run under 5 alternative scenarios that include: a) substitution of conventional fuels by alternative fuels along with improved fuel economy of vehicle engines, b) increased efficiency, and c) introduction of alternative technologies. All scenarios are evaluated to study the impact of different transport policies to energy demand and emissions in the Greek transport sector. The resulting energy demands and the $CO_2$ emissions under each scenario were compared with the base line case of the BAU scenario. The implementation of improved fuel economy vehicles combined with alternative fuels and technologies have a significant potential to reduce energy demand and mitigate pollutant emissions in this sector.

## 1. Introduction

Decarbonizing transport is proving to be one of today's major challenges for the global automotive industry due to many factors such as the increase in greenhouse gas and particulate emissions affecting not only the climate but also humans, the increase in pollution, rapid oil depletion, and issues with energy security and dependency from foreign sources and population growth. For more than a century, our society has been dependent upon oil, and major breakthroughs in low- and ultra-low carbon technologies and vehicles are urgently required [1]. Transport is closely linked with economic activity. For 2020-2040, it is not yet clear what type of cars will be used but it is likely that improved conventional cars will still dominate the market. Public policy has largely accommodated – and sometimes inadvertently stimulated – these developments via its spatial planning and infrastructure capacity decisions, so that economic development in advanced economies has gone hand in hand with strongly growing transport volumes [2].

Several alternative fuel/technology options are currently explored, mainly for automobiles, trucks and aircraft such as compressed natural gas and hybrid vehicles, fuel cells and hydrogen. Since, however, all these promising options are still at an early stage of development, additional assumptions would be required in order to obtain a more favorable picture for one or the other technology (e.g. assuming rapid technological progress, ample research funds or fiscal measures) and enable significant cost reductions in these technologies in the future [3].

Transport activity will continue to increase in the future as economic growth fuels transport demand and the availability of transport drives development, by facilitating specialization and trade. Freight transport has been growing even more rapidly than passenger transport and is expected to continue to do so in the future. Urban freight movements are predominantly by truck, while international freight is dominated by ocean shipping. The modal distribution of intercity freight varies greatly across regions. For example, in the United States, all modes participate substantially, while in Europe, trucking has a higher market share, compared to rail [4].

Over a time horizon of 20–30 years, the gasoline hybrid-electric vehicle offers a promising path to cost-effective reduction in fuel use. Relative to conventional spark-ignition and diesel engines, gasoline hybrids are projected to offer increasing efficiency gains and a narrowing price premium. At the same time, other advanced technology vehicles, including hydrogen fuel cell or battery electric vehicles, will continue to suffer from high cost and other limitations. Their limited market penetration means that their impact on fuel use and emissions is unlikely to be significant over the next few decades [5]. The investment in fuel supply infrastructure, i.e. re-fuelling stations, fuel pipelines, and fuel conversion kits for modified engine vehicles would be a serious concern because the equipment has to be imported at a very high cost [6].

Transport demand will remain dominated by oil (still 87% in 2035, mostly for road use), since alternatives are likely to remain uneconomic in many market segments without policy support. Natural gas (including gas-to-liquids) is the fastest growing alternative (6.8% p.a.) – particularly LNG for heavy duty vehicles and shipping – and is expected to overtake biofuels in 2022 before reaching almost 7% of transport by 2035. On an energy basis, the biofuels share grows from 2.5% currently to 4% by 2035 while the electricity share grows to just 1.5%. By 2035, sales of conventional vehicles fall to a quarter of total sales, while hybrids dominate. Plug-in vehicles, including full battery electric vehicles, are forecast to make up 7% of sales in 2035 [7].

No single technology development or alternative fuel can solve the problems of growing transportation fuel use and GHG emissions [5]. Biofuels have the potential to replace a substantial part but not all petroleum use by transport. A recent IEA analysis estimates that biofuels share of transport fuel could increase to about 10% in 2030. The global potential for biofuels will depend on the success of technologies to utilize cellulose biomass [4]. Ethanol and biodiesel can offer immediate benefits in reducing urban air pollution, and more importantly, in curbing petroleum demand because low-level blends such as E10 and B20 is compatible with existing vehicles and fuel infrastructure. Methanol (in the form of low-level blends with gasoline) and FT liquids are compatible with existing vehicles and fuel infrastructure while DME is able to use existing LPG infrastructure though modification to the vehicle engine and fuel system is necessary [8]. Hydrogen fueled Fuel Cell Vehicles will play a major role as a part of the change towards the hydrogen based energy system. When combined with the right source of energy fuel cells have the highest potential efficiencies and lowest potential emissions of any vehicular power source [9].

A forecasting transport model has been developed using the Long-Range Energy Alternatives Planning System software [10]. A variety of LEAP models have been used in the literature. Ahmad et al, 2010 [11], estimated the total energy demand of agriculture sector for the base year 2000 and extrapolated till 2030 for the future predictions. Fuel switching and alternative fuels could help to meet increased agricultural energy requirements. Khan S. et al, 2011 [4], used LEAP for energy forecasting of the gas sector in Bangladesh and Gilberto Mahumane et al, 2012 [12], for simulating Mozambique's energy sector. X.Y. Yan & R.J. Crookes, 2010 [8], presented the current status of China's road transport sector in terms of vehicles, infrastructure, energy use and emissions. Mitigation measures implemented and those that can reasonably be expected to be adopted in the near future are analyzed.

Base lines of the energy consumption and $CO_2$ emissions of the road transport sector in a business-as-usual scenario were estimated by using a bottom-up or an end-use analysis method. Alternative scenarios; substitution of conventional fuel by compressed natural gas, improved fuel economy of vehicle engines by using high efficiency internal combustion engines, and the introduction of high energy efficiency hybrid vehicles, were then examined [6].

The Greek road transport sector is simulated in this paper in order to analyze the current status of energy demands and pollutant emissions for a variety of future scenarios and policies. In section 2 the Greek road transport sector is presented while in Section 3, the total energy demands and the associated emissions are estimated for the base year 2010 and extrapolated till 2035 for future scenarios and predictions. Base lines of the energy consumption and $CO_2$ equivalent emissions of the road transport sector in a business-as-usual scenario are estimated employing a vehicle stock-turnover modeling approach. Finally, concluding remarks are presented in the last Section.

## 2. The Greek road transport sector

In the European Union, transport emits 21% of the EU's greenhouse gas emissions. Therefore, reducing $CO_2$ emissions and fuel consumption from road transportation is an important strategy for the European Union to fight against climate change [13]. Because of the dramatic increase in oil prices and concerns for environmental impact, various policy measures are sought after and introduced in order to reduce energy demand and also to mitigate related emissions in this sector. The measures include efforts to increase energy efficiency through vehicle technology options and to substitute conventional fuel by alternative fuel [6]. Higher fuel prices have been shown to incentivize consumer purchases of more efficient vehicles, although consumer responses have been shown to vary across regions [14].

During 2010 the vehicle fleet in Greece consisted of 5,216,873 cars and 1,026,362 light and heavy duty trucks. New vehicle sales were 141,501 for cars and 11,938 for trucks respectively [15]. The average car ownership in Greece was approximately 461 cars per 1000 inhabitants in 2010, which was lower than Europe's average (477 cars per 1000 inhabitants). The last 3-4 years this sector stayed stagnated, mostly because of the economic recession.

The types of fuel used or are considered as potential alternative in the near future, in the Greek road transport sector are classified into eight main groups: Gasoline, Diesel, Electricity, Hydrogen, Methanol, Ethanol, Biodiesel, Compressed Natural Gas (CNG) and Liquefied Petroleum Gas (LPG). To estimate the emissions from the energy consumption, for this study, the emission factors were obtained from the Intergovernmental Panel on Climate Change [16], which is included in LEAP's Technology Environmental Database. Finally in order to simulate the biofuels use for the base year 2010, biodiesel (B100) vehicle fleet was assumed to be the 7% of the total diesel fleet that is approximately 10,500 cars and 32,700 trucks respectively.

## 3. Scenario Analysis

Cost is a key factor in assessing the likelihood of technologies becoming widely adopted. Fleet fuel use responds with a lag of some 10 years to changes in the new vehicle market. The delay between the introduction of advanced vehicle technologies and their effects on total fuel use in the fleet is a necessary phase on the path to achieving long-term reductions. How rapidly that reduction occurs depends on the determination of the major stakeholder groups—vehicle and fuel suppliers, vehicle and fuel purchasers and users, and governments—to vigorously undertake the actions required [5].

Energy consumption growth in transport slows to 1.1% p.a. between 2012 and 2035 (from 1.9% p.a. 1990-2012) primarily due to accelerating gains in fuel economy [7]. When assessing mitigation options it is important to consider their lifecycle GHG impacts. This is especially true for choices among alternative fuels but also applies to a lesser degree to the manufacturing processes and materials composition of advanced technologies. Electricity and hydrogen can offer the opportunity to 'de-carbonize' the transport energy system although the actual full cycle carbon reduction depends upon the way electricity and hydrogen are produced [4].

In Greece, transport activity is expected to grow over the next decades. For the period 2010-2035, end year sales are assumed to grow by 0.8% and 1.3% for cars and trucks respectively [17], fuel economy is assumed to improve about 10% following efficiency trends [18] and mileage is assumed to stay constant for technologies already existing and increase for technologies that will be introduced in the near future.

The Business As Usual (BAU) forecast illustrates what state energy use will look like in the absence of additional policies beyond what is already planned. BAU energy demand model is established following the assumptions that at the end year 2035 the sales share of vehicles will be as in Tables 1&2, because of governmental transportation policies such as: the introduction of alternative fuels (biofuels, hydrogen, CNG etc.), the promotion of economical driving, the taxation of new cars according to $CO_2$ emissions, the replacement of old polluted private vehicles, technical inspections on vehicles and more.

Apart from the BAU scenario, the model is run under 5 alternative scenarios for cars (Table 3). In scenarios 1-5, the basic assumptions (such as 10% improvement on fuel economy) are inherited from BAU, while the changes considered in each scenario are the following:

- Scenario 1 present an increased introduction of biofuels against ICE;
- Scenario 2 present an increased gas introduction against ICE;
- Scenario 3 present an increased fuel cells introduction against ICE;
- Scenario 4 present an increased EVs introduction against ICE;
- Scenario 5 present increased hybrid introduction against ICE.

The resulting energy demands and the $CO_2$ emissions under each scenario were compared with the base line case of the BAU scenario. The reduction in energy demands and greenhouse gases emissions mitigation of each case show that the alternative scenarios of high energy efficiency vehicle promotion have a significant potential to reduce energy demand and mitigate emissions.

From the forecasting model, it is predicted that the number of vehicles will increase from 6.2 million vehicles in 2010 to almost 6.9 million vehicles in 2035. The total energy demand in the Greek road transport sector, in the BAU scenario, is expected to increase from 246.4 million gigajoules (corresponding to 5.885 Mtoe approximately) in 2010 to 259 million gigajoules in 2035 (corresponding to 6.2 Mtoe approximately), accounting for an -0.1% annual average decrease rate. Trucks appear to have the highest energy demand between the two modes, bot h in the base year 2010 and at the end year 2035, with about 53% share as it is presented in Figure 1.

**Table 1: Greece BAU scenario: sales share of cars and fuels per technology, in 2035.**

| Technology | Fuel | Percentage |
|---|---|---|
| Internal Combustion Engine (ICE) 75% | Gasoline | 80% |
| | Diesel | 20% |
| Hybrid 7% | Gasoline | 80% |
| | Diesel | 20% |
| Electric Vehicles - 2% | Electricity | 100% |
| Fuel Cells 1% | Hydrogen | 70% |
| | Methanol | 30% |
| Biofuels 10% | Ethanol | 50% |
| | Biodiesel | 50% |
| Gas 5% | CNG | 80% |
| | LPG | 20% |

**Table 2: Greece BAU scenario: sales share of trucks and fuels per technology, in 2035.**

| Technology | Fuel | Percentage |
|---|---|---|
| Internal Combustion Engine (ICE) 80% | Gasoline | 50% |
| | Diesel | 50% |
| Biofuels 10% | Ethanol | 50% |
| | Biodiesel | 50% |
| Gas 10% | CNG | 90% |
| | LPG | 10% |

**Table 3: BAU and alternative scenarios for cars.**

| *Scenarios* | *Technology* | | | | | |
|---|---|---|---|---|---|---|
| | **ICE** | **Hybrid** | **EV** | **Fuel Cells** | **Biofuels** | **Gas** |
| **BAU** | 75% | 7% | 2% | 1% | 10% | 5% |
| **1** | 35% | 7% | 2% | 1% | **50%** | 5% |
| **2** | 30% | 7% | 2% | 1% | 10% | **50%** |
| **3** | 26% | 7% | 2% | **50%** | 10% | 5% |
| **4** | 27% | 7% | **50%** | 1% | 10% | 5% |
| **5** | 32% | **50%** | 2% | 1% | 10% | 5% |

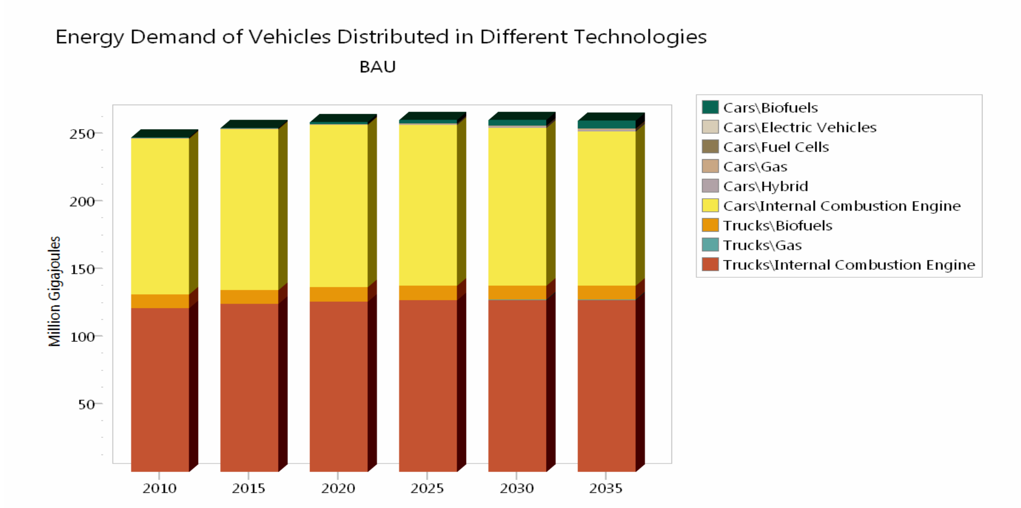



**Figure 1: Energy Demand of Vehicles Distributed in Different Technologies (BAU).**

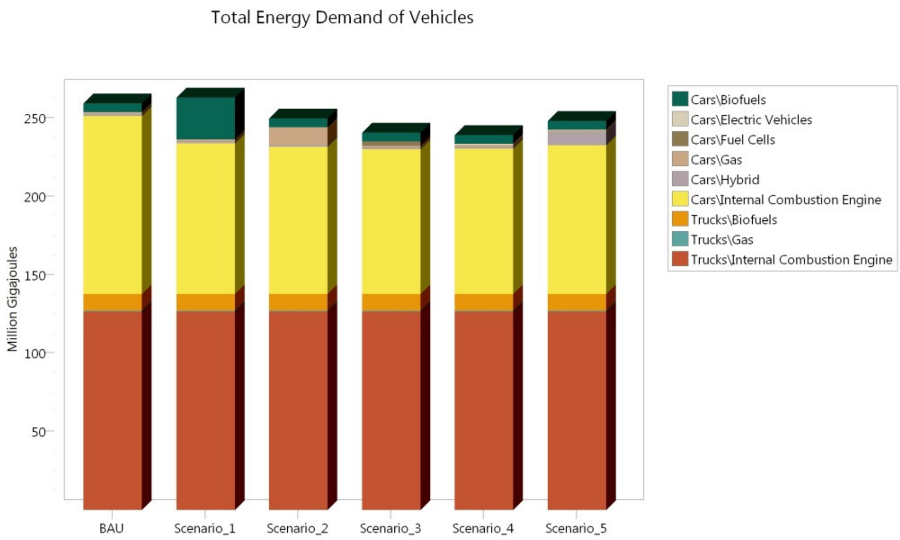



**Figure 2: Total Energy Demand of Vehicles (all scenarios).**

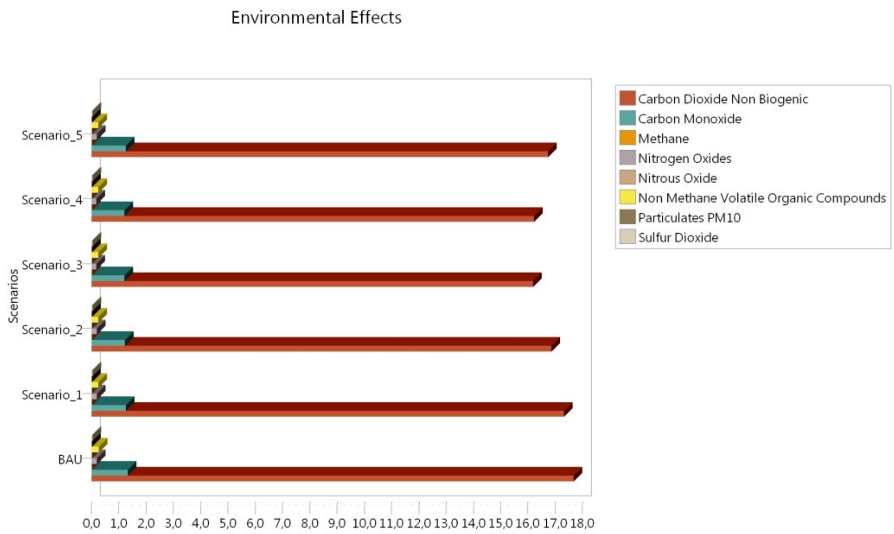



**Figure 3: Environmental Effects (all scenarios).**

Scenario 4, that corresponds to increased electric vehicles sales for cars in 2035 results to 238.9 million gigajoules of total energy demand (Figure 2).

Best emission reduction compared to BAU scenario is achieved in scenario 3 that corresponds to increased fuel cells vehicles sales for cars in 2035; resulting to 16.3 million metric tons of $CO_2$ equivalent (Figure 3).

## 4. Conclusions

The world is facing the ever-increasing twin challenges of energy shortage and environmental deterioration, mainly resulting from an over-dependence of our society on fossil energy. The transport sector worldwide almost entirely relies on fossil fuels, oil in particular [8]. Since currently available mitigation options will probably not be enough to prevent growth in transport's emissions, technology research and development is essential in order to create the potential for future, significant reductions in transport GHG emissions. This holds, amongst others, for hydrogen, fuel cell, advanced biofuel conversion and improved batteries for electric and hybrid vehicles [4].

The GHG reduction potential of plug-in-hybrids and electric vehicles depends ultimately on the emissions associated with the production of electricity [2]. In our case, we consider electricity produced only from renewables.

The future energy demand in the Greek road transport sector was analyzed via the LEAP model for different scenarios. By using the forecasting models, the number of vehicles, the energy demands and the associated emissions for various future scenarios with different technology options were examined and presented in this study.

The results show that the number of vehicles in 2010 is 6.2 million and increases to approximately 6.9 million vehicles in 2035, for all the scenarios, accounting for 0.5% average annual growth rate. Due to this increase in vehicle fleet in the Greek road transport sector, the emissions in terms of million metric tonnes $CO_2$ equivalent would increase from 17.1 million tons in 2010 to approximately 17.8 million tons in 2035 (BAU scenario).

Five alternative scenarios to BAU are introduced, presenting an increased penetration of alternative technologies in new cars sales – namely biofuels, gas engine vehicles, fuel cells vehicles, electric vehicles, and hybrid vehicles.

According to the results of this study, it has been found that the fuel economy improvement assumption combined with the electric vehicle scenario would be interesting strategies in order to reduce the total energy demand of the Greek road transport sector up to 2035. The greenhouse gas emissions related to the Greek road transport sector is slightly better decreased in the increased sales of fuel cells vehicles.

The alternative scenarios have shown that the continuously increase in energy demands and pollutant emissions can be limited through the implementation of measures such as alternative technologies and fuels, improvements on vehicles efficiencies, taxation schemes for the promotion of renewables etc.

It must be noted that energy demand is affected by various factors such as sudden fuel prices, consumers behaviors etc. For that reason the results that were predicted in this study, even though they can illustrate the energy demand trend, may deviate from the actual energy demand. Moreover, further work, focusing on the financial aspects of using alternative technologies, the infrastructure needed and their social acceptance, is necessary for the final assessment of a policy recommendation [20].

## Acknowledgement

The authors would like to thank Dr. G. Mellios of EMISIA (www.emisia.com) for providing Greek vehicle fleet data.

## References

[1] B. G. Pollet, I. Staffell and J. L. Shang, "Current status of hybrid, battery and fuel cell electric vehicles: From electrochemistry to market prospects ", Journal Electrochimica Acta , pp. 235 - 249.

[2] S. Proost, K. V. Dender, 2010, International Transport Forum, "What Sustainable Road Transport Future? Trends and Policy Options", Catholic University of Leuven, Belgium

[3] T. Zachariadis, N. Kouvaritakis, 2003, "Long-term outlook of energy use and $CO_2$ emissions from transport in Central and Eastern Europe", Energy Policy 31, pp. 759–773.

[4] Kahn Ribeiro, S., S. Kobayashi, M. Beuthe, J. Gasca, D. Greene, D. S. Lee, Y. Muromachi, P. J. Newton, S. Plotkin, D. Sperling, R. Wit, P. J. Zhou, 2007, "Transport and its infrastructure", In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[5] A. Bandivadekar, K. Bodek, L. Cheah, C. Evans, T. Groode, J. Heywood, E. Kasseris, M. Kromer, M. Weiss., 2008, "On the Road in 2035: Reducing Transportation's Petroleum Consumption and GHG Emissions", Report LFEE 2008-05RP, MIT.

[6] J. Pongthanaisawan, C. Sorapipatana, B. Limmeechokchai, 2007, "Road Transport Energy Demand Analysis and Energy Saving Potentials in Thailand", Asian J. Energy Environment, Vol. 8, Issue 1 and 2, pp. 49-72.

[7] BP Energy Outlook 2035, January 2014

[8] X. Yan, R. J. Crookes, 2010, "Energy demand and emissions from road transportation vehicles in China", Progress in Energy and Combustion Science 36, pp. 651–676.

[9] A. Veziroglu, R. Macario, 2011, "Fuel Cell Vehicles: State of the Art with economic and environmental concerns", International Journal of Hydrogen Energy 36, pp. 25-43

[10] Heaps, C.G., 2012. Long-range Energy Alternatives Planning (LEAP) system. [Soft-ware version 2012.0049] Stockholm Environment Institute. Somerville, MA, USA. http://www.energycommunity.org/

[11] S. S. Ahmad, S. Muhammad, R. Shabbir, A. Wahid, 2010, "Predicting Future Energy Requirements of Punjab (Pakistan) Agriculture Sector Using Leap Model", World Applied Sciences Journal 8 (7), pp. 833-838.

[12] G. Mahumane, P. Mulder, D. Nadaud, 2012, "Energy Outlook for Mozambique 2012-2030 LEAP –based scenarios for energy demand and power generation", Conference paper nº16, IESE

[13] S. Li , 2009, " Reduction Emissions From Transport Sector – EU Action against Climate Change", Modern Applied Science Journal, Vol. 3, No. 8

[14] V. Karplus , P. Kishimoto, S. Paltsev, 2012, "The global energy, $CO_2$ emissions, and economic impact of vehicle fuel economy standards", Global Trade Analysis Project 15th Annual Conference on Global Economic Analysis (Geneva, Switzerland, June 27-29).

[15] Emisia SA, 2013, available at: http://www.emisia.com/

[16] IPPC, 2006, “Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories, Vol. 2.

[17] EC, 2014, “EU Energy, Transport and GHG Emissions Trends to 2050 – Reference Scenario 2013”.

[18] OECD/IEA, 2010, “World Energy Outlook”

[19] S. I. Khan, A. Islam , A. H. Khan, 2011, "Energy Forecasting of Bangladesh in Gas Sector Using LEAP Software", Global Journal of Researches In Engineering, Vol. 11, Issue 1, pp. 15-20.

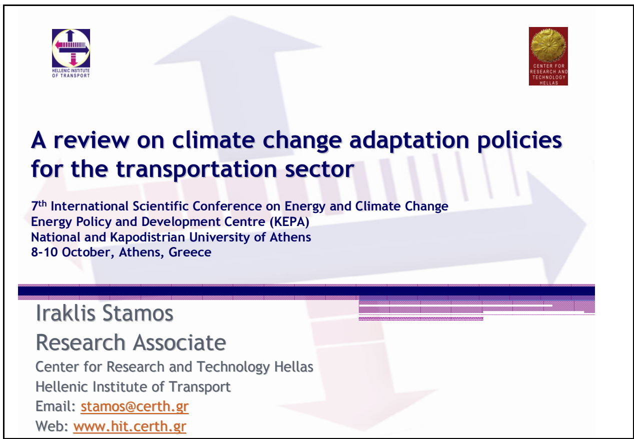
[20] C. Bitos, 2013, “Energy Demand Analysis and Energy Saving Potentials in the Greek Road Transport Sector”, MSc thesis, International Hellenic University

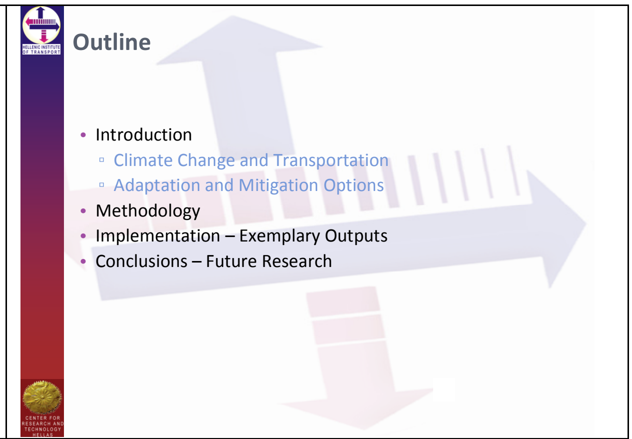
# A review on climate change adaptation policies for the transportation sector

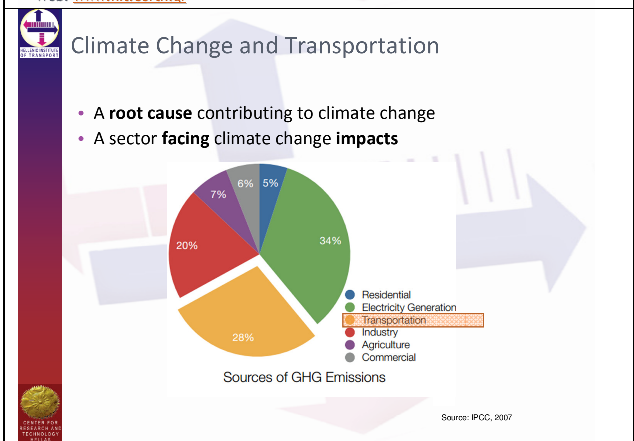
by

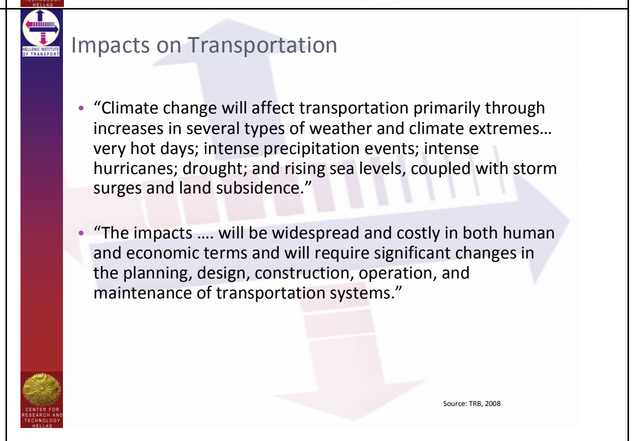
**Iraklis STAMOS**

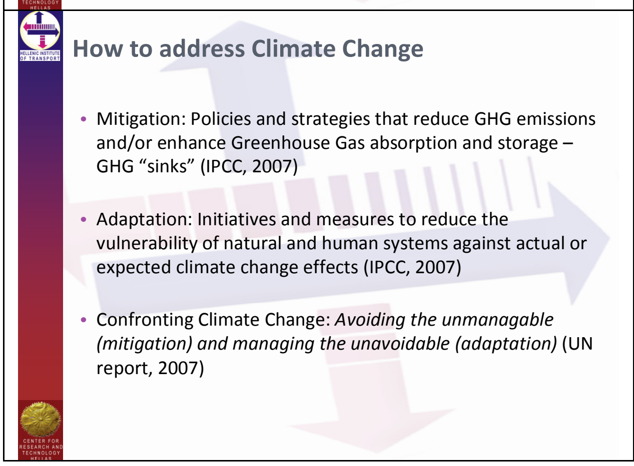
Centre for Research and Technology Hellas, Hellenic Institute of Transport, Research Associate

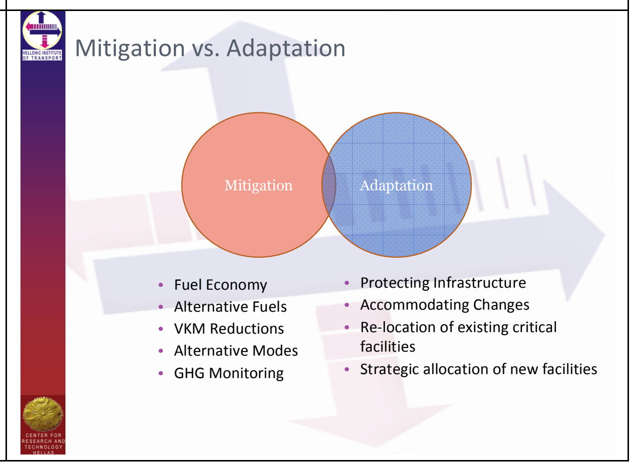


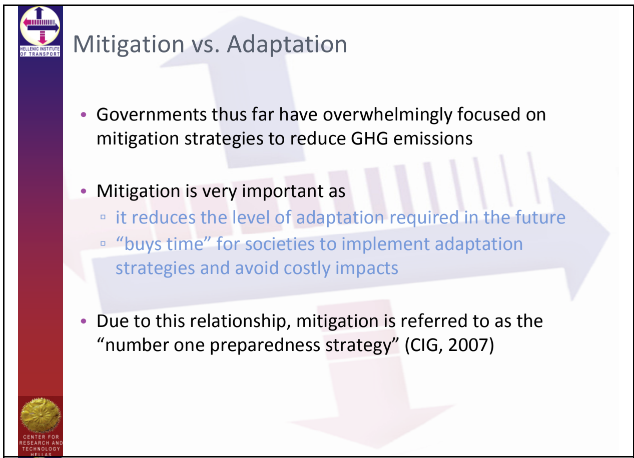



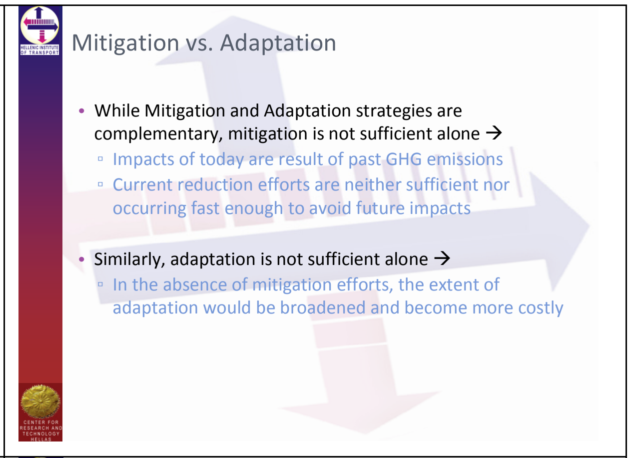



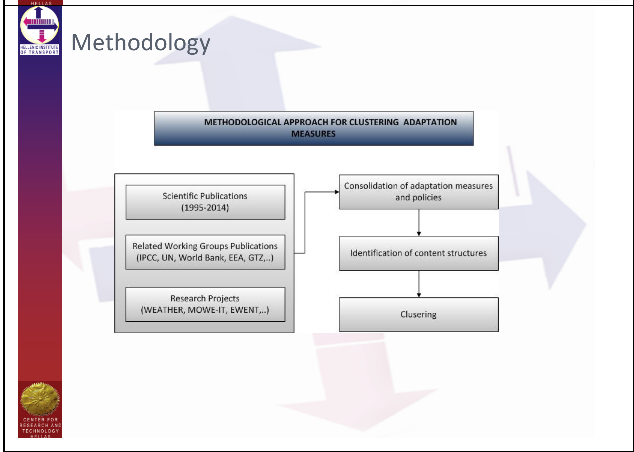



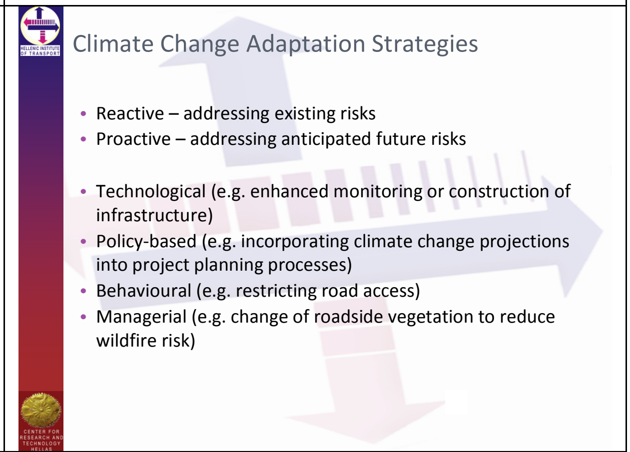



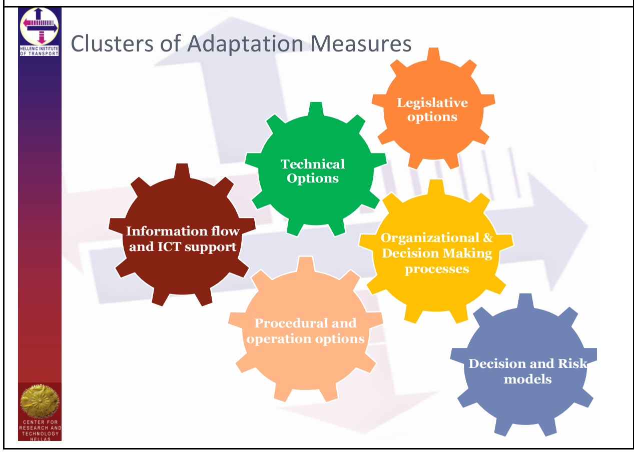



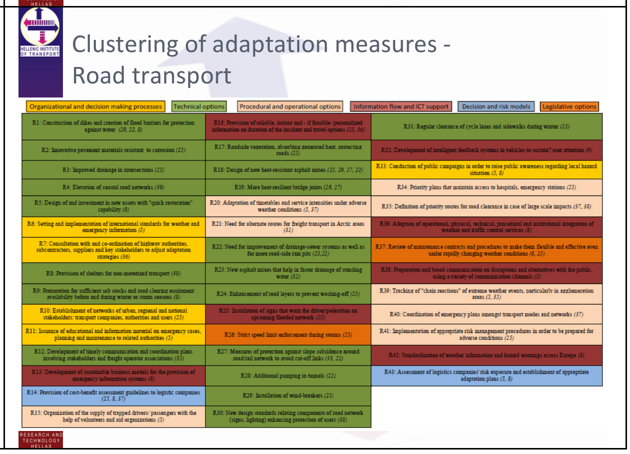

Mitigation vs. Adaptation
Governments thus far have overwhelmingly focused on mitigation strategies to reduce GHG emissions
Mitigation is very important as
it reduces the level of adaptation required in the future
"buys time" for societies to implement adaptation strategies and avoid costly impacts
Due to this relationship, mitigation is referred to as the "number one preparedness strategy" (CIG, 2007)

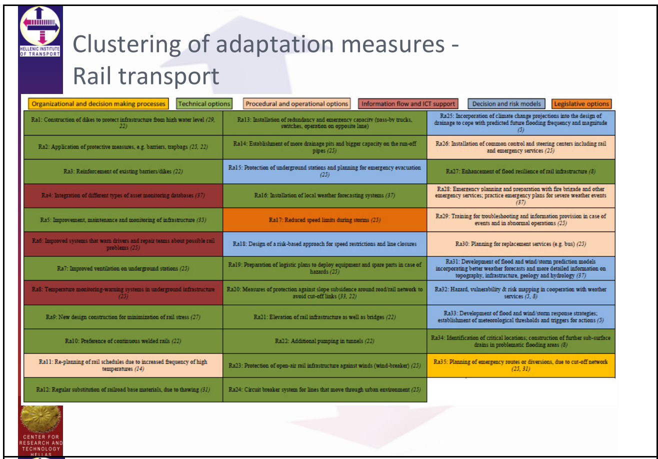

Mitigation vs. Adaptation
While Mitigation and Adaptation strategies are complementary, mitigation is not sufficient alone →
Impacts of today are result of past GHG emissions
Current reduction efforts are neither sufficient nor occurring fast enough to avoid future impacts
Similarly, adaptation is not sufficient alone →
In the absence of mitigation efforts, the extent of adaptation would be broadened and become more costly

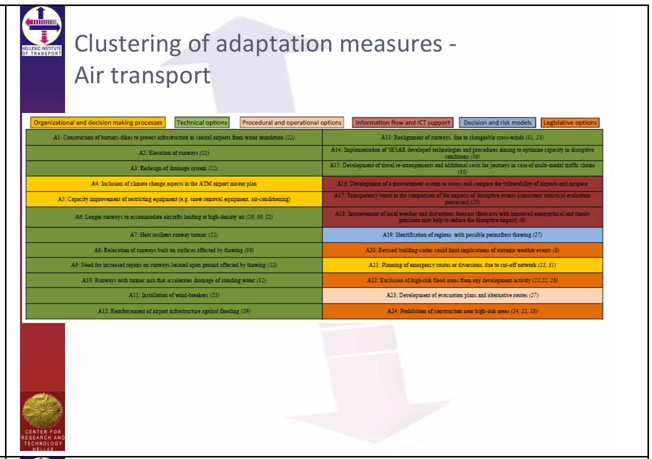

Methodology
METHODOLOGICAL APPROACH FOR CLUSTERING ADAPTATION MEASURES
Scientific Publications (1995-2014)
Related Working Groups Publications (IPCC, UN, World Bank, EEA, GTZ,..)
Research Projects (WEATHER, MOWE-IT, EWENT,..)
Consolidation of adaptation measures and policies
Identification of content structures
Clusering

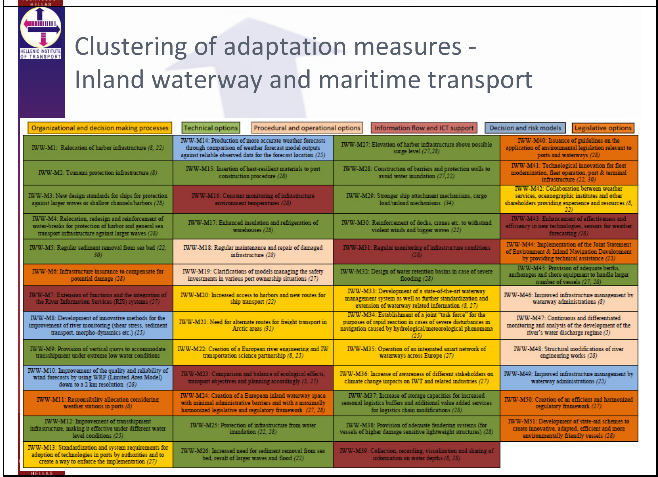

Climate Change Adaptation Strategies
Reactive – addressing existing risks
Proactive – addressing anticipated future risks
Technological (e.g. enhanced monitoring or construction of infrastructure)
Policy-based (e.g. incorporating climate change projections into project planning processes)
Behavioural (e.g. restricting road access)
Managerial (e.g. change of roadside vegetation to reduce wildfire risk)

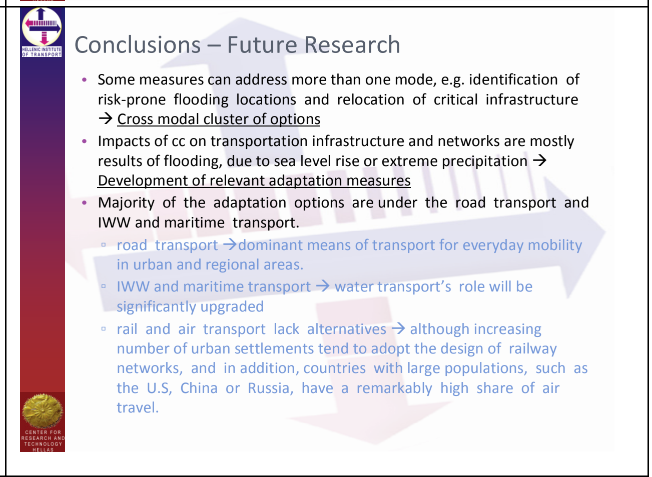

Clusters of Adaptation Measures
Legislative options
Technical Options
Information flow and ICT support
Organizational & Decision Making processes
Procedural and operation options
Decision and Risk models

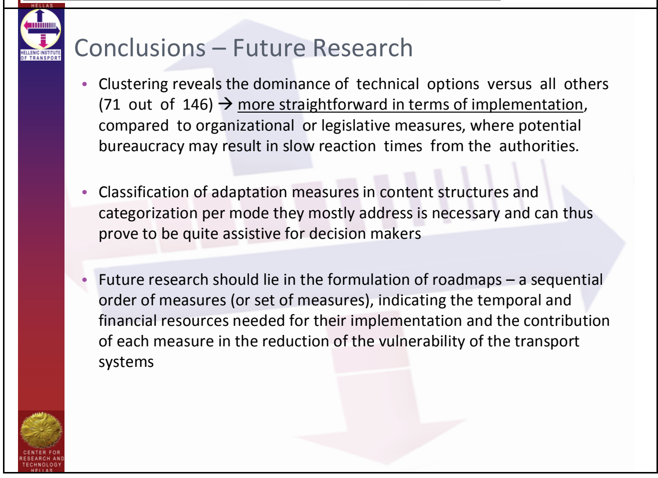

Clustering of adaptation measures - Road transport
Organizational and decision making processes
Technical options
Procedural and operational options
Information flow and ICT support
Decision and risk models
Legislative options


Clustering of adaptation measures - Rail transport
Organizational and decision making processes
Technical options
Procedural and operational options
Information flow and ICT support
Decision and risk models
Legislative options


Clustering of adaptation measures - Air transport
Organizational and decision making processes
Technical options
Procedural and operational options
Information flow and ICT support
Decision and risk models
Legislative options


Clustering of adaptation measures - Inland waterway and maritime transport
Organizational and decision making processes
Technical options
Procedural and operational options
Information flow and ICT support
Decision and risk models
Legislative options


Conclusions – Future Research
Some measures can address more than one mode, e.g. identification of risk-prone flooding locations and relocation of critical infrastructure → Cross modal cluster of options
Impacts of cc on transportation infrastructure and networks are mostly results of flooding, due to sea level rise or extreme precipitation → Development of relevant adaptation measures
Majority of the adaptation options are under the road transport and IWW and maritime transport.
road transport →dominant means of transport for everyday mobility in urban and regional areas.
IWW and maritime transport → water transport's role will be significantly upgraded
rail and air transport lack alternatives → although increasing number of urban settlements tend to adopt the design of railway networks, and in addition, countries with large populations, such as the U.S, China or Russia, have a remarkably high share of air travel.


Conclusions – Future Research
Clustering reveals the dominance of technical options versus all others (71 out of 146) → more straightforward in terms of implementation, compared to organizational or legislative measures, where potential bureaucracy may result in slow reaction times from the authorities.
Classification of adaptation measures in content structures and categorization per mode they mostly address is necessary and can thus prove to be quite assistive for decision makers
Future research should lie in the formulation of roadmaps – a sequential order of measures (or set of measures), indicating the temporal and financial resources needed for their implementation and the contribution of each measure in the reduction of the vulnerability of the transport systems


Thank you for your attention
Iraklis Stamos
Research Associate
Center for Research and Technology Hellas
Hellenic Institute of Transport
Email: stamos@certh.gr
Web: www.hit.certh.gr

# The Norwegian support and subsidy policy of electric cars. Should it be adopted by other countries?

by

**Prof. Anders SKONHOFT**

Economic Department of NTNU, Norway

**The Norwegian support and subsidy policy of electric cars. Should it be adopted by other countries?**

Anders Skonhoft
Economic Department NTNU

(*Environmental Science & Policy* 42, 2014)

Athen October 2014

## 1. Introduction

- As a result of generous policies to increase the use of electric vehicles (EVs), the sales of EVs in Norway are rapidly increasing
- This in sharp contrast to most other rich countries without such generous policies
- Due to the subsidies, driving an EV implies very low costs to the owner on the margin. Probably leading to more driving at the expense of public transport and cycling
- Because most EVs' driving range is low, the policy also gives households incentives to purchase a second car, again stimulating the use of private cars instead of public transport and cycling
- These effects are analysed in light of possible greenhouse gas (GHG) emission effects as well as other possible benefits of utilizing EVs versus conventional cars
- We discuss and analyze whether the EV policy can be justified, as well as whether this policy should be implemented by other countries

Trondheim september 2014

Plan for the presentation:

- Electrical vehicle(EV) sale growth
- Details of the Norwegian subsidy policy
- GHG emission related to EVs' demand for energy
- Cost per tonne CO2 – a numerical example
- The EV policy and houshold's use of transport
- On lock-ins, network and technology
- Summing up and conclusions….
  - The Norwegian subsidy policy should be ended asap!!
  - It should not be adopted by other countries!!

Trondheim september 2014

## 2. EV sale

- Road traffic gives rise to various health-damaging pollutants, noise and accidents. Therefore often heavily taxed through fuel taxes, road taxes and turnpike taxes. Norway no exception…
- But EVs treated much more leniently in Norway…. And the result…

Trondheim september 2014

**Table 1. Yearly new vehicle sales in Norway. Fraction of EVs in brackets (as a percentage)**

| | Number of conventional cars | Number of EVs |
|---|---|---|
| 2011 | 138345 | 1996 (1.4) |
| 2012 | 137967 | 3950 (2.8) |
| 2013 | 142151 | 7882 (5.5) |

Source: Opplysningsrådet for veitrafikken (ofvas.no)

- Sweden well below 1 % new car sale
- Same for Denmark, and most, if not, all other countries
- The world EV car sale 2012: Japan 28%, US 26%, China 16%, France 11%
- …. and Norway 7% (…population 5 mill)

Trondheim september 2014

## 3. Norwegian subsidy policy and the arguments

- The subsidy policy has been gradually implemented during the last 10 years, and is now an integrated part of the so-called Climate agreement among (all!) parties in the Norwegian Parliament
- Rooted in laws and regulations (Ministry of Finance, and Ministry of Transportation), together with policy measures implemented at the local level
- Main elements:
  - EVs are exempt from VAT and other taxes on car purchases and sales
  - Parking in public parking spaces is free
  - EVs can use most toll roads and several ferry connections free of charge
  - EVs are allowed to use bus and collective traffic lanes
  - The company car tax is 50 per cent lower on EVs, and the annual motor vehicle tax/road tax is also lower
  - Battery charging is free at a rapidly growing number of publicly funded charging stations

Trondheim september 2014

- The Norwegian EV policy is founded on the widespread notion (among politicians, and so-called environmental organizations) that EVs are far more environmentally friendly than conventional vehicles using gasoline and diesel fuel
- The arguments are partly related to the possible *short-term* benefits, and partly related to what may happen in the *long term*
- The reduction of local emissions and the reduction of GHGs to fulfil the Norwegian emission reduction goals are an important part of the short-term story
- Technological changes and possible battery technology improvements stimulated through demand effects form part of the long-term picture
- We discuss these arguments in turn and start with the long—term arguments

Trondheim september 2014

•The basic *long term* argument is:
  – Stimulating demand drives research and development of new battery technologies
  – Many, many examples history of technology where policy interventions and subsidies (and also state owned/driven labs) have encouraged new and groundbreaking technology

•But…. there are already strong incentives for research and development to improve battery technology as new battery technology is an essential part of laptops, tablets, mobile phones, etc.

•And don't forget: Two-thirds of the world's electricity, feeding the EV batteries, is currently generated from fossil sources (coal etc.). Come back to this…

•So if EVs are to contribute significantly to solving the world's $CO_2$ problem, there needs to be a fundamental revision of electricity production

Trondheim september 2014

- The short term arguments is first:
- Reduce l*ocal* emission problems, particularly in comparison with diesel vehicles
  – But if the purpose of the EV subsidy policy is to mitigate local environmental problems, promoting a switch from diesel vehicles to gasoline models is possibly both a simpler and a cheaper expedient

    But…. the Norwegian car tax policy favors diesel cars while sacrificing gasoline, meaning that the current (spring 2014) pumping price of gasoline is about 1 NOK/litre above that of diesel
  – the use of spike tyres during the winter …
  – Car noise is also often a local environmental problem. The tyres, not the engines, represent the most serious problem here

Trondheim september 2014

- The main short term argument:
  – The global environmental question and curbing greenhouse gases (GHGs) is possible the main argument behind the Norwegian EV policy
- Several issues here:
  – The 'driving effect'; GHG per km EVs vs. conventional cars
  – The total life cycle analysis; GHG embodied in the car construction and the driving over the whole life time of the cars
  – But also the 'replacement effect' (or 'rebound effect') ; that is, whether EVs replace, or come as an addition to conventional cars
  – Possible changes in the energy mix related to electricity production have also to be considered
- .

Trondheim september 2014

## 4. $CO_2$ emissions related to EVs' use of energy

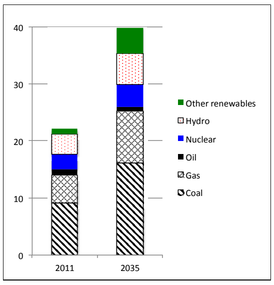
•Important background for the whole discussion: What type of energy is feeding the electricity production, and therefore what type of energy may feed the EVs?
  – *Globally*, coal accounts for approximately 40 per cent of the electricity generated today (IEA 2013)
  – The use of gas and oil is significant as well
  – In total; fossil energy accounts today for roughly 67 per cent of the world's production of electricity
  – Renewable sources account for about 19 per cent
  – The rest comes from nuclear energy

Trondheim september 2014

- Projections International Energy Agency IEA (2013):
- IEA expects a significant efficiency improvement in fossil power stations
- This together with Capture and Storage technology (CCS) may modify the modest prospect of reduced GHG emission related to world's future electricity production
- But CCS plays not a significant role in the coming decades in IEA's 'current policy scenario'
- Additionally; numerous new coal fired power stations are under construction and many more are supposed to be build the coming years without CCS technology (IEA 2013)
- IEA's projection 2035 'current policies scenario' indicates that still 65 % electrical energy still will come from fossil energy, and 25 % from renewables

Trondheim september 2014

- IEA 2011, and projection 2035




Trondheim september 2014

- The 'driving effect'; GHG per km EVs vs. conventional cars:
- $CO_2$ properties of the conventional car technology versus EV technology by comparing the use and driving-related emissions of gasoline- and diesel-powered vehicles with the fossil fuel mix and the related emissions in power stations producing electricity utilized for EV driving
- Calculations on fuel use and range are based on tests performed by the US Department of Energy (DOE). Comparing:
  – The gasoline-driven hybrids Toyota Prius and Lexus ES 300h
  – The EVs Nissan Leaf and Tesla Model S, the latter both having the 60 kWh and 85 kWh battery pack
- The vehicles' use of energy is crucial
- The composition of fossil fuel in the electricity production crucial (above)
- And the results are…

Trondheim september 2014

- Results (details in paper):

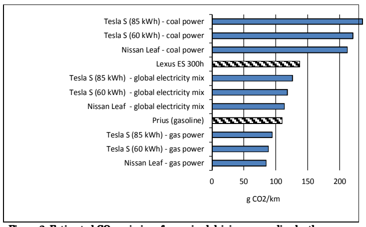



**Figure 2. Estimated $CO_2$ emissions from mixed driving on gasoline by the hybrids Toyota Prius and Lexus ES 300h and the EVs Nissan Leaf, Tesla Model S, with 60 and 85 kWh battery packs, based on consumer tests conducted by the US Department of Energy (DOE). A global electricity mix is assumed to comprise 40 per cent energy from coal, 25 per cent from gas and 5 per cent from oil, the rest being $CO_2$-free. Emissions related to the production of the cars are not included.**

Trondheim september 2014

- Sum:
- In a world in which energy come largely from fossil sources, EVs do not necessarily achieve lower CO2 emission than conventional cars running on gasoline or diesel
- Greatly depends on source of electricity, electricity mix and production efficiency

Trondheim september 2014

- Complete comparison…
- The total life cycle analysis; GHG embodied in the car construction and the driving over the whole life time of the cars
- Hawkins et al. 2012, Hawkins et al. 2013: Under certain assumptions on life time of the cars, total driving (km) over the lifetime, and electricity mix, they found that a switch from conventional car to EVs may give a 10 – 24 % reductions in the total lifetime GHG emissions for cars of comparable size
- An exemption is possible Tesla S (large battery pack, production of battery is energy intensive and the lifetime of the battery…)

- NOTE zero 'replacement effect': These life cycle analysis are based on assumption that any EV replaces a conventional car, and a trip with EV replaces a trip with a conventional car;

Trondheim september 2014

## 5. Cost per tonne $CO_2$ – a numerical example

- The power-producing sector in Europe is part of the European Union's emissions trading system (EU ETS), which also includes Norway

- Cap on emissions from the sectors and producers participating in this system, also including energy producers. Therefore, increased demand for electricity in Europe does not increase the total GHG emission, but *ceteris paribus* instead leads to higher $CO_2$ permit price

- If we consider the cap of the EU ETS to be fixed, and a trip with a conventional car to be replaced with an EV, the emission reduction is equal to the $CO_2$ emissions that would have been caused by the conventional car

- This is the assumption. And we ask whether the size of this emission reduction is reasonable in light of the costs

Trondheim september 2014

- The emission saving (the benefit side):
- Consider, as an example, a Nissan Leaf owner living in Sandvika, a commuting suburb slightly more than 10 km from the city center of Oslo, where his/her workplace is assumed to be located. The car owner has a 5-day working week. Altogether, this workload and travelling distance add up to about 5,000 km driving per year.
- If we also assume some additional driving (errands, etc.), we end up with a yearly mileage of about 7,500 km with this Nissan Leaf. We also assume that 75 % of these journeys replace trips with a Toyota Prius, which emits 110 g/km.
- Then we find that the EV driving saves about 0.6 tonne of $CO_2$ ($tCO_2$) emission yearly because the Prius is left in the garage under the binding EU ETS cap assumption.

Trondheim september 2014

- The cost side:
- We assume that our Leaf owner from Sandvika saves the following taxes and charges
  - Tax on the purchase of this car (mainly VAT) estimated at nearly 10,000 USD, based on its current cost (spring 2014) of about 230,000 NOK. With a discount rent of 5 per cent and a lifetime of 10 years, this converts into a yearly cost (annuity) of 1,300 USD;
  - Toll road charges in Oslo and Bærum (the municipality where Sandvika is located), estimated annually at 1,400 USD;
  - Parking fees in the city center of Oslo, estimated at about 5,000 USD per year;
  - Road use charges (fuel charges) and VAT on fuel, assumed to be about 400 USD per year.

Trondheim september 2014

- Sum: We end up with an annual amount of subsidies and support adding up to about 8,100 USD when ignoring the benefit of recharging the battery for free at public charging stations and the time-saving benefit of using bus lanes (which also involves certain social costs)
- In light of the above-calculated yearly fossil $CO_2$ emission reduction of about 0.6 $tCO_2$, the gain for the EV owner comes at a cost of roughly 13,500 USD/$tCO_2$
- In comparison, the price of $CO_2$ on the European permit market is currently (spring 2014) around 5 USD/$tCO_2$. Consequently, the cost of supporting the Leaf owner in Sandvika is 2,700 times higher than the current $CO_2$ emission price
- In other words, the yearly cost of subsidizing this single EV driver equals the value of 2,700 $tCO_2$ permits, and subsidizing 20,000 EVs, which is somewhat below the number of EV vehicles running on Norwegian roads today, under similar assumptions, adds up to the value of more than 50 million permits (about the GHG emission in Norway today)

Trondheim september 2014

## 6. The 'replacement effect' ('rebound effect') and related issues

- The Norwegian EV policy in an example of subsidizing the use of an alternative rather than taxing the problem; the GHG emission.
- Another example; the so called green certificate market in Sweden and Norway (today about 20 øre/kWh, and large negative external effects)
- Usually economists favor the more directly policy instrument: making emission more costly (taxation, or cap). More predictable
- The EV policy is certainly a success as a large number of EVs on the road:
  - More car driving
  - Incentives to by an additional car to reap the privileges of using bus lanes, and free parking in the big cities. Remember: EVs certain restrictions long-distance driving
  - But also replacing journeys otherwise taken by train, bus or bicycle.
- .

Trondheim september 2014

- Lack good data, but one indication… 93% of households that own an EV also own a conventional car

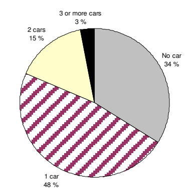



**Figure 3. Proportion of Norwegian car-owning families and families without a car, 2005 (as percentages)**
**Source: Statistics Norway**

Trondheim september 2014

- Also EV's for families with income/wealth well above average(Ministry of Finance 2014), and located in wealthy suburbs west of Oslo where using bus lanes saves a lot of time

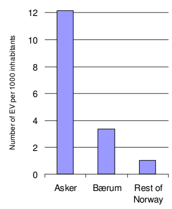



**Figure 4. EV ownership per 1,000 pop., December 2011**
**Source: Norwegian Public Roads Administration and Statistics Norway**

Trondheim september 2014

## 7. Conclusion

- Gone through the arguments for EVs. The merits of the short-term arguments are far from convincing
- This policy is extremely costly
- Also some flavor of 'privatizing the benefits and socializing the costs'
- Our reasoning is in line with some few others (Thomas 2012, Proud'homme and Koning 2012, Bosetti and Longden 2013)
- The Norwegian EV subsidy policy should be ended asap, and certainly should not be implemented by other countries
- And more: It should be food for the Policy Science Departments to find out how this EV policy really was realized

Trondheim september 2014

# Renewable Energy Sources

# Legal issues in Chinese international trade disputes on photovoltaic products—On the perfection of green subsidies WTO rules

**Chien Te FAN**
Professor of Law & Director, ILST,
National Tsing Hua University, Taiwan

**Ya-Chih LO**
M.Sc in Sustainable Development, Uppsala University, Sweden
Graduate Student, ILST, National Tsing Hua University, Taiwan

Address: 1037 Luoyu Road, Law School of Huazhong Univ. of Sci.& Tech., Wuhan, P.R.China. 430074

**Abstract:** This paper reviews WTO green subsidy rules by examining the trade conflicts including American and European Union's "Anti-Dumping & Anti-Subsidy" investigation over photovoltaic products from China. It aims to state the problems of existing subsidy rules of World Trade Organization (WTO). Many countries including China issued a number of measures including subsidies for renewable energy support to develop domestic industry and improved international competition. However, subsidies and countervailing rules of the WTO do not impose any distinction between general and green subsidies including renewable energy subsidies, which lead to the legitimacy of WTO members' renewable energy subsidies be challenged by other countries. For example, China's renewable energy subsidies had been challenged for several times by European Union and the U.S. based on existing WTO rules. This paper will apply a case study method to research the renewable energy subsidy problem. The cases include U.S. vs. China on Measures concerning wind power equipment, European Union's Anti-Dumping & Anti-Subsidy investigation over photovoltaic products from China. The sources can be divided into three aspects. First is the WTO rules such as GATT 1994, SCM Agreement, Protocol of Accession etc. Second is the WTO dispute settlement documents on related cases. Third is the case related official documents from Chinese, American and European administrations. The conclusion is that WTO should take the renewable energy subsidy problem as an opportunity to improve its green subsidy rules timely, and clearly defines the rules of prohibited subsidies, actionable subsidies and non-actionable subsidies on renewable energy resources.

## 1. Introduction

Since the 1992 United Nations Conference on Environment and Development, the issue of sustainability has been emphasized because of such problems as resource depletion and climate change. Moreover, regarding sustainable development, energy is always an important issue since energy, as a key input to production, is crucial in development process. In order to support development, sufficient and secure energy supply is required and renewable energy becomes important especially when fossil fuels become exhausted and the concern for GHG emissions increases. The final document of the Rio+20, the Future We Want, reaffirms the international supports for increased use of renewable energy sources to meet an appropriate energy mix for developmental needs[52]. The promotion of renewable energy is an inevitable trend.

Regarding the increasing usage of renewable energy nowadays, the development of solar power is still somehow backward compared to wind power. According to Green Rhino Energy, technology divides the solar power market into a photovoltaics segment and a concentrated solar thermal segment. Moreover, in absolute terms, photovoltaics segment market is still in the stage of a niche market. That is, at the end of 2012, the global installed capacity was mere 30GW, which equates to 0.1% of international electricity generation. The growth of photovoltaics segment market, however, has been considerable with double digits over the past years. In terms of worldwide market share, Germany still leads in new builds while other big solar nations like China, Italy, U.S. and Japan follow closely[53].

[52] United Nations General Assembly, Resolution adopted by the General Assembly 66/288. The future we want. p. 24-25.

[53] Green Rhino Energy Ltd, http://www.greenrhinoenergy.com/solar/market/micro_market.php [latest accessed: 2014/11/22]

The tipping point for solar PV adoption is supposed to be when the technology reaches grid parity, namely, the lifetime generation cost of PV-generated electricity being comparable with the one for conventional sources like fossil fuels[54]. In terms of the prices for silicon PV products, based on Deutsche Bank analyst report, they have declined considerably from the second quarter of 2008 to May 2009 with over 60% drop from $2/W to less than $0.6/W. In a similar fashion, the prices for polysilicon- based products such as wafers, cells and modules have also fallen. These sharp declines have been resulted from a decline in demand caused by the credit freeze in 2008/09, lower feed-in tariffs and overcapacity.

Even though the demand will return, polysilicon prices is not possible to reach 2008-levels again[55]. Many factors drive the market for PV-powered electricity, such as energy security, energy prices, cost of carbon, more demand for electricity and so on. Given that conventional-powered electricity prices are still cheaper, namely more competitive, than the PV-powered, regulatory frameworks are necessary.

To increase the demand, feed-in tariffs have proved to be the most effective while this means that public policy, which is sometimes fickle interferes the market and introduces additional risk. Yet, this concern can be eased given that public pressure can ensure stable support frameworks in place. After all, without the public policy, the electricity market will be dominated by the oil price and that will impede the urge for alternatives, which is not good for the development of renewable energy. Whether solar power can make profits depends on the installed costs, the location of the plant and the dominating electricity prices in the local market[56]. The main reason for public policy intervention is to facilitate the process in which the photovoltaic products can meet grid parity more efficient.

Given that PV-powered electricity needs governmental supports to encourage its development in the markets, disputes occurs in the field of international trade. Controversy occurs regarding the harmony between promotion of renewable energy and protection of international free-trade markets. China, in the pursuit of rapid development, is one of the big solar nations. It is inevitable that China will be highly engaged in the international trade disputes on photovoltaic products. Accordingly, the disputes regarding international trade and governmental supports, namely subsidies for photovoltaic products, are introduced and the legal issues are discussed in the following to gain some insights.

## 2. The Disputes

To develop renewable energy, subsidies have been a popular policy measure around the world and wind power has been a success story in reducing the need for subsidization. Such a statement, however, is not applicable so far for the two solar technologies. That is, study indicates that, in world average, financial subsidies for solar and wind power have been always higher than any other technology. The two solar technologies particularly rank the highest regarding per-kWh R&D support and solar power's need for subsidization, unlike the wind power fashion, does not drop[57].

Driven by the demand of global cost effective renewable energy supply, China also provides many subsidies to renewable energy. Study indicates, from 2006 to April 2011, China's subsidy for renewable energy power amounted to 33448.84 million CNY, and the subsidy cost per kWh is 0.248CNY[58]. In terms of solar power industry, China's government initiated the Golden Sun Demonstration Program and Rooftop Subsidy Program in 2009 and 2011 respectively and that has boosted the industry. In 2011, China's export value of solar cell amounted to USD 22.67 billion, accounting 60% share of the global market. Meanwhile, China's polysilicon production, as the first in the world, reached 84,000M/T[59].

Every year, China exports thousands of hundreds of photovoltaic products to European countries and USA. China's solar PV industry, however, is facing the international trade war as European countries and USA started to impose the anti-dumping and counter-vailing duties on China's solar PV manufacturers. That is, more and more investigations of "anti-dumping and anti-subsidy" are initiated by EU and the US governments and international trade disputes aroused. Many questions are discussed; for example, "does existing subsidy program (under WTO) violate the regulation?" and "does existing subsidy limit to any particular industry?" Moreover, concerns are raised since"photovoltaic products" dose not belong to

[54] K. Branker et al (2011) A review of solar photovoltaic levelized cost of electricity. Renewable and Sustainable Energy Reviews 15, p.4470-4482.

[55] Green Rhino Energy Ltd, http://www.greenrhinoenergy.com/solar/market/mkt_trends.php [latest accessed: 2014/11/22]

[56] Green Rhino Energy Ltd, http://www.greenrhinoenergy.com/solar/market/mkt_assessment.php [latest accessed: 2014/11/22]

[57] Jeremy Badcock & Manfred Lenzen (2010) Subsidies for electricity-generating technologies: A review. Energy Policy 38, p. 5038–5047.

[58] Hui-ru Zhao, SenGuo & Li-wen Fu (2014) Review on the costs and benefits of renewable energy power subsidy in China. Renewable and Sustainable Energy Reviews 37, p.538–549.

[59] Ibid.

any of the existing categories of goods. Responding to the international trade war regarding photovoltaic products, three cases of WTO consultations, including wind power and solar power, are cited in the following and the related legal issues are discussed accordingly.

***Case 1: USA & etc. v. China (DS419 China)***

This case is a dispute between China and USA regarding China's measures on wind power. USA, as the complainant requested consultations with China concerning "certain measures which provide grants, funds, or awards to enterprises manufacturing wind power equipment, including the overall unit, and parts thereof," namely subsidy in China. USA indicated that these measures are contingent on the use of domestic over imported goods and, consequently, they appear to be "inconsistent with Article 3 of the SCM Agreement." The evidence provided includes notice of the Ministry of Finance on Issuing the Provisional Measure on Administration of Special Fund for Industrialization of Wind Power Equipment, including the Annex on Provisional Measures on Administration of Special Fund for Industrialization of Wind Power Equipment. Moreover, China is seen failed to comply with its obligation such as translating these measures into one or more of the official languages of the WTO and reporting these measures to WTO, etc. The summary of the case is presented in Figure 1[60].

This case shows the concerns for prohibited subsidies, like those upon export performance, under the international trade agreements. Arguably, USA and such alliance as EU and Japan, asserted China illegally subsidizes exporters of crystalline silicon photovoltaic cells and solar panels based on the following common beliefs. Firstly, "low labor costs" and "deliberate currency undervaluation" existed in China. Secondly, China's industries were economically inefficient. If there were no subsidy, they would not be competitive globally. Thirdly, "China's subsidization led to manufacturing overcapacity, which affected both domestic and foreign producers," and inhibited consolidation among Chinese producers that otherwise, would occur.

Debates aroused between China and USA regarding the existence of dumping activities and prohibited subsidies. Firstly, USA argued China's solar manufacturers were dumping product into the U.S. market at below cost. China, on the other hand, asserted, in 2012, the price downturn of solar panels came from the cyclical correction of the industry and the entire solar industry was unprofitable due to a 70% drop in module prices over the prior year. Secondly, USA argued China's dumping activity was negatively impacting U.S. jobs. By contrast, China suggested that the growth of solar jobs in the U.S. was in Manufacturing, Distribution and Finance. There were more than 140,000 jobs and the figure kept growing. After all, low cost centers would always be the manufacturing centers for solar panels, just as they were for mobile phones, computers, network equipment and appliances. Companies making solar cells in the USA employed less than 1000 people. Last but not least, USA claimed China's solar manufacturers had access to below market rate financing, paying below market taxes and being unfairly subsidized. This statement, however, was refuted by the fact that South Korean central bank had supplied 1-2% interest rate debt to its main manufacturers. Accordingly, if cheap debt was a cause for an anti-dumping tariff then it should be applied to all Samsung & LG product. The tariff should apply to all iPhone, iPad, Mac, PC, etc., since they were all probably "made in China."

After all, U.S. Commerce Department decided to impose duties of as much as 250 percent on Chinese solar imports. EU decided to impose anti-dumping and anti-subsidy duties to Chinese solar imports. The average duty for exporters that cooperated in the investigation is 47.7%, which was the duty rate applicable to the majority of exporters. A duty of 64.9% would be applied to those exporters who did not cooperate in the European Commission's investigation, which were estimated to account for less than 20% of exports. China subsequently took action formally revoking the legal measure that had created the Special Fund program in 2011[61].

***Case 2: China v. EU, Italy & Greece (DS452 EU and Italy/Greece)***

In 2012, China as the complainant requested consultations with European Union, Italy and Greece regarding "certain measures, including domestic content restrictions that affect the renewable energy generation sector relating to the feed in tariff programs of EU member States, including but not limited to Italy and Greece."

The dispute in this case is also about subsidies and its violation of international trade agreement. Yet, China was the complainant in this case and

[60] World Trade Organization (WTO). DISPUTE SETTLEMENT: DISPUTE DS419 China — Measures concerning wind power equipment. http://www.wto.org/english/tratop_e/dispu_e/cases_e/ds419_e.htm [latest accessed: 2014/11/24].

[61] The Office of the United States Trade Representative (USTR). (2011) China Ends Wind Power Equipment Subsidies Challenged by the United States in WTO Dispute. http://www.ustr.gov/about-us/press-office/press-releases/2011/june/china-ends-wind-power-equipment-subsidies-challenged [latest accessed: 2014/11/24].

China claimed that measures in tariff programs of EU member States were inconsistent with (1) Articles I, III:1, III:4 and III:5 of the GATT 1994, (2) Articles 3.1(b) and 3.2 of the SCM Agreement and (3) Articles 2.1 and 2.2 of the TRIMs Agreement[62].

The summary of this case is presented in Figure 2. Besides, since this case is relatively new and is still in consultations, there is little information regarding the subsequence.

Yet, it is clear that this case reaffirms the explosive disputes about renewable energy subsidies. After all, problem is still as following. Could renewable energy subsidies, as an incentive to promote green energy, be justified under the WTO legal framework or do such subsidies risk being abused as disguised protectionism?

***Case 3: Canada — Certain Measures Affecting the Renewable Energy Generation Sector (DS412 Canada) and Canada — Measures Relating to the Feed-in Tariff Program (DS426 Canada)***

These two cases are converged by the dispute panel as the respondent is Canada in both case and the agreement cited is very similar. Disputes aroused regarding Canada's measures relating to domestic content requirements in the feed-in tariff program (the "FIT Program"). The requirements adopted by Canadian government were criticized as a violation to national treatment obligation and prohibited subsidies.

In the former case Japan requested consultations by pointing out such "domestic content requirements" that certain generators of electricity utilizing solar photovoltaic and wind power technology "must comply with in the design and construction of electricity generation facilities in order to qualify for guaranteed prices offered under the FIT Program," adopted by the Government of the Province of Ontario, as well as all individual FIT and micro FIT Contracts implementing these requirements since the FIT Program's inception in 2009. These requirements were considered as violation to (1) national treatment obligation by the complainant under Article III:4 of the GATT 1994; (2) the prohibition that is set out in Article 2.1 of the TRIMs Agreement on the application of any trade-related investment measures that are inconsistent with Article III of the GATT 1994; and (3) the prohibition on import substitution subsidies prescribed in Articles 3.1(b) and 3.2 of the SCM Agreement. Figure 3 presents the summary of DS412 Canada[63].

In the other case, European Union also requested consultations regarding the same domestic content requirements in Canadian feed-in tariff program. The European Union claimed that the requires are inconsistent with Canada's obligations under Article III:4 and III:5 of the GATT 1994 because they appeared to be "laws, regulations or requirements" affecting the internal sale, offering for sale, purchase, transportation, distribution, or use of equipment for renewable energy generation facilities "that accorded less favorable treatment to imported equipment" than that accorded to like products originating in Ontario. Moreover, the European Union alleged that it appeared that a subsidy existed under the measures because there would be "a financial contribution or a form of income or price support, and a benefit is thereby conferred." Figure 4 shows the summary of DS426 Canada[64].

## 3. The Rules & Legal Issues Concerned

After reviewing three cases of WTO consultations, many concerns for the rules and legal issues are presented and worthy of discussing. In the procedure aspect, approximate duration of a dispute settlement procedure under WTO is one year to one year and three months as shown in Figure 5. Among international treaty dispute settlement mechanism, WTO consultation has been relatively efficient to respond the rapidly changing situation in international trade. Even though the existing dispute settlement procedure may still require reflections and improvements, this article intends to put emphasis on the substantive issues arising from the three cases above.

The disputes presented in the three cases all points out the questions of energy subsidies under WTO legal framework. Even if the GATT/WTO legal framework has been implemented for over twenty years with considerable success in trade liberalization, energy-related trade is still a thorny issue.

---

[62] World Trade Organization (WTO). DISPUTE SETTLEMENT: DISPUTE DS452 European Union and certain Member States — Certain Measures Affecting the Renewable Energy Generation Sector. http://www.wto.org/english/tratop_e/dispu_e/cases_e/ds452_e.htm [latest accessed: 2014/11/24].

[63] World Trade Organization (WTO). DISPUTE SETTLEMENT: DISPUTE DS412 Canada — Certain Measures Affecting the Renewable Energy Generation Sector. http://www.wto.org/english/tratop_e/dispu_e/cases_e/ds412_e.htm [latest accessed: 2014/11/24].

[64] World Trade Organization (WTO). DISPUTE SETTLEMENT: DISPUTE DS426 Canada — Measures Relating to the Feed-in Tariff Program. http://www.wto.org/english/tratop_e/dispu_e/cases_e/ds426_e.htm [latest accessed: 2014/11/24].

| | |
|---|---|
| **Short title:** | |
| **Complainant:** | United States |
| **Respondent:** | China |
| **Third Parties:** | |
| **Agreements cited:**<br>**(as cited in request for consultations)** | GATT 1994: Art. XVI:1<br>Subsidies and Countervailing Measures: Art. 3, 25.1, 25.2, 25.3,25.4<br>Protocol of Accession: Part I, para. 1.2 |
| **Request for Consultations received:** | 22 December 2010 |

**Figure 1: summary of the case DS419 China.**

| | |
|---|---|
| **Short title:** | |
| **Complainant:** | China |
| **Respondent:** | European Union; Italy; Greece |
| **Third Parties:** | |
| **Agreements cited:**<br>**(as cited in request for consultations)** | GATT 1994: Art. I, III:1, III:4, III:5<br>Subsidies and Countervailing Measures: Art. 1.1, 3.1(b), 3.2<br>Trade-Related Investment Measures (TRIMs): Art. 2.1, 2.2 |
| **Request for Consultations received:** | 5 November 2012 |

**Figure 2: Summary of DS452 EU and Italy/Greece.**

| | |
|---|---|
| **Short title:** | **Canada — Renewable Energy** |
| **Complainant:** | Japan |
| **Respondent:** | Canada |
| **Third Parties:** | Australia; Brazil; China; El Salvador; European Union; Honduras; India; Saudi Arabia, Kingdom of; Korea, Republic of; Mexico; Norway; Chinese Taipei; United States |
| **Agreements cited:**<br>**(as cited in request for consultations)** | GATT 1994: Art. III:4, III:5, XXIII:1<br>Subsidies and Countervailing Measures: Art.1.1, 3.1(b), 3.2<br>Trade-Related Investment Measures (TRIMs): Art. 2.1 |
| **Request for Consultations received:** | 13 September 2010 |
| **Panel Report circulated:** | 19 December 2012 |
| **Appellate Body Report circulated:** | 6 May 2013 |

**Figure 3: Summary of DS412 Canada.**

| | |
|---|---|
| **Short title:** | **Canada — Feed-In Tariff Program** |
| **Complainant:** | European Union |
| **Respondent:** | Canada |
| **Third Parties:** | United States; Japan; Australia; China; Chinese Taipei; India; Saudi Arabia, Kingdom of; Brazil; Korea, Republic of; Mexico; Norway; Turkey; El Salvador |
| **Agreements cited:**<br>**(as cited in request for consultations)** | GATT 1994: Art. III:4<br>Subsidies and Countervailing Measures: Art.1.1, 3.1(b), 3.2<br>Trade-Related Investment Measures (TRIMs): Art. 2.1 |
| **Request for Consultations received:** | 11 August 2011 |
| **Panel Report circulated:** | 19 December 2012 |
| **Appellate Body Report circulated:** | 6 May 2013 |

**Figure 4: Summary of DS426 Canada.**

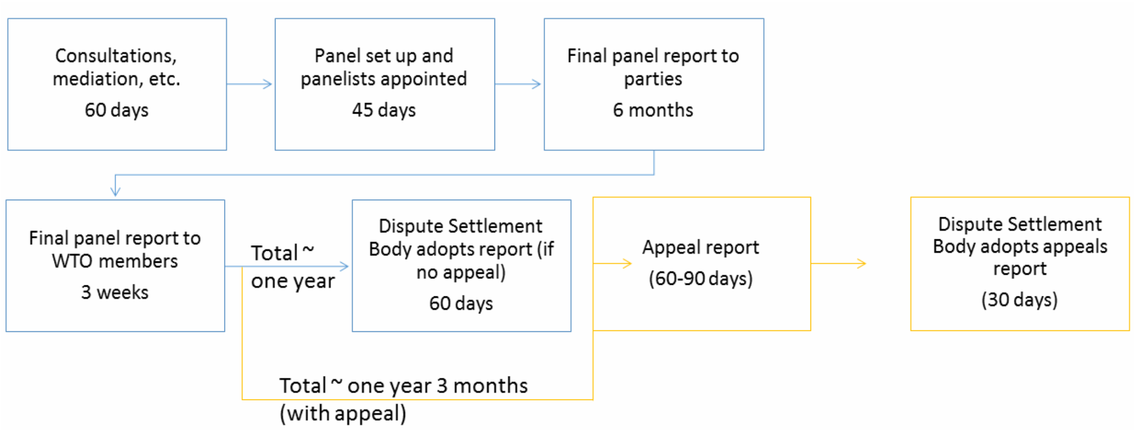



**Figure 5: Approximate duration of a dispute settlement procedure (the panel process).**

In 1998, the WTO Secretariat concluded a Background note by saying that "energy goods have been treated for a long time as being outside the scope of the reach of GATT rules, by relying on the general exception relating to the conservation of exhaustible natural resources (Article XX(g) GATT) and on the national security exception (Article XXI GATT)." [65]

This statement expresses the tricky aspect of energy-related since energy appears to be easily justified as exception. However, energy-related trade is not actually excluded from the GATT/WTO legal framework coverage. Besides, the necessity of a dialogue on energy trade was emphasized in the WTO currently[66]. After all, the basic GATT obligations restrict WTO Members; for example, National Treatment (Article III) applies to all items except screening quota and those belonging to government procurement and justifiable subsidies (Article III.8).

In sum, the GATT/WTO legal framework does not allow any protectionism to distort the progress of international trade and the justification of exception such as subsidies are under careful examination. Likewise, subsidies for renewable energy are required to follow the rules. Subsequently, two questions are important and they are: "how WTO/SCM sees subsidies?" and "what kind of subsidies is justifiable?"

To answer the questions, first of all, the fundamental principles provided by the GATT agreements should be noticed and this article suggests four principles as following.

- The agreement recognizes that subsidies may play an important role in economic development programs of developing countries, and in the transformation of centrally-planned economies to market economies.
- Poor countries are exempted from disciplines on prohibited export subsidies, and have a time-bound exemption from other prohibited subsidies.
- For developing countries, the export subsidy prohibition would take effect 8 years after the entry into force of the agreement establishing the WTO
- Countervailing investigation of a product originating from a developing-country member would be terminated if the overall level of subsidies does not exceed 2 per cent (and from certain developing countries 3 per cent) of the value of the product. (i.e. 2-3% subsidies are "allowed").

More specifically, Agreement of SCM defines subsidy as "a financial contribution by a government or any public body within the territory of a Member" and "a government practice involves a direct transfer of funds (e.g. grants, loans, and equity infusion), potential direct transfers of funds or liabilities (e.g. loan guarantees) are given as an example. That is, feed-in tariffs (FITs), in which government offers long-term contracts to energy producers at specified rates that typically above the retail price of electricity, can be considered as subsidies[67]. Since FITs are subsidies defined in

[65] World Trade Organization (WTO), Council for Trade in Services, Energy Services – Background Note by the Secretariat, Doc S/C/W/52, 9 September 1998.

[66] See "Workshop on the Role of Intergovernmental Agreements in Energy Policy - 29 April 2013." http://www.encharter.org/index.php?id=595&L=0 [latest accessed: 2014/11/24].

[67] U.S. Energy Information Administration (eia). (2013) Feed-in tariff: A policy tool encouraging deployment of renewable electricity technologies. http://www.eia.gov/todayinenergy/detail.cfm?id=11471 [latest accessed: 2014/11/24].

Agreement of SCM, the question becomes "what kind of subsidies is justifiable?"

Agreement of SCM indicates three categories of specific subsidies and they are (1) prohibited subsidies, (2) actionable subsidies and (3) non-actionable subsidies. Since the content of non-actionable subsidies is still under negotiation, the key point here is to judge whether renewable subsidies in the cases presented belong to prohibited subsidies. Prohibited subsidies defined in Agreement of SCM are (1) export subsidies, which are contingent, in law or in fact, whether solely or as one of several conditions, on export performance and (2) local content or import substitution subsidies. More importantly, SCM Agreement only aims at disciplining the use of subsidies that are "specific". Most notably, a subsidy is to be considered "specific" if access to it is explicitly limited to certain enterprises. The concept of specificity, as key concept of WTO agreement, is deemed to exist when access to the subsidy is limited, explicitly or in fact, to certain enterprises. That is, specificity is crucial to identify subsidy that should be examined under Agreement of SCM. Moreover, if a subsidy belongs to prohibited subsidies, the judgment of illegality is done regardless of specificity.

## 4. Lessons from China's Practices

The SCM Agreement differentiates between prohibited and actionable subsidies. Article 3.1(b) of the SCM prohibits subsidies conditioned on the use of domestic over imported goods – known as import substitution subsidies – because they are recognized to be especially trade distorting. In case 1, the Special Fund for Wind Power Manufacturing appears to fall within the prohibition of Article 3.1(b).

In contrast, actionable subsidies are permissible under the SCM unless they cause adverse effects or injury to the interests of another Member. In this situation, the obligations of WTO Members to submit notifications about their subsidies are set forth in Article 25 of the Agreement on Subsidies and Countervailing Measures (SCM Agreement). That is, regarding actionable subsidies, transparency is required to protect international trade mechanism as other members are able to respond the effects with proper information.

Renewable energy subsidies are supposed to be in the category of actionable subsidies since they are crucial for the transformation of centrally-planned economies to market economies. China, as a developing country, has a good reason to justify the implementation of subsidies as long as the requirements of the SCM are followed. After all, study indicates renewable energy develops better in markets with a FIT, employ anticipatory transmission planning, and so on[68]. Nevertheless, subsidies' effect on economic sustainability of renewable energy in the long-run might be troublesome since controversies arise between global competitiveness and domestic self-reliance; between centralized market and free market, etc.

## 5. Conclusion

The implement of renewable energy subsidies and the adoption of anti-dumping tariff both require careful and holistic considerations. The prevalence of international trade has tied the development of each country so closely that the effect of one decision cannot be judged within country boundary. The market for installing solar in the U.S. is nearly doubling per year, but it is facing with an anti-dumping tariff that has already increased the cost of solar panels and fallaciously affects development of solar industry in the U.S.

Considering the increasing share of renewable energy in international trade and the more intense disputes, WTO should take this chance, making the renewable energy subsidy problem as an opportunity to improve its green subsidy rules timely. Moreover, the balance between "development space" and trading rules (for developing countries) is always hard to strike. In the cases presented, China's subsides for renewables have characteristics violating WTO agreements. With the legal concerns reviewed, it is important to reduce potentially trade-distortive effects of certain subsidies by avoiding export subsidies as well as local content or import substitution subsidies and by implementing related obligations of WTO.

[68] U.S. Energy Information Administration (eia). (2013) Feed-in tariff: A policy tool encouraging deployment of renewable electricity technologies. http://www.eia.gov/todayinenergy/detail.cfm?id=11471 [latest accessed: 2014/11/24].

# Impact of distributed generation on power system: Case study

**Dr. Astrit BARDHI**[1]
Lecture at Automation Department

**Prof. Ass. Myrteza BRANESHI**
Professor at Electrotechnic Department

**Msc. Alfred PJETRI**
Lecture at Automation Department

[1] *Contact details of corresponding author*
Tel: +355-42-238-60
Fax: +355-42-238-60
e-mail: asibardhi@gmail.com
Address
Polytechnic University of Tirana (UPT)
Faculty of Electrical Engineering,
"Sheshi Nënë Tereza", Nr. 4, Tirana, Albania

**Abstract:** In recent years the renewable energy is placed at the focus by researchers of the field of the generation, transmission and distribution of electricity. Albania is rich on water sources that are found all across the area. As renewable energy water sources are environmentally friendly but on the other point of view they behave as a sort of distributed sources in power system. In this paper we will study the impact of small hydropower plants (SHP) built in recent years in Albanian's power system such as energy efficiency, improvement of voltage level and increase of capacity of transmission power lines. We have achieved a model of a part of power system and we have calculated the power flow, level of voltage in different nodes and the transmission power losses of the system with NEPLAN software. From the analysis in the case of small hydropower plants connections with power system results in an improvement of voltage level and increasing the efficiency of power system. Due to the fact that small hydropower plants are distributed sources, transmission power losses are reducing significantly.

**Key words:** Distributed generation, energy efficiency, SHP, renewable energy.

## 1. Introduction

Since the first use in the 1880s, the hydropower turbines are building to generate electricity in large scale. Expansion and increasing access to transmission networks has led to concentrating power generation in large units benefiting from economic of scale. This has resulted in a trend of building large hydropower installations rather than small hydropower plants for several decades.

However, liberalization of the electricity industry in some areas has contributed to the development of small hydropower generating capacity by independent power producers [Barker P.P., De Mello R.W., 2000]. In recent years, the interest of building small hydropower plants by operators working in the field of energy production is increased. These resources are usually connected at the distributed power system. The term "small hydropower plant" (SHP) is commonly used to refer to hydropower with capacity less than 10 MW [ESHA, 2004]. Other terms that are normally used are mini hydropower for SHP with capacity between 100 kW and 1 MW and micro hydropower for SHP with capacity below 100 kW [Khoan T., Vaziri M., 2005]. The power generated from SHP is quite large. The use of hydroenergytic reserves through construction of small hydropower plants, has not only the increase of the production of electricity but also some other too important advantages [Bastiao F., et al. 2008]

Small hydropower plants built in Albanian, which are distributed in all country, have been contributed to improve power quality, to reduce total power losses in transmission line and to increase efficiency of electricity consumption. Power generation from small hydropower plants is directly linked to the strategic objectives for the evaluation and development of hydropower capacity unused in Albania through private investment partnership or concessionary schemes. In last years in Albania are built several small hydropower plants with a total capacity about 200MW [Çelo M., 2013]

All these generation plants injected in power system, increase the power capacity generation, reduce the generation cost. Also all these plants give opportunity to optimise all generating capacity, ensuring harmonization of all aspects related to indicators of security of power system, of good quality electricity service.

The aim of this article is to analyse the impact of new SHP. We will analyse the impact of small hydropower plant, built in Gramsh district with capacity 10 MW. In this zone the before building of SHP the quality of power is poor. The voltage level is unstable, it has voltage fluctuation, power interruption, no reserve at power transmission line and power significant losses. After building of Tervol small hydropower plant and connection at distribution power system, the power quality is improved. The voltage fluctuations, the power transmission losses are reduced, and the power line capacity reserve, the efficiency of power system are increased. The bulding of Tervol small hydropower plant not only impact in power distribution system, but it has a social impact. The building of Tervol small hydropower plant has affected directly in the development of the zone and the improvement of road infrastructure. Also this hydropower plant, built in rural areas, which are with low incoming, has affected in the reduction of poverty by employing people from this zone.

## 2. Distributed generations

In the distributed energy resources can be included the energy derived from biomass and biogas, geothermal, solar, wind and hidric energy.

Biomass is one of the most plentiful and well-utilised sources of renewable energy in the world. Broadly speaking, it is organic material produced by the photosynthesis of light. The most common biomass used for energy is wood from trees. Wood has been used by humans for producing energy for heating and cooking for a very long time. Wood is still used extensively for energy in both household situations, and in industry, particularly in the timber, paper and pulp and other forestry-related industries [Kumar, A.A., 2008]. In this term the biomass energy works as natyral battery to accumulate of sun energy. Albania has not large forest and large farms to produce a quite amount of biogass, so the studies in our country for this topic are absent.

The source of geothermal power is the heat contained inside the Earth. There are a few different types of geothermal energy that can be tapped. Some geothermal systems are formed when hot magma nears the surface (1,500 to 10,000 meters deep) directly heats groundwater. The heat generated from these hot spots flows outward toward the surface, manifesting as volcanoes, geysers, and hot springs. Naturally-occurring hot water and steam can be tapped by energy conversion technology to generate electricity or to produce hot water for direct use [Heanel R., 2002], [Frashëri A., et al., 2001].

There are some geotermal sources in Albania, which mainly are used for medical treatment such as geothermal sources on Elbasan, Peshkopi etc. In Progadec district from a private innovation had realised a heating system of school building by geotermal sources.

The wind energy had been attractive in centuries. In recent years, production of electricity by wind turbine farms has received a grouth development. This energy production is clean and renewable. It also has minimal impact on the environment. A wind turbine can be installed on lands, seas and ocean. Some studies for building wind power farms to produce energy and to inject it in power system are performed last years in Albania. From these studies, we can mention Karaburuni, Lezha, Peshkopi, Kryevidh projects. For examble Karaburuni project has a power capacity about 500 MW and consist by 250 wind turbines with power capacity of 2 MW one's [Bardhi A., 2010]. But any by these projects until now are not formalized

Solar energy is mainly used to produce hot water. Due to increase of efficiency of solar panels and decrease of their costs, in recent years it's made possible to created electricity through solar energy. In Albania the sun's energy mainly is used for heating, but there are some experimental solar panel intsallations to produce electricity especially for telecomunication equipments.

Hydroenergy is the most popular over world as a renewable energy. Albania is reach by hydroenergy. Until now, only 30–35 % of hydric capacity is used. In recent years in Albania, many private investors are involved in the construction of small hydropower plants [Çelo M., et al., 2013]. At paragraph 5 we will give some information about the progress of the construction of small hydropower plants in Albania.

## 3. Impact of distributed generation in power system: Case study

Over 90% of Albanian electricity is produced by hydropower plants. HPPs, mainly are located at north Albania and are built on Drin and Mat rivers with 1446 MW capacity. The Drin river cascade comprises Fierza, Komani and Vau Deja hydropower stations, in downstream descending order. The Mat river stations are Ulza and Shkopeti. Due this reason the power quality, mainly south Albania area is not at good and optimal conditions. It seems at low voltage levels of nodes in this part of Albania and significant transmission power losses. Since the distributed generation (DG) penetrated the system, losses are reduced and the voltage profile is improvement. In order to study of impact of distributed generation in power system, we have analysed Gramsh district. To make a quantitative comparison we have analysed Gramsh district before and after of Tervol hydropower plant construction.

3.1 *The state of regional power system before Tervol SHP*

The Gramsh district is fed by two 110 kV radial transmission lines from Elbasan substation to Cerrik. From Cerrik substation two 35 kV lines fed Radio substation and finally a 35 kV line go to Gramsh substation. In the middle of the last line there is a branch to supply Cerunja area. The schematic of regional power system is shown at Figure 1, whereas the electric network of regional power system Gramsh before Tervol SHP construction is shown in the Figure2.

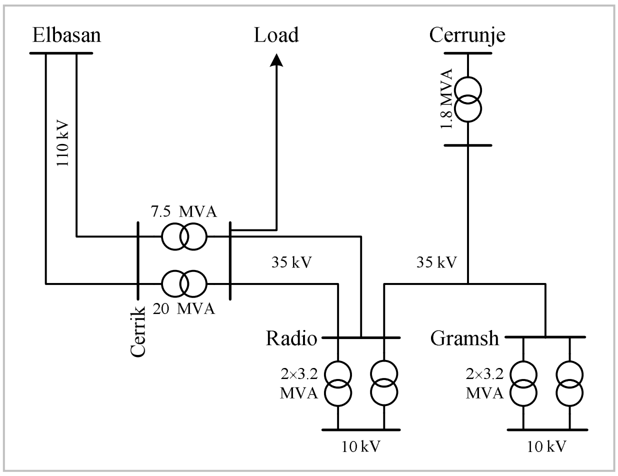



**Figure 1: Schematic layout of regional power system Gramsh.**

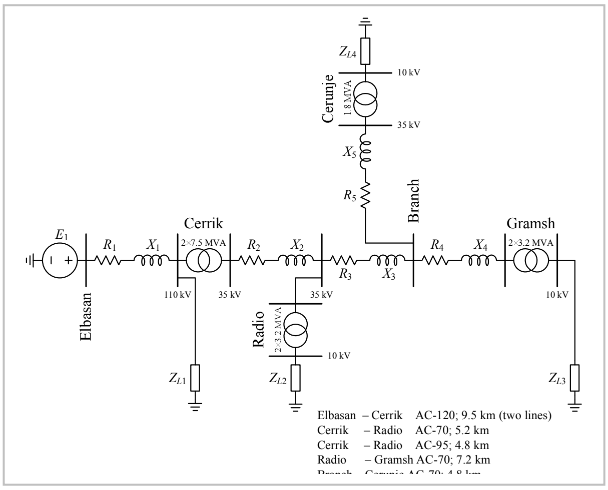



**Figure 2: Electric network of regional power system Gramsh before Tervol SHP construction.**

In Table 1 are shown the length of transmission lines ($L$) in kilometer, resistance ($r_0$) and reactance ($x_0$) per unit length (Ω/km), and total resistances ($R$) and reactances ($X$) of the lines. In Table 2 are shown the transformer data of substations as nominal power, primary and secondary nominal voltages of windings and transformer impedances. In our analysis, the transformer power losses are ignoring. The regional power system is analysed at different of loads and in all transmision lines are calculated the transmission power losses and voltage nodes. The loads are changed from zero to 100% of nominal power of area. To perform the calculations the NEPLAN software is used. These data are presented at table 3.

**Table 1: Power transmission line parameter.**

| Line | $r_0$ [Ω/km] | $x_0$ [Ω/km] | $L$ [km] | $R$ [Ω] | $X$ [Ω] |
|---|---|---|---|---|---|
| Elbasan-Cerrik | 0.248 | 0.427 | 9.5 | 2.356 | 4.057 |
| Cerrik-Radio | 0.46 | 0.4 | 5.2 | 2.392 | 2.08 |
| Cerrik-Radio | 0.33 | 0.4 | 4.8 | 1.584 | 1.92 |
| Radio-Tervol | 0.46 | 0.4 | 12.2 | 5.612 | 4.88 |
| Radio-Gramsh | 0.46 | 0.4 | 7.2 | 3.312 | 2.88 |
| Branch-Cerunje | 0.46 | 0.4 | 4.8 | 2.208 | 1.92 |

**Table 2: Transformer substation data.**

| Substation | No. of transormators | $S_n$ [MVA] | $V_n$ [kV] | $X_T$ [Ω] |
|---|---|---|---|---|
| Cerrik | 2 | 1×20<br>1×7.5 | 110/35<br>110/35 | 17 |
| Radio | 2 | 2×3.2 | 35/10 | 30 |
| Banja | 2 | 2×1.8 | 35/6 | 44 |
| Gramsh | 2 | 2×3.2 | 35/6 | 30 |

**Table 3: Node voltage level.**

| Load | Voltage nodes [nominal percentage voltage] | | | | | Power losses |
|---|---|---|---|---|---|---|
| | Cerrik | Radio | Cerrunje | Branch | Gramsh | kW |
| 0 | 100 | 100 | 100 | 100 | 100 | 0 |
| 20 | 98.91 | 98.22 | 97.92 | 98.01 | 97.79 | 25.7 |
| 40 | 97.69 | 96.29 | 95.67 | 95.85 | 95.40 | 106.6 |
| 60 | 96.30 | 94.14 | 93.17 | 93.45 | 92.75 | 250.1 |
| 80 | 94.69 | 91.68 | 90.33 | 90.73 | 89.76 | 472.5 |
| 100 | 92.77 | 88.80 | 87.03 | 87.55 | 86.27 | 811.5 |

From this table one can see that the voltage levels are below the level allowed by international standards when the loads are fifteen per cent of nominal power.

The total transmission power losses are significantly increased with increase of loads, for example when the power system is loaded at nominal power the total losses of transmission lines are 811.5 kW. Also the transmission lines Elbasan to Cerrik are loaded at maximum capacity. As a conclusion for the regional power system of

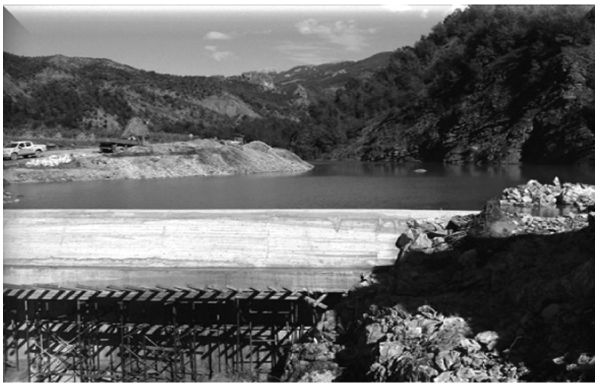


**Figure 3: Intake of small hydropower plant of Tervol.**

**Figure 4: View of electromechanical equipment room of Tervol hydropower plant.**

Gramsh we can state that the voltage levels are under allowed values, the transmission lines are at maximal capacity and we have not reserve to cover the connection of a new load. In this case a new transmision line (very expensive) must built.

*3.2 The state of regional power system after Tervol SHP*

Tervol hydropower plant is connected at power system in year 2010. Its installed capacity is 12 MW, with two Francis turbine from 5 MW capacity each other and a Pelton turbine with 2 MW capacity. The head of hydropower plant is 193 meters. Through a 35 kV line the Tervol hydropower plant is connected with regional power system at Radio substations. The length of line is about 7.5 km. The intake of Tervol hydropower plant and electro-mechanical equipment room are shown in Figures 3 and 4.

The simplified electrical diagram of regional power system with Tervol hydropower plant connected at power system is show at Figure 5.

The regional power system is analysed at different of loads and different power injected by Tervol hydropower plant. The power losses and voltage nodes are calculated in all transmission lines. The power injected by Tervol hydropower plant is changed from zero to 100% of its installed capacity. Also, the regional power system with varied loads from zero to 100% and constant power (4 MW) injected by Tervol SHP is analysed.

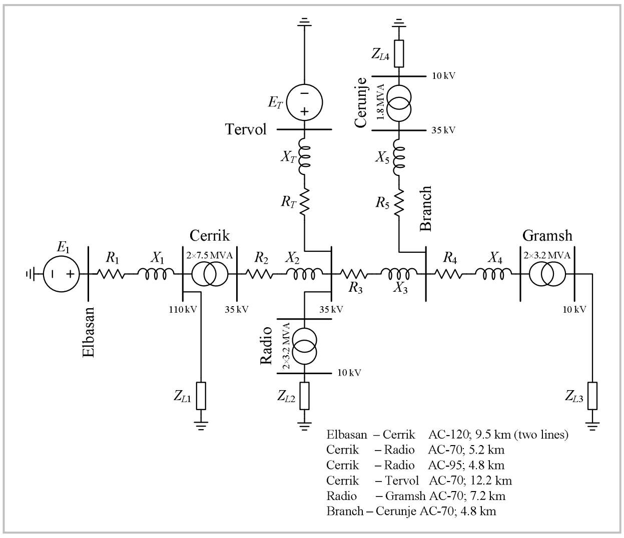



**Figure 5: Electric network of regional power system Gramsh after Tervol SHP construction.**

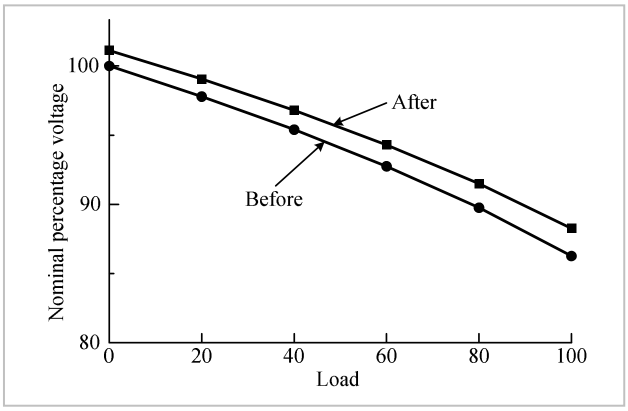



**Figure 6: Voltage level at Gramsh node versus load before and after Tervol SHP connection.**

The calculations are presented in Table 4. From the results one can see that the voltage node levels for all nodes of transmission lines are improved. Also, the power losses at transmission lines are reduced significantly compare with case when the Tervol hydropower plant was not connected at power system. To emphasise the impact of Tervol SHP, the voltage node at Gramsh substation, before and after Tervol SHP connection at power system, are represented in Figure6. Also, Fig 7 shows the transmission power losses before and after Tervol SHP connection at power system. From these figures, it is clearly seen that voltage node level (at Gramsh substation) is improved and transmission power losses are reduced. Also, when Tervol hydropower plant operates at rated capacity the power flow in the transmission lines that connected Elbasan and Cerrik substations, changes the direction. It means that the Elbasan substation behaves as a consumer and Gramsh region acts as source. In addition, a reserve in the transmssion line Elbasan to Cerrik is obtained, so addittional power to the regional power system can bee tranmsited.

**Table 4: Voltage level node.**

| Load | Voltage nodes [nominal percentage voltage] | | | | | Power losses |
|---|---|---|---|---|---|---|
| | Cerrik | Radio | Cerrunje | Branch | Gramsh | kW |
| 0 | 99.92 | 100.69 | 101.14 | 101.14 | 101.13 | 145 |
| 20 | 98.91 | 99.03 | 99.19 | 99.28 | 99.06 | 74.5 |
| 40 | 97.77 | 97.20 | 97.06 | 97.25 | 96.80 | 83.2 |
| 60 | 96.47 | 95.17 | 94.71 | 94.99 | 94.30 | 146.5 |
| 80 | 94.98 | 92.88 | 92.06 | 92.45 | 91.50 | 261.5 |
| 100 | 93.21 | 90.23 | 89.01 | 89.52 | 88.27 | 452.5 |

**Table 5: SHP Data in Albania.**

| Year | Installed power | | Annual production | |
|---|---|---|---|---|
| | kW | % | MWh | % |
| 2006 | 26,017 | 1.82 | 61,918 | 1.12 |
| 2007 | 27,454 | 1.92 | 59,177 | 2.02 |
| 2008 | 27,759 | 1.94 | 62,025 | 1.65 |
| 2009 | 28,009 | 1.96 | 89,306 | 1.72 |
| 2010 | 53,194 | 3.72 | 159,040 | 2.11 |
| 2011 | 77,854 | 5.77 | 136,831 | 3.51 |
| 2012 | 142,104 | 10.53 | 290,998 | 7.23 |
| 2013 | 226,004 | 16.74 | 548,148 | 9.43 |

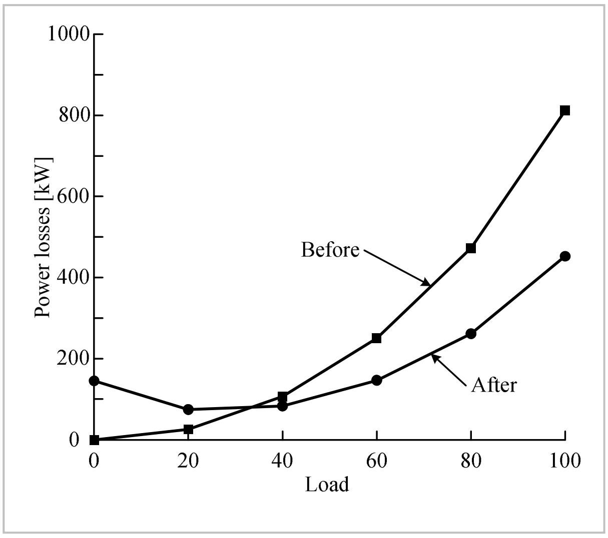



**Figure 7: Transmission power losses versus power injected by Tervol hydropower plant.**

## 4. Small hydropower plants in Albania

During the last years in Albania the interest of private investitors concerning to small hydropower plants is increased, so around 80 concessionary contracts for construction of SHPs have been approved. The total capacity of SHPs is around 400 MW with annual energy production of 1,827 GWh. The amount of investment of construction of SHP plants is about 289 million euros. In Albania, the authority which monitors the progress of construction of concessionary contracts is National Agency of Natural Resources (AKBN). Actually, AKBN monitors 101 concessionary contracts of 276 small hydropower plant in construction, with a total capacity 1,251 MW with predicted energy annual production about 5,037 million kWh. Nowdays, there are a number of private companies licensed to produce electricity and 23 of small hydropower plants are operated. In table 5, for the period 2006 to 2013, the number of SHPs and their power capacity are given.

The progress of annual energy production from SHPs in Albania during time period 2006 to 2013 is represented in Figure 8 [KESH], whereas in Figure9 is presented the energy progress of SHPs compared with the public company (KESH) hydropower plants [ERE].

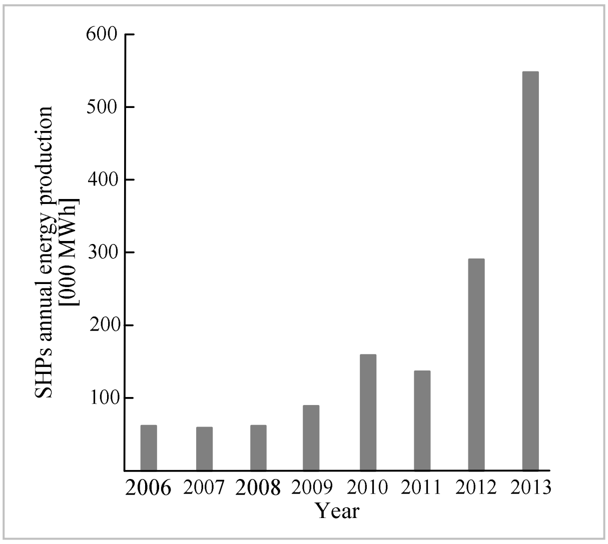



**Figure 8: Annual energy production by SHP during period 2006-2013.**

## 5. Environmental and social impact of renewable energy

Hydropower plant energy, as renewable energy, is very friendly with environment. It also has some social and economical benefits. Small hydropower plants, with devijation canal have a minimal impact in environment. SHPs have an impact in the improvement of the air quality by reducing released $CO_2$ in atmosphere. On the other hand, small hydropower plants have an economical impact in the region by employing local residents for service and maintenance. Also, the construction of a small hydropower plant acts directly in development of local area by improving the road infrastructure. At

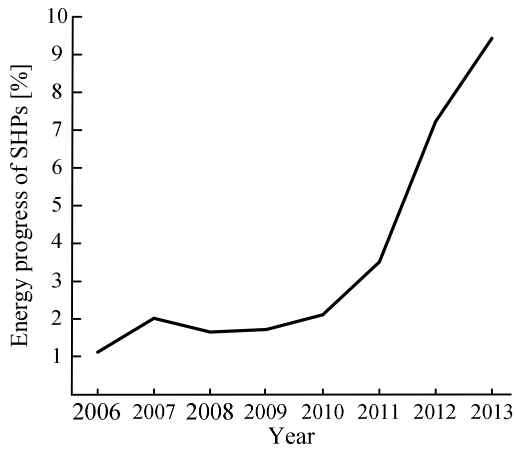



**Figure 9: Energy progress of SHPs compared with the public company hydropower plants.**

Tervol hydropower plant are employing around 15 persons from different proffesions.

## 6. Conclusion

In this paper the impact of a distributed generation unit on power transmssion losses and voltage profile of distribution network is presented.

Albania, as mountain country, has many possibilities to contruct SHPs. The power produced by SHPs is generated at the consumer end, so the possibility to supply the consumers with affordable power at a higher level of quality is increased. Also, the SHPs reduce the power losses of transmission lines, increase the capacity and improve the efficiency of power system.

The SHPs are easy to maintain and easy to operate as they consist of simple constructions.

Construction and operation of small hydropower plants provides better utilization and optimization of water sources at Drin river cascade, which are the main resources of power generation in Albania.

SHPs are a priarioty to produce a green energy, with minimal environmental impact and reduce $CO_2$ in atmosphere.

## References


ADA, 2005. *Evaluation report of the Austrian cooperation with Albania 1991/1992-2004,* prepared in December 2005, Austrian Development Agency.

*Barker P.P. and R. W.De Mello,* "*Determining the Impact of Distributed Generation on Power Systems: I. Radial Distribution Systems,*" Proceedings of IEEE Power Engineering Society Summer Meeting, Seattle, Vol. 3, 16-20 July 2000, pp. 1645-1656. doi:10.1109/PESS.2000.868775.

*Bastiao F., P. Cruz and R. Fiteiro,* "*Impact of Distributed Generation on Distribution Networks,*" Proceedings of the 5th International Conference on European Electricity Market, Lisboa, 28-30 May 2008, pp. 1-6. doi:10.1109/EEM.2008.4579049.

*Bardhi, A. R. Bualoti, and M. Qemali*, "*Simulation of wind power generation*", Vol. 2, no. 3, pp. 365-380 ISSN 2072-5620, BSHV, 2010.

*Çelo M., E. Zeqo, A. Ibrahimi and R. Bualoti* "*The Impact of Small HPP's in the Energy Balance of Albanian Power System*", International Conference on Renewable Energies and Power Quality (ICREPQ'13) Bilbao (Spain), 20th to 22th March, 2013

ERE, 2006 – 2013*, Annual Report.*

ESHA (European Small Hydro Association), "*Guide on How to Develop a Small Hydropower Plant*", 2004.

*Frashëri A. 2001,* "*Outlook on Principles of Integrated and Cascade Use of Geothermal Energy of Low Enthalpy in Albania*", 26th Stanford Workshop on Geothermal Reservoir Engineering. 29-31 January, 2001, California, USA.

*Heanel R. and S. Hurter,* (*Eds*)*,* "*Atlas of Geothermal Resouces in Europe*". European Commission, International Heat Flow Commission, Hanover 2002.

KESH, 2006 – 2013*, Annual Report*.

*Khoan T. and M. Vaziri, "Effects of Dispersed Generation (DG) on Distribution Systems," IEEE in Power Engineering Society General Meeting, Sacramento, 16 June 2005,Vol. 3,pp.2173-2178.*

Kumar A A., A.R. Massannagari, A.K. Srivastava and N.N. Schulz, "Impact of Biomass Based Distributed Generation on Electrical Grid," Proceedings of Clean Technology Conference, Boston, 1-5 June 2008, pp. 222-225.

# Feed-in Tariff Reform in PV Sector: What's the Next Step?

**Dr. Anton Ming-Zhi GAO**

Assistant Professor

The Institute of Law for Science and Technology (ILST), National Tsing Hua University, Taiwan [1]

Tel: +886 (03) 571-5131#42430
Fax: + 886(03)5629380
e-mail: antongao@mx.nthu.edu.tw

Address: 101, Sec. 2, Kuang-Fu Road, HsinChu 30013, Taiwan

*(This article is funded by the National Science Council, Taiwan, Project Number: 103-2410-H-007 -016 -MY2; 103-3113-P-007 -006 –)*

**Abstract:** Photovoltaic (PV) technology is a promising solution for climate change and energy security issues but is expensive to develop. Feed-in tariff (FIT) schemes have become the most successful supportive policy approach to promoting PV but have also led to over-development. This article provides an overview of the development and implementation of FIT in major countries and identifies design elements affected by FIT reforms. It is possible to predict the next FIT reforms and evaluate if their extent is appropriate. This guidance may be helpful for FIT adopters, including Taiwan, Japan, Germany and China, to refine their schemes and promote sustainable PV development. Finally, a combination scheme of FIT and FIT-indexed tendering could be a way-out to take into account of both the advantage and disadvantage of FIT, and to avoid the weakness to set a reasonable but not too high tariff for the development of PV.

*Keywords:* feed in tariff (FIT), photovoltaic technology, tendering, renewable portfolio standards, RPS

## 1. Introduction

The technology solution approach is the prevalent approach to tackling climate change and reducing greenhouse gas emissions around the globe. For instance, the famous 2050 blue map scenario and the six key emission reduction technologies proposed by the Organization for Economic Co-operation and Development (OECD) and the International Energy Agency (IEA) are shown in almost all climate-change-related international conferences or meetings [1]. Of the six types of technologies, much attention has been paid to the development of renewable energy (RE), which is ranked as the third most-important way of achieving the 2050 emission reduction goals.

Further on, policy measures and legal mechanisms are developed to facilitate the deployment cycle of such technology from the upstream research and development (R&D) stage to the downstream demonstration (demo) and large-scale market deployment stages. Similarly, the OECD and IEA also provide a very famous and comprehensive figure of "Market Deployment Policy Instruments" to guide each country in cultivating the potential of RE, including important measures such as capital grants, obligations, and guaranteed prices or feed-in tariffs (FIT) [2]. This article found that this figure, in spite of being a bit old-fashioned, is still dominant internationally with regard to promoting RE. However, the importance of each scheme in the promotion of RE is undergoing a process of evolution. Early stage schemes emphasize the role of net-metering and grants to promote R&D, demos, and small-scale market deployment, whereas new paradigms of large-scale market deployment focus on the role of FIT, renewable portfolio standards (RPS) or tendering schemes [3]. After much debate about the effectiveness of these mechanisms, FIT, which is promoted by Germany, a second comer of adopting FIT, has become the most successful and prevalent approach to the promotion of RE around the globe [4]. Due to the high cost and long investment recovery period associated with photovoltaic (PV) technology, FIT has almost always played an important role in the policy arena to facilitate the development of PV technologies in the past decades [5]. Even countries and several states in the US that insisted on RPS in the past, such as California, Japan, and the UK, have recently begun to move toward FIT [6]. FIT (92 countries or states) beats RPS (71 countries or states) in the promotion of RE.

However, it seems PV FIT schemes have become too popular, prevalent, and successful, thereby becoming very controversial in many countries. Because the wrong price signals are sent by pre-set tariffs that are too favorable, many countries are now facing PV booms. For instance, Spain famously experienced dramatic growth in PV from 2007 to 2008 but this boom became a tragedy because Spain's solar bubble has since collapsed [7]. Similar stories have been told in Germany [8], Italy [9], the Czech Republic [10], the UK [11], France [12], and South Korea [13]. To respond, PV FIT countries such as Germany, Spain, and the UK adopted further measures to revise and fine-tune their FIT schemes, while countries like France and Taiwan moved to a combined FIT and tendering scheme. South Korea went even further, abolishing FIT and changing to RPS, while China has also recently begun considering a RPS regime. The sudden "rise and fall" of PV FIT within such a short time frame really drew my interest and motivated this research on its reform.

This article aims to study the historical development and implementation of FIT schemes in major FIT countries including Germany, Italy, France, Spain, and the UK over the past decades, as well as to identify the specific design elements affected by different rounds of FIT reform. In particular, this article will dismantle the design elements of FIT and provide guidance on "how" to fine-tune "which" one(s) first, at "which boom stage," when facing the PV boom problem. Such specific step-by-step guidance may also be helpful for late-comers and prospective participants to FIT to refine their scheme and promote the sustainable development of PV. Further, perhaps these lessons can be applicable to some early PV FIT adopters, such as Spain and Germany, with regard to the next steps of their PV FIT schemes. After this thorough investigation, it is possible to predict the next FIT reforms in each country and evaluate their extent is too great or insufficient.

The remainder of this article is structured as follows. First, the article will provide a summary of the main findings concerning FIT design elements in five countries based on at least three rounds of FIT scheme implementation cycles and more than twenty related legislations and ordinances. Although the main discussion in the literature focuses on the core of FIT scheme, i.e., "tariffs" (rate schedules), there are other elements that can be used to control PV booms, including tariff degression mechanisms, tariff progression mechanisms, technology eligibility, FIT duration, capacity caps (hard or soft), and loading hours. This article will further investigate the evolution of the favorability of each element from the past until the present. Apparently, many of the elements have progressed from insufficient to excessive favorability and finally adjusted to more reasonable and rational levels. After observing such patterns, two-stage (before/after PV boom) and five-stage step-by-step guides will be provided to help countries facing turmoil in PV proliferation under feed-in tariff schemes. Furthermore, this article then will use these guides, particularly the five-stage step-by-step one, to discuss the "assessment" function in each major FIT country and evaluate its application to other FIT countries such as Taiwan, South Korea, and China. Finally, this article will provide several final remarks.

## 2. Research scope and context

*2.1 Historical evolution of PV FIT schemes in five major countries*

This article has carefully studied FIT schemes and their implementation cycles over the past twenty years in five FIT countries. To a considerable degree, the cycles are quite similar.

- In the early stages, in the 1990s or early 2000s, each element of the FIT mechanism was insufficient and unable to promote the development of PV.
- A more favorable FIT scheme came into play (mostly around the time of the Renewable Electricity Directive of 2001 or the Kyoto Protocol of 2005).
- The proliferation of PV, and bubble, spread like wildfire, with many countries adopting FIT schemes.
- Strong intervention from governments led to the decline and suffering of the PV industry.

For instance, the first generation of FIT schemes introduced in France by a law in 2000 and realized in a 2002 ordinance[69] was insufficient to promote RE. Then, an upgraded version promulgated in 2006[70] led to the PV golden age and boom. Two intervention and rationalization measures in 2010[71]

[69] Loi n°2000-108 relative à la modernisation et au développement du service public de l'électricité (Act 2000 - 108 on the modernization and development of the public electricity supply; 2000); Décret n°2000-1196 fixant par catégorie d'installations les limites de puissance des installations pouvants bénéficier de l'obligation d'achat d'électricité (Decree on capacity limits for different categories of renewable energy plants that are eligible for the feed-in tariff; 2000); Annexe 1 Tarifs mentionnés a l'article 5 de l'arrêté, Arrêté du 13 mars 2002; Loi n°2000-108 relative à la modernisation et au développement du service public de l'électricité (Act 2000 - 108 on the modernization and development of the public electricity supply; 2000); Décret n°2000-1196 fixant par catégorie d'installations les limites de puissance des installations pouvants bénéficier de l'obligation d'achat d'électricité (Decree on capacity limits for different categories of renewable energy plants that are eligible for the FIT; 2000).

[70] Arrêté du 10 juillet 2006 fixant les conditions d'achat de l'électricité produite par les installations utilisant l'énergie radiative du soleil (Order on the eligibility requirements for solar energy systems; 10th July 2006); Arrêté du 10 juillet 2006 fixant les conditions d'achat de l'électricité produite par les installations utilisant l'énergie radiative du soleil (Order on the eligibility requirements for solar energy systems; 10th July 2006).

[71] Arrêté du 31 août 2010 fixant les conditions d'achat de l'électricité produite par les installations utilisant

and in 2011[72] led to an outcry from the PV industry. A similar cycle of the creation and implementation of FIT laws, a PV boom, and a round of reforms can be also found in Germany[73], Spain[74], Italy[75], and the UK[76]. We have investigated the numerous PV cycles of key FIT countries including Spain, the UK, Germany, Italy, France, Taiwan, South Korea, and Japan.

*2.2 A thorough understanding of the comprehensive design elements of FIT schemes*

Because the core of FIT is the "tariff" element, thus far, most countries have focused on the tariff element, i.e., the rate schedule, of the FIT scheme during the PV booms [14]. However, in order to address the proliferation of PV, other FIT design elements can also be used.

In addition to the overall cycle noted above, this article also has investigated each element of the FIT scheme in detailed among including not only representative European countries but also Asian

l'énergie radiative du soleil (Order on the eligibility requirements for solar energy systems (31st August 2010); Décret n° 2010-1510 suspendant l'obligation d'achat de l'électricité produite par certaines installations utilisant l'énergie radiative du soleil (Decree 2010-1510 suspending the feed-in tariff for solar energy; 2010); Arrêté du 31 août 2010 fixant les conditions d'achat de l'électricité produite par les installations utilisant l'énergie radiative du soleil (Order on the eligibility requirements for solar energy systems (31st August 2010); Décret n° 2010-1510 suspendant l'obligation d'achat de l'électricité produite par certaines installations utilisant l'énergie radiative du soleil (Decree 2010-1510 suspending the feed-in tariff for solar energy; 2010).

[72] Arrêté du 4 mars 2011 fixant les conditions d'achat de l'électricité produite par les installations utilisant l'énergie radiative du soleil (Order on the eligibility requirements for solar energy systems; 4th March 2011) CRE, Cahier des charges de l'appel d'offres portant sur la réalisation et l'exploitation d'installations photovoltaïques sur bâtiment de puissance crête comprise entre 100 et 250 kW, available at: http://www.cre.fr/documents/appels-d-offres/appel-d-offres-portant-sur-des-installations-photovoltaiques-sur-batiment-de-puissance-crete-comprise-entre-100-et-250-kw/cahier-des-charges-de-l-appel-d-offres-portant-sur-des-installations-photovoltaiques-sur-batiment-de-puissance-crete-comprise-entre-100-et-250-kw (last visited July 10, 2014). (Cahier des charges de l'appel d'offres portant sur la réalisation et l'exploitation d'installations de production d'électricité à partir de l'énergie solaire d'une puissance supérieure à 250 kWc, available at: http://www.cre.fr/documents/appels-d-offres/appel-d-offres-portant-sur-la-realisation-et-l-exploitation-d-installations-de-production-d-electricite-a-partir-de-l-energie-solaire-d-une-puissance-superieure-a-250-kwc/cahier-des-charges (last visited July 10, 2014).

[73] Stromeinspeisungsgesetz (Law on feeding electricity from renewable resources into the public grid)1991; Erneuerbare Energien Gesetz [EEG] (Renewable Energy Sources Act) 2000; Erneuerbare Energien Gesetz [EEG] (Renewable Energy Sources Act) 2004; Erneuerbare Energien Gesetz [EEG] (Renewable Energy Sources Act) 2008; Erneuerbare Energien Gesetz [EEG] (Renewable Energy Sources Act) 2009; Erneuerbare Energien Gesetz [EEG] (Renewable Energy Sources Act) 2010; Erneuerbare Energien Gesetz [EEG] (Renewable Energy Sources Act) 2011; Erneuerbare Energien Gesetz [EEG] (Renewable Energy Sources Act) 2012.

[74] Ley del Sector Eléctrico (Law on the Electricity Sector) 1997; Real Decreto 436/2004, por el que se establece la metodología para la actualización y sistematización del régimen jurídico y económico de la actividad de producción de energía eléctrica en régimen especial (Royal Decree 436/2004 establishing the legal and economic framework for the operation of generators under "Régimen Especial"); Real Decreto 661/2007, por el que se regula la actividad de producción de energía eléctrica en régimen especial (Royal Decree 661/2007, on electricity production through a special feed-in tariff scheme ("Régimen Especial"); Real Decreto 1578/2008, de retribución de la actividad de producción de energía eléctrica mediante tecnología solar fotovoltaica para instalaciones posteriores a la fecha límite de mantenimiento de la retribución del Real Decreto 661/2007, para dicha tecnología (Royal Decree 1578/2008 on photovoltaic electricity generation); Real Decreto 1565/2010 por el que se regulan y modifican determinados aspectos relativos a la actividad de producción de energía eléctrica en régimen especial (Royal Decree 1565/2010, modifying certain aspects of the operation of generators under "Régimen Especial").

[75] *Decreto 28 luglio 2005. Criteri per l'incentivazione della produzione di energia elettrica mediante conversione* fotovoltaica della fonte solare ("DM 28/07/05"), available online at: http://www.parcodelpo-vcal.it/Word/Scheda_fotovoltaico.pdf; Delibera n. 34/05. Modalità e condizioni economiche per il ritiro dell'energia elettrica di cui all'articolo 13, commi 3 e 4, del decreto legislativo 29 dicembre 2003, n. 387, e al comma 41 della legge 23 agosto 2004, n. 239, available online at: http://www.autorita.energia.it/docs/05/188-05.htm (last visited: July 10, 2014). Decreto Fotovoltaico 22/02/07. DM 06/08/10.

DM 05/05/11. DM 05/07/12 Decreto Ministeriale 5 luglio 2012. Attuazione dell'art. 15 del decreto legislativo 3 marzo 2011 recante incentivazione della produzione di energia elettrica da impianti solari fotovoltaici (c.d. Quinto Conto Energia) - Ministerial Decree 5 July 2012. Enactment of Art 25 of Legislative Decree 28/2011 related to the incentive system for PV installations (Quinto Conto Energia)). DM 06/07/12. ARG/elt 199/11. L 239/04. DL 387/03. DM 05/07/12. DM 06/07/12. AEEG 34/05. AEEG 280/07. ARG/elt 199/11.

[76] Energy Act 2010. Energy Act 2011. Department of Energy & Climate Change, Summary of Responses to the Fast-Track Consultation and Government Response, at 6, *available online at*: http://www.decc.gov.uk/assets/decc/Consultations/fits-review/fits-fast-track-government-response---final.pdf (last visited: July 10, 2014). Consultation on fast-track review of FITs for small scale low carbon electricity (11D/0038). FITs Comprehensive Review Phase 1. FITs Comprehensive Review Phase 2A. FITs Comprehensive Review Phase 2B.

countries. This understanding of the design elements can offer a more sophisticated solution in order to promote the sustainable development of PV. The design elements have been provided by many important literature[77]. However, in these literature, these FIT elements are discussed in a manner to apply to "all" RES, rather than PV. Apparently, not all of design elements are of the same important to PV. For instance, the mechanism of "Front-end Loading" 78is more related to wind farm than PV.

After a preliminary filtering of the legislations mentioned above, taking into account the design elements of the key literature, this article identifies the following PV FIT elements: eligibility, duration, tariff elements (including tariff rate schedules, tariff degressions, and Consumer Price index (CPI) response schemes), caps (soft and hard), and loading hour limitation. This article will further investigate how legislation in different countries used each element to refine FIT and address the PV proliferation issues.

## 3. Results

*3.1 FIT reform before/after PV proliferation in Spain, Italy, the UK, Germany, and France*

Historical observation of PV-focused FIT reforms can provide tremendously useful lessons to guide each country in adjusting its own FIT scheme and ensuring the sustainable development of PV. Instinctively, curbing the PV boom requires narrowing and cutting the incentives to PV as much as possible, such as by cutting tariffs and the duration of subsidies or narrowing the scope of eligibility, among other options. However, because the main goal of FIT reform is to "rationalize" PV development, certain "extra" incentives may be also introduced, such as the encouragement of self-use PV, responsive tariff degressions, soft caps, favorable scheme for Building-integrated photovoltaic (BIPV), etc. A comprehensive table comparing reforms before and after PV booms is illustrated in Table 1.

*3.2 Step-by-step guidance to help countries facing PV proliferation turmoil under feed-in tariff schemes*

Interactions among the reforms of all "design" elements can be very dynamic and can be regarded as a gradual process. Because painful PV booms usually resulted from extraordinarily high "tariffs," a reasonable counter-measure could be to focus on the "tariff elements," including mainly tariff schedules and tariff degression, in Figure 1, in the first phase of reform. However, if the PV boom remains, each country would begin to address such challenges by dealing with other FIT elements (in Figure 1) in the latter phases (phases II and III). "Hard caps" could be considered to be the ultimate weapon to reform FIT. However, continuous PV booms could also cause changes to existing PV FIT schemes through the incorporation of tendering schemes. It seems that in certain regimes, a FIT with a cap may be considered to be insufficient to tackle PV booms. In this case, a combined FIT and tendering scheme is set up. Finally, the most serious scenario would be to totally give up on FIT reform efforts and abandon FIT schemes altogether, switching to other large-scale deployment mechanisms such as RPS or tendering schemes. The step-by-step guidance to help countries facing PV proliferation turmoil under feed-in tariff schemes is illustrated in Table 2.

*3.3 Summary*

Combined with the comprehensive design elements noted above, the interaction between FIT laws and their implementation can provide tremendously useful lessons on how countries can reform their faulty FIT schemes gradually rather than suddenly and reduce harmful impacts on the PV investment environment. For instance, Germany acquired a reputation of being a "capless" FIT before the Renewable Energy Act of 2012 (EEG 2012), whose reform measures maintain tariff cuts, tariff degression schemes and soft caps. However, because these measures cannot curb the PV boom, Germany is beginning to move into Phase III and the introduction of FIT with hard cap. Thus, for FIT countries, these two tables can be very useful.

In addition, these two tables are not only meaningful for European FIT countries, but can be also used to provide lessons for the rest of the world. For instance, when talking about FIT reform, most governments do not pay too much attention to the possibility of reforming existing schemes by dealing with design elements and rather prefer to consider other alternative schemes. For instance, the South Korean government began to adopt a series of legal programs to establish a FIT scheme under the 2001 Electricity Act,[79] the 2002 Revision of the New & Renewable Energy Law,[80] the "Utilization of New and Renewable Energy for Generation of Electric Power Standard Tariff Guide"[81] and other schemes[82].

[79] Article 49 of Electric Business Law.

[80] Article 17 of the Development, Use, Supply and Promotion of New and Renewable Energy Law.

[81] 'Utilization of New and Renewable Energy for Generation of Electric Power Standard Tariff Guide' (Ministry of Commerce, Industry and Energy Official Notice No. 2002-108, 2002.5.29, 2002.9.26 amendment notification, 2003.10.9, 2004.10.19 amendment)

However, the rapid development of PV in 2008 [13] led to a dramatic FIT rate cut for PV in 2008 [18]. In October 2008, the South Korean government slashed the feed-in tariff by 8-30%, and, as a result, the Korean PV market installed only 10MW between October 2008 and March 2009 [19]. Even so, South Korea began to consider changing its FIT scheme to an RPS scheme. An RPS law, the Act on the Promotion of the Development, Use, and Diffusion of New and Renewable Energy, Amended by Act No. 10253, 12 April 2010, was adopted in 2010 and became effective in January 2012.

#### *3.3.1 FIT u-turns*

This type of shift in thought and FIT u-turn can also be found in Taiwan and China. For instance, the Taiwanese Parliament passed the Renewable Energy Act in mid-2009 and it came into effect in mid-2010. However, due to the preferential PV tariff in the initial stage, it led to a "dash for PV" in 2010. The originally scheduled target for 2010 was 75MW but the accelerated development of PV resulted in 754MW being reached, which is equivalent to the target for the years between 2015 (430MW) and 2020 (1250MW). Then, suddenly, Taiwan adopted a combine FIT and tendering scheme in 2011[83]. Moreover, the introduction of RPS in China has also been discussed recently [20].

#### *3.3.2 Lack of understanding of detailed FIT design and essence in the rest of the world*

Such FIT u-turn problems in these Asian countries demonstrate their lack of understanding of the essence of FIT and its detailed European design elements. Most European FIT countries continue to employ FIT schemes despite several years of PV booms. The solution seems to lie in adjusting the FIT scheme itself. Comparatively, the aforementioned Asian countries decided to have a FIT u-turn only after short PV booms. These countries seem to ignore the inherently adjustable nature of FIT design elements. With proper adjustments, FIT functioning can more closely approximate the "quantity limitation" of tendering and RPS schemes under the quota systems. Finally, such proportionate measures may also lead to "using a sledgehammer to crack a nut" and result in a "chilling" effect to on PV development. In terms of investment security, gradual reforms of existing regimes could be much better than sudden jumps into other regimes. The FIT countries should learn from the lessons of European-style step-by-step FIT reforms.

[82] E.g., Articles 4 and 10 of Other Energy Support Business Operation Outline (MCIE Notice No. 2002-034).

[83] Phase I of Bidding Guideline of PV Installations Electricity Generation Plant of 2011, Ministry of Economic Affairs (經濟部一百年第一期太陽光電發電設備競標作業要點), available at: http://web3.moeaboe.gov.tw/ECW/populace/content/Content.aspx?menu_id=1098

## 4. Conclusion and future perspectives of FIT

### *4.1 Bad years for PV*

This year will be a bad year for PV [21]. Although many countries announced new energy policies in favor of RE after the Fukushima nuclear crisis in 2011, many important PV companies are facing a difficult financial situation [22]. In this "tough" moment for the PV industry, how FIT schemes are adjusted to respond to hard times will greatly affect the future of the PV industry and its development. Many important countries are facing a critical decision of choosing between dropping FIT or modifying it. This article aims to provide a simple step-by-step guide or roadmap to help these FIT countries refine their FIT schemes before dropping them.

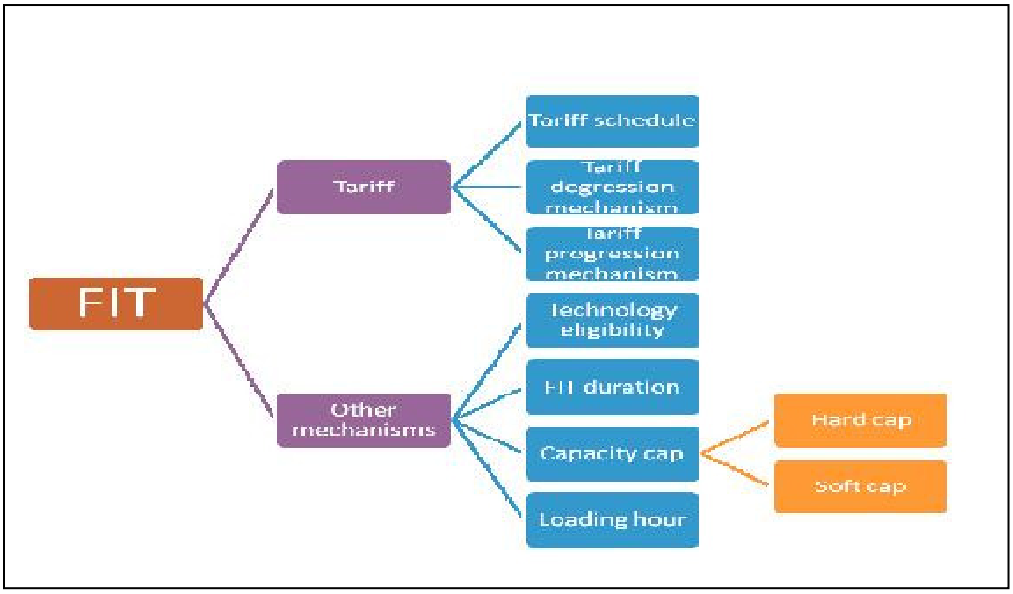
### *4.2 Important Research Findings*

From the in-depth investigation into the development, incentive schemes and cycles of FIT schemes in these five European countries, this article found that it is possible to identify similarities among these countries when conducting FIT reform, even during this year, which has been characterized by the unusual European debt crisis and the post-Fukushima elements, among other factors. FIT schemes have their own way of "evolving." These similarities can also provide some lessons for other non-European FIT countries in the modification of their own FIT schemes.

### *4.3 A new paradigm for PV: A new wave of FIT-based tendering scheme to alleviate PV bubbles and contribute to the sustainable development of the PV industry*

Despite these efforts to improve FIT, there seem to be limits to altering FIT schemes to prevent PV proliferation and bubbles in certain countries. Among the four main types of subsidy schemes to promote large-scale deployment of PV (including FIT, feed in premium (FIP), tendering, and RPS), there is a trend in moving from pure FIT schemes to mixed schemes combining FIT and tendering or pure tendering schemes. The use of PV tendering over traditional German-style FIT schemes is interesting; this option is favorable for wind power; however, led by the pioneering efforts of France and Taiwan, this scheme is now gaining popularity in many countries around the world, such as Australia [23], the US state of California [24], South Africa [25], and India [26].

**Figure 1: Comprehensive illustration of the elements of FIT.**




For a variety of reasons, it is very difficult for governments to set proper tariff levels and appropriate price signals to control the proliferation of PV. A combined pre-set tariff level under FIT and a competition value under a tendering scheme, i.e., a FIT-based tendering scheme, could be very helpful in controlling PV booms and contributing to the sustainable development of the PV industry, which cannot be achieved under a FIT-scheme with cap. This gradual development of PV can help prevent hikes in the electricity bills of citizens, improve public perceptions, and encourage enduring public support for the development of PV. Will this method of promoting PV become a new paradigm? Continual observation is required in the future.

**Table 1: FIT reforms before/after PV proliferation in Spain, Italy, the UK, Germany, and France** (Source: compiled by the author).

| Design elements | | Before PV boom | After PV boom |
|---|---|---|---|
| Subsidized entity (eligibility) | | All PV installations (ground-mounted, partly integrated, rooftop, large- and small-scale BIPV) | Small-scale rooftop and BIPV installations are prioritized<br>Self-use types are more encouraged<br>Restriction on large-scale rooftop, large and small-scale ground-mounted, farmland types, or PV installations in ecologically sensitive locations |
| Duration | | 20 years, 25 years, and 30 years | Maintain subsidy duration<br>Shorten subsidy duration |
| Tariff schedule | Rate scheme | Favorable<br>Multi-year rate scheme in advance: originally designed for long-term application<br>Differentiation of tariffs for each type of installation | Large cuts<br>Promptly revise the multi-year rate scheme<br>Singularization on the ground-mounted rate; maintain tariff differentiation for rooftop and BIPV installations<br>Bidding system paired with a hard cap mechanism under high governmental control |
| | Tariff degression for new contractors | Pre-scheduled tariff degression rate<br>Yearly or biennial degression | Promptly increase and aggressively revise the degression rate<br>Shorter degression periods, such as half year, month, or season<br>Implement responsive tariff degression rate |
| | Increased tariff rate for signed contracts | In place or none | Maintained<br>Annulled |
| Hard or soft cap | | No cap or soft cap | Introduction of soft cap for installations, such as responsive tariff degression with seasonal or annual caps<br>Introduction of hard cap, such as total caps for a certain length, annual caps, or seasonal caps<br>Other types of hard caps, such as FIT total budget caps |
| Installation annual loading hour cap | | None | Yes |

**Table 2: Five-stage plan to reform feed-in tariff schemes** (Source: compiled by the author).

| Phase-by-phase reform in Germany, Spain, France, the UK, and Italy | |
|---|---|
| Phase I (after the PV boom) | Tariff cut or prompt introduction of a tariff degression scheme |
| Phase II | Creation of annual loading hour caps |
| | Responsive tariff degression and soft caps |
| | Aggressive tariff degression schemes |
| | Cancellation of tariff increasing schemes |
| Phase III | Restrictions on eligibility requirements (favoring small-scale rooftop (or BIPV) PV installations, more restrictions on farmland and ground-mounted installations) |
| | Creation of hard caps |
| | Creation of annual loading hour caps |
| | Retroactive tariff degression |
| Phase IV | Combined FIT, bidding system, and hard cap schemes |
| Phase V | Abolishment of FIT<br>Move to tendering only or RPS schemes |

## References


[1] OECD/IEA. Energy technology perspectives 2010. Key graphs, page 2. http://www.iea.org/techno/etp/etp10/key_figures.pdf. Accessed May 2014.

[2] OECD/IEA. Renewable energy: Market & policy trends in IEA countries. 2004; 85.

[3] Fräss-Ehrfeld, C. Renewable Energy Sources: A Chance to Combat Climate Change. 2009; 262:3.
[4] EU Commission 2008. The support of electricity from renewable energy sources. Commission staff working document, accompanying document to the proposal for directive of the European Parliament and the Council on the Promotion of the Use of Energy from Renewable Sources, SEC; 2008; 57. 23.01.2008, Brussels. Available online.

[5] Committee on Assessment of Resource Needs for Fuel Cell and Hydrogen Technologies. Transitions to alternative transportation technologies: A focus on hydrogen. National Research Council, 2008; p. 25-26.

[6] REN21, Global Status Report of 2012. 2012; 118.

Mettam GR, Adams LB. How to prepare an electronic version of your article. In: Jones BS, Smith RZ, editors.Introduction to the electronic age, New York: E-Publishing Inc; 1999, p. 281–304.

[7] Plumer, B. Lessons from Spain's solar bubble. The New Republic; 2009. http://www.tnr.com/blog/lessons-spains-solar-bubble.

[8] Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. Federal Cabinet confirms adaptation concerning solar support and green electricity privilege- New provisions announced for biogas support from 2012. http://www.bmu.de/english/current_press_releases/pm/47055.php (last visited July 10, 2014).

[9] Communication from the Commission to the Council and the European Parliament. The renewable energy progress report: Commission report in accordance with Article 3 of Directive 2001/77/EC, Article 4(2) of Directive 2003/30/EC and on the implementation of the EU Biomass Action Plan. COM; 2005:628 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2009:0192:FIN:EN:PDF (last visited July 10, 2014). {SEC(2009)503 final}.

[10] Dorda, J. Czech Republic 'taming'solar boom. PV Tech; 2010. http://www.pv-tech.org/guest_blog/guest_bog_iii_czech_republic_taming_solar_boom.

[11] Britain to slash feed-in tariff rates for PV system over 50kW. SolarServer. http://www.solarserver.com/solar-magazine/solar-news/current/2011/kw12/britain-to-slash-feed-in-tariff-rates-for-pv-systems-over-50-kw.html (last visited July 10, 2014).

[12] Gipe, P. Flexible French FITs: Higher biogas--lower PV tariffs coming. Alliance for Renewable Energy; 2011. http://www.allianceforrenewableenergy.org/2011/03/flexible-french-fits-higher-biogas-lower-pv-tariffs-coming.html (last visited July 10, 2014).

[13] Agrawal, B, Tiwari GN. Building integrated photovoltaic thermal systems: For sustainable developments.RSC Publishing; 2010:188.

[14] Fräss-Ehrfeld, C. Renewable energy sources: a chance to combat climate change 2009;262-3:268; BMU, Novellierung des EEG 2012 durch die PV-Novelle, http://www.erneuerbare-energien.de/erneuerbare_energien/pv-novelle_2012/doc/48542.php. (last visited July 10, 2014).

[15] Mendon, M. Feed-in tarriffs: Accelerating the deplpyment of renewable energy. In Couture, TD, Cory, K, Kreylick, C, Williams, E. A policymaker's guide to feed-in tariff policy design. NREL; 2010. P. 89-102 http://www.energy.eu/publications/A_Policymakers_Guide_to_Feed-in_Tariffs_NREL.pdf.

[16] Klein, A. Feed-In Tariff Designs. VMD Publishing; 2008.

[17] Mendon, M. Powering the green economy: The feed-in tariff handbook. London: Earthscan; 2010.

[18] Burgermeister J. South Korea taps Germany to help grow its solar industry. Renewable Energy World; 2009. http://www.renewableenergyworld.com/rea/news/article/2009/04/south-korea-looks-to-germany-to-help-grow-its-solar-industry. (Visited on September 1, 2012).

[19] Choudhury, N. South Korea. PV Tech; 2011. http://www.pv-tech.org/tariff_watch/south_korea (visited on September 1, 2012).

[20] Patton, D. China debates renewables quotas to cut wind curtailment. Recharge; 2012. http://www.rechargenews.com/wind/article1297395.ece; Li Qonghui Said: Required RPS Policy in China. China Renewable Energy Information Portal http://en.cnrec.info/policy/policyinterpretation/2012-06-25-267.html

[21] McCarrick, D. A bad year for solar energy. Environmental Leader; 2011. http://www.environmentalleader.com/2011/12/13/a-bad-year-for-solar-energy/.

[22] How first solar lost more than $10 billion in market cap in one year. World News; 2012. http://article.wn.com/view/2012/05/04/How_First_Solar_Lost_More_Than_10_Billion_In_Market_Cap_In_O/.

[23] Thiess-Silex Solar Consortium confirmed as major bidder to build large scale solar photovoltaic (PV) power station in Australia. 2010. http://www.aeol.com.au/databases/news/thiess_silex_solar_sonsortium_confirmed.htm.

[24] Winning bids for California's RAM come in under USD 0.089/kWh. SolarServer; 2012. http://www.solarserver.com/solar-magazine/solar-news/current/2012/kw14/winning-bids-for-californias-ram-come-in-under-usd-0089kwh.html.

[25] Solar Capital also successful in South African PV bid. PV Magazine; 2011. http://www.pv-magazine.com/news/details/beitrag/solar-capital-also-successful-in-south-african-pv-bid_100005222/#axzz1uFDSFBY1.

[26] India's Karnataka invites solar bids worth 80 MW. PV Magazine; 2011.

http://www.pv-magazine.com/news/details/beitrag/indias-karnataka-invites-solar-bids-worth-80-mw_100003925/#ixzz2NXqocgHT.

# Horizon scanning for social sustainability in the bioenergy value chain

**Elena FEDOROVA***

**Eva PONGRACZ**

Thule Institute, NorTech Oulu, FI-90014 University of Oulu, P.O.Box 7300, Finland
*Corresponding author, E-mail: elena.fedorova@oulu.fi

**Abstract:** This paper focuses on scanning and analyzing the horizon of social sustainability issues in order to provide a strategic background for anticipating future developments and thereby gain lead time. While environmental and economic impacts of bioenergy production have been studied and assessed for many years, the social aspects are still often neglected. There are substantial challenges in identifying and understanding the social impacts associated with bioenergy production activities. The increasing complexity of the bioenergy sector, uncertainty and the rise of hidden social issues created the growing demand for tools which can be used for anticipatory intelligence, such as modelling , tendency analyses, scanning and simulation tools. Using horizon scanning to identify potential social issues related to bioenergy sector will help to priorities future research and inform policy developers and strategic planners about upcoming emerging issues.

**Keywords:** Social sustainability, biofuels, policy -making

## 1. Introduction

During the last decade, high demand and growing potential for renewable energy exports from developing countries to the EU have raised public and private sector interest and attention to the issues surrounding the production of renewable fuels. Infrastructural and political factors in developing countries, especially variety of accessible land and low labour costs made biofuels production potentially highly profitable sector.

In 2011, 83% of the biofuels consumed in the EU were produced in the EU, one fifth of which was produced from imported feedstock, which is the first and most socially vulnerable stage of bioenergy value chain (EU Biofuel Annual, 2012). Considering the fact that the main countries exporting e.g. biodiesel to the EU are Brazil, Argentina and USA for soy biodiesel and bioethanol, and Indonesia and Malaysia for palm oil, it was noticed that the most alerting case of social injustice are coming from these regions.

While environmental and economic impacts of bioenergy production have been studied and assessed for many years, the social aspects are still often neglected. There are substantial challenges in identifying and understanding the social impacts associated with bioenergy production activities.

The increasing complexity of bioenergy sector, inherent uncertainty of supply and the rise of hidden social issues created the obvious growing demand for tools which can be used for anticipatory intelligence, such as modelling, tendency analyses, scanning and simulation tools.

Several European countries have initiated new horizon scanning programs, which may help to identify disruptive events which are not yet covered by policies. The main goal of bioenergy social sustainability horizon scanning is to develop an effective system for early identification of emerging issues within the bioenergy sector. Usage of effective horizon scanning systems will help to identify challenges, trends, opportunities and constraints, and dissemination of outcome materials among decision makers. It will also help to characterize the social impacts of bioenergy production throughout the entire life cycle of a product.

Bioenergy stakeholders not only represent the production sector, but also include consumers and affected parties along the entire value chain and particularly population groups whose living conditions are changing rapidly due to biofuel production expansion (Starick, 2013). As a result, both the landscape and society are constantly changing. All social impacts must be taken into account to ensure sustainable development under growing demand for new biofuel sources exploration.

Need for an effective social sustainability management tool has appeared. This paper concentrates on the horizon scanning methodology to define the most important social issues. Using the horizon scanning approach, we draw exploratory qualitative tendencies on the global level for the potential development of bioenergy industry in a social context.

## 2. Horizon Scanning

Usually, the word scanning is used in connection with frequent and systematic observation of a space or a body, in order to identify and differentiate phenomena that for some reason need to be watched more carefully in the nearest future. It is used not only for warfare tactics to develop early warning for attacks (for example radar) but also in medicine, where it is used to detect infected tissues (ultrasound, MRI etc).

In the dynamic and complex business world environmental scanning is often performed by strategic managers. Using systematic observation of developments helps them to identify threats or opportunities for the business earlier. Those threats and opportunities may appear in the immediate business environment, as well as can show other broader social or regulatory trends. (Rij, 2008)

Based on the previous experiences and results derived from UK Governmental Foresight Program, Professor Bill Sutherland from the University of Cambridge, together with other scientists and conservationists, developed a methodology which allows 'scanning the horizon' for potential issues that could become a problem for life on Earth in the near future. His methodical exercise helps to define what threats and opportunities might appear in the immediate future. Being surprised by unpredicted events can be costly and threaten the well-being of next generations. That is why the main idea behind horizon scanning is to spot issues that need attention and deeper research before they turn to major problems (Sutherland, 2009).

Table 1 describes the scanning stages of successful horizon scanning. It shows the methodology and approaches of each stage.

## 3. Scanning Social Sustainability for Bioenergy Sector

Although modern bioenergy represents only a small share, about 10% in the global use of biomass for energy, notwithstanding, it is rather diverse. On the other hand, increasing bioenergy supplies and bioenergy sources diversification is the main objective in the EU, which is financially supported and politically encouraged. This challenge of diversity of bioenergy sources and high demand create risks and undesirable developments if the expansion of bioenergy development is unregulated.

The roots of these issues can be traced back to 2006, when US president Bush declared a commitment to promote biofuels and the EU also followed with a similar commitment. Unfortunately, prior research on the potential impact of biofuels had not been done. This research was performed only after the strategic policy decision had been approved. This research revealed many negative environmental and socioeconomic impacts of biofuel expansion, which could have been prevented if the policy making was based on prior scientific research (Sutherland, 2009).

Using horizon scanning to identify potential social issues related to bioenergy sector may help to prioritise future research and inform policy developers and strategic planners about upcoming emerging issues.

The need for horizon scanning of social sustainability issues is illustrated by recent failure to predict the widespread of diverse biofuels which lead to rise of serious socioeconomic issues in developing countries

Social aspects of sustainable bioenergy involve embracing long- term considerations on well-being in order to safeguard affordable access to food and water, guaranteed energy supply and ensuring the safety of people, facilities, and regions. Also transparent participatory processes such as active engagement of stakeholders, establishing obligations to respect human rights, and embrace a long-term sustainability plan with periodic monitoring are helping are playing an import role for improving social sustainability of bioenergy sector.

Economic aspects of bioenergy sustainability include keeping reasonable production, distribution and consumption of goods and services. Marketing communication and consumer behaviour change which often affect rural economic development of bioenergy production regions are also very important aspects of sustainable bioenergy. Economic factors are influenced by government policies, technology, energy and raw material prices, demand resulting from diverse energy uses, and environmental costs (Dale, 2013).

## 4. Social Sustainability Issues Tree

The Horizon Scanning of social sustainability requires clear understanding of issues which create the highest concern among experts and stakeholders. Interactions and one-on-one interviews with major players of industry help to identify issues. The issues tree also reveals main driving forces and areas of biggest uncertainty and risks.

The specific set of social sustainability indicators is needed for socioeconomic assessment of bioenergy. Selecting appropriate and effective socioeconomic indicators may potentially help new bioenergy projects and stakeholders to identify and measure sustainability elements of their future developments.

**Table 1: A taxonomy of horizon-scanning methods used in identifying and prioritizing future possible issue (modified from, Sutherland 2009).**

| Scanning stage | Method | Approach |
|---|---|---|
| **Scoping** | Screening | Identify issues and explore important driving forces and areas of uncertainty |
| | Issue tree | Breaks down key question into a mutually exclusive and completely exhaustive set of sub-questions |
| **Gathering information** | Literature searches and state-of science reviews | Search for published threats and opportunities |
| | Expert workshops | Bring together team of experts to suggest possible issues based on their own experience and knowledge of the literature |
| **Watching trends** | Trend analysis | Study historic performance to identify future trends |
| **Making sense** | Global Tendency | Consider a range of possible future states and then explore the possible consequences of each |
| | Systems maps | Show the relationships between all factors influencing the central issue, and whether their effect is positive or negative |
| **Agree the response** | Backcasting | Describe a vision of the preferred future, then identify the key steps needed to reach it |

**Table 2: Bioenergy Social Sustainability Issue Tree.**

| SS Indicator | Threats | Opportunities |
|---|---|---|
| **Labour** | Labour rights | Training<br>Employment |
| **Human rights** | Indigenous Rights | Empowering |
| **Society** | Land Use Rights | Rural Development (local economy) |
| **Economy** | Food Security | Energy Security |
| **Product Development** | Consumer behavior change | Marketing Communication |
| **Environment** | Water Access | Diversity of Energy sources |

Each issue should go through a range of stages before it becomes a problem. A major challenge is to be ready at each stage against the costs of preparing for issues that may never become important. According to Sutherland's horizon scanning methodology, before setting an issue tree following key questions must be addressed:

- How the issue might impact on the interests of the organization
- If the issue does develop, how long would the organization need to respond to, for example, carry out research or national or regional develop policies?
- How much advance warning of developments is likely?
- What planning and preparation is appropriate considering the uncertainty, the speed at which it might develop, and the time required to act?
- What specific developments (such as extension of biofuel production in the region) could change the potential impacts or urgency?
- Is the current knowledge proportionate with the identified impact and urgency, and how should gaps be filled?

Following the above methodology, the list of bioenergy Social Sustainability (SS) indicator have been identified and described. After discussions and screening process, a large number of issues have been scaled down to 13 most important and critical. Table 2 represents the Social Sustainability Issue Tree, where these indicators are represented.

## 5. Threats

Among the selected indicators, the following have being identified as threats to future social sustainability: *Food Security, Access to Water, Labour Rights, Indigenous Rights, Land Use Rights and Consumer Behaviour*. Those indicators may potentially create many obstacles for biofuel production extension. The concern about Food Security comes from the fact that there is a growing tendency of using cropland to grow biofuel feedstock. This generates the threat that benefits of biofuel production may come at very high expense of food security particularly in developing countries where it will strongly affect the poorest part of population.

Biofuel production is also threatening the availability and fair distribution of other natural resources such as land and water. Many alarming cases are reported in third world countries, if large biofuel production enterprises are not taking into consideration the water needs of local population and, even worse, are moving entire communities from the land of their ancestors without any compensation. Recent conflicts in Africa demonstrate how Water Access and Land Rights Use are increasingly being politicized. Despite the existence of international human rights laws to regulate water and land use, the right of access to resources in rural African communities have often been compromised. (Mutopo 2014)

The threat of rising issues in diversity, equal opportunities and bridging Labour and Indigenous rights during bioenergy feedstock production are also associated with large-scale bioenergy feedstock production. The human costs of biofuels production are often overlooked by international organizations, focusing only on environmental and ecological effects. The lack of regulations and accountability on the part of the new biofuel production facilities allow them to ignore national labour laws even if it designed to protect the workers and local communities. Usage of low-skilled seasonal workers, many of whom are migrants or come from local indigenous communities and often settle for low-paid jobs with harsh working conditions is another sign of social injustice.

The threats that have not been dealing with on the site of biofuel production may have strong influence on the future of biofuels due to international society perception. Consumer Behaviour and perception of biofuel production is already been influenced by mass media and cases of social injustice during bioenergy feedstock production in developing countries is starting to attract a lot of attention. The increased amount of such information will definitely influence future acceptability of bioenergy and may change consumer behaviour toward it. Consumer demand is the strongest argument for a company to change to a more sustainable way (Belz & Schmidt-Riediger, 2010).

## 6. Opportunities

The number of opportunities related to expansion of biofuels has also been identified. They have been described in order of importance starting with the most essential one –Energy Security. Achieving energy security thought well developed bioenergy industry has a great potential in the future. Small scale projects as well as large enterprises may bring energy security benefits in a different way depending on geographical location and overall energy strategy in particular region. For many African countries a positive future trend can be achieved by moving from global fuel supply to local self-supply giving them energy security. Regional policy objective will move forward local biofuel production that increases rural access to energy, and not just rural access to income-generating activities.

Providing energy security will also lead to Rural Development opportunity. Sustainable development depends not only on a country or region's overall economic performance; but social aspects need to be incorporated at all levels as well. (Goldemberg 2010) In addition, it has been defined that there is a direct link between insufficient energy supply and poor development. New biofuel productions projects especially in developing countries tend to improve correlation between those two factors.

In Europe, Sweden serves as an excellent example how usage of small –scale biofuel production enterprises substantially improved rural communities’ well-being.

Many countries are already enjoying other benefits of biofuel production expansion – The Diversity of Energy Sources. This diversity has a potential to decrease the dependence from fossil fuel in many countries. The economy of Brazil is has been using a diversity of biofuels for almost 30 years. The future development of diversity of biofuels may provide benefits into both: improving the environment and increasing the security of supply. Potential developments of various feedstock sources and the use of a wide range of feedstock will reduce the level of risk across the biofuels value chain.

Marketing Communication is yet another opportunity for the bioenergy sector. Successfully applied marketing communications tools are able to provide free promotional materials offering “socially sustainable bioenergy” tips and advice on which bioenergy sources use brings benefits to everybody. What is especially important for managers in the bioenergy sector is to develop good practices of communicating specific technological and scientific concept and features of biofuels to non-technical audience.

Training and Employment are benefits that directly improve personal well-being and a successful future of bioenergy industry may boost the need for well-trained personnel. Due to a rising interest in green products and sustainability, and unstable oil prices, companies will look for individuals with professional training and education in bioenergy feedstock processing, biomass based materials and issues related to sustainable bioenergy development.

Empowering or transferring good practices, polices and knowledge from well developed countries to third world countries is another opportunity that biofuel production companies should consider while launching new business.

## 7. Bioenergy social sustainability global tendencies

Although the demand for biofuels grows globally, bioenergy establishment is still open to different socio-economic development opportunities as well as potentials threats. Understanding cause–effect relationships may potentially drive bioenergy development and explore different opportunities and threats and their effects on national, regional and local development. Qualitative bioenergy social sustainability global tendencies have been drafted based on the results of initial screening, literature review and establishment on issue tree, the possible future developments and trends of separate issues were identified and driving forces have been determined, summarized in Table 3.

Three global tendencies for future development of bioenergy in relationship with social sustainably and policy development have been identified. These tendencies make it possible to examine potential developments, opportunities and threats and investigate the possible future socio-economic consequences of various development options. Defining such tendencies can stimulate the social learning process among stakeholders and inhabitants in general and facilitate the decision-making process. (Sohl, 2010)

The main purpose for defining bioenergy social sustainability tendencies is not forecasting future event rather, but to present possible outcomes under specific circumstances, show particular driving forces that may potentially influence the path of bioenergy development upcoming trends.

Many potential future tendencies and scenarios for Bioenergy Sustainability have been published recently. However, most of them concentrate only on environmental and pure economic indicators and are primary based on quantitative forecast methods. The rise of public discussions on national, regional and local levels and the increase in bioenergy production calls for qualitative analyses that focus also on socio-economic issues.

## 8. Conservative Tendency

In the Conservative Tendency, the demand for biofuels across the regions is growing rapidly. The increase in oil prices will push nations to extended research and development (R&D) for new biofuel technologies that may support the expansion of biofuels supply. At the same time the productivity will be kept on the same level. Sustainable increase in bioenergy systems productively will be difficult to achieve since the focus is kept on the big picture not on the small issues. Conservative Tendency will lead to large profits for biofuel production corporations, particularly in Europe, where they already enjoy high subsidies from using "green products" and consumers do not know the hidden social cost of the product.

The biofuel industry will continue to stay capital-intensive with large-scale enterprises, highly centralised and high demand for year-round feedstock supply to keep operations efficient (Msangi, 2007). As been projected by many studies, the biggest increase in biofuel demand will come from transportation needs. (Fulton, 2004) It means that replacing liquid fuels for transport is the main priority.

As for today, the most efficient ethanol production can be achieved only using dedicated energy crops, such as corn and sugarcane. These dedicated ethanol crops likely to have the greatest and in many cases negative impact on social sustainably indicators including food and water supply security, labour and land rights.

**Table 3: Driving forces.**

| Forces | Conservative | Moderate | Decentralized |
|---|---|---|---|
| **Policy Development and Promotion** | Aggressive promotion, little policy development | Always in continued development | Well-developed in connection with small-scale bio projects |
| **Economic Development Growth** | High in developed countries, low in developing | Moderate growth globally | Moderate in developed countries, high in developing |
| **Technology Development and Transfer** | Technology development and transfer for large facilities | Well-balance | Good technology development and transfer of small plants |
| **Stakeholders Concern** | Stakeholders stay unaware of social issues | Moderate involvement | Highly concerned and engaged |

Many other social sustainability indicators may be affected along the entire biofuel production value chain especially, if the large biofuel production takes place on prime agricultural land and constantly trying to reduce transportation costs of both the feedstock and biofuel products to and from, centralised biofuel production facilities.

In this tendency willingness of farmers to sell land for profit will increase. Small farmers will not survive completion. Large-scale investors including main global energy market players and big agricultural enterprises are attracted by the land potential of southern regions. Their main purpose is to supply developed countries with biofuel products. The energy provider establishes business relationships with these agricultural and other biomass production enterprises. They have no concern about social sustainability.

The Conservative Tendency does not require strict policy development. The general policies are followed but social sustainability issues still not revealed to the consumer.

Driven by the progress in technological options, technology research and EU policy on subsides for green products the further enhancement of established bioenergy production technologies takes place. However technology development and transfer only put its efforts into improvement of large production facilities

Even though bioenergy production stakeholders groups are identified along the value chain, there is little cooperation on local or regional levels. Population stays unconcerned by questions of bioenergy provision and its effects on social sustainability, although big part of global population expresses environmental and economic concerns.

## 9. Moderate or Balanced Change Tendency

In a Moderate or Balanced Change Tendency, global demand for biofuels is growing but is supported by constantly updated EU policy on Social Sustainability. Current concerns about food-versus energy issues in developing countries and complexity of social issues control make decision-makers to move away from food agricultural biomass products. Non-food agricultural biomass, agricultural and food residues and waste are the main sources for bioenergy feedstock production.

EU created internationally accepted policy instruments for fair and sustainable land-use options for biofuel crop production. The International Standardization Organization (ISO) developed the ISO 13065 standard for sustainable bioenergy. Socio-economic aspects of bioenergy production, diverse value chains and use of bioenergy defined and implemented in harmony with sustainability criteria.

Stakeholders' involvement is moderate; however, growing interest from main players on local and regional levels in using biomass for energy provision prevails. Farmers, local business and local communities become key players for decision making on launching new bioenergy feedstock enterprises in the area. The size of enterprises is varying. Local power companies and municipalities play an important role in bioenergy providing. In general, the stakeholders' activities are selective but their overall commitment increases.

Large-scale foreign investors are faced with scepticism. Large enterprises are not welcome if they do not present structured and legally supported social programs complimenting new developments. The rate of social acceptability in the regions and consumer behaviour of the end-user will be the main driving force to sustain bioenergy production New facilities are installed on the basis of existing local infrastructure and logistics, bringing new technological and knowledge- based developments and involving local labour forces. Transfer of new technologies improves energy storage practices that allow energy supply to be based on demand. These new technologies are efficient.

Due to diversity and complexity of technological development stakeholders have to face new options and challenges. Small farmers and medium size companies in particular must choose among various economic opportunities, partnerships with various interested parties and social perception of feedstock production.

As a result of rapid bioenergy technologies development, bioenergy training and educational needs are high.

## 10. Small-scale Projects Shift Tendency

The number of negative cases of large-scale biofuel production is increased, EU policy development is pushed to its limits, biofuel production stakeholders are not happy and the consumers are concerned about social sustainability impacts from biofuel production. This could be a milestone where Small-scale Projects Shift tendency can become a solution for continuous sustainable development. EU develops strict policy into favour of decentralized bioenergy production.

Even now many scholars suggest that small-scale decentralized bioenergy production enterprises may have higher potential for social, economic and environmental sustainably development. Large centralized production systems are driven by production efficiency benefits with high commercial validity and have been criticized for hiding social cost of production and increasing risks of unsustainable practices. Small-scale decentralized projects support local and rural development, create employment, provide energy security, and contribute to climate change control. They could be better controlled by local governments.

The main constraint for Small-scale Projects Shift Tendency is the economic validity. However, there are many opportunities for combined benefits generated through value chains of integrating small-scale decentralized bioenergy projects with other production systems. Integrated bioenergy production, that includes closed loop models, allows waste materials from one process to be consumed as inputs in other production processes, increasing economic, social and environmental benefits. Synergies may create many opportunities along the bioenergy production chain, including feedstock production and bioenergy marketing and distribution. Those opportunities could be exploited by communities and other investors to minimize risk from decentralized bioenergy production. (Mangoyana, 2011)

Some examples of decentralized bioenergy production are seen in the small- to medium-scale biomass based heat and power plants in Europe, particularly in Sweden where number of small bioenergy enterprises successfully operate already for years. An important element of Small-scale Projects Shift Tendency is localization of ownership, overall management, production, and developed marketing communications system of bioenergy production organization.

Another positive outcome this Tendency can deliver is combination of right policy implementation at place and effective technology transfer practices. It becomes applicable not only to developed countries such as Sweden, but also to developing countries.

This tendency has a great potential if implemented properly. New investments into R&D of biofuel industry and knowledge based technology and practices transfers into agricultural sector from countries with proficient experience in biofuel production can lead to more favourable outcome, and enhance consumer-level impacts. Moreover, Small-scale Projects Shift Tendency seems to be the most acceptable from social sustainably development point of view. Issues like labour rights abuses, including child labour are easier to tackle on the small-scale.

Small-scale Projects Shift Tendency is possible if only current debates on Bioenergy Sustainability Policies and Certifications Systems will address the importance of expansion rate for biofuels and relate it to particular biofuel source, level of economic development, set-up of farming or industrial systems and available technologies of each country.

## 11. Conclusion

The objective of this research was to perform a horizon scanning of social sustainability issues in the bioenergy industry and its sectors. Bioenergy social sustainability reflects how production of biomass for energy impacts national, regional and local development. In particular, it shows how social sustainability aims to ensure food and energy security and addresses any issues in respect with labour, land and water rights.

Our study was inspired by the research of Professor Bill Sutherland from the University of Cambridge and his conservationists colleagues, who developed methodology which allows 'scanning the horizon' for potential issues that could become a problem in the near future. Bill Sutherland's horizon-scanning system allows the identification of challenges, trends, opportunities and constraints related to different sectors of bioenergy globally. We applied and developed his taxonomy of horizon-scanning methods into more generic approach for studying impact of social sustainability issues on future development of the bioenergy industry. Our research contributes with the Bioenergy Social Sustainability Tree and identified Three Global Tendencies for future development of bioenergy in relationship with social sustainably and policy development.

In the process of building the Issue Tree, we reviewed more than 50 social sustainability indicators suggested by Global Reporting Initiative (GRI) and narrowed it down to 12 indicators, with six potential threats and six opportunities related to bioenergy industry, which, in our opinion, will have the most influence on future development on the industry. The Tree can be further used for defining social impact of bioenergy production throughout the entire bioenergy industry's value chain. The complexity and diversity of bioenergy value chains shows that social impacts occur almost at every stage of the chain from the level of feedstock production to the level of end user. That is why there is a need for developing an effective instrument to assess those impacts. Moreover, all social impacts must be taken into account to ensure sustainable development in light of growing demand for new biofuel sources and their exploration.

The identified bioenergy social sustainability global tendencies reflect the socio-economic and technological reaction on four major forces within the bioenergy development driving forces. The four major forces are Bioenergy Policy Development and Promotion, Economic development Growth, Technology Development and Transfer and

Stakeholders Concern. Their effect was categorized into three categories, thus giving us Conservative, Moderate and Decentralized tendencies with a considerate impact on the future development of the global bioenergy social sustainability phenomenon.

Therefore, after we performed our research and identified the global tendency, we concluded that more focused case studies of bioenergy companies and/or institution in one or several countries and/or regions should be performed for better comprehension of the bioenergy social sustainability phenomenon.

Potentially, the horizon-scanning results can be effectively integrated into the social sustainability reporting process. Horizon scanning is not just about looking for alarming signals, but it is more about grasping the societal contexts behind the entire scanning process of identifying, evaluating and disseminating signals. That is why the diverse information on emerging issues may give an advantage to policy-makers, investors and stakeholder in preventing harmful issues before they arise.

## References


Belz, F.M. and Schmidt-Riediger, B. 2010 "*Marketing strategies in the age of sustainable development: evidence from the food industry*", Business Strategy and the Environment, Vol. 19 No. 7, pp. 401-416.

Dale V., 2013 "*Environmental and Socioeconomic Indicators for Bioenergy Sustainability as Applied to Eucalyptus*", International Journal of Forestry Research, Vol. 1
Available at: http://www.hindawi.com/journals/ijfr/2013/215276/

EU Biofuel Annual, 2012. Available in PDF at:
http://www.usdafrance.fr/media/Biofuels%20Annual_The%20Hague_EU-27_6-25-2012.pdf

Fulton, L., T. Howes, and J. Hardy. 2004 "*Biofuels for Transport: An International Perspective*". International Energy Agency, Paris. Available at PDF: http://www.cti2000.it/Bionett/All-2004-004%20IEA%20biofuels%20report.pdf

Goldemberg J., 2010 "*Energy, environment and development*" Earthscan, London

Mangoyana R., Smith T., "*Decentralised bioenergy systems: A review of opportunities and threats*", Energy Policy, Vol. 39, Issue 3, March 2011, Pages 1286-1295

Mutopo P., Chiweshe M., 2014 *"Water resources and biofuel production after the fast-track land reform in Zimbabwe",* African Identities, 12:1, 124-138, DOI: Available in PDF at:
http://www.tandfonline.com/doi/pdf/10.1080/14725843.2013.868673

Msangi S.,2007 Global Scenarios for Biofuels: Impacts and Implications, International Food Policy Research Institute
Available in PDF at:
http://www.fao.org/uploads/media/07_Global_Scenarios_for_Biofuels_Impacts_and_Implications_01.pdf

Sohl, T. L., Loveland, T. R., Sleeter, B. M., Sayler, K. L., & Barnes, C. A. 2010 "*Addressing foundational elements of regional land-use change forecasting. Landscape Ecology*", 25(2), 233–247.

Starick A, Syrbe R., Steinhaußer R., 2014 "*Scenarios of bioenergy provision: technological developments in a landscape context and their social effects"* Environment, Development & Sustainability. Vol. 16 Issue 3, p 575-594.

Sutherland W., Woodroof H., 2009 "*The need for environmental horizon scanning"*. Trends in Ecology and Evolution. 24(10): 523-527

Van Rij, 2008 *"Joint Horizon Scanning: Identifying Common Strategic Choices and Questions for Knowledge."* Draft prepared for the Third International Seville Seminar on Future-Oriented Technology Analysis, 16-17

# Validation and utilization of numerical weather model data in energy systems analysis of decentralized electricity production

**Hans SCHERMEYER** [1]
Research associate

**Valentin BERTSCH**
Head of research group 'Distributed energy systems and networks'

**Wolf FICHTNER**
Holder of the Chair of Energy Economics and Director of the Institute for Industrial Production

[1] *Contact details of corresponding author*
Tel: +49 (0)721 608-44458
Fax: +49 (0)721 608-44682
e-mail: hans.schermeyer@kit.edu

Address: Chair of Energy Economics, Institute for Industrial Production (IIP), Karlsruhe Institute for Technology (KIT), Hertzstraße 16, 76187 Karlsruhe, Germany

**Abstract:** Electricity from renewable energy sources (RES-E) is gaining more and more influence on traditional energy and electricity markets in Europe and around the world. Long term decisions like power plant investments as well as short term decisions like the dispatch of generation or storage units depend to a high degree on the expected and realized RES-E feed-in. Therefore when modelling electricity markets, a profound knowledge about the characteristic behavior of RES-E feed-in on a high temporal and spatial resolution is crucial. Since there are no spatially inclusive and comprehensive measuring data by meteorological stations available, energy systems analysts frequently use data generated by numerical weather models which interpolate observed data and create time series on a higher temporal and spatial resolution. However, the suitability of such model data for energy systems modeling and analysis depends on the research questions at hand and should be evaluated individually. This paper focusses on a new methodology of how to carry out a performance evaluation of solar radiation data provided by a weather model on a 20km x 20km European grid (temporal resolution: hourly and higher) when investigating the feed-in of RES-E and the effects on the electricity grid on a decentralized level. Suitable approaches of time series analysis from literature are applied to both modelled and measured data. The findings and limits of these performance indicators are illustrated and the concept of spatial volatility is introduced as new validation parameter. It complements the validation by measuring the volatility in radiation supply over space. Thus, the results of this paper contribute to the scientific community of energy systems analysts and researchers who aim at modelling RES-E feed-in on a high temporal and spatial resolution using weather model data.

## 1. Introduction

The goal of this paper is to answer the question if solar radiation data provided by a weather model on a 20km x 20km European grid and a temporal resolution of one hour is suitable for the subsequent analysis of decentralized[84] energy systems. This is relevant considering the fast growing number of decentralized units generating electricity from renewable energy sources (RES-E) throughout the world. In contrast to conventional power plants, most RES-E is generated on a decentralized level, challenging the established decision making and infrastructure in the electricity sector. New approaches to research decentralized energy systems and the corresponding RES-E generation are necessary.

In order to qualify the considered model data for further analysis, a thorough comparison between the model data and a reference data set based on established scientific methods and performance indicators is essential. Therefore, a number of well-established tests and computations of key performance figures are carried out in order to quantify the similarity of the model output and the measurement data taken from 57 sites in Germany.

[84] In the context of this paper the term 'decentralized' refers to electricity consumption and supply connected to the electricity grid on a voltage level far below the transmission grid (e.g. in Germany 30kV and lower).

The model data used for this work was supplied by downscaling reanalysis radiation data from the NASA program Modern-Era Retrospective Analysis For Research And Applications (MERRA) applying the mesoscale model MM5 (PSU/NCAR (2003)). The data of the 57 measurement stations was provided by the German National Meteorological Service (DWD).

Existing validation approaches focus on well-known first order statistics. Some additionally apply advanced instruments from second order statistics. They have in common that they rank different modelling approaches to simulate solar radiation against each other using a similar set of statistics. The development of a validation framework which focusses on the intended utilization of the data in energy systems analysis has not been carried out so far.

This paper intends to fill this gap through filtering existing work on weather model validation for the most helpful indicators. Those include common instruments from statistics for time series analysis. The reviewed techniques are complemented by a new indicator developed in this work which is more capable to capture the degree of uncertainty and fluctuation of renewable energy supply. Together they provide decision support to find out how well the model data can be used to work on problems related to energy systems on the decentralized level.

## 2. Review of validation methods in the literature

In the following, the paper gives an introduction on literature dealing with the validation of various solar radiation models. The common approach is to compare the simulated time series (also called 'predicted' or 'forecasted' time series) with measurement data from ground stations. The selected works were chosen for their quantitative approach, recognition and experience dealing with weather models or for being related to energy economics:

Murphy (1995) highlights that the correlation coefficient is a frequently used indicator to quantify how well a forecast performs with regard to the corresponding observations (traditionally and in variations as the "anomaly correlation coefficient"). While he acknowledges that the coefficients of correlation (R) and determination ($R^2$) describe linear relationships between model data and observation data he highlights their lack of ability to account for absolute differences in the observed and simulated time series. He recommends the Mean Square Error (MSE) to measure and aggregate these differences.

In Myers et al. (2005) the authors describe their update of the U.S. National Solar Radiation Data Base (NSRDB). They take into account three different models producing radiation data and validate those on the basis of measurement data from 31 U.S. sites covering two years. The hourly model and measurement data are compared by means of Root Mean Square Error (RMSE), Mean Bias Error (MBE) and a regression analysis covering the parameters of the regression line and the coefficient of determination ($R^2$). The tested models performed similarly with regard to RMSE (<100 $W/m^2$) and MBE (<10$W/m^2$) between the modelled and measured hourly global radiation data. Further analysis is done by a visual comparison of the frequency distribution and the probability distribution.

Polo et al. (2008) derive solar radiation data from satellite images and evaluate the modelled time series against measurements by means of RMSE and MBE on an hourly and daily basis. In order to compare a model's ability to simulate time series of the global radiation as a percentage, they normalize by the mean daily radiation. According to their results the general accuracy of satellite models lies within 17 – 25% in RMSE when modelling global hourly radiation and 10 – 15% for averaged daily values. They derive a MBE around -2.6% and +4.3%.

Gueymard and Myers (2008) provide a helpful introduction into the validation of solar radiation models including a classification to qualitative and quantitative assessment. Their list of quantitative performance indicators covers the following: RMSE, MBE, R, $R^2$, t-statistic, skewness and kurtosis of the respective observed distribution function. They mention approaches to aggregate various parameters into one key performance parameter e.g. an 'accuracy score'.

The model validation described by Badescu et al. (2012) covers an extensive number of 54 different models simulating hourly global and diffuse irradiation. The reference data for comparison originates from two measurement stations in Romania. The MBE and RMSE are chosen to indicate whether a model shows a "good performance", both normalized using the arithmetic mean of measured values. A MBE between +5% < MBE < -5% and a RMSE < 15% qualifies as "good performance".

Similar to the above described update of a U.S. radiation data base, Huld et al. (2012, pp. 1803–1815) describe their application of a new data source to the Photovoltaic Geographical Information System (PVGIS) and the outcome with respect to the models ability to simulate global horizontal irradiation on a monthly basis. The data update is derived from the Climate Monitoring Satellite Application Facility (CM-SAF) and validated using measurement data from 20 sites in

Europe. As performance indicator they use the MBE and the Relative Mean Bias Error (RMBE) expressed as a percentage. The authors conclude that the new data set is improving PVGIS' ability to model irradiation data on a monthly basis reaching an overall RMBE of all measurement stations of about +2% varying by a standard deviation of 5%.

Ineichen (2013) validates the model results of six different "nowcast satellite products" simulating hourly, daily and monthly values for global, direct and diffuse radiation. For the performance analysis he generally distinguishes means of first and second order statistics. The first order statistics include the MBE, RMSE, standard deviation ( $\sigma$ ) and R and also a visual check of the frequency of occurrence and cumulative frequency of occurrence plot. He finds that the considered models are able to simulate hourly global radiation with a negligible MBE: Averaged over all sites the MBE lies between -2.7 W/m² and +6.2 W/m² (the relative value varying between -0.8% and 1.8%). The standard deviation of the MBE with respect to different sites amounts to 2.1% – 5.1%. These results are limited to sites located at latitudes from 20° to 60° and an altitude from 0m to 1600m. For the second order statistics Ineichen (2013) names the Kolmogorov-Smirnov test which measures the difference between the frequency of occurrence (or probability density function) of the simulated and measured data respectively. Drawing the distribution of the differences between measurement and model data is another useful way of validation mentioned by the author particular helpful for a graphical assessment.

Liebenau et al. (2013) analyze the necessary electricity grid extension induced by RES-E power plants and calculate the tradeoff between curtailing RES-E feed-in and grid extension. They use simulated time series (wind speed and global radiation) from the COSMO-EU model of the German National Meteorological Service (DWD) and convert those to electricity feed-in by photovoltaic and wind power plants. The validation of the generated wind and radiation time series is done using measurement data from a small number of sites in Germany. The RMSE serves as single performance indicator and is calculated to about 13%. While the performance evaluation conducted by Liebenau et al. (2013) is not as sophisticated as most of the examples mentioned before, it is relevant in the context of this paper, since their underlying research question is similar to our research of decentralized energy systems and networks. Their focus on the RMSE indicates its significance as performance indicator.

An interesting initiative on the standardization of the evaluation of satellite driven model data is represented by the IEA Solar Heating and Cooling Programme's Task 36 called "Solar Resource Knowledge Management".[85] It produced the following four publications particular relevant for this paper:

Hoyer-Klick et al. aim at establishing a set of evaluation guidelines to enable comparable benchmarking results of solar radiation models. They name the MBE, RMSE, standard deviation ( $\sigma$ ) and R being especially important when measuring the accuracy of a model to produce data as similar to the reference data as possible. For system design studies they recommend parameters based on second order statistics applying the Kolmogorov-Smirnov (KS) test. The analyzed model data stems from three different models. They state a MBE of -1% to 4% and a RMSE of 36% to 48% for the hourly radiation data of the evaluated models, relative to the arithmetic mean of the data set. Having calculated KS integrals with mostly above 100% they conclude that the four tested radiation models do not match the solar radiation's distribution function very well.

Espinar et al. (2009) apply the validation on daily radiation data from the geostationary meteorological satellites Meteosat-5, -6 and -7 compared to an extensive number of 38 sites in Germany. Their validation is done on the basis of daily radiation values which excludes their results to serve as benchmark of this work.

Hoyer-Klick et al. (2010) derive two general tables that aggregate information about possible data sources and minimum requirements of performance when validating the data. They suggest for the hourly global radiation the MBE to be lower 5% and the RMSE < 125W/m². Both Espinar et al. (2009) and Hoyer-Klick et al. (2010) apply the Kolmogorov-Smirnov test comparing the probability density function or frequency of occurrence of the measured and modelled data respectively.

A similar set of performance indicators is used by Ineichen (2011) to validate five satellite models. He presents a large number of tables containing the validation results of various comparison indicators.

Reviewing the above mentioned approaches it becomes clear that present approaches on weather model validation mostly focus on common statistical indicators from first and second order statistics. Especially the mentioned first order statistics instruments are limited to capturing the tendency of a model's ability to reproduce real data with regard to a certain site and point in time. However, for energy systems analysis it is not so

[85] http://archive.iea-shc.org/publications/task.aspx?Task=36 , checked on 30/4/2014

important to reproduce weather time series as identical as possible but to capture the relevant characteristics and reproduce those in a realistic manner $m_t - o_t$ . In order to validate a model's ability to simulate realistic rather than real data we complement the performance indicators from the literature and introduce and introduce the spatial volatility capturing the fluctuating character of RES-E supply over numerous locations.

## 3. Performance indicators for the validation of radiation model data

In this chapter we choose a selection of the existing instruments from the literature reviewed above. We will argue that these indicators, chosen for their popular and widespread application, are helpful to analyze the similarities of two time series in a general way but lack the ability to assess relevant characteristics when doing energy systems analysis. If weather models would produce output very close to reality, then the above mentioned statistics from literature would be sufficient to measure this similarity. However because of the complexity of modelling weather on a high temporal and spatial resolution the model results reproduce reality not very accurately. Therefore the mentioned indicators are not sufficient for the validation since they look for an exact reproduction of observation. For weather time series to qualify for energy systems analysis it is not so important to reproduce observed weather situations from the past as accurately as possible but to generate typical and realistic behavior.

Therefore, complementing the validation indicators from literature, we introduce several novel instruments for the validation of solar radiation model data in the context of energy systems analysis. They assess how well a model's data output captures the fluctuating character and the occurrence of extreme values compared to measurement data.

## 4. Model validation parameters from literature

In order to evaluate how well time series elements at the same place and time compare with each other we choose the following indicators based on first order statistics from literature presented in chapter 2: MBE, RMSE, R. The MBE describes how well the model is calibrated and the RMSE reflects the scattering of the model output against the measurement data. The correlation coefficient R quantifies the model's ability to capture linear relationships. From the authors' point of view, these parameters represent the most adequate indicators from literature. A definition of these parameters is for example given in Murphy (1995), Badescu et al. (2012) and Ineichen (2013).

The Mean Bias Error (MBE) adds up the "error" or equivalent the "deviation" $m_t - o_t$ between the modelled $m_t$ and the observed $o_t$ values for each (time) step t within these two time series. The sum is normalized by the number of elements of the time series. The MBE represents a kind of average deviation and can therefore be seen as the extent of systematic over- or underestimation between the model and measurement data:

$$MBE = \frac{1}{N}\sum_{t=1}^{N}(m_t - o_t) \qquad (1)$$

Using equation (1), the MBE is expressed as an absolute value having the same measurement unit as the examined time series. In order to compare MBE performance from different samples with different means or fluctuation levels, the MBE is normalized by the arithmetic mean $\bar{o}$ of the observed measurement data. The second important performance indicator selected from the literature review is the Root Mean Square Error (RMSE), often also referred to as Root Mean Square Difference (RMSD).

$$RMSE = \sqrt{\frac{\sum_{t=1}^{N}(m_t - o_t)^2}{N}} \qquad (2)$$

While the MBE measures a systematic and average deviation between modelled and observed time series, the RMSE is an indicator for the scattering of the model data. Differences between measured and observed data are added up by the second power, therefore high deviations have a strong influence. In order to express the RMSE dimensionless it can also be normalized, e.g. using the range of observed measurement data.

The correlation coefficient R represents the third chosen comparison indicator. It varies between -1 and 1 and is an indicator for a simultaneous change behavior of sample data in a linear way. As a function of covariance Cov and standard deviation σ it is formulated as:

$$R = \frac{Cov(m,o)}{\sigma_m \sigma_o}$$

$$R = \frac{\frac{1}{N}\sum_{t=1}^{N}((m_t - \bar{m})\cdot(o_t - \bar{o}))}{\sqrt{\frac{1}{N}\sum_{t=1}^{N}(m_t - \bar{m})^2}\cdot\sqrt{\frac{1}{N}\sum_{t=1}^{N}(o_t - \bar{o})^2}}$$

$$R = \frac{\sum_{t=1}^{N}((m_t - \bar{m}) \cdot (o_t - \bar{o}))}{\sqrt{\sum_{t=1}^{N}(m_t - \bar{m})^2} \cdot \sqrt{\sum_{t=1}^{N}(o_t - \bar{o})^2}} \qquad (3)$$

A good way to visualize a model's performance with respect to linear correlation is drawing a scatterplot. Figure  shows an illustrative scatterplot of the modelled and observed radiation data at the Bochum site. The scatterplot draws two time series, e.g. modelled and measured data, against each other. A perfect match of each modelled and measured data point would result in a single 45° line from the origin.

As already mentioned above, the Kolmogorov-Smirnov Test (KS Test) is a second order statistics approach to validate solar radiation model data on the basis of a time series' cumulative distribution function (CDF). The test compares the estimators of the CDF of both the measured and the modelled data and quantifies the differences. It tests the hypothesis that the modelled and measured data points are drawn from the same CDF. Therein it is somewhat similar to the $\chi^2$ test but more powerful (Massey (1951)). Espinar et al. (2009) describe the advantage of the KS Test as being a non-parametric, distribution-free test, since it makes no assumption about the data distribution.

In our analysis we found that the instruments of the KS Test do not prove helpful when applied to hourly data sets of model data and measurements respectively. On the one hand the large sample size makes it quite challenging to fall below the test's performance threshold. On the other hand it is not expectable that measured solar radiation data from a single site possesses a similar distribution as data from a model simulating the radiation over a larger area.

## 5. Validation in the context of energy systems analysis

While the above described instruments from first and second order statistics represent established indicators to assess a model's ability to reproduce real data as accurate as possible, we aim for the ability to produce realistic rather than real data. In the context of this paper this means that the model output captures the identified relevant characteristics of a time series and reproduces those in a realistic manner regardless from the sequence of events in the measured time series.

As mentioned at the beginning of this chapter, we are looking for an indicator to compare a solar radiation model's ability to capture the fluctuating and uncertain character of radiation supply. The spatial volatility indicates the difference in RES-E generation potential within the same time but at different locations. While the application of the standard deviation as an indicator for the fluctuating character of a time series over time is well known in literature, the concept of spatial volatility, to the knowledge of the authors, represents a new concept to characterize renewable energy supply.

In contrast to the performance indicators described in chapter 4 the spatial volatility introduced in this chapter stands for a certain characteristic of a single time series. Thus for interpretation it is compared to the same indicator of other time series or another performance indicator.

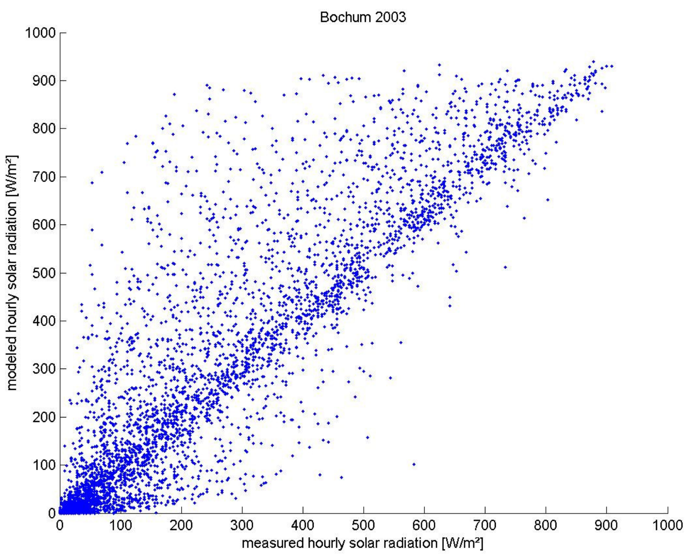



**Figure 1: Scatterplot of modelled against measured data for one year of data.**

The spatial volatility calculates the deviation between the radiation supply at different sites and serves as an indicator for spatial differences in RES-E generation. This is important information when doing energy systems analysis since it influences major elements as for example the necessary grid capacity or the distribution of conventional power generation capacities.

Comparing the model's and the measurement's spatial volatility it is possible to judge how well territorial differences in radiation supply are reproduced by model data. In the context of this paper the spatial volatility during time step t of the radiation supply $x_t^1 \ldots x_t^S$ is defined as:

$$vola_t = \frac{\sigma_t}{\mu_t^S} = \frac{\sqrt{\frac{1}{S-1}\sum_{S=1}^{S}(x_t^s - \mu_t^S)^2}}{\mu_t^S} \quad (4)$$

The variable $\mu_t^S$ denominates the arithmetic mean of the solar radiation over the number of available stations S during time step t and $\sigma_t$ the respective standard deviation.

In order to reach as significant results from the spatial volatility as possible the available measurement data are filtered as follows: Since during the night the radiation supply is zero at all stations and therefore the spatial difference of radiation supply is also zero, only time steps with model and measurement data greater than zero are taken into account for the calculation. Thus all parts of the time series during the night are deleted. Secondly, only time steps with model and measurement data available for at least five different stations are considered for calculating the spatial volatility.

## 6. Results and discussion of the validation

### MBE, RMSE and R

The first order statistics chosen for the assessment in this work are the mean bias error (MBE), the root mean square error (RMSE) and the correlation coefficient R, described in chapter 4. Those three indicators are calculated for each of the 57 sites for which both modelled and measured data are available. The average value over all stations is calculated by uniform weighting.

When looking at the MBE calculated for each site it becomes clear that the model data is positively biased. The averaged MBE over all locations amounts to 24.7 W/m² per hour or 22%. This means that on average the model overestimates the solar radiation supply in every hour by 24.7 W/m². In order to express the MBE as a percentage it is normalized using the arithmetic mean of the respective measurement data sets which vary between 95 W/m²– 132 W/m².

The RMSE is an indicator for the scattering of data which sums up all deviations weighted to the power of two, giving more impact to high values. The respective values for the RMSE are 108 W/m² and 11%, the relative value normalized using the range of each measurement data set.

With regard to the publications introduced in chapter 2 the MBE should be around -5% to +5% (e.g. Badescu et al. (2012)) and the RMSE below 125 W/m² (e.g. Hoyer-Klick et al. (2010)) in order qualify as good results. Taking that into account the validation parameters do not produce a clear picture. While the high MBE implies a relative strong systematic overestimation by the radiation model, the RMSE appears to qualify for a good modelling performance.

After calculating R it is noticeable that the correlation between model and measurement data is very high for nearly all sites. Except for the site 'Hohenpeissenberg' all correlation coefficients vary less than 5 basis points from the mean of 90%. In order to visualize the linear correlation we generated scatterplots for each site and all sites together respectively. Figure shows two illustrative plots with five years of data for the sites at Mannheim (left) and Leipzig (right) respectively. While the correlation between the data sets is clearly recognizable there are a considerable number of events when measured and modelled values differ substantially. The trend of the model's overestimation, measured by the MBE, can also be observed in the scatterplots by the high number of pixels above the 45° line. Altogether we conclude that the mean correlation coefficient of 90% indicates a decent model performance, although some of the authors presented in chapter 2 find a higher correlation between the model and measurement data subject to their study.

Summarizing the findings above about MBE, RMSE and R, two main reasons become evident why the previously calculated indicators are not sufficient in order to validate the model's performance in simulating radiation data:

Firstly, they contradict each other and produce different rankings of performance. While on average the model shows a high MBE, the RMSE appears to be within the limits of a good model performance. Looking at the site 'Hohenpeissenberg', we find the lowest MBE of all considered measurement stations 0.4 W/m² and 0.3%. However, the RMSE is only about average with 104 W/m² and the correlation coefficient R is the lowest of all stations. These indicators by themselves appear to be insufficient to assess a model's performance as also remarked by other authors (e.g. Gueymard and Myers (2008)).

Secondly, the above calculated indicators do not capture the relevant properties of a radiation time series when doing analysis of decentralized energy systems. They look for the degree of similarity between measured and modelled data but not for the ability to simulate fluctuations and extreme values as realistic as possible. For energy systems analysis it is not crucial to forecast or reproduce weather time series as identical as possible. In fact it is more important for the model output to capture the relevant characteristics of a time series and reproduce those in a realistic manner. One relevant characteristic identified in this work is the spatial volatility. It is important since the variation in renewable energy supply over space determines fundamental attributes of an energy system as the necessary grid capacity and the allocation of flexible back-up generation capacity.

In the following we summarize the results from applying the new indicator spatial volatility introduced in chapter 0. The spatial volatility is designed to capture and compare the fluctuations and volatile character of time series over numerous sites which is particularly important for energy systems analysts.

## 7. Spatial volatility

The concept of the **spatial volatility** is to measure the spatial differences of solar radiation supply and thereby the difference in possible RES-E generation in space. It is an indicator for regional disparities in solar radiation supply caused by astronomical principles on the one hand and spatial weather variety on the other hand.

The respective spatial volatility of the model data and the measurements are depicted in Figure . The calculation of the spatial volatility considers only those hours of the 24 years of data that meet the following criteria: The solar radiation is greater zero (hours with no radiation are excluded) and both measured and modelled data are available for at least five sites.

At first glance it seems, that the model's spatial volatility exceeds the measurement's spatial volatility because of its frequent positive spikes. However the spatial volatility of the model data averages 29% and is only slightly higher than the measurement's mean spatial volatility of 24%. In fact taking a closer look at the time series (Figure ) it unfolds that during the day the spatial volatility of the measurement stations is regularly higher than the model's spatial volatility. This goes along well with the results from the MGRS assessment where we found on the hourly level that the gradients of the model are higher during the hours of sunrise and sunset while the greater fluctuations of the measurements at a single site lead to higher diurnal gradients. Looking at Figure  we find a similar trend: The model produces a rather high spatial volatility during the morning and afternoon hours compared to the measurement data. During the day this trend reverses. The morning and afternoon peaks in spatial volatility of both time series can be attributed to the spatially distribution of the locations which leads to a time shift between sunrise and sunset.

It should be noted that both modelled and measured time series generally produce higher spatial volatility during the hours of sunrise and sunset compared to midday. This seems reasonable since the spatial distribution of the 57 sites is connected to differences in their respective position to the sun. This results in additional variations during those hours.

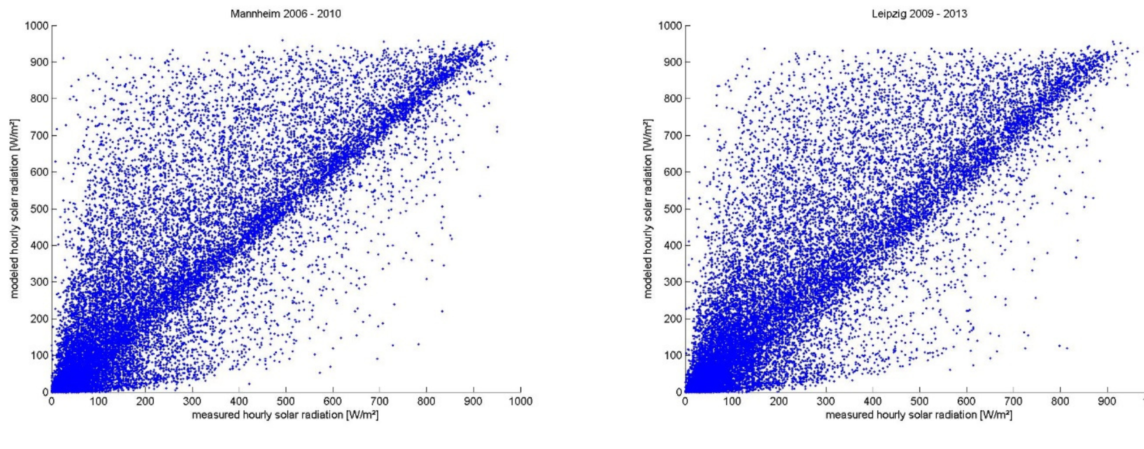



**Figure 2: Scatterplots showing five years of measured and modelled data for two selected sites at Mannheim (left) and Leipzig (right).**

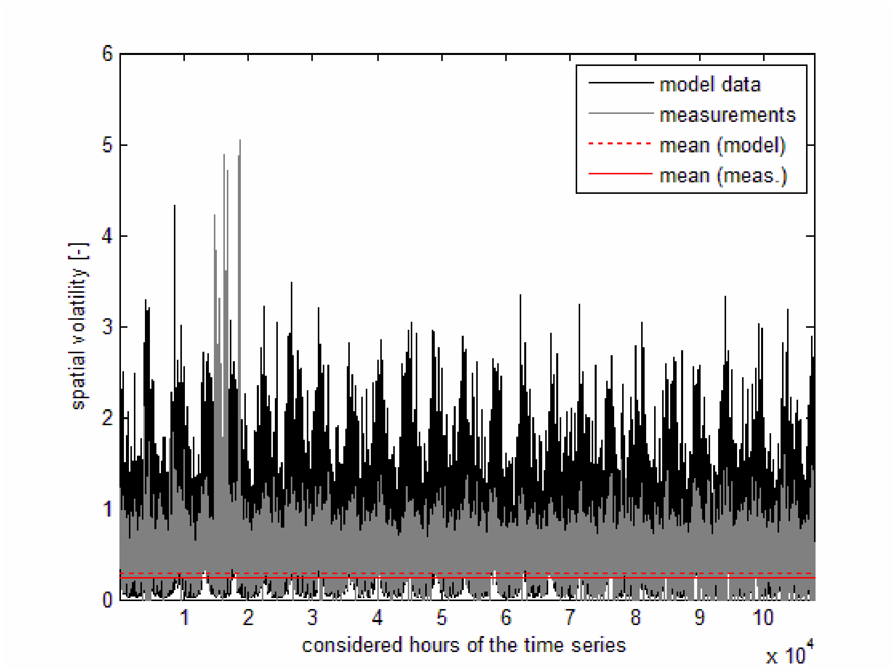



**Figure 3: Spatial volatility of the measured and modelled data respectively.**

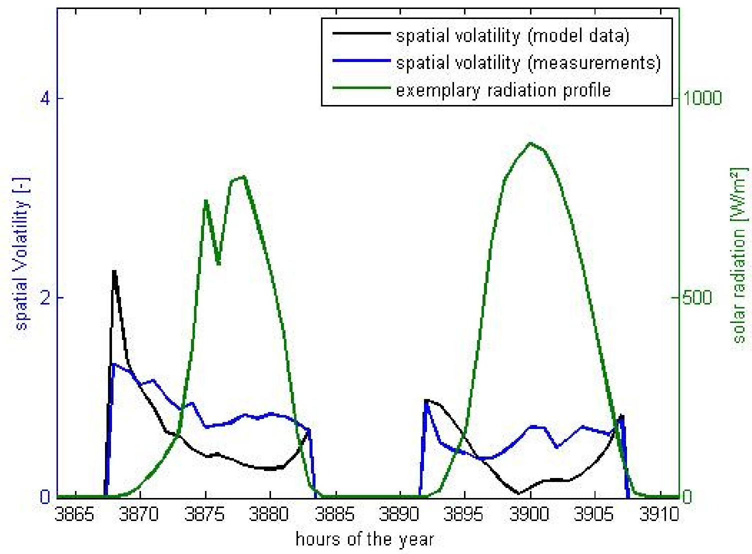



**Figure 4: Spatial volatility of the measured and modelled data on two illustrative days.**

Comparing the average spatial volatility of model and measurement data the model data's spatial volatility exceeds the measurement data's by 21%. This appears a rather high difference and might partially be explained by the time stamps of the data sets: Since the measurement data are administrated using the 'apparent local time' it was necessary to convert the time stamps of the data of every single location allowing for temporal shifts of up to one hour. While the model data is available at a resolution of 10 minutes, the measurement data was only available on an hourly basis. This inevitably leads to an inaccurate conversion of temporal differences. The conversion algorithm for the time stamps of the measurement data used in this work can be considered as underestimating the spatial volatility. Therefore the observed difference in the spatial volatility between model and measurement data is rather overestimated.

Taking into account the arguments about the overestimation of the difference between the spatial volatilities and the visual validation, the spatial volatility does not deliver a definite judgment of the model's performance. However it produces valuable information about the spatial fluctuations of radiation supply during the day, consistent for both modelled and measured data. The spatial volatility also identifies the hours of sunset and sunrise as particular critical with respect to interregional fluctuations of RES-E feed-in and delivers a quantifying indicator.

## 8. Conclusion and outlook

The goal of this paper is the assessment of existing and the development of new and relevant performance indicators for the validation of data output from a numerical weather model in the context of decentralized energy systems.

From literature we extract three first order statistics indicators that aggregate information from comparing two time series: MBE, RMSE and R. Applying them on the historic data from 57 measurement stations and corresponding model data they produced an inconsistent validation results. More important, they did not measure the relevant properties of the time series when analyzing decentralized energy systems. Grid constraints caused by RES-E occur on a decentralized level and can only be simulated appropriately if extreme and rare values of solar radiation and fluctuations of the radiation supply in space and time are modelled in a realistic way. In order to measure these relevant parameters we introduce the MARS, MGRS and the spatial volatility and apply these to the data set.

The spatial volatility proves to be an effective tool to measure regional differences of RES-E generation potential. It quantifies diurnal spatial fluctuations of radiation supply and identifies the hours of sunset and sunrise as particularly critical with respect to interregional fluctuations. Applied to the data set the spatial volatility reveals substantial differences between modelled and measured data. Taking a closer look it becomes clear that a large amount of these differences arise from systematic differences in the data formats and their temporal resolution. The spatial volatility promises a high potential for future development. For example, a further improvement of data input or a thorough investigation of diurnal and geographic patterns of the spatial volatility appear as promising enhancements of the spatial volatility's findings.

The spatial volatility captures the systematic difference between the different spatial resolutions of the data sets quite well. While the measurement data represent single sites, the model data represent radiation supply averaged for a spatial resolution of about 20km x 20km. Measurements at a single location capture every cloud reducing radiation supply whereas the model data might allow for balancing effects within one 'weather cell'. When analyzing energy systems with some regional extent it is likely for balancing effects between photovoltaics and other RES-E generation units to occur. Therefore the model's lack of ability to reproduce high diurnal gradients and spatial fluctuation appears to be a more realistic simulation of the solar radiation supply received by an underlying energy system.

For future development of the spatial volatility introduced in this paper, it might prove helpful to eliminate deterministic trends of the solar radiation time series. Thus frequent and repetitive changes in radiation supply that are easier to predict do not affect the indicators. Moreover a higher temporal resolution will help to improve the significance of the spatial volatility. This would enable a more accurate preprocessing of the data on the one hand and allow conclusions on the higher temporal resolution on the other hand.

Furthermore it is suggested to complement the selected indicators from literature and the presented spatial volatility from this work by indicators measuring extreme values within a time series and the change rate (gradient) of the renewable energy supply. Both statistics represent crucial characteristics when designing and analyzing a decentralized energy system.

## Acknowledgments

This paper is partially based on research conducted within the project "Dezentrale Energiesysteme, Marktintegration und Optimierung" (DEMO) at KIT. The authors gratefully thank the "Stiftung Energieforschung Baden-Württemberg" for the financial support.

The authors also thank the German National Meteorological Service (DWD) for the delivery of the measurement data and anemos Gesellschaft für Umweltmeteorologie mbH for the provision of numerical weather model output data.

## References

Badescu, Viorel; Gueymard, Christian A.; Cheval, Sorin; Oprea, Cristian; Baciu, Madalina; Dumitrescu, Alexandru et al. (2012): Computing global and diffuse solar hourly irradiation on clear sky. Review and testing of 54 models. In *Renewable and Sustainable Energy Reviews* 16 (3), pp. 1636–1656

Espinar, Bella; Ramírez, Lourdes; Drews, Anja; Beyer, Hans Georg; Zarzalejo, Luis F.; Polo, Jesús; Martín, Luis (2009): Analysis of different comparison parameters applied to solar radiation data from satellite and German radiometric stations. In *Solar Energy* 83 (1), pp. 118–125

Gueymard, ChristianA.; Myers, DarylR. (2008): Validation and Ranking Methodologies for Solar Radiation Models. In Viorel Badescu (Ed.): Modeling Solar Radiation at the Earth's Surface: Springer Berlin Heidelberg, pp. 479-510

Hoyer-Klick, Carsten; Beyer, Hans-Georg; Dumortier, Dominique; Schroedter Homscheidt, Marion; Wald, Lucien; Martinoli, Mario et al.: MESoR - Management and exploitation of solar resource knowledge. In : SolarPACES 2009

Hoyer-Klick, Carsten; McIntosh, Jennifer; Moner-Girona, Magda; Renné, David; Perez, Richard; Puig, Daniel (2010): Developing a Guide for Non-experts to Determine the Most Appropriate Use of Solar Energy Resource Information. Available online at http://archive.iea-shc.org/publications/downloads/Developing_a_Guide_for_Non-expert_v0.9-20100707.pdf, checked on 4/2/2014

Huld, Thomas; Müller, Richard; Gambardella, Attilio (2012): A new solar radiation database for estimating PV performance in Europe and Africa. In *Solar Energy* 86 (6), pp. 1803–1815

Ineichen, Pierre (2011): Five satellite products deriving beam and global irradiance validation on data from 23 ground stations. Edited by International Energy Agency. University of Geneva. Geneva, checked on 4/4/2014

Ineichen, Pierre (2013): Long term satellite hourly, daily and monthly global, beam and diffuse irradiance validation. Interannual variability analysis. Edited by International Energy Agency. University of Geneva. Geneva, checked on 4/4/2014

Liebenau, Volker; Schwippe, Johannes; Kuch, Stefan; Rehtanz, Christian (2013): Network extension planning considering the uncertainty of feed-in from renewable energies. In : 2013 IEEE Grenoble PowerTech. Grenoble, France, 16.-20.06.2013, pp. 1–6

Massey, Frank J. (1951): The Kolmogorov-Smirnov Test for Goodness of Fit. In *Journal of the American Statistical Association* 46 (253), pp. 68–78

Murphy, Allan H. (1995): The Coefficients of Correlation and Determination as Measures of performance in Forecast Verification. In *Wea. Forecasting* 10 (4), pp. 681–688

Myers, D.; Wilcox, S.; Marion, W.; George, R.; Anderberg, M. (2005): Broadband model performance for an updated National Solar Radiation Database in the United States of America. In D. Y. Goswami (Ed.): Proceedings of the Solar World Congress 2005. Bringing Water to the World. Solar World Congress 2005. Orlando, Florida, USA, August 2005. American Solar Energy Society (ASES)

Polo, Jesús; Zarzalejo, LuisF.; Ramírez, Lourdes (2008): Solar Radiation Derived from Satellite Images. In Viorel Badescu (Ed.): Modeling Solar Radiation at the Earth's Surface: Springer Berlin Heidelberg, pp. 449-462

PSU/NCAR (2003): MM5 Community Model Homepage. MM5 Modeling System Overview. Pennsylvania State University / National Center for Atmospheric Research. Available online at http://www.mmm.ucar.edu/mm5/overview.html, updated on 4/1/2003, checked on 5/16/2014

# Reforming Energy Subsidies for a Better Implementation of Renewable Energies in Tunisia

**Asma DHAKOUANI** [1]
PhD Student

**Dr. Essia ZNOUDA**
Professor in Ecole Nationale d'Ingénieurs de Tunis

**Pr. Chiheb BOUDEN**
Professor in Ecole Nationale d'Ingénieurs de Tunis

[1] *Université de Tunis El Manar, Ecole Nationale d'Ingénieurs de Tunis, LR11ES16 Materials, Optimization and Energy for Sustainability, 2092, Tunis, Tunisia*
Tel: + 216 71 874 700 ext. 551
Fax: + 216 71 872 729
e-mail: asma.dhakouani@medrec.org

**Abstract:** The policy of energy subsidies and control of domestic prices has characterized the political and economic environment in Tunisia. Lately, with energy consumption incremental growth, from 4.4 to 8.5 Mtoe during 1990- 2012, international energy prices increase, and the decrease in production, energy subsidies have become a burden on the state budget, reaching globally 5300 MD in 2012, representing a barrier for investment on sustainable development and rather tending to favor high-income classes.
Hence, a long-term strategy of the electricity mix is crucial, taking into consideration the reform of energy subsidies, focusing public support on socially vulnerable groups; and enlargement of the shares of renewable energies to face the shortage in fossil fueled energies and to decrease the GHG emissions. Many developed economies have resorted to Energy Systems Models (ESM) for planning energy transitions and strategies since it generates a range of insights and analysis on demand and supply, with regard to climate change and economic development concerns. There is a myriad of models that have been developed since the first oil crisis, roughly categorized as bottom-up models, for technical purposes, and top-down for economic concerns. Recently, open-source models have appeared, characterized with high flexibility, transparency and adaptability to capture specific characteristics. This paper overviews the Tunisian context and argues that energy subsidies are a barrier for the implementation of renewables. Such a reform should be based on clear strategy drawn using adequate ESMs, namely their identification is made through a comparison of selected models capturing developing economies' characteristics.

## 1. Introduction

The evolution of the energy balance in Tunisia has been marked by three main periods, the 1960's to1970's, 1980's and 1990's, where the government intervention has tried to adapt to the different situations through the implementation of institutional, legal and regulatory framework. However, starting from the year 2000, Tunisia switched from an energy excess status to a deficit status due to several socio-economic conditions, i.e. the improvement of the living conditions, the increase of consumption and the declining production. However, the government continued to subsidize energy which has played a major role on overcharging the budget and a principal barrier in the implementation of sustainable development. Facing these challenges, adopting a new model based on a better diversification of energy resources and securing the supply of energy products might assure the improvement of this situation. Therefore, this work aims to describe firstly the energy situation in Tunisia and the urgent need for a reform of the sector. Secondly, it points out the tool of long-term strategies by reviewing Energy System Modelling. The remainder of this paper discus models' adequacy to the case of Tunisia.

## 2. Energy situation in Tunisia

Having regard to the limited energy resources in Tunisia, the supply has been for several decades dependent on the international market of energy, where the government had to adapt to different situations by imposing policies managing the supply and demand of energy. In this concern, the history of energy policies could be divided in four main epochs; firstly, from the 1960's to 1980's, the period was characterized by the development of supply and the implementation of an institutional framework in the energy sector, i.e. STEG for electricity and gas, ETAP for exploration and production of hydrocarbons, and STIR for refining. Later on, in the mid 1980's, the government was aware of the foreseeable energetics deficit and as a result integrated the component of energy demand conservation and created ANME. During the 1990's, the period was characterized by many institutional reforms, the entrance of the private investment in the electricity production (IPP), decree 1996-1125, and the sharp penetration of natural gas. The last era initiated with the structural deficit in the energy balance, the conservation of energy became a principal pillar of energy policies alongside with the promotion of natural gas consumption, e.g. decree 2002-3232, law 2009-7 for cogeneration, and the self-generating electricity from renewable energies based on law 2009-7.[86]

Based on the figure above, Tunisia has switched since 2000 from an energy excess to an energy deficit status reaching a shortage of 1.67Mtoe in 2012 and has been growing to 2.4Mtoe during 2013 because of the evolution of primary energy consumption which itself has almost doubled during the last two decades. In 1990, the energy consumption was at 4.4Mtoe composed of 28% natural gas needs and 71% oil products; it reached 8.5Mtoe in 2012 where the consumptions of natural gas and oil products were almost equal. Thus, the energy mix is currently based on natural gas and oil products.

In the other side, the evolution of supply was mainly marked by a decline in resources. Indeed, the local production of oil products is mainly extracted from four sites which are marginal fields and have an average production estimated at 67 000 barrels/day in 2012, presenting a national coverage of 40% shared between oil at 39%, petrol at 40% and LPG at 21%. In order to satisfy the consumption's needs, Tunisia resorts to imports. For natural gas, the demand has quadrupled from 1990 to 2012 reaching 4.6Mtoe, where 73% is designated to electricity production and 27% to end uses, against a national production of approximately 2.8Mtoe presenting only 53% of the demand. The rest is fulfilled with the Algerian gas; known that 16% is lump sum taxation and 31% is purchased. Nevertheless, the international prices of natural gas between 2000 and 2013 eightfold; and taking into consideration the politic of distorted energy prices, the natural gas price in Tunisia, which was almost equal to the international prices in 2000, ended up in 2013 with almost half value. The electricity mix is actually based on fossil fuels, it's composed of 98% natural gas and 2% renewables, i.e. wind and hydro. The rate of annual growth of electricity demand was around 5% in 2013, accompanied with a rapid development of the peak, compared to 150MW installed per year. During, the last couple of decades, the electricity demand has steadily risen and passed from 5000GWh to 15000GWh, respectively in 1990 and 2012, as mentioned in figure 2.

The high dependence on imports and the increase in difference between the local and international prices have affected the state budget. As a matter of fact, an increase by 1 USD in oil barrel generates an extra debit on the budget by 40MTND, and a growth of the exchange rate by 10 cents engenders an increase on the budget by 30 MTND (National Energy Observatory, 2013).

Facing this situation, the government emphasized the policies' tools for energy control and has set the goal of reducing energy intensity by 2% yearly through the development of institutional and regulatory framework, and for that reason implemented two programmes of energy conservation, a three-year programme (2005-2007) and a four-year programme (2008-2011) which have resulted on an accumulated reduction of 6.8Mtoe from 2004 to 2012, known that the energy savings have achieved 1Mtoe in 2012. On this regard, it is important to mention that the energy intensity in Tunisia is about 0.31toe/1000$ which is equal to the world average intensity (IEA, 2012).

To sum up, the Tunisian government is facing several kinds of issues and challenges in the energy sector, namely in terms of structure related to the security of supply, economically to the clearing evolution, socially to the improvement of living and environmentally to the reduction of pollution. The politic of distorting prices with subsidies exacerbated the situation and played a major barrier in dealing with energy problems. The global subsidies, i.e. direct and indirect, in the energy sector paid by the government, are approximately 5300 MTND where 43% are allocated for oil products, 41% for electricity, 16% for natural gas, and 0.9% for energy conservation (energy efficiency and renewable energies). Energy subsidies have served for assuring and expanding energy access, which allowed an electrification access of 99.6% in 2012; it is a tool for protecting low income classes by assuring the affordability of energy prices, fostering industry development, known that energy-intensive industries are likely to benefit the most, smoothing consumption, avoiding inflationary pressures, and for political considerations.

[86] See the Official Gazette of the Republic of Tunisia, 2009


**Figure 1: Evolution of energy demand and resources in Tunisia between 1990 and 2012.**

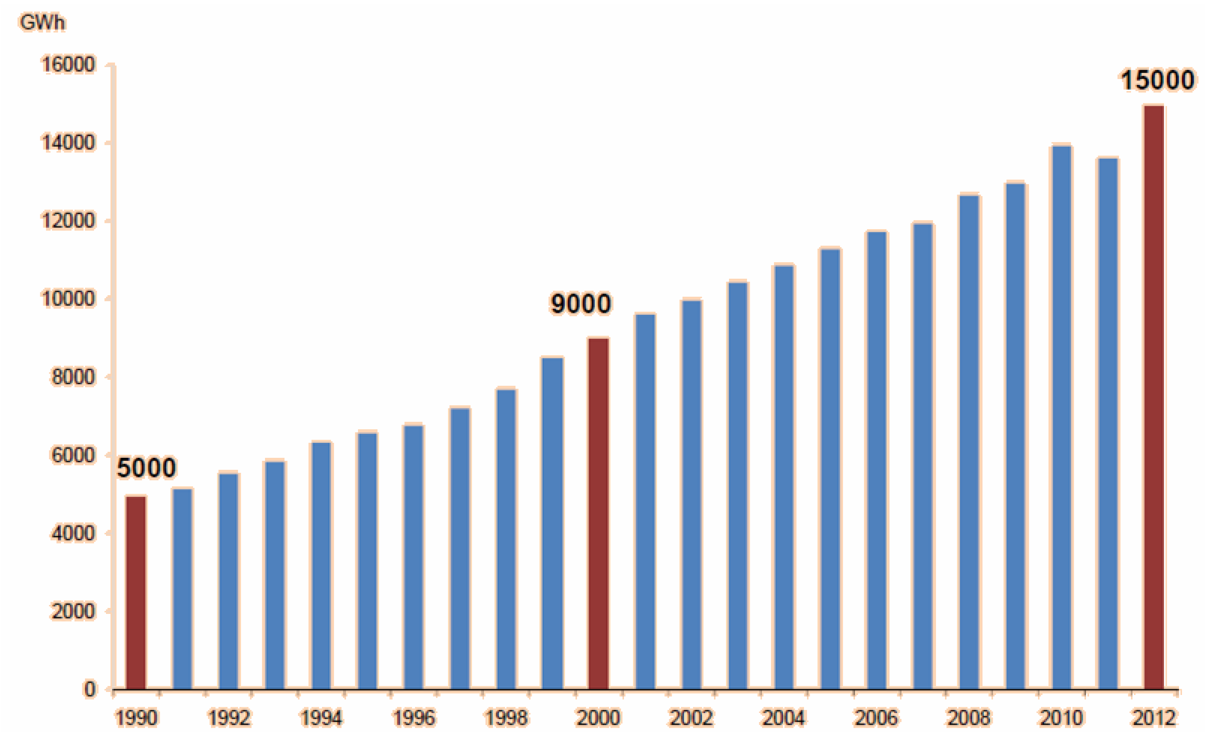



**Figure 2: The evolution of electricity demand during the two last decades.**

Figure 3 summarizes the development of direct energy subsidies during the last decade. The graph is mainly composed of two parts. Firstly, from 2004 to 2010, there is a steady development in energy subsidies. And from 2010, the subsidies have sharply increased. Apart of the burden on the state budget, energy subsidies have highly deviated from the main objectives of their implementation and have led to an over-consumption of energy, high income classes are the most benefiting from incentives and high pollution… These conditions present strong reasons for the reform of energy subsidies and the energy sector in general. The energy sector in Tunisia is based on fossil fuelled resources where the share of natural gas is tremendously growing due to the promotional policies. But, given the actual situation, it is crucial to switch to a model based on a better diversification of energy resources and securing the supply of energy products.

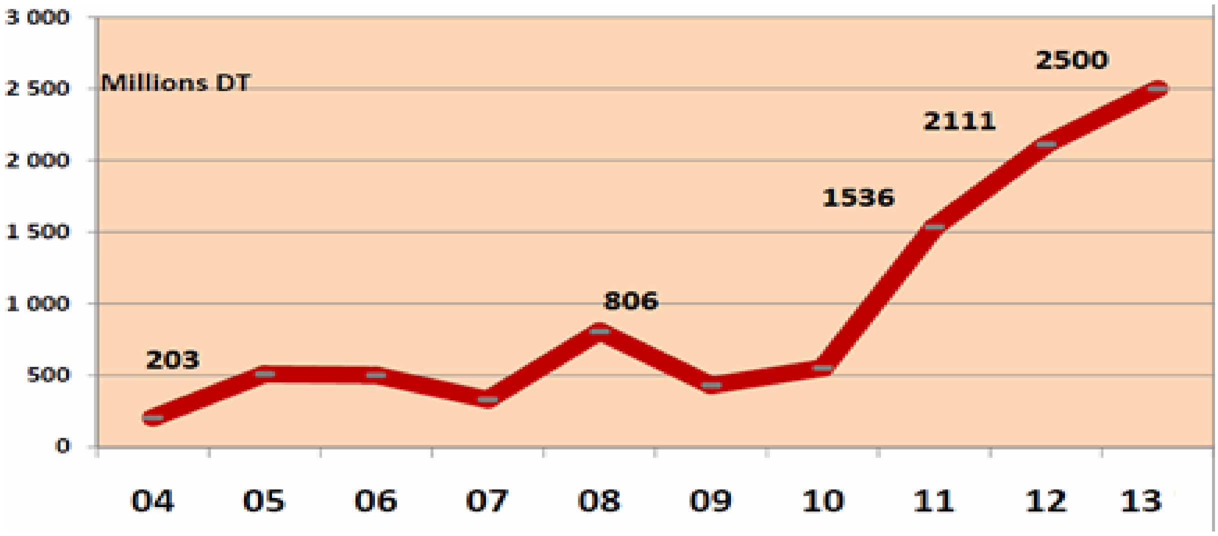



**Figure 3: Development of energy subsidies during 2004 – 2013.**

Experienced already a first transition during the 1980's and 1990's which allowed a high penetration of natural gas in the energy mix, consequently, the second strategy transition should take into consideration a myriad of factors applied in short and long-run to be "successful". As there is a high potential of different resources, conventional and renewable, e.g. significant wind resource reaching an overall speed superior to 6m/s and important solar resource presenting 1800kWh/m$^2$/year in the north and 2600kWh/m$^2$/year in the south, hydrocarbon reserves 600Mtep, the development and research of energy resources through exploration, penetration in the market of new technologies and providing infrastructure, will diversify energy resources and minimize the dependence on fossil fuelled energy and their imports. In order to lighten the burden on the state budget, institutional and budgetary reforms have to be implemented in the energy sector covering subsidies. Ultimately, experts believe that the energy mix should be based on renewable energies, oil products, imported gas, national gas, i.e. new discoveries, and introduction of coal for electricity production. The "voluntarist" scenario of electricity mix for Tunisia in 2030 is expected to be composed of 30% of renewables and 70% of fossil fuelled with a total capacity of 37000GWh. The increase of shares in renewables (solar, wind, and PV) allows a diversification of resources and their industrial integration grants a creation of employment opportunities and regional development. On the other hand, the actual situation and its constraints boost the use of immediate investments satisfying actions of energy conservation and adoption of a coherent strategy in function of the financial means and challenges. Thus, a short-term solution to cover the energy shortfall is adopted within the long-term strategy. However, the share and the budget allocated to the energy conservation are modest compared with those for conventional energies and specifically for conventional energy subsidies, which is illustrated through the National Fund of Energy Conservation (FNME) on the period 2005-2012. Indeed, the subsidies allocated for renewable energies and energy efficiencies reached 65.3 million TND presenting only 0.9% of the total energy subsidies. To promote energy conservation, the reform of energy subsidies should point out the shares between different kinds of energies and do not focus only on conventional energies (Tunisian Ministry of Industry, Energy and Mines, 2013).

This vision is part of the reform sustainability which should be politically acceptable, financially viable, economically efficient, socially desirable, environmentally benign, implementable and manageable. The reform of energy sector started in the 1980's in the power sector of Chile, followed by several countries such as U.K and Argentina, where the reform process consisted in changing the rules of the game, the organisational structure, the governance mechanism, and/or the process of adaptation of the institutional arrangement. In order to have coherence in these modifications, a clear objective and strategy of the reform are crucial; appealing the need of the utilization of Energy Systems Modelling which is considered as a tool for designing the energy system and taking into consideration the interrelations between the sub-sectors related to energy transition.

## 3. Energy System Modelling (ESM) (Bhattacharya S.C., 2011)

The various models that have been appearing lastly aim in general to introduce a better energy supply system design with an improved understanding of the present and future interactions between demand-supply, environment, and economy. According to Hoffmanand Wood (1976), ‘‘Energy system models are formulated using theoretical and analytical methods from several disciplines including engineering, economics, operations research, and management science.’’ ESM are represented in function of data requirements, technology specifications, skills, and computations. The models that have been designed for industrialised countries cannot be transferred for usage and application in developing countries for the non-adequacy due to the several socio-economic changes. Adapted models for developing countries have been recently developed taking into consideration the characteristics of these economies.

The classification of ESMs might differ based on the perspectives and objectives of the research. This paper argues that their historical evolution could be a manner of their categorization and identification in a later stage of the appropriate ESMs for Tunisia taking into consideration the market structures. Mainly, there are three periods which marked the development of ESMs; firstly and following the oil crisis that occurred in the 1970’s, energy demand management appeared, later on and during the 1980’s the shortage in energy supply has led to the development of supply and demand management models, and lastly with the appearance of the climate change concerns in the 1990’s, the models were targeting as well environmental concerns alongside with the decrease in energy consumption.

i. Energy demand side:

“Demand side management (DSM) is the systematic utility and government activities designed to change the amount and/or timing of customers’ use” (CRA, 2005). Other used terms are load management, energy conservation, fuel substitution and load building. Energy demand presents the energy required in a country and the energy supplied to consumers; it is, id est, the relationship between the price and the quantity of energy. The consumption in the other hand is the satisfied demand. There are various factors influencing the energy demand, such as the improvement of living conditions levels, the rise in concerns about global warming, changes in market operations, security of fuel, and computing and communication facilities, which are certainly associated with difficulties in analysing energy demand especially in developing countries where the scene is outlined by a lack of data on traditional energy, lack of consumers purchasing power, supply shortage making the consumption different from the demand, availability and consumption of energy affected by certain social classes of consumers, and the response to price changes difficult to assess. The main determinants of demand are generally the price of the good, prices of related goods, prices of others goods, income of the consumer, preferences… In instance, Ceteris Paribus Assumption[87] holds other determinants fix and draw the relation between the price and the quantity of goods consumed.

The historical evolution of energy demand has allowed researchers to analyze energy demand. Accordingly, it exists so far four types of analysis:

- Descriptive analysis which appeals economic parameters like growth rates, demand elasticity, energy intensities; and it is composed of a general description of the overall energy demand trends in the past and a set the scope and priorities of the analysis.

In order to calculate these trends, we can identify some indicators such as:

Year-on-year growth rate:

$$\alpha = \frac{E_{t+1} - E_t}{E_t} \quad (1)$$

Where a = annual growth in demand, $E_{t+1}$ = energy consumption in year t +1 and $E_t$ = energy demand in year t

Demand elasticity:

$$e_t = \frac{\frac{\Delta EC_t}{EC_t}}{\frac{\Delta I_t}{I_t}} \quad (2)$$

Where t is a period given EC is energy consumption, I is the driving variable of energy consumption such as GDP, value-added, price, income etc. Δ is the change in the variable

- Factor (or decomposition) analysis is the total change in energy consumption and is composed of activity effect, intensity effect and structural effect. There are several methods used for decomposition such as Laspeyres method of decomposition or Divisia Index Method.

$$E = Q \cdot EI = Q \cdot \sum_i \left( \frac{E_i Q_i}{Q_i Q} \right) = Q \sum_i EI_i S_i \quad (3)$$

$$\Delta E = I_{effect} + Q_{effect} + S_{effect}$$

Where

$EI_i$ = energy intensity in sector i

[87] *Isolation and Aggregation in Economics*, Ekkehart Schlicht, 1985

$S_i$ = structure of sector i

Q = overall economic activity with $Q_i$ as the activity of sector i,

E = energy consumption and $E_i$ is the energy consumption in sector i

- Analysis using physical indicators consists on determining the ratio of annual energy consumption by driving techno-economic variable.

$$UE_t = \frac{E_t}{Q_t} \quad (4)$$

Where

$E_t$ is the annual energy consumption

$Q_t$ is the value of the driving techno-economic variable

- Energy demand analysis using econometric approach where the energy demand is estimated by combining the effects of inter-fuel substitution, stock adjustment of appliances and the rate of utilization of devices. However this model doesn't capture the difference between short and long-run adjustment.

The approach is applied using Fisher and Kaysen model, consisting of:

$$Q_i = \sum_{k=1}^{M} R_{ki} A_{ki} \quad (5)$$

Where:

Qi is the fuel consumption by an appliance type k

A is the product of the stock of such appliance

R is the utilization rate.

As an extension, the most widely used single equation appealing lagged variables is:

$$\log E_t = \log a + b \log Q_t + c \log P_t + d \log E_{t-1} \quad (6)$$

Where

E is the per capita real energy consumption

P is the relative price of energy

Y is the per capita real income or output

$E_{t-1}$ is one time-lagged $E_t$

Unfortunately, aggregated analysis fails to capture the characteristics of each sector or sub-sector. Thence, final energy demand sectors analysis has been developed, dealing apart with industry, transport, residential, commercial, agriculture and non-energy uses and where the industry is split into sub-sectors, i.e. mining, manufacturing, and construction. Disaggregated energy demand analysis is prepared using sectoral Energy Accounting which provides information by sub-sector, process type, or end-users through decomposition, e.g. Laspeyres, Paasche, or Divisia methods, econometric approach, e.g. application of the flexible functional form TRANSLOG Model which is a cost function, and the techno-economic approach, appealing engineering and technical characteristics of energy consumption and is useful with the lack of data. These methods are widely used in the industry sector, however the residential and commercial sectors differ especially within developing countries with the appearance of traditional energy and the demand varying in function of income and location.

Forecasting is another important aspect in energy demand based on the analysis and aims to predict the evolution of demand and draw a concrete long-term strategy. For instance in developing countries, there is an urgent need to analyse the past trends to forecast the likely paths of energy demand growth. For these reasons, several approaches have been developed varying from simplistic to sophisticated, economically or technologically targeted. Simple approaches consist of forecasting using simple indicators or trend analysis which is composed of three steps, i.e. the assumption of change in growth pattern, finding the best trend line that fits the data and utilization of the trend line to forecast, or direct surveys. Advanced techniques could be classified following the bottom-up and top-down approaches or based on the type of the model: economic, engineering-economic (accounting), input/output, combined or hybrid. Econometric approach is suitable for short and long-run, policy analysis, flexible, captures the effect of price on energy demand and important determinants of demand and energy-economy interactions; however, it requires experienced modellers, a high quantity and quality of data, government intervention, and doesn't capture technologies. End-use method disaggregates the demand into homogeneous modules and sectors after it links each module to economic and technical indicators. It emphasis on the role of technology, consumers' behaviours, economic environment and it is suitable for medium and long-term visions. Input/output models capture the contributions of activities through inter-industry linkages using Leontief inverse matrix. Scenario approach is rather appropriate for climate change and energy efficiency and it presents the integral part of the end-use approach, captures structural changes explicitly, and is characterized by disaggregation and inclusion of traditional energy and informal activities. Artificial neural networks compose the system into units which are connected through links and nodes and follow the "training" method where the output is compared to the desired value with certain errors. Current models following hybrid approach are difficult to classify since they reconcile “efficiency gap” then they estimate parameters, capture technological, micro, macro, and economic details and take into consideration induced policies.

ii. Energy supply side:

The economic problem of allocating limited resources to various needs often requires decision-making about appropriate investments where the basic analytical framework is based on a cost-benefit analysis which might be a financial analysis, i.e. used for private investments, or an economic analysis, i.e. used for public investments. An economic analysis identifies if the project should be undertaken by public or private investor, fiscal impacts of the projects, efficiency and equity of cost recovery and environmental impacts (World Bank, 1996).

The characteristics of energy projects to take into consideration while analysing the supply side are related to capital intensiveness, e.g. electricity industry is twice or three times capital intenser than manufacturing, asset specifity, long life of assets which involves the uncertainty about the future costs and the benefits, long gestation period, and the size of the project to take advantage of scale economies. The economics of supply differ greatly by source; however there are some common points for evaluation:

- Valuation of projects Input/Output: using the methodology of shadow price which presents the price that would exist if the market operated perfectly and allocated resources efficiently. The existence of distortions due to a lack of competition and government intervention would lead to mistaken values of energy project input/output.
- Border prices for traded goods: appealing four types where the project output is exportable, imports substitute outputs, imported inputs, and exportable input.
- Price of labour: theoretically under full employment and perfect competition the cost of labour is market-determined, however in reality there is an opportunity cost of the labour.
- Price of land: the appropriate price is an opportunity cost as well.
- Price of foreign exchange: in a competitive market foreign exchange rate is decided by the interaction of supply and demand for currencies and in non-competitive market the government intervenes either by fixing a rate or by rationing supply.

For the basic analytical framework, the indicators of cost benefit comparison follow either methods without time-value such as pay-back period and average simple rate of return, or methods employing time value such as Net Present Value and discount rates.

In mathematical terms:

$$\sum_{t=1}^{n} b_t \left(\frac{1}{1+r}\right)^t \succ \sum_{t=1}^{n} c_t \left(\frac{1}{1+r}\right)^t \quad (7)$$

Where

$b_t$ and $c_t$ are annual savings and costs respectively for year t

r is the discount rate

The energy supply is highly related to uncertainty and risk, which are respectively the unknown and unquantifiable situation and unknown situation with quantified outcomes. Sensitivity analysis is usually applied when uncertainty occurred and helps to identify variables affecting project’s variables, investigate their changes, present a potential of reversals and identify mitigation actions. And concerning risk, there is the systematic risk analysis which can appeal a qualitative method giving insights of risk at early stages using a risk matrix or quantitative through assigning a probability distribution to the parameters and determines the expected outcomes, for example Monte Carlo Simulation.

iii. Integrated analysis of the energy system

The interest in managing both demand and supply sides of energy and the concerns about climate change, has induced the development of energy system analysis. Alternative modelling approaches are either bottom-up, top-down or hybrid.

Bottom-up models are traditionally technology-oriented and treat energy demand as either given, for example expressed as useful energy demand, or as a function of, for example, energy prices and national income, where supply is explicit. In the latter case, bottom-up models may be regarded as partial-equilibrium models in the sense that economic equilibrium is achieved between supply and demand for energy. Energy demand is satisfied by a chain of supply and distribution technologies that, generally, are comprehensively described in the model. Technology change occurs through replacement of existing technology by new technologies if these have better cost performance under the circumstances given. Technology change is thus explicitly described technology by technology. There are two kinds of technological models, optimisation-based models such as MARKAL which identify the optimal feasible configuration that would ensure the least-cost supply of energy to satisfy the demand, and accounting models which generate a consistent view of energy demand and supply based on the physical description of the energy system then they draw possible paths of energy system evolution.

On the other hand, top-down, econometric models, describe energy supply and demand for a country where prime drivers are price and economic activities.

The hybrid models, such as NEMS, POLES or WEM, are known with their four components, i.e. final demand module, power generation module, fossil fuel supply, and emissions trading. All these models have a transferability issue, and specifically econometric and optimisation models are not suitable for developing countries because of informal sectors, non-monetary transactions, shortages of energy supply and transition from traditional to modern energies. In brief, macroeconomic models generate economic, demographic, policy framework, and macroeconomic impacts of particular scenarios. Bottom-up models lead to technical developments in the final energy sectors and optimization of electricity generation. And, the hybrid models link the two approaches of bottom-up and top-down models and improve the consultation process in governmental and international institutions. Even though the improvements that have been achieved in each type of models, the need for linkage is crucial which pushes the research to develop hard linking, the different impacts on materials substitution or efficiency in energy-intensive industries, and the implementation of company sizes and influences of barriers and supporting factors.

In regard to the energy economy interactions, energy supply is related to input factors such as imports, and demand is influenced by prices, supply situations, and the economic conditions of the country, therefore the energy system is interlinked with adequate energy supply through correct pricing and adequate investments in supply. To conclude, the price, demand, profitability, investment and cost are related to each other in an energy system.

There are two methods of analysis, the structural accounting matrix (SAM) based on national accounting information presenting the starting point of any multi-sectoral modelling exercise and drawing a picture of a circular flow of funds within an economy, where columns are equal to rows and are all expressed in monetary units, and computational general equilibrium models (CGE) capturing the relationship of energy industries along with other economic activities where all markets are considered to be clearing, i.e. decide the price first and after markets clear and equilibrium price is reached. These models have a solid macro-economic foundation, use basic elements of neo-classical theory of optimizing behaviour of producers and consumers. Thus, they are based on transparency, integrated analysis and adoption of numerical solutions. However, when the level of disaggregation increases, the model becomes more complex, they don't take into consideration non-competitive markets, technological specifications, require high skills, and are using representative consumers which are making them less appealing.

SAM could be translated by the following formula:

$$p_1 = p_1 A_{11} + \overline{p_2} A_{21} + \overline{p_4} A_{41} = (\overline{p_2} A_{21} + \overline{p_4} A_{41})(I - A_{11})^{-1} = \theta_1 M_{11} \quad (8)$$

Where

$\theta_1$ is the exogenous cost vector

$A_{ij}$ is the normalised coefficient matrix

$M_{11}$ is the multiplier $q = Min\left(\frac{z_1}{a}, \frac{z_2}{b}\right)$

Which leads to the generalist equation:

$$p = pA + \theta = \theta(1 - A)^{-1} = \theta M \quad (9)$$

## 4. Selection of ESM

### a. Identification of suitable ESMs for Tunisia case

Based on the attempt of ESMs comparative studies, it is deductible that bottom-up accounting models are the most appropriate for developing countries characteristics since they are flexible, require limited skills, are able to capture imperfections, and take into consideration non-price policies. Even though, their inability to analyse price induced effects, they are still more suitable than econometric models which don't capture informal sector or traditional energy. It is important to mention that the problem of subsidies and shortages are also not adequately captured as the demand is not explicitly covered in these models. (Pandey R., 2001)

In general, it has been demonstrated that ESM is incapable of reflecting specific features of energy systems that are affecting the results of decision making in developing countries. In one hand, we have econometric models which analyse the effects by identifying statistically relationships using economic theories. However, these models didn't capture several of the characteristics of developing countries, energy access, rural-urban divide, difference in consumption behaviour and supply conditions within income classes, traditional energy usage, informal economies, technological diversities and inequity and inefficient technologies, misallocation of resources and choices, non-monetary transactions (inefficient institutional arrangements), transition to modern energies, and data limitation (quality and quantity), known that a lack in time series data could cause biased elasticity and lead to a shortage in the system's robustness. In the other hand, end-use models could suffer from information burden which is substantial, especially that these models cover many fields, e.g. consumption, income, location, end-use types… Moreover, assuming an average level of, e.g. consumption, for the entire population does not fairly represent the demand behaviour because of the differences between the social classes in urban, peri-urban, and rural areas which leads to biased results, non-adequacy of data, and incorrect policy prescription and inadequate development for years; this could be avoided with more disaggregated analysis using detailed consumer characteristics.

According to the comparative study presented in paragraph 3, the inadequate capture was more obvious with econometric and optimisation models than with accounting end -use models because their flexible data requirements and focus on scenarios rather than optimal solutions. Furthermore, the models need to take into consideration rural-urban divide, consumer categories by income, and spacial distribution by giving accurate characterisation of energy problems.

Decisions makers have to take into consideration some barriers that play an important role in the diffusion of efficient and environmentally sound technologies, namely insufficient capital stock, tariff and non-tariff trade barriers, organization of international trade, inadequate R&D policy, lack of institutions for upgrade and use of indigenous technical capabilities and inadequate support infrastructure for training, sustained maintenance/improvement of such technologies and uncertainties which could be under policy uncertainties, related to infrastructure development, rural development, R&D, privatization/regulation and trade, in future demands in different end-use sectors of the economy, and in prices of domestic and imported energy fuels; or non-policy uncertainties, including international trade-influenced prices of imported energy fuels and technologies, international policy arrangements relating to global environment like emission limits, carbon taxes or carbon trading norms, and availability of natural resources like fossil fuels both domestically and internationally. These uncertainties are handled by sensitivity analysis, expected value analysis, and variants of stochastic programming techniques (Foleya A.M. et al, 2010).

In the view of making the right decisions through ESM, the modellers should use effective software, introduce high quality of input data and be as a user well trained. However, there isn't a fit-all model and software sources might be difficult to adopt, adapt and combine for re-use in other contexts since the economic, environmental and social barriers differ from one case to another. With the evolution of energy systems, the modern models are characterized with complex interactions and high quality of analytical tools and data. Using them correctly require: 1. Validated models must be available and appropriate for the target environment. 2. Suitable data must be available for input into the model and for verifying model-based results. 3. Models must be operated by people trained in the use of the tools and in interpreting the outcomes for local conditions. To satisfy these conditions, the development of Open Source Software (OSS) and accessible data started spreading. Yet in an early stage, they allow to set targets and monitor outcomes, design strategies and policies, make evidence-based decisions and enable citizens to make informed choices. Open data sources are then an application of transparency besides allowing the elimination of datasets assembling efforts. Since access to energy remains a critical issue in developing countries, the open energy tools should be adapted as well to traditional energy planning tools, and researchers should aim for the minimum acceptable fidelity because modelling resources are limited. OSSs represent a common paradigm known to have a high adaptation and enough promising characteristics to be used in developing countries and can meet high standards relative to the proprietary software sources. In addition to OSSs and access to data, capacity building and education in the field of energy modelling should be accessible to satisfy the condition of trained users; some institutions started developing this vision. In conclusion, energy analytics is essential to the design information, implementation and operation of energy systems. OSSs and free access to data facilitate energy modelling, avoid replicating efforts of data collecting, and allow the development of this field with regard also to accessible training and education in order to appropriately use these models. The examples of open source models are numerous; two examples are discussed below and connected with the scope of this paper:

i. Global Trade and Environment Model (GTEM) (Saunders M. Schneider K., 2000)

This model was designed to capture harmful energy subsidies and presents scenarios tackling this burden on the state budget. GTEM is characterized by multi-region and multi-sector coverage and dynamic general equilibrium taking into consideration the world economy reflected through global change policies. The origin of this model is MEGABAR and GETAP models, the added value of GTEM is that it takes into account the interactions between different sectors of an economy and estimates the impacts of policies on key economic variables which are price of consumer goods, inputs into production, sectoral and regional outputs, trade and investment flows, regional income and expenditure levels. Regarding the environmental aspect, GTEM models emissions, i.e. $CO_2$, methane and nitrous oxides. GTEM uses a business as usual simulation and presents a commodity disaggregation since it has been used in 45 regions and over 50 industries. The GDP used as an input is obtained from IMF. It applied Leontief function summarized as follow:

$$q = Min\left(\frac{z_1}{a}, \frac{z_2}{b}\right) \quad (10)$$

Where

$q$ is the quantity of output produced

$z_1$ and $z_2$ are the utilised quantities of input 1 and input 2 respectively

$a$ and $b$ are technologically determined constants.

ii. The Open Source Energy Modelling System (OSeMOSYS) (Howells M. et al, 2011)

Known for its flexibility, OSeMOSYS is modifiable depending on the target of the modelling, e.g. it has been applied to South Africa for energy planning, and is composed of three main parts which are a plain English description, an algebraic formulation and a detailed description of the model inputs, outputs and parameters. OSeMOSYS is an optimization model and aims to calculate the lowest net present cost of an energy system to meet given demands. It is used for long-term energy planning by developed and developing economies' researchers even though developing countries are characterized by high $CO_2$ emissions, high resource use and an elevated demand for energy services. The model is easily updated and modified under the form of series of components "Blocks" where each block is composed of: a plain English description- of sets, parameters, variables, constraints and objectives-, an algebraic formulation of the plain English description, the model's implementation in a programming language, and the application of the model depending on the study. There are 7 disaggregated, compatible and replaceable blocks: objective, costs, storage, capacity adequacy, energy balance, constraints and emissions. The plain English description helps on matching the policy maker and energy system analyst's expectations.

## 5. Conclusion

Energy subsidy is any action or policy made by the government that lowers the price paid by consumers. Initially, in developing countries, energy subsidies were adapted to ensure that all the social classes have access to energy and to assure local industrial growth. Nowadays, subsidies distort price signals, fail to reflect the true economic cost of supply, represent a burden on the government budget and crowding out other necessary expenditures or investments. Subsidies of fossil fuelled energies resulted in an over-use, inefficient and wastage of energy and an extra-pollution. Many countries are keeping or implementing subsidies to overcome market failure, however this method is highly harmful for the economic efficiency. The removal of energy subsidies increases energy efficiency and decreases environmental damages. The interactions between energy and other sectors such as transport made the reform of subsidies complicated especially for energy intensive industries. A reform of energy policy plans should prioritize ancillary services, such as storage, long term energy generation planning projects with tax incentives, in order to engender development, sustainable secure and efficient energy system, employment and fossil fuel resources preserve. Demand Side Management (DSM) is necessary to improve efficiency in energy and particularly electricity consumption. Uncertainties due to risk and error have to be fully quantified and sensitivity analysis is necessary to evaluate the outcomes of various scenarios and to accentuate the effectiveness of a policy. The choice of a model to study energy system is critical and should be fully scoped prior to selecting the software to use, and the results of one model should be fully validated by another similar model.

In plain English and in the purpose of making the right energy planning, decision support methods are highly used in recent years through models, which have been tremendously increasing based on the different criteria reflecting the needs. These models are applicable through computer programs. Choosing the adequate model is based on the criteria characterizing the energy planning. There are some general characteristics shared by all models and other specific ones that the developer judged necessary at a certain situation. Therefore, classifying ESM is becoming very complex given the increasing number of programs and the huge criteria that could be taken into consideration. Selecting the proper model requires an overview of the different classes. However, such an overview covering all classes arbitrary is not yet examined by the literature. This paper points out a classification of models based on their evolution within time and therefore adopting their main purposes, i.e. demand side, supply side, or energy system. Last comparative studies have shown that bottom-up, accounting models are the most suitable for capturing developing economies characteristics. Nonetheless, developing countries specifications differ greatly. Tunisia may be quoted as an example for the dilemma of energy access which is presenting most of developing states major problem; the network of STEG is covering 99.6% of the territory. Depending on the flexibility of the model and its transparency, the case of open-source models, researchers might develop the adequate model depending on the needs and conditions.

## References

Bhattacharya S.C. (2011). *Energy Economics: Concepts, Issues and Governance.* London: Springer.

Foleya A.M. et al. (2010). A strategic review of electricity systems models. *Journal of Energy*, 4522-4530.

Howells M. et al. (2011). OSeMOSYS: The open source energy modelling system: An introduction to its ethos, structure and development. *Energy Policy*, 5850-5870.

Pandey R. (2001). Energy policy modelling: agenda for developing countries . *Energy Policy*, 97-106.

Saunders M. Schneider K. (2000). 23rd Annual IAEE International Conference. *Removing energy subsidies in developing and transition economies.* Sydney: ABARE.

Tunisian Ministry of Industry, Energy and Mines. (2013, September). *National Debate on Energy*. Retrieved from www.tunisieindustry.gov.tn.

# Biodiesel Production from Microalgal Systems: A Resource Based Feasibility and GHG Assessment

**Lazaros KARAOGLANOGLOU[1*],**

**Spyros DAMILOS[1],**

**Dr. Dimitrios KOULLAS[1],**

**Dr. Ioannis TZOVENIS[2],**

**Prof. Emmanuel KOUKIOS[1]**

[1] Organic Chemical Technologies Laboratory, School of Chemical Engineering, NTUA
Address: NTUA Zografou Campus, GR-15700 Athens,Greece
Tel: +302107723288; Fax: +302107723163; e-mail: lkaraog@chemeng.ntua.gr
[2] School of Science, Department of Biology, NKUA
[*] *Corresponding author*

**Abstract:** Microalgae provide a promising alternative feedstock for biodiesel production due to their high lipid content and productivity compared to other biodiesel sources. Their current high costs of production can become competitive by R&D on: (i) process optimization; (ii) joint production of high value added co-products and services, and (iii) environmental impact-based justification of their benefits. The object of this paper is to present an overview of the scenarios for biodiesel production from potential microalgae units. A review of the available tools for the assessment of the GHGs, along with the potential modifications to be applied to the microalgae supply chain will be discussed. Modified tools applied to the above mentioned scenarios and results are compared with fossil diesel data, as well as the available literature. The outcomes are: (i) A large variety of system scales, depending on the resource availability (land, water, nutrients) is possible; however, the relatively small scale systems (in islands), combining water treatment services are most attractive. (ii) Favourable environmental conditions (solar radiation intensity and temperature during the year) improve the system efficiency, while land availability remains as a major obstacle to overcome, especially when large production systems are under consideration. (iii) The GHG emission assessment of the micro algae-to-biodiesel systems should also take into account the co-product credits that will play a crucial role in the overall environmental impact. (iv) System configuration and corresponding productivity should be optimized to make the biofuel production pathway environmentally sustainable. The integration of environmental services into the chain; i.e., use of $CO_2$ from flue gas of large energy intensive production units, will play a crucial role in this direction.

## 1. Introduction & background

The use of liquid biofuels is expected to play a crucial role in the sustainability of the future global energy system. The growing research on sustainable and renewable alternatives to fossil-derived fuels stems from the increasing global concerns on energy security and environmental deterioration due to the carbon emissions from combusting fossil fuels. Biofuels (such as biodiesel, bioethanol, biohydrogen, biogasoline, and biogas) can be considered, under certain conditions, sustainable and renewable sources of energy, due to their relatively short processing time as well as the availability and continual replenishment of their feedstock [1] [2].

Under this point of view, EU policy for the transport sector determined that each Member State has to ensure that the share of energy from renewable sources in all forms of transport combined in 2020 should be at least 10%. The seemingly 'green' first -generation biofuels (from palm oil, corn, and other food crops) have spawned huge disputes over their contribution to increased food prices and the neglect of accounted greenhouse gas emissions due to land use changes [2]. As a consequence, one of the major sustainability conditions set from the relative new EU directive is the minimization of the direct or indirect impact of the transport biofuels on the food and feed supply chain [3].

Within this framework, microalgae attract the research attention since they have the capacity not to have to compete with food crops for arable land or other scarce agricultural inputs. Many microalgal strains grow rapidly and can be cultivated in open ponds or photobioreactors [1]. Microalgae, with their large diversity, high yield and lipid content is considered as a promising feedstock for the production of new generation biodiesel, where more efficient use of the resources will be required [4]. The exponential increase of the published work, on the use of algae for bioenergy applications during the last years [5], along with the worldwide scaling-up efforts of the algae related technology indicate the importance of the specific pathway for the future energy map.

This interest is also due to the fact that microalgae, by their nature, are the most efficient converters of sunlight and $CO_2$ into biomass in comparison with any other plant. Coupling the photosynthetic efficiency of microalgae with biomass production therefore offers exciting prospects for the utilization of biogenic carbon for producing renewable biofuels [2], and a large spectrum of other products.

The actual assessment of microalgae related biofuel generation potentials, and their impacts, as well as the optimization of the production system require support by a large body of multi-disciplinary research, from microbiology and bioinformatics to system operations and from life-cycle analysis to social impacts and policy. The relevant research focuses on the feasibility and sustainability of microalgae-based biofuels industry in terms of resource-use, feedstock demand, net energy production, system benefits, and economics [2].

The environmental burden associated with the biofuel production process is primarily due to energy requirements such as fuel and electricity for feedstock and end product transport, power machinery, heating during processing, land use change, as well as embodied energy to produce raw materials (e.g. fertilizers, methanol and construction materials). The overall net savings achieved by biofuels are dependent on the particular feedstock, production and management process, the synergies with other alternative energy production systems (i.e. power generation) and the location of biofuel production [1] [6]. The relevant complexity and the major available options for each process step of the under study technological pathway [7], [8], along with the potential inputs and outputs are presented in Figure 1.

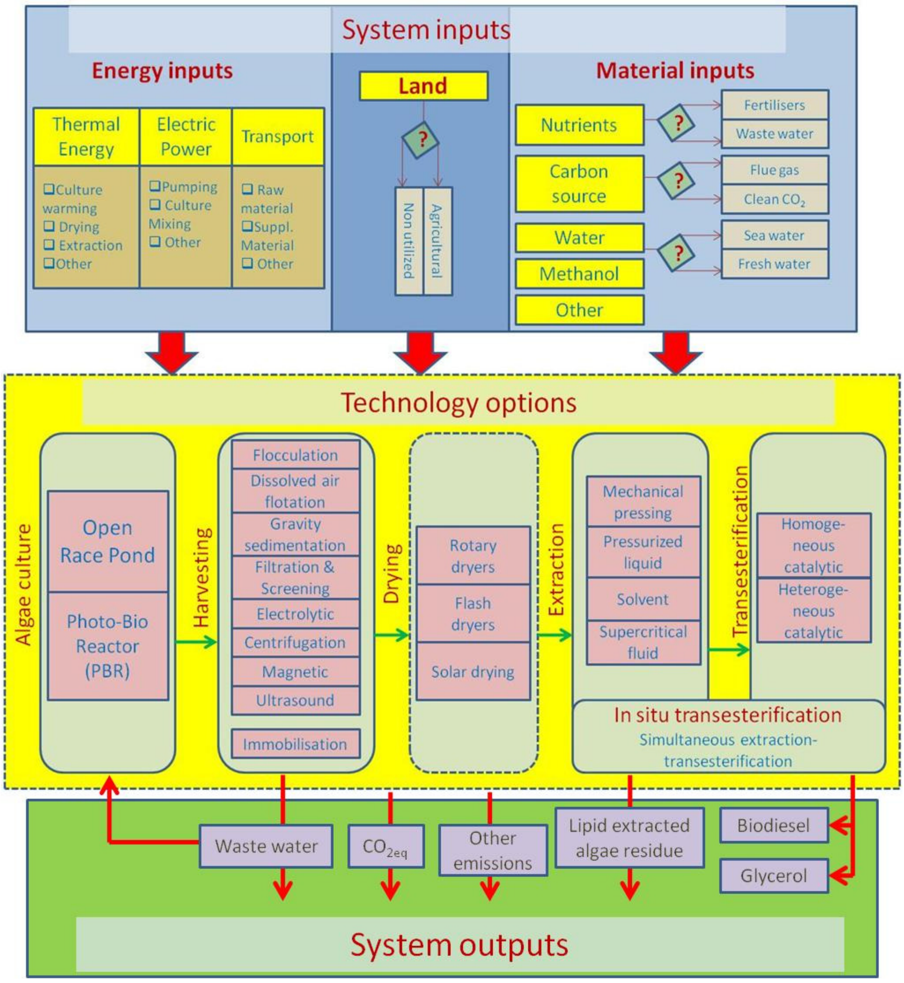



**Figure 1: System description and technology options in each system component.**

The key objective of this study is not to offer a sustainability analysis of the current microalgal biodiesel technology, but to identify the crucial system components and limitations which should receive specific research efforts to make the whole system environmentally sustainable. Furthermore, through the use of specific boundary conditions and assumptions the identification of GHG related upper emission limits, as well as the limiting factors which can block the development of the specific technology took place. Last but not least, insights to the available standardized tools, for GHG emissions assessment, were gained and the experimental data needs were identified for their proper and trustworthy utilization. This knowledge will be used for data gathering from pilot scale microalgae production facilities, which are expected to operate in five Mediterranean regions, within the context of, "MED ALGAE" project (ENPI-CBC Programme) [http://med-algae.com/], because fully understanding and evaluating the environmental burden of microalgal biodiesel production requires pilot-scale tests [1].

## 2. Approach and Methodology

Since the use of $CO_2$ emissions from power plants and other energy intensive industries is presented as a competitive advantage of the specific technology in various literature sources [9]; [10]; [11]; [12]; [13] the potential application of this technology in three different power plant capacities throughout Greece was taken into consideration as a major scenario parameter. The land which will be needed for the sequestration of a considerable amount of their emissions was estimated in order to assess the realistic importance of this approach for any major GHG generating industrial player under the view of the current technological state of the art.

The assessment of the GHG emission impacts of this technologically immature system will follow, using a standardized approach. For this reason one of the above mentioned three initial scenarios was selected. The methodology followed aimed at the below presented discrete targets:

- Application of two LCA based GHG emission assessment tools for biofuels; BIOGRACE and ARGONNE GREET; their adaptation, comparison and efficiency assessment of their utilization for the under study systems;
- Identification of the crucial design parameters, of algal biodiesel production systems, and the uncertainties due to the lack of data from large scale production;
- Compared results of GHG emission of the studied scenarios with those of fossil fuel and other biofuel production systems, as they are given from recent EU studies;
- Identification of the gap between the current state of the art and the GHG emission based sustainability threshold and the improvement prospects.

## 3. System boundaries and assumptions

For the purpose of this study, and due to the lack of primary data from large scale algae production facilities, at the moment, data collected from the literature were combined with, theoretical and empirical models, as well as with known processes developed for first generation biofuels and other industrial applications, in order to design a realistic industrial production system.

The considered functional unit of the LCA is 1 MJ as available energy content of biodiesel (Lower Heating Value based calculation). It is a "from well to tank" analysis for the fuel, consequently, the analysed system includes algae cultivation, harvesting, drying, oil extraction, and transesterification steps. The extraction and production of supplementary raw materials is also included within the scope of study, whereas biofuel elaboration, and use in the engine are kept out of this scope. Moreover, facility construction and dismantling, and $CO_{2eq}$ emissions due to the relevant activities was also kept out of the calculations, following the relevant guidelines of the EU Renewable Energy Directive [14].

The more specific overall system boundaries and assumptions are presented in Table 1.

## 4. Technologies selected for the system components

Multiple steps of the above described system components are characterized by immature or non-optimized technological options. Although the algae cultivation technology is a well established technology, given the relevant experience for several decades, especially in Asia, their previous high value added food sector end products led the system optimization effort to different directions. The massive cultivation for fuel production, which is a low value end product, and the specific energy use restrictions for achieving positive energy balance, set some new challenges and require certain improvements in the system.

The apparent system complexity and the diverse level of availability for large scale application data for each individual process unit, required the selection of one specific technological pathway, to be studied within the context of this work. The selected technological pathway and the further assumptions related with it are presented in Table 2.

**Table 1: System boundaries.**

| System component | System configuration |
|---|---|
| **Location** | Samos island[1] |
| **Reference unit** | 1 MJ of biodiesel |
| **Cultivation type** | Autotrophic algal bloom (multi algal system)[2] |
| **Cultivation system** | Open race pond (ORP) |
| **Cultivation system temperature** | Ambient temperature[3] |
| **Nutrient supply** | $CO_2$: From flue gas produced from the local diesel based power plant<br>N, P: From fertilizers Ammonium Nitrate – (AN) – $NH_4NO_3$ and Diammonium Phosphate – (DAP) – $(NH_4)_2HPO_4$ |
| **Water** | Sea water |

[1] Any LCA based GHG and environmental impact study should be site specific, since not only the assessment of the emissions of complex systems is important, but also the receiving environment should have the capacity to handle the system outputs. In our case an island was selected as a model system, where potentially an energy wise self sufficient, low emission producing, “green” island can be structured in the future. A further future reconfiguration where the initial fertilizers will be replaced by the N and P content of the waste water streams, from the already existing waste water plant, may create additional benefits. Moreover, value added product generation options through the exploitation of multiple non lipid substances of algae may have also a positive contribution to the direction of sustainability and can create synergies with already existing activities of the island.

[2] Chlorella sp., was used as a model micro-organism, to simulate the algal bloom, whenever specific yield and oil content data was necessary.

[3] Assuming that in a multi algal system the oil output will not be largely affected by the temperature within the range of the expected temperature changes in the specific location during the year, despite the changes which may be observed in the dominant algae species.

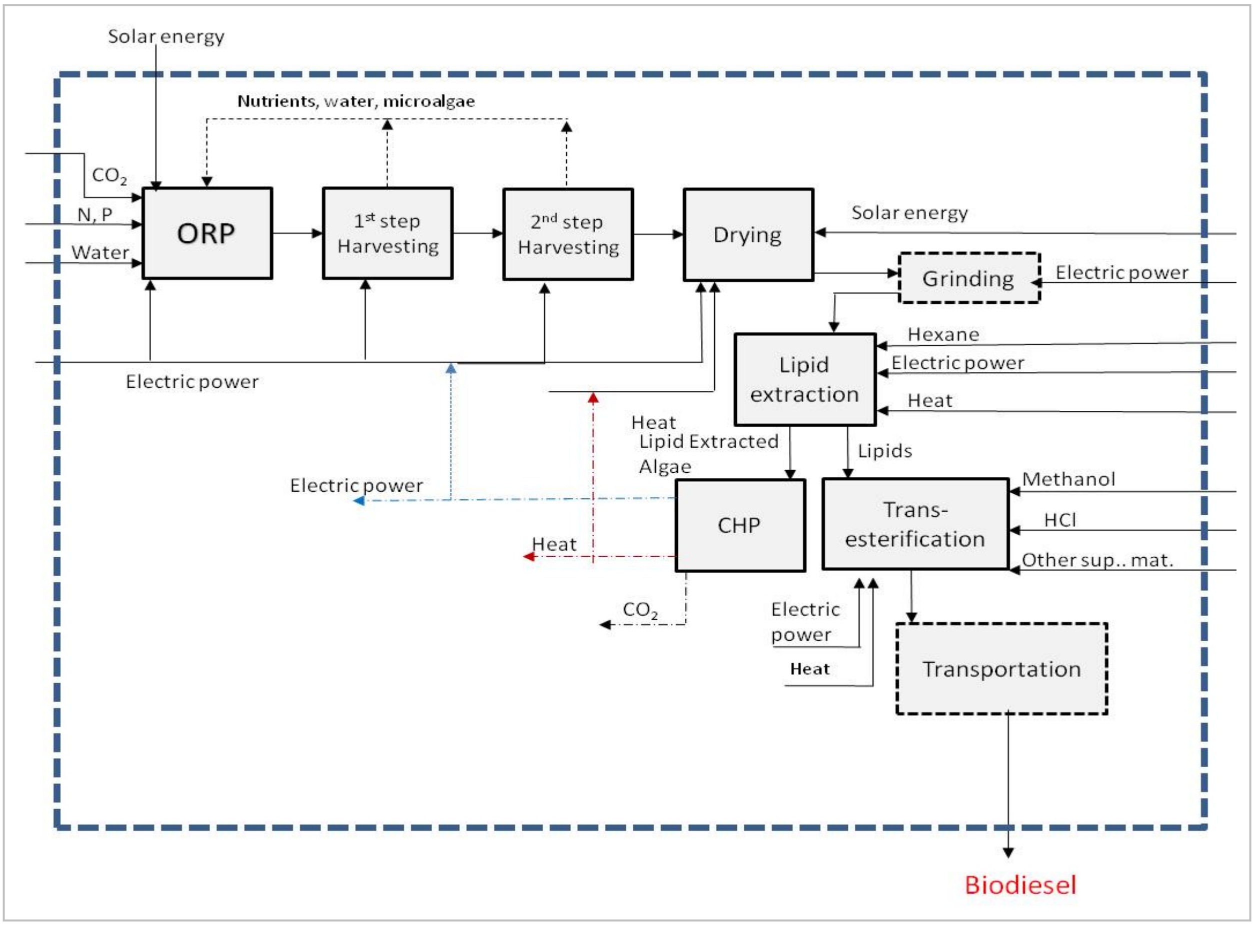



**Figure 2: System boundaries.**

**Table 2: Selected, base case, technology scenario.**

| Process unit | Selected technology | Base case assumptions |
|---|---|---|
| Algae cultivation system | Multialgal system in open race pond | ➢ Use of paddle wheel mixing system<br>➢ A completely open system, which will require water addition, from time to time due to evaporation<br>➢ Operation period: 300 days/a<br>➢ Maintenance period: 60 days, during the winter, where the system productivity will be at its lowest level<br>➢ The climate related behaviour of the system categorized into three individual periods during the year: summer (3 months); winter (3 months, two of which maintenance period); intermediate (6 months: spring and autumn)<br>➢ The culture density is determined as 0.3 kg/m$^3$, according which each microalgae culture cycle is defined<br>➢ $CO_2$ requirements: 1.8 kg/kg$_{microalgae}$ [15] 70% $CO_2$ processing efficiency of microalgal system: 2.57 kg/kg microalgae supply is assumed<br>➢ Ammonium nitrate (AN) and Diammonium Phosphate (DAP) assumed as nutrient sources<br>➢ Nutrient requirements for Nitrogen: 46,0 g N/kg$_{microalgae}$ and Phosphorus 9,9 g P/kg$_{microalgae}$ [15]<br>➢ For the correlation of system productivity with temperature and irradiation empirical relations from the literature were used [16]; [17]<br>The system energy needs are limited by paddle wheel operation, flue gas transport power and water pumping needs |
| Harvesting | Two-step harvesting | ➢ Step one: Vibrating screen filter up to 6% dry microalgae containing sludge<br>Step two: Filter press up to less than 22% algae containing paste |
| Drying | Indirect solar drying system | ➢ The further drying, up to less than 10% moisture content, was selected given the decision taken for the oil extraction technology, dry extraction, which will be followed;<br>➢ Hot air technology for drying was selected, where air flow about 90$^o$C was assumed to be used in the algae drying chambers;<br>The heating process of the air will take place using the combination of a solar energy system with conventional fossil fuel boiler. |
| Grinding | Hammer mill | The efficient use of microalgae feedstock in a soxhlet system require further processing into a finely ground material. Hammer mill was used as it is a well known process used also for other type of biodiesel producing feedstocks. |
| Oil Extraction | Solvent extraction | ➢ Hexane extraction in a close soxhlet system was assumed;<br>➢ The solvent to feedstock ratio was taken equal to 20:1;<br>The solvent loss was assumed to be very small in such a close system. And this loss, estimated at 1% of the extracted oil, is the actual $CO_2$ emission contribution of the solvent used, in a steady state operation of this process. |
| Transesteri-fication | Catalytic process | ➢ A base catalysed (NaOH) process was selected, as a common transesterification process presently used by biodiesel industries;<br>➢ Methanol was used for the process, as well;<br>Glycerine production as process co-product was also taken into consideration. |
| Co-product valorisation | CHP plant for system energy needs | ➢ The lipid extracted algae (LEA) residue has 12% moisture content;<br>➢ LEA: ~ 2.5 t/t algal oil produced<br>➢ Power production: ~ 7 GJ/t LEA<br>Heat production: ~ 10 GJ/t LEA |

The overall system boundaries along with the major inputs and outputs are schematically presented in the Figure 2.

## 5. Calculations

As it is already mentioned above, for data which is not available from real life or pilot scale operation, multiple theoretical or empirical equations were used for the estimation of their value. The equations, for data calculated for three different process steps, are presented below:

**a.** ***Effective growth rate for the calculation of the microalgal culture growth under the site specific temperature and irradiation conditions [18]***

$$\mu_{eff} = \mu_{light} \cdot \left[ \frac{T_{let} - T_w}{T_{let} - T_{opt}} \right]^{\beta} \cdot e^{-\beta \cdot \left[ \frac{T_{let} - T_w}{T_{let} - T_{opt}} - 1 \right]}$$

$\mu_{effective}$ ($d^{-1}$): is the effective growth rate of the system at a certain depth.

$T_{let}$ (°C): is the lethal temperature

$T_{opt}$ (°C) is the optimal temperature

$T_w$ ($^oC$) is the water temperature

$\mu_{light}$: Growth rate as a function of light

β is the curve modulating constant

**b.** ***The calculation of the temperature change in the ORP [19]***

$$\rho_W \cdot (1-\varepsilon) \cdot Cp_W \cdot A \cdot z \cdot \frac{dT}{dt} = Q_{cv} + Q_{fg} + Q_{cd} - Q_{evap} \cdot A + Q_{IRR} - Q_{rd}$$

Pw: water density (998 kg/m$^3$)

ε: The gas hold-up (gas volume fraction in the liquid)

$Cp_w$: water specific heat coefficient (4180 $Jkg^{-1}C^{-1}$)

A: Pond area (1000 m$^2$)

z: Pond depth (20 cm)

$Q_{cv}$ :Heat transfer due to convection (W)

$Q_{fg}$: Heat transfer due to flue gas (W)

$Q_{cd}$: Heat transfer due to conduction (W)

$Q_{evap}$: Heat loss due to evaporation (W)

$Q_{IRR}$: total solar radiation (W/m$^2$)

$Q_{rd}$: Heat transfer due to radiation

**c. The *Page Model for calculations relevant with the water removal in the drying process [20]***

$$MR = \frac{M(t) - Meq}{Mo - Meq} = e^{-k \cdot t^n}$$

MR: The dimensionless moisture ratio, is the unaccomplished moisture change defined as the ratio of free water still to be removed at any time t to the total free water initially available.

M(t): Is the instantaneous moisture content (dry basis)

$M_o$: Is the initial moisture content (dry basis)

$M_{eq}$: Is the equilibrium moisture content (dry basis)

k: Drying constant ($min^{-n}$)

n: Drying constant

t: time (min)

## 6. GHG emissions assessment tools

The assessment of the GHG emissions of the under study system took place through the application of collected and estimated data into two freely available GHG assessment tools. Some more specific details of their use follow:

- ***Argonne GREET Model:*** It is a model developed by Argonne National Laboratory operating under US Department of Energy. It provides a platform for systematically exploring biofuel production options,including algae biofuels. The model allows analysts to readily define an algal biofuel pathway by selecting processes from a process inventory. The inventory is used to (1) define the production pathway; (2) itemize consumed fuels and materials; (3) define unit process inputs, outputs, and yields; and (4) summarize the pathway steps for GREET. GREET then considers the conversion of lipids into fuel, material transportation steps, co-product treatment, and emissions calculations. [21] The model was used through the application of above mentioned assumptions and empirical relations based calculations of system parameters. For the assessment the model database concerning the energy and material production was used. Certain deviations are expected due to the differences of US and EU energy systems and relevant emissions per MJ electricity.

- ***BIOGRACE (Harmonized calculations of biofuel greenhouse gas emissions in Europe):*** The BioGrace greenhouse gas (GHG) calculation tool has been recognised as a voluntary scheme by the European Commission. It is in line with the sustainability criteria of the Renewable Energy Directive (2009/28/EC, RED) which are equally stated in the Fuel Quality Directive (2009/30/EC) [http://www.biograce.net/]. The tool in its current form includes only spreadsheets for the calculation of GHG emissions of a limited number of biofuel production pathways. However, it is considered as a dynamic tool, which is expandable by the users. Given that algae biodiesel was not included in the ready-to-use spreadsheets, an already available biodiesel production pathway was partly modified, as far as the feedstock production and pretreatment are concerned, in order to calculate the system emissions.

**Sensitivity analysis**

The impact of four separate system parameters on the overall GHG emissions of the system was also estimated, through a sensitivity analysis, in order to have further insights into the specific system components. The parameters studied in the sensitivity analysis along with the range of the considered values are presented in Table 3.

## 7. Results and discussion

**Overview of the power plant capacity and location based scenarios in Greece**

The three base scenarios were selected according to the order of magnitude of their yearly $CO_2$ emission.

An overview of the region specifications along with the land which would be needed for the sequestration of the total $CO_2$ emissions of each plant, assuming a typical microalgal operation efficiency, is given in Table 4.

The above table indicates that targeting on the sequestration of a significant amount $CO_2$ emissions from large scale power plants using algae production unit, is not a realistic scenario, given that the land needs will be a limiting factor which will block any further discussion.

On the other hand, when smaller plants are considered, like the ones in the two islands, the whole concept seems more sensible. On this basis, the further investigation took place for Samos island case.

**Table 3: Sensitivity analysis parameters.**

| Control parameters | Values |
|---|---|
| **Electricity used in the production system** | Originated from:<br>➢ 100% oil fired power plant<br>➢ 100% natural gas fired power plant<br>➢ 50%+50% oil fired+natural gas power plant |
| **Algae lipid content** | 20% w/w<br>30% w/w<br>40% w/w |
| **Microalgal concentration in the ORP output** | 0.2 kg algae/m$^3$<br>0.3 kg algae/m$^3$<br>0.4 kg algae/m$^3$ |
| **Selected secondary harvesting technology** | Filter press<br>Decanter |

* Red fonts for the base scenario

**Table 4: Case studies in three power plants in Greece [22].**

| Site specific characteristics | | | | | |
|---|---|---|---|---|---|
| | Units | **Ptolemaida** | **Samos** | **Milos** | **Source** |
| Irradiation | kWh/m$^2$/a | 1.810 | 2.110 | 2.120 | http://ec.europa.eu |
| Population | capita | 45.450 | 32.759 | 4.959 | http://www.statistics.gr/ |
| Area | ha | 21.790 | 78.060 | 16.770 | http://www.geodata.gov.gr |
| Non utilized land | ha | 3.340 | 3.680 | 1.380 | http://www.geodata.gov.gr |
| $CO_2$ emissions | t/a | **9.650.000** | **105.260** | **8.038** | http://carma.org |
| Land need for total use of $CO_2$ emissions | ha | **180.000** | **2000** | **150** | |

**Table 5: System inputs and outputs (1000 $m^2$ ORP), seasonal variation and overall results.**

| | | Winter | Intermediate | Summer | Total (annual basis) |
|---|---|---|---|---|---|
| **Output** | Biodiesel (kg) | 81,400 | 1.191,691 | 599,101 | 1.872,192 |
| **Co-product** | Glycerol (kg) | 17,386 | 254,537 | 127,964 | 399,887 |
| **Inputs** | Lipids (kg) | 84,656 | 1.239,359 | 623,066 | 1.947,081 |
| | Methanol (kg) | 1,881 | 27,533 | 13,842 | 43,256 |
| | NaOH (kg) | 0,079 | 1,158 | 0,582 | 1,820 |
| | $P_2O_5$ (kg) | 0,081 | 1,191 | 0,599 | 1,870 |
| | Citric acid (kg) | 0,059 | 0,869 | 0,437 | 1,365 |
| | HCl (kg) | 3,531 | 51,691 | 25,987 | 81,208 |
| | Electric power (Wh) | 63,796 | 933,967 | 469,535 | 1.467,298 |

**Table 6: GHG emissions of algae to biodiesel production system.**

| Emissions | GREET | BioGrace |
|---|---|---|
| $CO_2$ (g/$MJ_{biodiesel}$) | 157,511 | 182,017 |
| $N_2O$ (mg $MJ_{biodiesel}$) | 180,880 | 240,869 |
| $CH_4$ (mg/$MJ_{biodiesel}$) | 179,612 | 135,397 |
| $CO_{2\text{-}eq}$ (g/$MJ_{biodiesel}$) | 233,864 | 227,635 |

**Table 7: Energy balance and NER for the 1000 $m^2$ ORP.**

| | | Overall |
|---|---|---|
| **Output** | **Biodiesel (kg)** | 1.872 |
| | **Biodiesel (MJ)** | 70.260 |
| **Input** | **Electric power (MJ)** | 9.728 |
| | **Heat (MJ)** | 4.994 |
| **Energy balance (MJ/kg-biodiesel)** | | -27,6 |
| **NER*** | | 1,65 |

**Base case energy, material needs and emissions assessment using the two models**

The system inputs and outputs as they are calculated within the framework of this study, for a 1000 $m^2$ ORP, using also the Argonne GREET model are presented in Table 5. It can be seen that the yearly production potential of the system is much higher than any traditional energy crop cultivation, although moderate assumptions for the algae production yield and lipid content were made.

Furthermore, the overall GHG emissions of the system, according to the above presented energy and material needs were assessed though the use of the two models. The results are presented in Table 6.

It can be observed that the outcomes from the two models show just small differences in the assessed overall GHG values (the results are definitely in the same order of magnitude).

The Net Energy Return value, which is the ratio of the total energy input to the total energy output was also calculated and the relevant results are presented in Table 7. The results indicate that the algae biodiesel production pathway in its specific configuration does not produce environmentally sustainable results, since the energy spent for produced biodiesel is much more than its energy content.

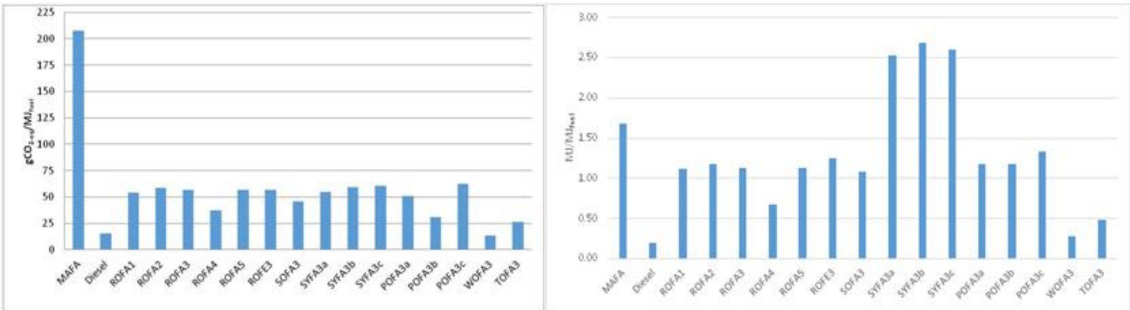
**Comparison of study results with other fossil fuel and biodiesel production pathways**

The results of the present study were compared with other diesel and biodiesel production pathways. For this purpose the most recent results of "Well-to Tank" analysis [3] carried out for EU was taken into consideration.

It can be observed that the GHG emissions of the studied system are far beyond all the compared pathways, whereas its NER performance is comparatively better, although being, yet, in the unsustainable zone (its value is over one). It should be noted that in our case the energy credit for glycerol, as it is calculated by BIOGRACE model was taken into account; in order to have comparable results with the competing technologies.

**Sensitivity Analysis**

The results of the sensitivity analysis for the 4 already defined control parameters are presented in Figure 4.




**MAFA:** Algae methyl ester**; Diesel***:* Fossil diesel; **ROFA:** Rape seed methyl ester; ***ROFA1***: Glycerol use as chemical; ***ROFA2*****:** Glycerol as animal feed; ***ROFA3*****:** Glycerol use for biogas production; ***ROFA4*****:** Glycerol use for biogas production; ***ROFA5:*** Glycerol use for biohydrogen production; **ROFE:** Rapeseed ethyl ester; ***ROFE3*****:** Glycerol use for biogas production; **SOFA:** Methyl ester from sunflower oil; ***SOFA3*****:** Glycerol use for biogas production; **SYFA:** Soya bean methyl ester; ***SYFA3a*****:** Glycerol use for biogas production and oil import to EU; ***SYFA3b*****:** Glycerol use for biogas production and soya beans imported to EU; SYFA3c: Glycerol use for biogas production typical soy bean cultivation for the import of the beans to EU; **POFA:** Palm oil methyl ester; ***POFA3a*****:** Glycerol use for biogas production; Without $CH_4$ recycling; Heat credit; ***POFA3b*****:** Glycerol use for biogas production; Recycling of $CH_4$ emissions; Heat credit; ***POFA3c*****:** Glycerol use for biogas production; Without $CH_4$ recycling; Without heat credit; **WOFA:** Waste cooking oil biodiesel; ***WOFA3*****:** Glycerol use for biogas production; **TOFA**: Biodiesel from steatic fatty acids; ***TOFA3*****:** Glycerol use for biogas production;

**Figure 3: Comparison of $CO_{2eq}$ emission and Net Energy Return (NER) values of the study system with other biodiesel production systems**

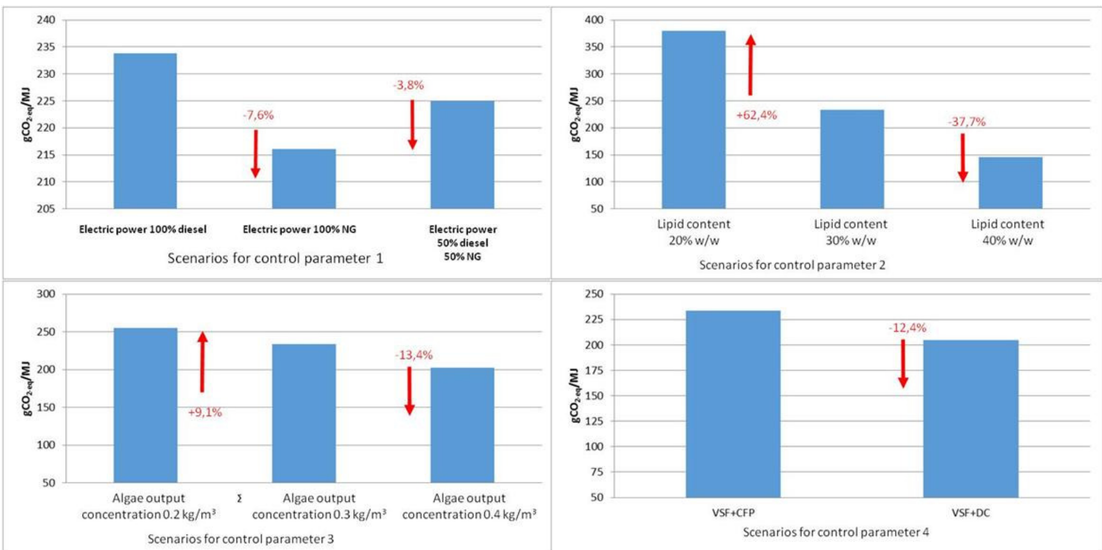



**Figure 4: Sensitivity analysis results.**

The sensitivity analysis indicates that the lipid content is the parameter which may have the most important impact on the GHG emission per MJ biodiesel. Consequently, the selection of the correct microalgae species, or multialgal system operation conditions, can improve significantly the system performance. The harvesting technologies and the algae output concentrations may also have a relatively important impact on the emissions. Using different primary energy source, switching between diesel and natural gas, seems to have a more limited impact on the overall efficiency.

## 8. Conclusions & Future Work

Although the use of $CO_2$ emissions from industrial activities in the production of microalgal biofuels can be a feasible option for the algae cultivation unit, the actual benefits of industries, from $CO_2$ emission reduction will be very limited, unless the scale of the algal cultivation unit is extremely large. Consequently, only in the cases where the land availability is not a limiting factor; i.e. dessert land, off-shore applications etc.; it can be considered as an option attracting the attention of energy intensive industries for $CO_2$ sequestration.

The overall system GHG emissions calculated in the present study are much higher than the ones of competing alternative biofuel production technologies of first generation biofuels. However, it should be considered that even under these circumstances, the utilisation of non agricultural land, and seawater, can lead to benefits from the specific production pathway, under the condition that the economic feasibility of the system is also ensured.

The Net Energy Ratio (NER) based results of the studied system also indicate that there is an important gap to cover for making the whole system energy-wise sustainable. Two complementary directions for this purpose should be the reduction of the system energy needs through process optimisation efforts and the increase of the share of renewable energies in the energy spent for the system operation.

The study results showed that the most energy intensive process steps are the algae culture and harvesting. In both steps large amounts of water are handled. The results would have been even worse if heating and cooling processes were used for the ORP system. Current research efforts are focused on these two processes, in order to improve both ensuring environmentally more sustainable and financially feasible technologies. It should be also noted that as the sensitivity analyses indicated, even under the current conditions, increase in the yield or lipid content can improve significantly the efficiency of the system performance.

The comparability of the results with other similar studies is limited, given the variety of system boundaries, technologies, assumptions and data sources utilised for those assessments. The limited real life process outputs add also to the uncertainties of any LCA based GHG assessment efforts. However, it should be noted that the results in most relevant studies are in the same order of magnitude, except the cases where extreme and rather unrealistic microalgal yield and oil content assumptions are made.

To conclude, despite the promising and overoptimistic literature about the use of the microalgae biofuel production, the current state of the art is quite far from the feasibility and sustainability threshold. The gap can be bridged with coordinated technology and system optimisation efforts in the direction of:

- ✓ productivity improvements;
- ✓ plant location optimisation;
- ✓ process energy need optimisation;
- ✓ process material input optimisation;
- ✓ process output optimisation through a biorefinery approach of fractionation and multiple customised product output;
- ✓ integration of the services offered by the system into the overall outputs; i.e. environmental services through the use of nitrogen and phosphorus outputs of waste water treatment plants.

The present work constitutes a methodology development and technology review study, which will be used as a pilot for five relevant studies which will be carried out in different Mediterranean country regions in Cyprus, Egypt, Italy, Lebanon and Malta. In the context of these studies real data produced from pilot scale open pond and photo-bio-reactor systems, along with site dependent environmental data will be used for the assessment of GHG emissions under multiple operation scenarios.

## Acknowledgements

The authors gratefully acknowledge the support of the project by ENPI CBC Mediterranean Sea Basin Programme.
The present work is part of the Diploma Thesis of S.P. Damilos, carried out in NTUA Postgraduate course, “Energy Production and Management”, presented in October 2014.

## References


[1] V. O. Adesanya, E. Cadena, S. a Scott, and A. G. Smith, "Life cycle assessment on microalgal biodiesel production using a hybrid cultivation system.," *Bioresour. Technol.*, vol. 163, pp. 343–55, Jul. 2014.

[2] H. H. Khoo, P. N. Sharratt, P. Das, R. K. Balasubramanian, P. K. Naraharisetti, and S. Shaik, "Life cycle energy and CO2 analysis of microalgae-to-biodiesel: preliminary results and comparisons.," *Bioresour. Technol.*, vol. 102, no. 10, pp. 5800–7, May 2011.

[3] J. E. C. B. Programme, A. R. Concawe, K. D. Rose, and T. V. Concawe, *EU renewable energy targets in 2020 : Revised analysis of scenarios for transport fuels*. 2014.

[4] L. Ahmad, N. H. M. Yasin, C. J. C. Derek, and J. K. Lim, "Microalgae as a sustainable energy source for biodiesel production: A review," *Renew. Sustain. Energy Rev.*, vol. 15, no. 1, pp. 584–593, Jan. 2011.

[5] O. Konur, "The scientometric evaluation of the research on the algae and bio-energy," *Appl. Energy*, vol. 88, no. 10, pp. 3532–3540, Oct. 2011.

[6] O. Bernard, "Policy Analysis Life-Cycle Assessment of Biodiesel Production from Microalgae," pp. 6475–6481, 2009.

[7] *Algal Culturing Techniques*. Elsevier; 2005; 205-218.

[8] L. Gouveia, *SpringerBriefs in Microbiology*, Microalgae. Springer, 2011.

[9] D. Bilanovic, M. Holland, and R. Armon, "Microalgal CO2 sequestering – Modeling microalgae production costs," *Energy Convers. Manag.*, vol. 58, no. 2012, pp. 104–109, Jun. 2012.

[10] A. Demirbas, "Biodiesel from oilgae, biofixation of carbon dioxide by microalgae: A solution to pollution problems," *Appl. Energy*, vol. 88, no. 10, pp. 3541–3547, Oct. 2011.

[11] A. Kumar, S. Ergas, X. Yuan, A. Sahu, Q. Zhang, J. Dewulf, F. X. Malcata, and H. van Langenhove, "Enhanced CO(2) fixation and biofuel production via microalgae: recent developments and future directions.," *Trends Biotechnol.*, vol. 28, no. 7, pp. 371–80, Jul. 2010.

[12] M. K. Lam, K. T. Lee, and A. R. Mohamed, "Current status and challenges on microalgae-based carbon capture," *Int. J. Greenh. Gas Control*, vol. 10, pp. 456–469, Sep. 2012.

[13] J. C. M. Pires, M. C. M. Alvim-Ferraz, F. G. Martins, and M. Simões, "Carbon dioxide capture from flue gases using microalgae: Engineering aspects and biorefinery concept," *Renew. Sustain. Energy Rev.*, vol. 16, no. 5, pp. 3043–3053, Jun. 2012.

[14] EU, "L 140/16," *Dir. 2009/28/EC Eur. Parliam. AN; EU RED Dir.*, pp. 16–62, 2009.

[15] Lardon L. et al., *Life Cycle Assessment of Biodiesel Production From* Microalgae, Environmental Science & Technology (2009) 43 (17), 64756481

[16] Geider, R.J., H.L. MacIntyre, T.M. Kana, *A Dynamic Model of Photoadaptation in Phytoplankton*, Limnology and Oceanography 41(1) (1996) 115.

[17] Blanchard, G.F. et al., *Quantifying the Short Term Temperature Effect on Light saturated Photosynthesis of Intertidal Microphytobenthos*, Marine Ecology Progress Series 134 (1996) 309313.

[18] M.B. Lösing, Modelling & simulating microalgae production in an open pond reactor, Thesis Systems and Control, Agrotechnology & Food Sciences, Wageningen University, January 2011

[19] H. Shang et al. / Chemical Engineering Science 65 (2010) 4591–4597

[20] T. Viswanathan et al. / Bioresource Technology 126 (2012) 131–136

[21] E.D. Frank, et al.; User Manual for Algae Life-Cycle Analysis with GREET: Version 0.0; Argonne National Laboratory; September 2011

[22] Kollias L.; "Biodiesel production using Microalgae as a feedstock", Dipl. Eng. Thesis; NTUA; July 2013.


## Web sources


http://ec.europa.eu (Accessed in May 2013)

http://www.statistics.gr/ (Accessed in May 2013)

http://www.geodata.gov.gr (Accessed in May 2013)

http://carma.org (Accessed in May 2013)

http://www.biograce.net/ (Accessed in September 2014)

# Potentials of Biofuel Generation from Organic Waste: A Pilot project at a Composting Facility in Darmstadt, Germany

**J. KANNENGIESSER*,**

**T. MRUKWIA***

**J. JAGER ***

**Institute IWAR, Department of Civil Engineering and Geodesy, Technische Universität Darmstadt, Germany*

Address: Franziska-Braun-Straße 7, 64287 Darmstadt, Germany

**Abstract:** New ideas of producing a different kind of biofuels from biodegradable waste are presented. A modified rotting box is installed at a composting facility. Organic waste collected and shredded is first treated in the rotting box. Water is supplied continuously in the box and the leachate of the waste is collected and recirculated in the system to enrich the water-soluble organic components in the liquid phase. The rotting box is operated under facultative anaerobic conditions to suppress oxidation as well as methanation reactions. The organic-rich bulk liquid is collected periodically from the rotting box and stored in an intermediate bulk container under certain conditions to bring about fermentation. During the fermentation process, fatty acids are produced. Using a variety of fatty acids generated in a chain elongation process, different kinds of biofuel can be produced. Three different kinds of biofuels will be produced. The first technique is to produce a biodiesel with a lower viscosity. The idea here is to use biodiesel, which is a non-polar solvent, to extract longer chain fatty acids. Longer chain fatty acids available in the biodiesel will be esterified with alcohol. As a result, biodiesel with a reduced viscosity will be generated. Another possibility is to use the fatty acids ethyl esters as an additive for a vegetable oil fuel after re-extraction from biodiesel. The third possibility is to use the re-extracted fatty acids to produce bio-based hydrocarbon through bio-electrolytic-conversion Kolbe synthesis.

*Key words:* Biowaste, Fatty Acids, Waste to fuel, Biofuel

## 1. Introduction

This paper provides an overview of investigations for a new technology to generate biofuel additives by using bio-waste. The investigations are taking place at the composting plant in Darmstadt-Kranichstein (Germany). The aim is to integrate a facultative anaerobic process into the normal aerobic waste treatment process to earn bio-based products in addition to compost. [Kannengiesser et al., 2012]

## 2. Waste Composition

All investigations are based on the biological waste of Darmstadt, which is collected from private households and treated at the composting facility in Darmstadt (Kranichstein). In this chapter the composition and the treatment process of the organic material will be described.
A screening process was used to determine the composition of the biological waste delivered to the composting facility screening, the waste was sorted into different fractions, like green waste, kitchen waste, vegetable waste, plastics, residual waste and the sorting rest. All these fractions were put up together into three main fractions, namely, (1) "green waste", (2) "food waste", which consists of the fraction of kitchen waste and vegetable waste and (3) "unwanted" containing the fraction of plastics and residual waste. The change in composition of the biological waste in Darmstadt is shown in Figure 1.

The biological waste treated in the composting facility contains a high amount of green waste. In average more than 65% of these wastes can be assigned to the fraction "green waste". Only 21% can be defined as "food waste" and approx. 13% are unwanted materials. The composition of the organic waste is typical for a composting process.

## 3. The Treatment Process

The bio-waste has to be treated in four steps to produce biofuels. The first step is the facultative anaerobic treatment of the waste in a rotting box to generate a liquid fraction, namely, percolate, which is rich in fatty acids. In the second step, afermentation process will be initiated to activate the present microorganism in order to degrade the organic components that are still remaining in the percolate to produce additional fatty acids.

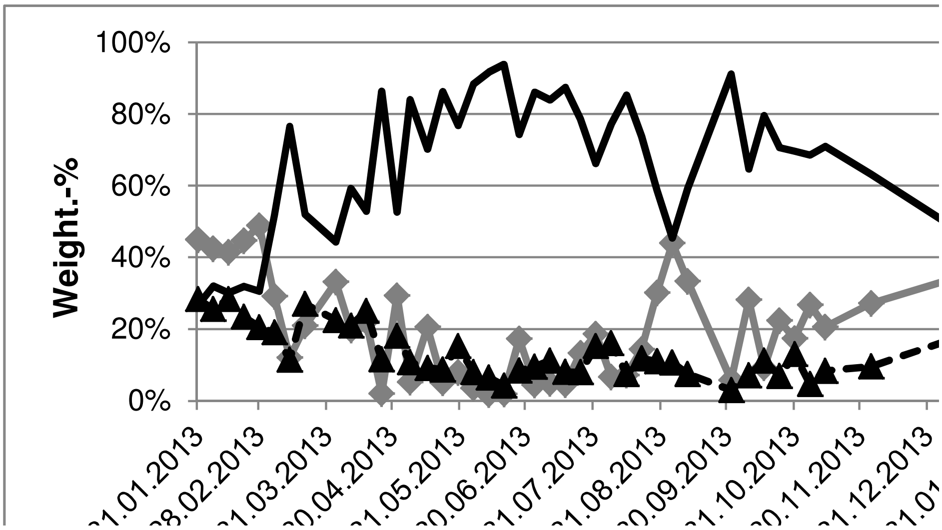



**Figure 1: Composition of biological waste from municipal waste collection in Darmstadt.**

Next to the fermentation process, a chain-elongation step is started by adding ethanol to the fatty acid rich percolate [Bornstein and Baker, 1947; Thauer et al., 1967]. After these three pre-treatments, the percolate is brought to a refinery to extract the non-polar fatty acids by using bio-diesel, which was generated from used kitchen oil at the refinery. After extraction, the bio-diesel enriched with the fatty acids is esterified. As a result bio-diesel with a lower viscosity than usual is produced. The fatty acids remaining in the percolate after the extraction can be used in another fermentation process to earn biogas.

## 4. Results

The investigations have shown that liquid substrate with rich fatty acid contents can be produced by integrating a percolation process of biological waste at a composting facility in Darmstadt. The fatty acid content of the percolate strongly depends on the composition of the used bio-waste. Percolation tests with a high amount of food waste have shown that the concentration of fatty acids in the percolate is much higher than using bio-waste with a high amount of green waste.

In comparison of the both treatment steps before the extraction, the fermentation leads to much higher fatty acid concentrations than the chain-elongation step. Because of these results and the additional costs, which are caused by adding ethanol to the percolate, the maturation process according to the Kluyveri principle is not recommended for a general use. Other investigations have to be done in order to determine the impacts on the maturation process to improve the effectiveness of this treatment.

Under the counter characteristics at the composting facility in Darmstadt where 13,200 Mg bio-waste is handled per year, an extraction capacity about 6.1 to 9.7 kg of fatty acids in one m³ percolate can be found, if 20 Mg of waste will be used for each percolation process with a yield of 3-4 m³ percolate. This will end in 15.7 to 24.5 Mg fatty acids extracted at the facility per year. Based on these yearly extraction amounts, approx. 105 Mg bio-diesel could be produced when 117.5Mg of used kitchen oil was used to produce bio-diesel.

The remaining fatty acids in the percolate after extraction could also be used in another fermentation process to generate biogas. Approx. 2.200 m³ (± 244 m³) Biogas could be produced per year with an energy content of six kWh/m³.

## References

Bornstein, B.T., Baker, H.A. (1947): The energy metabolism of Clostridium Kluyveri and the synthesis of fatty acids“

Fair, J. R., Humphrey J. L. (1983): Liquid-liquid extraction process. In: Fifth Industrial Energy Technology Conference Volume II, Houston, TX, April 17-20

Hoffmann, M. (2012): Abfalltechnische Erweiterung von Bioabfallbehandlungsanlagen für die Herstellung biobasierter Produkte. Dissertation. Publisher: Verein zur Förderung des Instituts IWAR der TU Darmstadt e.V., Schriftenreihe IWAR Nummer 218, ISBN 978-3-940897-16-9

Jager, J.; Rohde, C. (2006): Semizentrale Ver- und Entsorgungssysteme für urbane Räume Chinas. Final report of Chair of Water Supply and Groundwater Protection, Chair of Wastewater Technology, Chair of Waste Technology and the chair for Spatial and Infrastructure Planning, BMBF-Reseachreport, FKZ 02WD0607

Kannengiesser, J., Jager, J., Lahl, U. (2012): Generation of liquid fermentation products from biodegradable waste, In: Book Of Abstracts, SOWAEUMED INTERNATIONAL WORKSHOP – „Innovative Technologies for Solid Waste and Water Treatment", Publisher: National Center for Studies and Research on Water and Energy, ISBN: 978-9954-31-193-6

Levy, P.F., Barnard, G.W., Garcia-Martinez, D.V., Sanderson, J.E., Wise, D.L. (1981): "Organic Acid Production from C02/H2 and CO/H2 by Mixed-Culture Anaerobes". Biotechnology and Bioengineering, 23, P. 2293-2306

Levy, P.F., Sanderson, J.E., Kispert, R.G., Wise, D.L. (1981): "Biorefining of biomass to liquid fuels and organic chemicals". Enzyme Microb. Technol., 3, P. 207-215

Rohde, C. (2007): Milchsäurefermentation von biogenen Abfällen; Dissertation, In: Schriftenreihe WAR 186, Publisher: Verein zur Förderung des Instituts IWAR, Darmstadt, Germany

Thauer, R.; Jungermann, K.; Henninger H.; Wenning J.; Decker, K. (1967): "The Energy Metabolism of Clostridium Kluyveri". European Journal of Biochemistry 4, P. 173 – 180

# Economic analysis of an offshore wind farm near Samothraki island

**Dipl. Eng. E. I. KONSTANTINIDIS [1]**

**Dipl. Eng. D. G. KOMPOLIAS**

**Associate Professor P. N. BOTSARIS**

Democritus University of Thrace, School of Engineering, Department of Production Engineering and Management, Section of Materials, Processes and Engineering

[1] *Contact details of corresponding author*

Tel: +30-25410-79878
Fax: +30-25410-79878
e-mail: ekonstan@pme.duth.gr

http://medilab.pme.duth.gr/

Address: 12 Vas. Sofias str. Building I, Office 103, Central University Campus, 67100 Xanthi, Greece

**Abstract:** Offshore wind power generation is a very important and promising source of clean energy. Even though offshore power generation demands higher investments and has increased operational and maintenance costs, the stronger winds that imply greater productivity in the vast offshore areas make offshore power generation more competitive compared to onshore. The scope of this study is the economic analysis and the investigation of the viability of an offshore wind farm in the Greek sea area, northeast of the island of Samothraki.In the context of this study an offshore wind farm which is previously studied from a technical aspect (location, wind data, type of the wind turbines, losses due to the wind turbines interaction, visual impact, interconnection) is further analyzed. The cost estimation of the project is mainly based on a fairly reliable model developed by the National Renewable Energy Laboratory of U.S.A, as well as other sources (manufacturers' data, international literature). The estimated capital cost (€/MW) is close to the average cost for offshore projects in Europe and the U.S.A for the years 2012-2014. The viability of the investment is studied through specific economic indicators (net present value, internal rate of return, benefit- cost ratio) that are calculated by using the software RETScreen® International, indicating whether the realization of such an investment is viable or not. In addition to this a sensitivity analysis of some economic variables of the study is carried out in order to investigate how these economic parameters affect the viability of the investment. Even though in the greater Samothraki sea area there is a notable offshore wind potential at low depths and at relatively short distances from the shore, these facts are not a sufficient condition for the development of offshore wind farms in this area. The economic estimations based on data calculated for the years 2012-2013 showed that the project could be viable (with the current constant prices of electricity sold), only when there is a significant subsidy of the investment by the state.

**Keywords:** renewable energy, offshore wind farms, economic analysis, viability

## 1. Introduction

The last decade wind energy has become a significant factor for promoting sustainable development. Offshore wind farms seem to be advantageous due to the enormous energy potential associated with the large continuous areas and the stronger winds that imply greater power generation. The development of offshore wind energy is expected to expand dramatically over the next few years since the application of renewable energy sources is a key policy of both the EU and most countries. According to the European Energy Roadmap 2050 (1. European Commission, 2011) the share of renewable energy rises substantially in all scenarios, achieving at least 55% in gross final energy consumption in 2050, an increase of 45 percentage points from today's level of around 10%. At the same time the greek national energy policy for 2050 (2.YPEKA,2012), which is aligned to the European one, predicts changes of the present legal and finance framework, in order for the renewable energy investments to become more attractive.

Greece has a significant offshore aeolic potential (Figure1). By the end of 2013 a total wind power capacity of 1,865 MW (3.

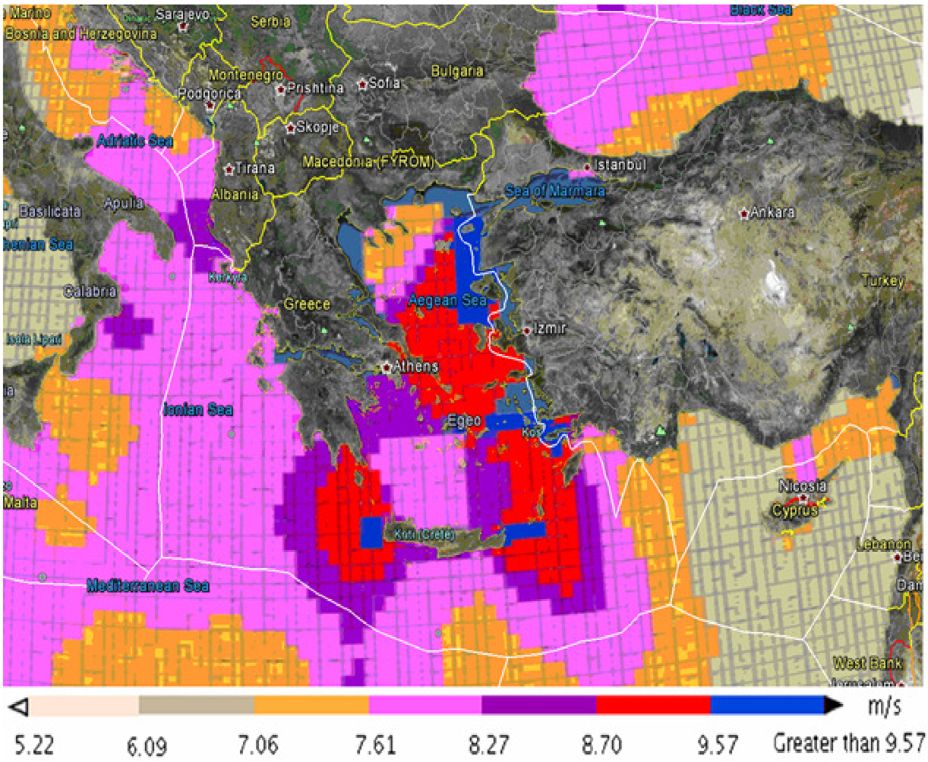



**Figure 1: Average offshore wind speed at 90 m height by NREL (2006, 2008, 2009). The wind resource graph was created using data from the National Oceanic and Atmospheric Administration (NOAA) which is hosted through the International Renewable Energy Agency (IRENA) by an agreement with NREL.**

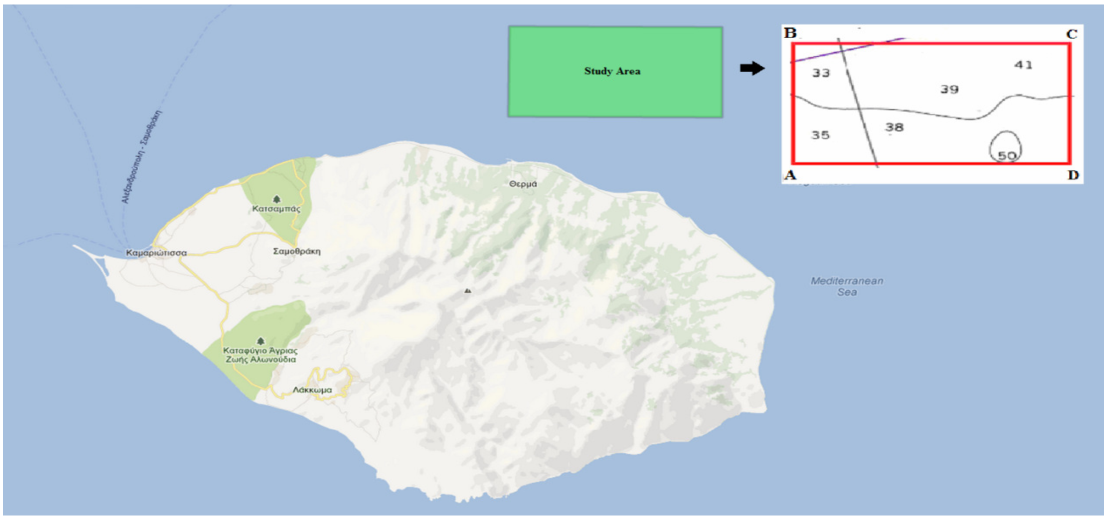



**Figure 2: Study area for the offshore wind farm of Samothraki.**

http://www.thewindpower.net/country_en_15_greece.php, 2014) was installed, but there are no offshore projects in operation or even in the construction phase, The present study focuses on an offshore wind farm near Samothraki island located in the North Aegean (Thracian) Sea and examines the viability of the designed wind farm. The pre-selection of the present study area was made in a previous stage study (4. Botsaris and Konstantinidis, 2011). In order to result in the proposed area for offshore wind turbine installation, environmental issues and other sectors of the economy such as touristic development, fishery and transportation had to be taken under consideration. This holistic view of the offshore wind farms installation issue indicates the proper way to the sustainable development of the country.

## 2. Siting and planning of the wind farm

Samothraki is a small island in north Aegean Sea in Greece. The study area of ***Samothraki*** is located in the sea area by the northeastern part of the island and it is defined by the points **A, B, C, D** (Figure 2). The extent of the intervention is estimated at approximately 20 km$^2$. Figure 2 shows the study area proposed for the development of the offshore wind energy installation near Samothraki island.

Coordinates for the demarcation points of the study area of Samothraki

| A | B | C | D |
|---|---|---|---|
| 40°31'06"N<br>25°36'07"E | 40°32'51"N<br>25°36'07"E | 40°32'51"N<br>25°40'48"E | 40°31'06"N<br>25°40'48"E |

For the siting process of the offshore wind farm of Samothraki the following criteria were applied:

- Appropriate marine depth within 6 nautical miles (*nm*), which can ensure the technical possibility to install wind turbines at the specific locations;
- Avoidance of sites with significant environmental effects (Natura 2000);
- Remarkable wind potential (> 6 m / sec at altitude of 10m).

The study area of Samothraki has an average marine depth of about 39 m. (Figure2). The study area is sited in such location and distance from the shore, that the Natura network is not affected. The wind data were provided by the National Observatory of Athens (N.O.A) and were processed using the predictive model of the Bologna Limited Area Model (BOLAM) (5. Lagouvardos et. al. 2003).

BOLAM is a meteorological forecasting model that can calculate wind speeds at 10 m above the sea level and for grid surface 6.5 km X 6.5 km. The wind forecasts of the proposed areas were given by the N.O.A. The estimation of the wind energy potential (from a 10 meter anemograph) concerns a period of time of 4 years (01/01/2007-01/01/2011) and 3 hour intervals between the values calculated. The calculations of the wind are performed at the centers of the study area of Samothraki with latitude and longitude ***C: 40° 31' 59''N, 25° 38' 27''E***.

The software ***WindRose PRO3*** was used for the analysis of the wind speed and direction and the results are presented in the form of a circular statistical diagram. For the imprinting of the graph (Figure 3) 11.684 measurements were used (01/01/2007 - 01/01/2011) concerning wind speed, direction, time and date. Based on this circular diagram, it is shown that for the area of Samothraki the average speed is 6.2 m/sec (at 10 m height) with a maximum value of 23.2 m/sec. The main direction of wind is the northeast (45$^0$). The software **RETScreen® International** was used for the calculation of wind speed at the hub height and also for the calculation of the annual energy production and the capacity factor for different wind turbine models. The wind turbine model ***RE Power (Senvion)-5M*** was chosen as it has a higher capacity factor compared to other models as well as a higher annual energy production.

For the siting of the wind turbines the Wake lost model was applied (6. Rajai, 2007). The *N.O. Jensen Wake Model* (7. Schepers et al., 2001) is one of the main models applied at most wind potential software and is used for the siting of the wind turbines in the area of Samothraki. According to this model the wind direction is an important parameter for the siting of the wind turbines (8. Kusiak and Song, 2010).

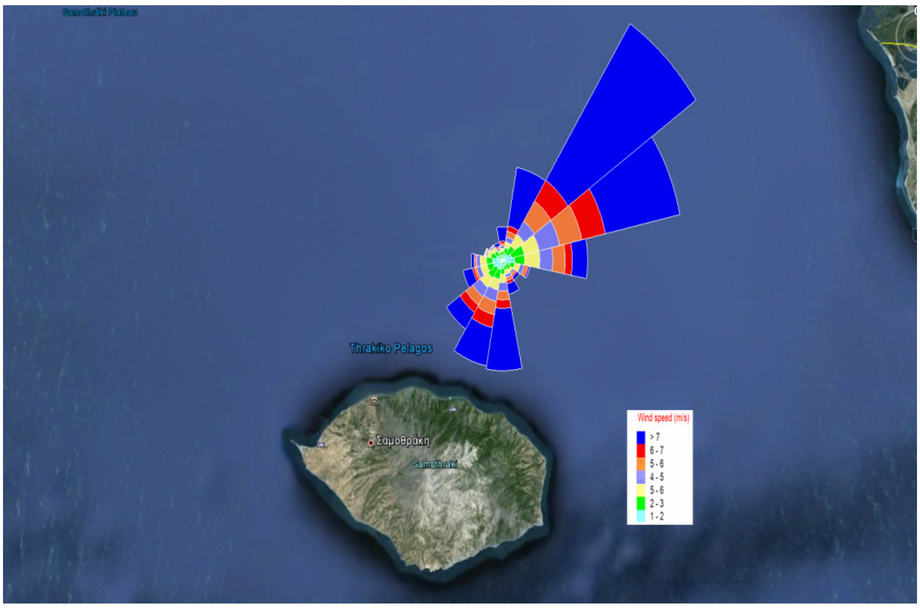



**Figure 3: Wind Rose – Samothraki.**

For the present offshore wind farm, the distances between the wind turbines were selected 8D (D: the rotor diameter) along the rows and 8D between the rows (rotor diameter D of RE Power (Senvion) - 5M is 126m) to ensure as fewer losses as possible of about 10% (9. Nielsen, 2003). For sea surface roughness equal to 0.001m (10. Burton et al., 2011), the decay constant is estimated at *0.04* according to the technical specifications of *RE Power(Senvion) - 5M*. Therefore, according to the *N.O. Jensen* model the required distance is *103* m. The planning of the siting of the offshore wind turbines was performed by using the ***AutoCad® 2012*** software, according to the criteria mentioned before and the *N.O. Jensen* model. The distances of the wind turbines from the nearest part of the coastline were calculated by using the *AutoCad* software, which was also used to test the criterion of the visual impact. In order to avoid the bunching of wind turbines near to the shore the criterion of visual impact was considered. To determine the level of visual impact created by a wind turbine located at a distance L from the observation location, the projection of the height and the surface are used at a distance of 0.5 m from the observer's location (11. YPEKA, 2010). For the RE Power (Senvion) – 5M model the maximum height is H= 90 + 63 = 153 m and the maximum surface is A= H × D=153 × 126= 19,278 $m^2$. The visible height of the wind turbine is:

$$H_{vi} = \frac{0.5m}{L} \cdot H$$

and the visible surface of the wind turbine is:

$$A_{vis} = \left(\frac{0.5m}{L}\right)^2 \cdot A$$

The total level of impact is the sum of these projections and has the following limitations, based on the average distances to the shore of a large number of already installed offshore wind farms (11. YPEKA, 2010): $\Sigma H_{vis}<0.6$ m & $\Sigma A_{vis}<0.0025$ $m^2$. The distances of the wind turbines from the shore were calculated by using the *AutoCad* software. Also, by using these values in the above formulas all the wind turbines that affect the visual impact were indicated and therefore rejected. The offshore wind farm at the sea area of Samothraki will consist of 20 wind turbines (Figure 4).

The type of foundation we chose is the "Jacket" support structure, which is the best solution proposed for the water depths of our study areas (12. Vries et al., 2007). Furthermore, the interconnection of all wind turbines and between them and the shore is shown in Figure 5.

## 3. Cost estimation of the project

The cost estimation of the wind turbines is based on a fairly reliable model developed by the National Renewable Energy Laboratory of U.S.A (13. Fingersh et al., 2006). Cost estimation is based on the power of the wind turbine, the rotor diameter, the hub height and other key features of the wind turbine. The results of the cost estimation of the wind turbines for the offshore wind farm of Samothraki are shown in Table I. During the assessment of the offshore wind turbines, the following additional information was taken into consideration: a) marinization (special preparation of the equipment for the "survival" in extreme weather conditions of the marine environment -it includes special dyes and improved connections for gearboxes, generators, electrical components and electrical connections), b) port and staging equipment (special vessels and cranes that will be needed to transport the equipment to the port), c) personal access equipment (equipment for the safety of accessibility), d) scour protection: (protection against corrosion), e) surety bond (guarantee in case the replacement or removal of some structures is needed), f) offshore warranty premium (guarantees for protecting wind turbines from hazards such as their operation in extreme weather conditions).

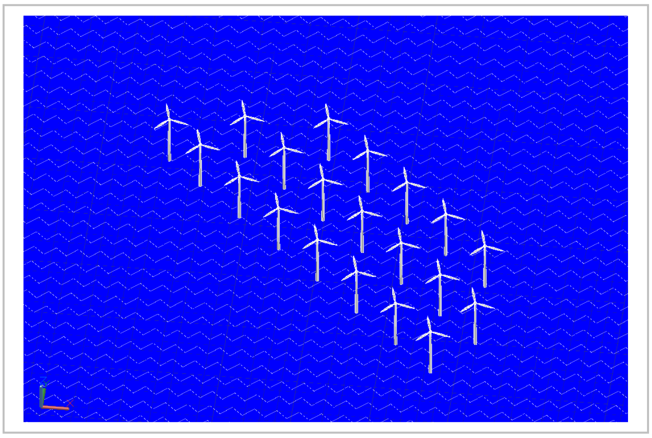


**Figure 4: Final layout of the wind turbines for the offshore wind farm of Samothraki.**

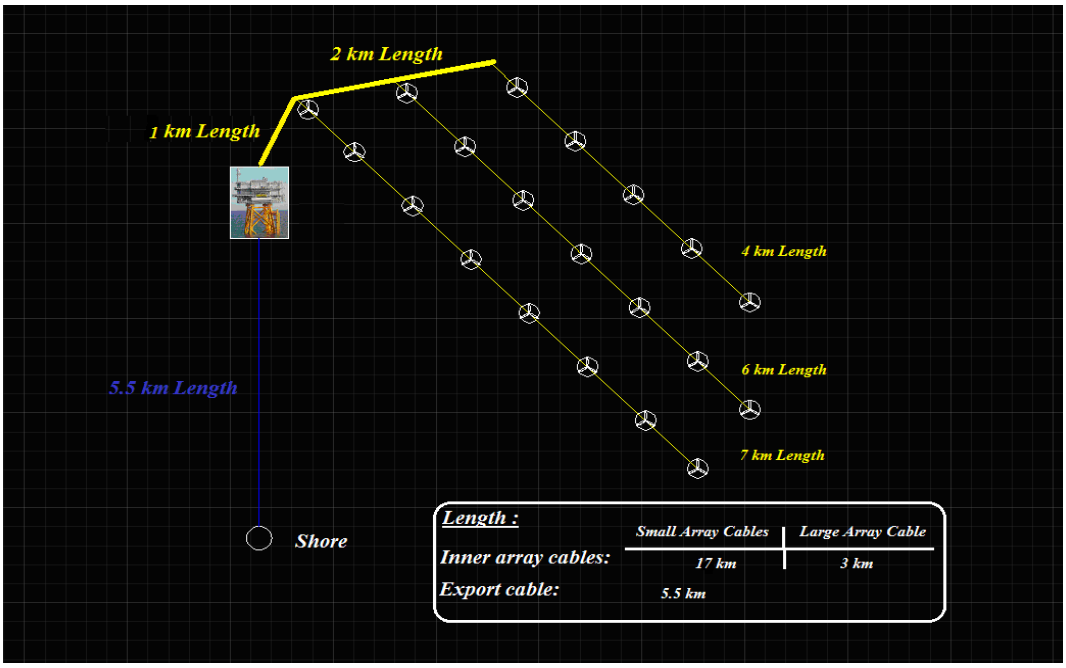



**Figure 5: Wiring of the offshore wind farm of Samothraki.**

The estimation of the initial capital cost according to the model is performed based on the weights of the parts of the selected wind turbine (RE Power (Senvion)-5M) and its technical specifications, such as the rated engine power, swept area, hub height and rotor diameter (14. Uraz, 2011). For the estimation of the cost up to 2012 the Producer Price Indices (PPI) were used.[15, 16, 17, 18] For indices that are not included in the PPI categories the conversions are made in accordance with the annual General Inflation Indices based on the Gross Domestic Product of European Union.

In this research for the cost estimation of the interface to the network, line cables of 20 kV and small cross section (240mm$^2$) as well as large cross section (640mm$^2$) have been chosen. The total cost estimation for this wiring (supply & installation) is ***7.720.477 €***. For the HVAC system the total cost for the connection to the network consists of the HVAC cables (terrestrial and submarine), the installation of cables, the onshore substation and the offshore substation. The cost of the submarine three – phase cable of 150kV (500mm$^2$) is ***553.100 €/km***. Based on the number of sources and the data from the manufacturers the installation price for the submarine HVAC cables is ***300.000 €/km***. The cost of the terrestrial cable, which consists of 3 single-phase cables, is ***33.900 €/km***. For the offshore wind farms of Samothraki the distance of the terrestrial interface is about 1 km. The installation cost for the 3 single-phase terrestrial cables is estimated at ***190.000 €/km*** for 2012 (19. DTI, 2007). The costs for the onshore substation HVAC depend on the voltage of transfer and the voltage of the network to which the wind farm will be connected. When the cable voltage is equal to the voltage of the network (in our case this is 150 kV) there is no need for a substation and only some installation work is required, such as installation of switches, system protection, grounding etc. The cost estimate of this work is ***1.000.000 €*** for the three-phase cable system, which is cost information used for several grid connection points for planned offshore wind farms. The total cost for the design and installation of the offshore substation HVAC including foundation is estimated at ***140.000 €/MW*** for 2012.

The annual operational expenditure is the sum of the annual levelized replacement cost, the annual operation and maintenance cost and the annual bottom lease cost. The calculation of the annual energy production (AEP) was performed based on the RETScreen software and for data such as the average annual wind speed (wind speed 6.2 m/sec at a height of 10 m above sea level) and the selected model of wind turbine of the RE Power (Senvion)-5M.

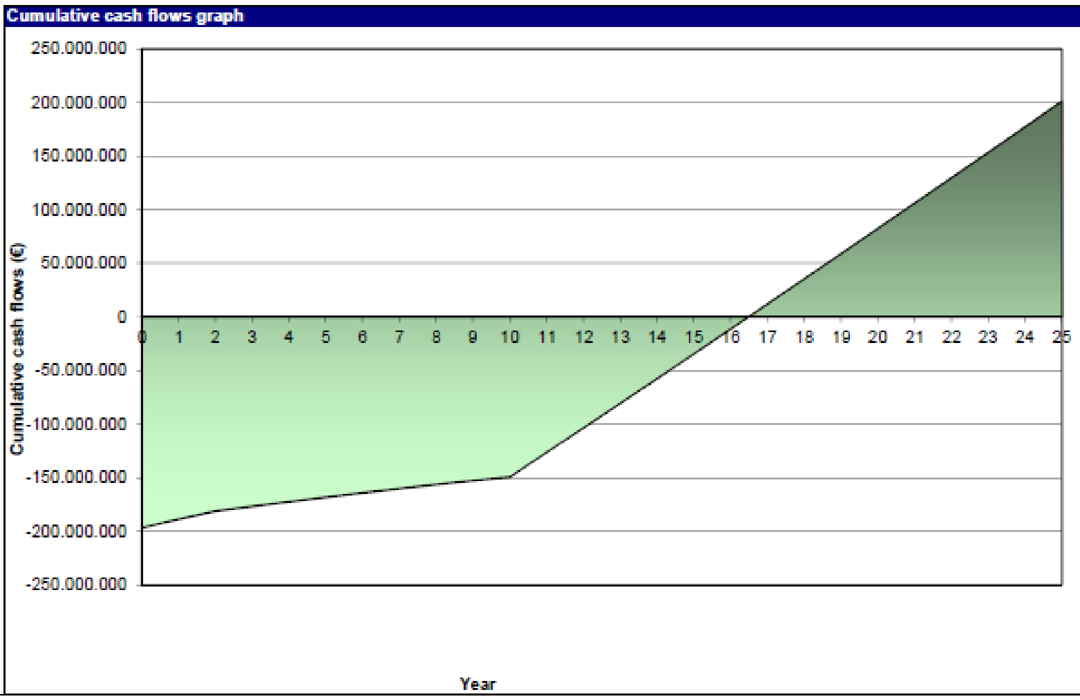
In Table I the total cost estimations per wind turbine of the project is presented. The “Wind Turbine Capital Cost” is 6.084.640 €. The “Balance Of System” cost is **9.492.609 €,** the “Initial Capital Cost” per wind turbine is **16.381.386 €**, which means a total cost of **3.276.277** € per installed MW and a total initial cost of the project equal to **327.627.720 €**. The “Annual Operational Expenditure” per wind turbine is **404.508 €**.

**Table 1: Cost estimation per wind turbine of RE Power (Senvion)-5M for the offshore wind farm of Samothraki.**

| *Items / description of expenditure* | *Costs 2012($)* | *Costs 2012(€)* |
|---|---|---|
| ***Rotor*** | **1.394.778** | **1.131.940** |
| Blades | 927.062 | 752.363 |
| Hub | 189.632 | 153.897 |
| Rotation mechanisms & bearings | 268.000 | 217.497 |
| Hub frame | 10.084 | 8.183 |
| ***Nacelle/Drive*** | **3.135.413** | **2.544.561** |
| Low rotational axis | 196.170 | 159.203 |
| Bearings | 133.056 | 107.982 |
| Gearbox | 961.725 | 780.494 |
| Mechanical brakes, joints / parts | 10.096 | 8.193 |
| Generator | 458.900 | 372.423 |
| Variable speed electronics | 533.250 | 432.762 |
| Yaw system & bearings | 178.907 | 145.193 |
| Main frame | 187.395 | 152.081 |
| Electrical connections | 332.000 | 269.436 |
| Hydraulic cooling systems | 67.962 | 55.155 |
| Nacelle/chamber | 75.952 | 61.639 |
| ***Safety & Monitoring System*** | **71.236** | **57.812** |
| ***Tower*** | **2.004.300** | **1.626.603** |
| ***Marinization (13.50% of the cost of the system of the wind turbine & Tower)*** | **891.773** | **723.724** |
| **(WIND) TURBINE CAPITAL COST (TCC)** | **7.497.500** | **6.084.640** |
| Supply of foundation structure *Jacket* | 125.977 | 102.237 |
| Installation of foundation structure *Jacket* | 5.863.367 | 4.758.456 |
| Installation of the wind turbines | 738.500 | 599.334 |
| Special machinery & equipment | 150.000 | 121.733 |
| Permits, designs and measurements of meteorological conditions | 214.933 | 174.430 |
| Equipment for the safety of accessibility | 69.708 | 56.572 |
| Protection against corrosion. | 406.175 | 329.634 |
| Transport of the wind turbines | 1.863.395 | 1.512.251 |
| Wiring | 843.140 | 684.256 |
| Offshore substation (cost per wind turbine) | 881.790 | 700.000 |
| ***Guarantees (3.0% of the initial capital cost– ICC)*** | **559.635** | **453.706** |
| **BALANCE OF SYSTEM (BOS) COST** | **11.716.620** | **9.492.609** |
| ***Guarantees – Offshore warranty premium (15.00% of the cost of the system of the wind turbine & Tower)*** | **990.860** | **804.137** |
| **INITIAL CAPITAL COST (ICC)** | **20.204.980** | **16.381.386** |
| **COST PER MW** | **4.040.996** | **3.276.277** |
| ***Levelized Replacement Cost (LRC)*** | 98.753 | 80.143 |
| ***O&M Cost*** | 378.909 | 307.506 |
| ***Bottom Lease Cost*** | 20.774 | 16.859 |
| **ANNUAL OPERATIONAL EXPENDITURE** | **498.436** | **404.508** |

**Table 2: Viability analysis of the project carried out with software RETScreen® International.**

| Offshore Wind Farm of Samothraki | | | | | |
|---|---|---|---|---|---|
| **Installed Power (MW)** | **Number of wind turbines** | **Total Initial Costs (€)** | **Cost (€/MW)** | **Power Factor (%)** | **Electricity at the Network (MWh)** |
| 100 | 20 | 327.627.720 | 3.276.277 | 37,2 | 326.137 |
| **Price of the electricity sold (€/MWh)** | **Inflation price (%)** | **Annual Operational Expenditure (€)** | **Annual Operational Expenditure (€/MW)** | **Discount rate (%)** | **Project lifetime (yr.)** |
| 108,30 | 2.00 | 8.090.160 | 80.901 | 6.5 | 25 |
| **Economic parameters** | | | **Economic Sustainability** | | |
| **Incentives & Grants** | % | 0 | **Internal rate of return before tax-shares** | % | 6,8 |
| **Debt** | € | 131.051.088 | **IRR after tax-shares** | % | 4,4 |
| **Lending rate** | % | 8,0 | | | |
| **Debt period** | Year | 10 | **Net Present Value** | € | -50.480.053 |
| **Debt Payments** | €/ year | 19.530.477 | **Annual savings of the lifecycle** | €/ year | -4.138.430 |
| **Tax rate of income impact** | % | 20.0 | **Benefit-Cost Ratio** | [-] | 0,74 |
| **Depreciation rate** | % | 10.0 | **Energy production cost** | €/MWh | 122,94 |



## 4. Viability analysis

The evaluation of the investment is based on certain criteria, indicators that summarize the characteristics of the investment. Amongst the most important is the net present value (NPV), internal rate of return (IRR), the benefit-cost ratio (BCR) and the cost of energy production (COE). The calculations for estimating these indicators were carried out by using the software RETScreen® International. The baseline price of the electricity sold according to the Greek legislation (20.Greek Law, 2011) is 108,30 €/MWh. The data processing of the input led to significant results (Table 2). Initially the net present value for the offshore project of Samothraki is -50.480.053 €. The benefit-cost ratio of the investment is equal to 0,74. Since the NPV<0 and the benefit-cost ratio is lower than 1, the investment is considered economically unacceptable. Moreover the after-tax Internal Rate of Return is 4,4% which is very low (any after-tax IRR value below 8.0% -debt interest rate- would mean that the project is not viable). The COE corresponding to the project is 122,94 €/MWh (which is higher than the price of the electricity sold). According to the above analysis the investment in Samothraki is considered economically not viable.

A sensitivity and risk analysis are provided in Tables 3 – 4. For the sensitivity analysis two variables (initial cost and debt interest rate) are considered, as well as six variables (initial cost, O&M, electricity export rate, debt ratio, debt interest rate and debt term) for the risk analysis.

In Table 3 results are showing how the variability of the sensitivity parameters may affect the viability of the project, as estimated in this case by the Net Present Value. For example, an increment or decrement of the initial costs by 10% (from 294.864.948€ to 360.390.492€) affects the project NPV from -17.779.616€ to -83.180.491€ respectively. Moreover, a combination of increments or decrements of the initial costs and also the debt interest rate by 10%, influences the NPV with values from -14.224.671€ to -87.600.077€.

The risk analysis (Table 4) in "Tornado Chart" presents the parameters that have the highest impact on the variability of the Net Present Value. In our case these parameters are the electricity export rate and the initial costs. These results were extracted by providing different ranges of uncertainty as input for the different parameters according to author's choice. Finally, the risk analysis gives us the sense of how much the input parameters may deviate from the given levels. In this case the risk level of 10% is chosen. There is a 10% probability the NPV to be -44.611.414€ and 90% certainty the NPV to deviate between -16.381.010€ and -74.168.886€.

As it was mentioned before the parameters that have the highest impact on the variability of the Net Present Value are the electricity export rate (i.e. price of the electricity sold) and the initial costs. These could be the answer to the question under which conditions our project with its specific characteristics (wind field, depth, distance from the shore etc) could be viable. The one case is to sell the electricity in higher prices and the other is a part of the total initial costs to be granted.

**Table 3: Sensibility analysis of the project carried out with software RETScreen® International.**

**Sensitivity analysis**

| | |
|---|---|
| Perform analysis on | Net Present Value (NPV) |
| Sensitivity range | 10% |
| Threshold | € |

| | | Initial costs | | | | € |
|---|---|---|---|---|---|---|
| Fuel cost - base case | | 294.864.948 | 311.246.334 | 327.627.720 | 344.009.106 | 360.390.492 |
| € | | -10% | -5% | 0% | 5% | 10% |
| 0 | 0% | -17.779.616 | -34.129.835 | **-50.480.053** | -66.830.272 | -83.180.491 |

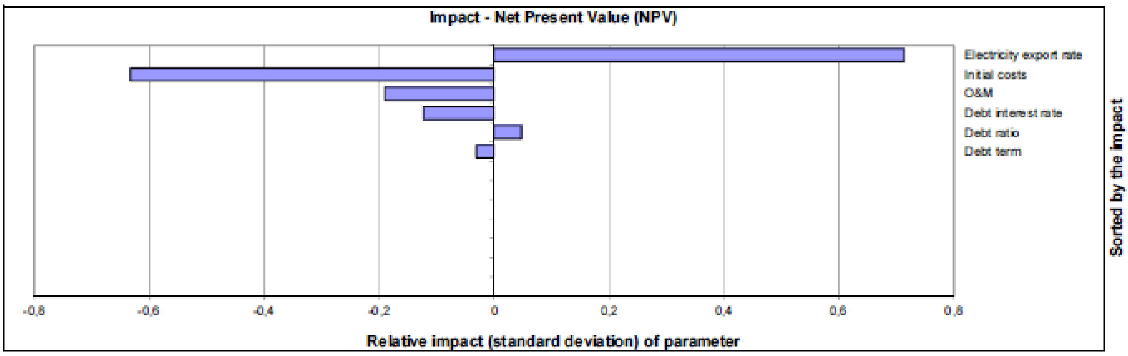
| | | Initial costs | | | | € |
|---|---|---|---|---|---|---|
| Debt interest rate | | 294.864.948 | 311.246.334 | 327.627.720 | 344.009.106 | 360.390.492 |
| % | | -10% | -5% | 0% | 5% | 10% |
| 7,20% | -10% | -14.224.671 | -30.377.392 | -46.530.114 | -62.682.836 | -78.835.557 |
| 7,60% | -5% | -15.994.425 | -32.245.467 | -48.496.508 | -64.747.550 | -80.998.591 |
| 8,00% | 0% | -17.779.616 | -34.129.835 | **-50.480.053** | -66.830.272 | -83.180.491 |
| 8,40% | 5% | -19.580.077 | -36.030.321 | -52.480.566 | -68.930.810 | -85.381.054 |
| 8,80% | 10% | -21.395.641 | -37.946.750 | -54.497.859 | -71.048.968 | -87.600.077 |

**Table 4: Risk analysis of the project carried out with software RETScreen® International.**

**Risk analysis**

Perform analysis on: Net Present Value (NPV)

| Parameter | Unit | Value | Range (+/-) | Minimum | Maximum |
|---|---|---|---|---|---|
| Initial costs | € | 327.627.720 | 10% | 294.864.948 | 360.390.492 |
| O&M | € | 8.090.160 | 10% | 7.281.144 | 8.899.176 |
| Electricity export rate | €/MWh | 108,30 | 10% | 97,47 | 119,13 |
| Debt ratio | % | 40% | 20% | 32% | 48% |
| Debt interest rate | % | 8,00% | 15% | 6,80% | 9,20% |
| Debt term | yr | 10 | 20% | 8 | 12 |




| | | |
|---|---|---|
| Median | € | -44.611.414 |
| Level of risk | % | 10,0% |
| Minimum within level of confidence | € | -74.168.886 |
| Maximum within level of confidence | € | -16.381.010 |

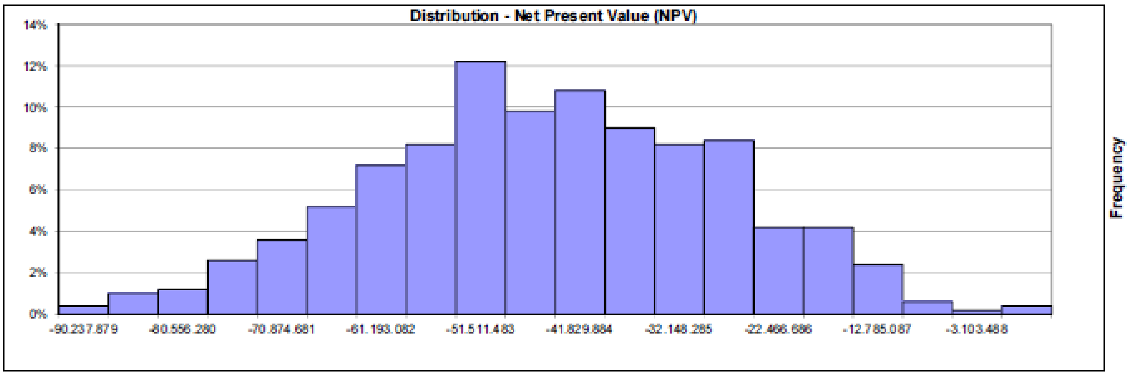



**Table 5: The impact of incentives and grants on the economic indicators of the project (calculations made with software RETScreen® International).**

| Electricity export rate (€/MWh) | Incentives/ Grants (+% Total initial costs) or (+%Electricity sold price) | Cost of Energy (€/MWh) | Benefit-Cost Ratio | After-tax IRR (%) | Net Present Value (€) | Payback period of the investment (years) |
|---|---|---|---|---|---|---|
| 108,30 | 0 | 122,94 | 0,74 | 4,4 | -50,480,053 | 16,8 |
| 108,30 | +20% (65.525.544€) | 103,94 | 1,08 | 7,3 | 15,045,491 | 13,9 |
| **108,30** | **+40% (131.051.088€)** | **84,93** | **1,41** | **13,2** | **80,571,035** | **11,1** |
| 119,13 | (108,30€/MWh +10%) | 122,94 | 0,93 | 6,0 | -13.142.851 | 14,8 |
| 129,96 | (108,30€/MWh +20%) | 122,94 | 1,12 | 7,5 | 24.194.351 | 13,3 |
| 140,79 | (108,30€/MWh +30%) | 122,94 | 1,31 | 8,9 | 61.531.553 | 12,1 |

But what happens if the investment is favored by incentives and grants? The previously mentioned Greek Government Law (20.Greek Law, 2011) have an option where an investment in certain cases could be favored by the Regulatory Authority for Energy and the price of the electricity sold could reach even 140,79 €/MWh (108,30+30%). In that case the above indices change dramatically. The NPV becomes 61.531.553€, the after-tax IRR 8,9%, the BCR 1,31. In addition, as the payback period of an investment is also of great importance, in our case is about 12 years. The Cost of Energy is also 122,94 €/MWh but in this economic scenario is higher than the price of the electricity sold (140,79 €/MWh).

The second interesting investment scenario is the case that the price of the electricity sold remains the same (108,30€/MWh) and the investment is granted by the state or by European financial resources. For example, a common grant could reach even 40% of the total initial cost. In that case the NPV equals 80.571.035€, the after-tax IRR equals 13,2%, the BCR is 1,41 and the COE is 84,93€/MWh. The payback period of the investment becomes even shorter (11,1 years). According to the analysis above the investment for the offshore wind farms near Samothraki is considered economically viable and sustainable. In particular, the case of the granted initial capital seems to be quite advantageous, as the economic indicators (NPV, IRR, BCR) are more favorable than the scenario of the higher price of the electricity sold. Table V shows how the higher prices of electricity sold and the percentage of the grants influence the economic indices of the investment.

## 5. Conclusions

In the last years offshore wind has been a very important and promising source of energy. By the end of this decade wind parks with a total capacity of thousands of megawatts will be installed in the European seas and also around the world. There are also some offshore projects that have been proclaimed in Greece, but not scheduled yet.

The subject of the present study has been the economic analysis and the investigation of the viability of an offshore wind farm in the Greek sea area, northeast of the island of Samothraki. Wind data, the type of wind turbines, the total number of wind turbines and the minimum distance from the shore in order to eliminate the visual impact and other techno-economic data of the constructions, have lead to an initial cost of the project.

Economic indicators that summarize the result of the investments were used in order to evaluate the viability of the project. The "Net Present Value", the "Internal Rate of Return", the "Benefit-Cost Ratio" and the "Cost of Energy Production" show that the economic evaluation of the investment with the current price of electricity sold (108,30€/MWh) is not favorable. This result was further analyzed by applying sensitivity analysis and risk analysis of the Net Present Value. The analysis showed that the development of an offshore wind farm near the island of Samothraki is not feasible and economically viable, unless there is an economic motivation by the state either by the form of higher prices of electricity sold (129,96€/MWh -140,79€/MWh) or by the form of grants on the initial cost (20-40%) of the investment.

Further research using wind data received by local meteorological stations which will be installed in the proposed areas is suggested. Research in areas within the designed greek Exclusive Economic Zone (EEZ) is also suggested, as the declaration of the EEZ will lead to larger offshore wind farms beyond 6 nautical miles as a result of the elimination of the visual impact (21.Konstantinidis et al.2013).

## Acknowledgements

The National Observatory of Athens and the Hellenic Centre for Marine Research are kindly acknowledged for providing data used in this study. Special thanks are given to Dr. K. Lagouvardos (National Observatory of Athens) for his contribution in providing BOLAM forecasting data. The European Environment Agency (EEA) and the European Marine Observation and Data Network (EMODNet) are kindly acknowledged for providing map services. The "Natural Resources Canada" and the RETScreen International are kindly acknowledged for the use of RETScreen® International software, which as all programs provides good results as good as the input set by the authors is (RETScreen is free at www.retscreen.net).

## References

1. European Commission, Energy Roadmap 2050, December 2011.
2. YPEKA (Ministry of Environment, Energy and Climate Change of Greece), National Energy Planning, Roadmap for 2050, March 2012.
3. http://www.thewindpower.net/country_en_15_greece.php
4. Botsaris, P.N., Konstantinidis, E.I. Feasibility study of offshore wind turbine installation in North Aegean – Thracian Sea. Proceedings of the 4th International Scientific Conference on Energy and Climate change, Athens, 2011, 100-111.

5. Lagouvardos, K., Kotroni, V., Koussis, A., Feidas, H., Buzzi, A., Malguzzi, P., 2003. The meteorological model BOLAM at the National Observatory of Athens: assesment of two – year operational use. Journal of Applied Meteorology, Vol 42, 1667-1678.
6. Rajai, A.R., 2007. Master thesis: Optimization of offshore wind farm layouts", DTU, UK.
7. Schepers, G., Barthelmie, R., Rados, K., Lange, B., Schlez, W., 2001. Large off-shore wind farms: linking wake models with atmospheric boundary layer models. Wind Energy, Vol. 25, No. 5, 307-316.
8. Kusiak, A., Song, Z., 2010. Design of wind farm layout for maximum wind energy capture. Renewable Energy 35, 685–694.
9. Nielsen, P. Offshore wind energy projects feasibility study guidelines, Seawind altener project 4.1030/Z/01-103/2001, ver.3.0, Aalborg, June 2003.
10. Burton, T., Jenkins, N., Sharpe, D., Bossanyi, E., 2011. Wind Energy Handbook, 2nd Edition, John Wiley & Sons.
11. YPEKA (Ministry of Environment, Energy and Climate Change of Greece), 2010. http://www.ypeka.gr/LinkClick.aspx?fileticket=95ebrUR7xoo%3D&tabid=546
12. De Vries, W.E., Van der Tempel, J., Carstens, H., Argyriadis, K., Passon, P., Camp, T., Cutts, R., March 2007. Assessment of bottom-mounted support structure types with conventional design stiffness and installation techniques for typical deep water sites, project Up Wind, Contract no.: 019945 (SES6), Delft University of Technology.
13. Fingersh, L., Hand, M., Laxson, A. Wind turbine design cost and scaling model, technical report NREL/TP-500-40566, National Renewable Energy Laboratory, December 2006.
14. Uraz, E. Offshore wind turbine transportation and installation analysis. Master thesis, 2011, Gotland University.
15. Kowal, J., Lombardozzi, A., Borgie, L., Hergt B. Producer price indexes detailed report. Data for February 2012, Vol. 16, No. 2, U.S. Department of Labour, U,S. Bureau of Labor Statistics.
16. U.S. Bureau of Labor Statistics (BLS), 2012a. http://data.bls.gov/timeseries/PCU332991332991?data_tool=XGtable,
17. U.S. Bureau of Labor Statistics (BLS), 2012b. http://data.bls.gov/timeseries/WPU101507,
18. U.S. Bureau of Labor Statistics (BLS), 2012c. http://data.bls.gov/timeseries/NDUBHVY--BHVY--
19. DTI. Study of the costs of offshore wind generation, URN Nr 07/779, 2007, UK.
20. Greek Government Law Nr. 4030, Article 42, paragraph 20, 25 November 2011.
21. Konstantinidis, E.I., Kompolias, D.G., Botsaris, P.N. Feasibility study of offshore wind farms installation within the Greek Exclusive Economic Zone. Proceedings of the 5th International Congress on Energy and Environment Engineering and Management / Lisbon, 17-19 July 2013. ISBN: 978-989-98406-5-2.

# Recycled waste plastics composite: Possible construction material for wind turbine blades

**Ms. Janet M. MWANIA** [1]
Postgraduate Student
**Dr. Michael J. GATARI & Mr. David M. MAINA**
Lecturers, University of Nairobi, Nairobi, Kenya
**Prof. Robert KINYUA**
Director, IEET, Jomo Kenyatta University of Agriculture and Technology, Juja, Kenya

[1] Institute of Nuclear Science & Technology, College of Architecture and Engineering, University of Nairobi

Tel: +254728480919
Fax: +254245566
e-mail: jamutts@gmail.com
Address: University of Nairobi, P.O. Box 30197-00100, Nairobi, Kenya

**Abstract:** Electrical power supply in Sub Saharan Africa (SSA) is expensive and very low, and most families have no chance of accessing clean lighting and cooking power. Off grid systems are the best viable solution in SSA and wind energy has a potential. However, the components of this system are expensive and beyond reach of the communities due to the weak economies in SSA. Whereas some researchers have recommended use of wood for construction of wind turbines in the developing countries, wood has many competing uses that lead to destruction of forests, impacting negatively on the environment. This study focuses on the possibilities of recycling waste plastics (mostly High Density Polyethylene), and using steel and copper wires as reinforcements to make a composite as an alternative to wood and other materials currently used for the same purpose. A plastic injection moulding machine was made for production of mechanical test specimens. The materials were subjected to tensile test and Three point Bending test. Scanning Electron Microscopy (SEM) was also carried out to study the microstructure. Specimens at varied content and reinforcement levels were tested for ultimate tensile strength (UTS), modulus of elasticity (E) and interlaminar shear strength (ILSS). Use of increased recycled plastic in samples improved UTS while E declined. Addition of reinforcements slightly improved UTS while E exhibited greater improvement and ILSS showed little improvement. SEM revealed poor bonding between reinforcement and plastics matrix. While improved tensile properties were observed further research work is recommended.

*Keywords:* Wind power, Recycling, Injection molding, Composites.

## 1. Introduction

Wind power is one of the key solutions to improving electrical power supply in SSA. One inhibiting factor to wind power adoption is the cost of manufacture and maintenance (Tegen et al. 2012). Studies have shown that the cost implications of this technology to some great extent stem from cost of the rotor, which is made expensive by the materials that make it (Ancona and McVeigh, 2001, Mishnaevsky et al., 2011). Studies have shown that the rotor accounts for about 16% of the installed capital costs (Tegen et al., 2012). Modern wind turbine blades are made from Glass Fiber Reinforced Plastics (GFRP) (Wilburn, 2011), Carbon Fibers or Aramid have also been used but they are uneconomical in addition to the fact that they cause manufacturing difficulties. Wood, wood epoxy and wood fiber epoxy composites are yet to penetrate the market. However for smaller applications, Steel and Aluminium alloys are mostly used (D.W.I.A, 2001) in Developed countries. In studies conducted in Nepal (Mishnaevsky et al., 2011), it was recommended that wood would be best suited for making wind turbine blades for developing countries and more so for off grid applications. This however is not a very environmentally sound decision for Kenya, where rampant destruction of forests is affecting rainfall quantities and impacting negatively on food security. This situation has been aggravated by the wide scope of applications for timber in general. For example in a UNEP report (UNEP, 2012), fuel wood and charcoal provided the most important energy source for majority of the Kenyan population, leading to a destruction of

50,000 hectares of the water towers between 2010 and 2011 alone. With this worrying statistics, the need was felt for an alternative material that would provide a safer option for production of cheaper wind turbine blades, hence enhance electrical power supply without impacting negatively on the environment. This research was aimed at engineering a cheaper material for construction of wind turbines. For this High Density Polyethylene (HDPE) was viewed as a possibly suitable matrix material due to the fact that it is a thermoplastic, hence recyclable, and also its abundance as it is used in making shopping bags, but its disposal has been a challenge resulting in a serious environmental menace. Steel and copper wires were added to improve on stiffness, and it was hoped that a cheap composite would be developed. Thermosetting composites currently used for making wind turbine blades are disposed in landfills as they cannot be recycled. It is projected that between the year 2010 and 2030, 84,000t of Fiber glass could be sent to landfills (Wilburn, 2011). Materials in landfills take too long to degrade, and therefore alternative solutions to the disposal problem need to be sort. HDPE is a thermoplastic and therefore recyclable. This research is geared towards complementing already existing efforts in solving the disposal problem, with emphasis on using what is locally available, in the hope that a quality material can be obtained but at a lower cost, and one that can easily be recycled or reused.

## 2. Materials and methods

### *2.1 Materials*

Waste plastic bag flimsies were procured from a local recycler, many of the consumer plastic bags are made of HDPE, and therefore it was the major constituent in the obtained material. Some virgin HDPE was also added to the recycled plastic to ease processing.

### *2.2 Sample preparation*

Injection molding was the process used to prepare the samples for testing, however due to lack of an alternative, a machine had to be custom made for this purpose. Due to budgetary technical limitations, the machine was hand operated and was not standardized in some of its operations. To test the machine's ability to process recycled plastic, initially plastic samples were made and tested for tensile strength. It was observed that under the circumstances, the machine could not process the pure recycled plastic since this plastic had very high viscosity resulting in poor flow into the moulds and incomplete specimens, therefore mixtures of virgin and recycled plastic were made at 20, 40 and 60% recycled plastic content respectively.

Reinforced samples were then made using the 60% recycled plastic content, with 14.4% weight content steel reinforcement and copper reinforcement with 8% and 13% by weight. The reinforced samples and the 60% recycled plastic samples were tested for Interlaminar Shear Strength (ILSS) and Ultimate Tensile Strength (UTS). The ILSS specimens were also used to obtain samples for Scanning Electron Microscopy (SEM), with the fracture sites and cut samples being imaged.

As earlier stated the machine used in this research was made locally, Table 1 illustrates variation in processing temperature due to increasing viscosity with increase in the content of recycled plastic. Figures 1 and 2 show the dimensions for specimens made for tensile and ILSS respectively.

**Table 1: Variation of process temperature with increased recycled plastic content.**

| Description | Processing temperature °C |
|---|---|
| Virgin plastic | 210 |
| 20% Recycled content | 225 |
| 40% Recycled content | 240 |
| 60% Recycled content | 260 |
| Steel Reinforced | 260 |
| Copper Reinforced | 260 |

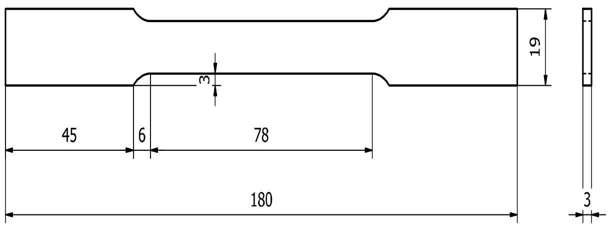



**Figure 1: Dimensions of the tensile specimen.**

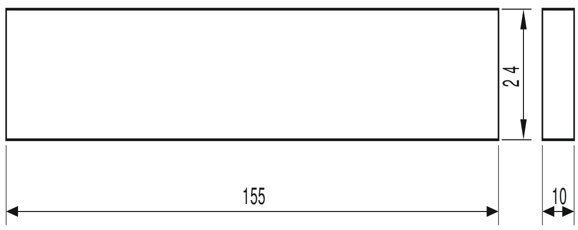



**Figure 2: Dimensions of the Interlaminar Shear Strength specimen.**

### *2.3 Testing and characterization*

Both mechanical tests were carried out using a Hounsfeld tensometer, at cross head speeds of 0.5mm/min. The tensile test was conducted in accordance to ASTM D3039/ D3039M - 08 (ASTM, 2008), while the three point bending test for ILSS was conducted according to ASTM D2344/D2344 – 00 (ASTM, 2006). The SEM tests were carried out using the Zeiss-Merlin SEM. Charge compensation was used to develop the images, and therefore there was no need to coat the samples with conductive material. The SEM Samples were 10mm by10mm with a thickness of about 2.5mm.

## 3. Results and discussions

*3.1 Plastic samples*

In assessing consistency of the machine developed in this research, plastic samples consisting of virgin HDPE, mixed with 20, 40 and 60% recycled plastic were tested for tensile properties. Gauging the suitability of the machine for the given purpose involved comparing the properties of the virgin plastic to some documented value, the findings were as shown in Table 3. From data obtained in testing the plastic samples, the trends in Figures 3-5 were observed for various tensile properties.

**Table 3: Comparative mechanical properties of virgin HDPE processed with the research machine with a documented value.[1] Adopted from engineering toolbox website.**

| Material | E (GPa) | UTS (MPa) |
|---|---|---|
| HDPE (Documented value)[1] | 0.8 | 15 |
| HDPE (From research, virgin) | 0.9 | 13 |

From Figures 3-5, it is apparent that as the percentage content of recycled plastic was increased, the engineering strain increased. This is attributed to the fact that the samples with 60% recycled plastic content elongated more before failure. The percentage elongation to failure increased as the content of recycled plastic was increased. This therefore meant that the change in length over the original length gave higher and higher values percent. However with reference to Figure 4, the trend for the *UTS*, the plastic sample with 20% recycled plastic content was able to with stand higher loads to failure, and therefore for similar cross sectional area, produced higher values of *UTS*. There is a slight decline in the *UTS* as the percentage of recycled plastic is increased further and a decline is noted between the 40% moving on to the 60% recycled plastic content.

Overall, the change in value of *UTS* between the samples is not large and the materials generally have similar characteristics in terms of *UTS*. The modulus of elasticity (*E*) has great variation in behavior. It is known that *E* is obtained as a ratio of the stress to the strain and therefore higher values of strain do not favor *E* since they are inversely proportional. Hence, the observed trend in E was expected, where the plastic sample with 60% recycled plastic had the lowest value of *E*, since it experienced the highest elongation to failure and hence, high strain. Therefore, it can be seen that addition of recycled plastic content had the effect of reducing stiffness and hence the lower *E* values. The drop in stiffness is quite significant since E drops from the order of hundreds of MPa to tens of MPa.

Kiaeifar et al.,(Kiaeifar et al., 2011) also did research on pure and recycled plastic composites and their results show a decrease in E with use of recycled plastic as opposed to virgin which is similar to what was found in this research. Results of this research are also similar to findings of a report published by CWC (CWC, 1999) after a survey which sort to test the use of recycled plastic in injection molding process.

A survey of Calorado's injection molding companies about recycling issues was conducted. Their tests included processing trials of recycled plastics in an injection molding process and laboratory testing of recycled content parts to establish their strength and melt flow characteristics. They focused their tests on HDPE, virgin and recycled. Their findings were that there was increased tensile strength and decreased melt flow, with increase in recycled content.

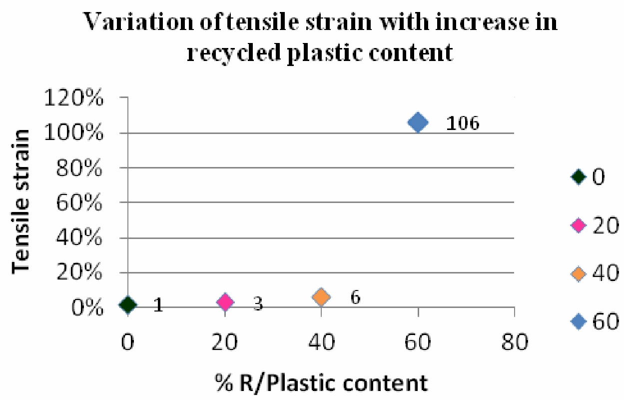



**Figure 3: Variation of tensile strain% with percentage content of recycled plastic.**

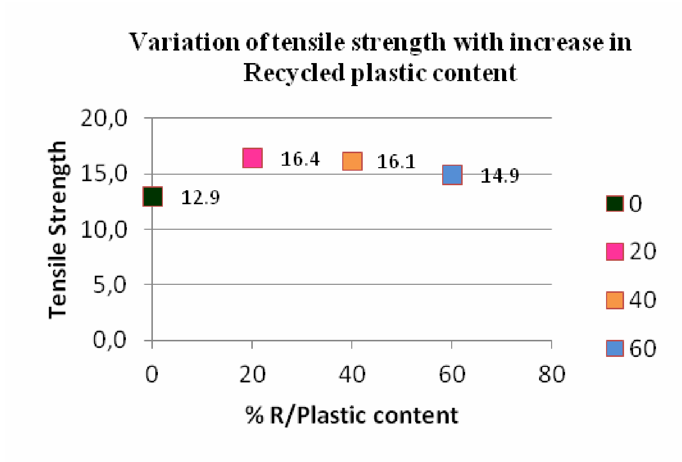



**Figure 4: Variation of Ultimate Tensile Strength (MPa) with percentage recycled plastic content.**

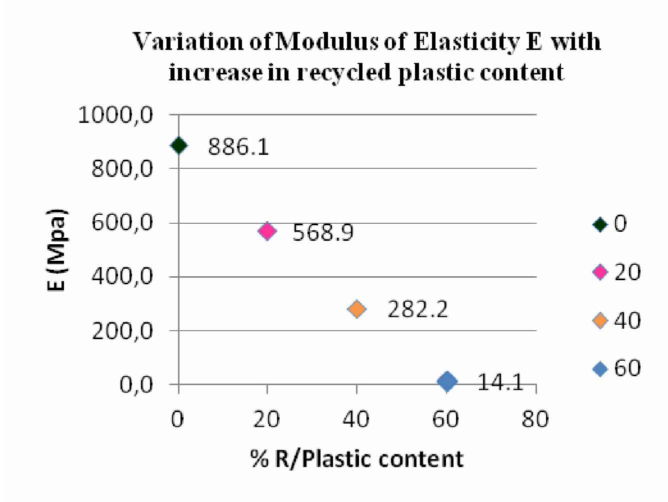



**Figure 5: Variation of modulus of elasticity with percentage recycled plastic content.**

From Figure 4, the results of this research had similar findings, with increase in strength initially when recycled plastic was added to the virgin, but in this case further increase in recycled plastic content saw a slight decline in strength. Although the melt flow was not measured in this research, it was observed that using recycled plastic alone was difficult to process with the hand driven injection machine fabricated, indeed at higher contents of recycled plastic the molten plastic could not flow to the end of the prepared molds, unless the temperature was increased and this had detrimental effects on the structure of the plastic. This sentiments are echoed by Chianelli et al. (Chianelli et al., 2013) who did research on reinforced, recycled HDPE. They attributed low strength of the recycled plastic composites to the fact that repeated heating and cooling degraded the plastic.

*3.2 Reinforced samples*

*3.2.1 Tensile results*

The aim of the research was to prepare composite samples from recycled plastics (mainly HDPE), and reinforcing them with Steel and Copper, and test their mechanical properties, and compare this to existing wind turbine materials. Since the fabricated machine could not produce samples exclusively from recycled material, samples were made using the 60% recycled plastic content, with Steel reinforcement at 14% content and Copper at 8% and 13% content by weight. As per the standards, five samples of each test condition were tested and the results averaged to give the tensile and ILSS properties of the materials tested. Results of the tensile properties are presented in Figures 6-8.

From Figure 6 it is evident that the various reinforcement types had the effect of reducing the engineering strain, that is, the percentage elongation to failure was in general reduced with addition of reinforcements. In particular it is observed that although the contents of Copper were less than the Steel content, they had the effect of reducing the strain of the plastic more than the Steel reinforcement. It is interesting to note however that for the copper reinforced samples, strain increased with increase in reinforcement content.

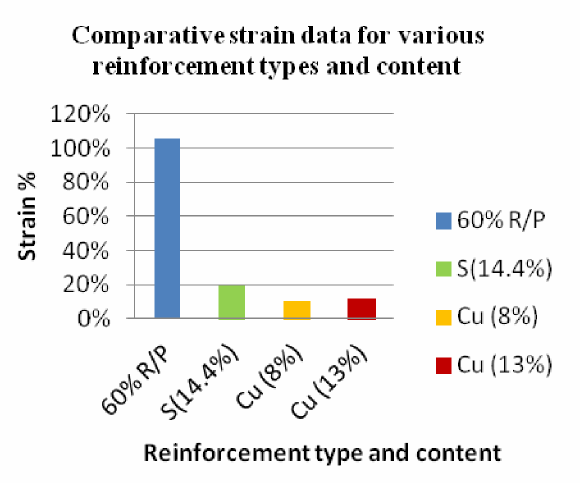



**Figure 6: Tensile strain percentage values for various reinforcement types and content.**

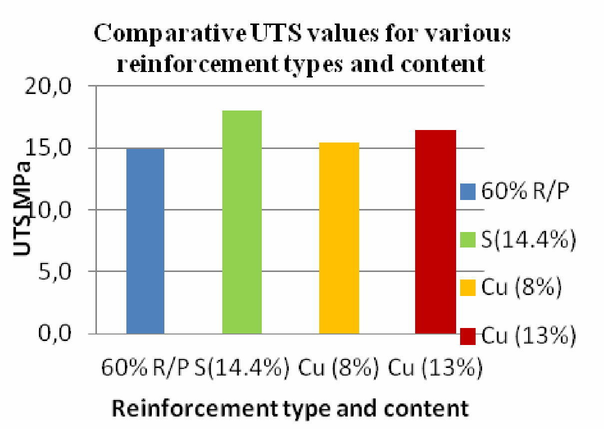



**Figure 7: *UTS* values for various reinforcement types and content.**

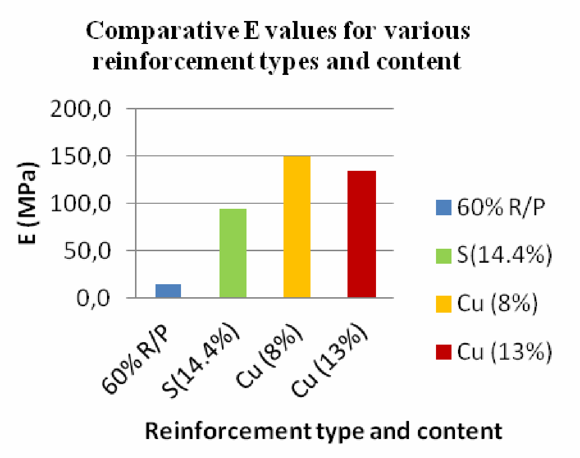



**Figure 8: *E* values for different reinforcement types and content.**

Chianelli et.al (Chianelli et al., 2013) made similar observations when they reinforced recycled HDPE with sisal fibers, that is, strain decreased as they increased fiber content. From Figure 7 it can be seen that the Steel reinforcement seemed to yield higher values of *UTS*, since the samples failed at higher loads, this is significantly higher than the *UTS* of the pure plastic sample, and the samples with Copper reinforcement at both contents. In addition, increase in the Copper content had the effect of increasing the *UTS* of the plastic matrix. However considering both reinforcement types and concentrations for the copper reinforced samples, it is clear that at this low content there was only a slight improvement of the *UTS* compared to the plastic sample. These findings differ with those made by Chianelli et al and Kiaeifar et al (Chianelli et al., 2013, Kiaeifar et al., 2011), the former used sisal fibers to reinforce recycled HDPE, while the latter used wood as filler on PE and PP composites. In these studies increasing fiber content had the effect of reducing the tensile strength and modulus of the plastics used. This differs also for the findings of modulus of elasticity obtained in this research as explained in the next paragraph.

From Figure 9, and bearing in mind the fact that the *E* is inversely proportional to strain, it is no wonder that addition of reinforcement improved the E of the plastic matrix and hence increased its stiffness, a factor necessary for wind turbine blade materials. It is also apparent that the samples with copper reinforcement prove to be stiffer than the steel reinforced sample. Interesting to note is the seeming decline in stiffness when the copper content is increased. It is also of interest to note that with the chosen matrix and the used reinforcements, comparing values on Figure 3 and those on Figure 8, the plastic matrix is stiffer with lesser content of recycled plastic compared to the reinforced 60% recycled plastic samples. A possible reason why the findings of E varied with those of Kiaeifar and Chianelli(Chianelli et al., 2013, Kiaeifar et al., 2011), is because in these two researches, organic fibers were used. Clearly, these fibers are less stiff compared to metal reinforcement, which ultimately affects E

*3.2.2 Interlaminar shear strength results*

The three point bending test was used to establish the interlaminar shear strength for samples reinforced with Steel at 14% and Copper at 8% and 13% contents. This section provides a summary of the results obtained from testing of five samples in each experimental condition.

It is clear from the plot in Figure 9, that addition of the two different types of reinforcement, in general, had no significant effect on the shear strength of the plastic matrix. Indeed it seems at these low concentrations, the effect may actually be retrogressive. However it maybe that increasing the content of reinforcement may actually improve interlaminar shear properties, since the higher copper content seems to have improved the strength compared to the 8% content. A study conducted by Putic et al.,(Putic et al., 2009) indicates much higher values of ILSS for the GFRP, in the range of between 5.6 – 32.4 Mpa. This therefore means that for whatever application, and with the current reinforcement types and concentrations in our material, GFRP are still superior.

*3.2.3 Scanning electron microscopy*

SEM was carried out on samples cut from the three point beam test specimens and also on the sample fracture sites. Analysis was done on the Steel and Copper reinforced samples. Figures 11-14 are images obtained from SEM.

From the SEM images in general, it can be seen that the plastic matrix was devoid of faults such as air pockets and discontinuities that would have resulted from a poor production process, and therefore this SEM images give weight to the injection machine used for processing the plastics. This is of particular importance bearing in mind that the process influences the structure and hence the properties and performance of a material (Callister, 2007).

Moreover, since the machine was locally fabricated, it was important to gauge its products so as to identify any faults in the production process so as to be able to make necessary improvements on the machine.

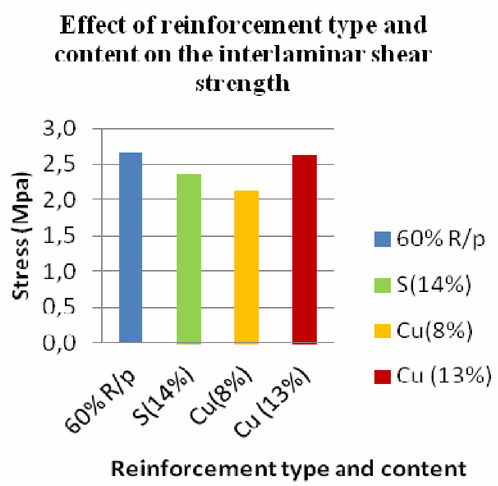



**Figure 9: Variation of interlaminar shear strength with different reinforcement types and content.**

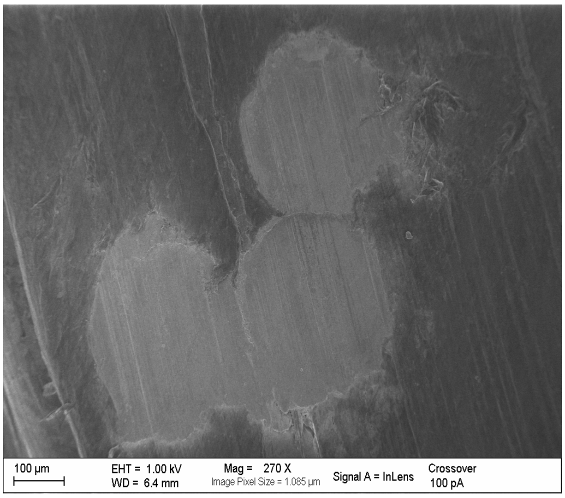



**Figure 10: SEM image of Steel reinforced sample cut from the three point bending test specimen.**

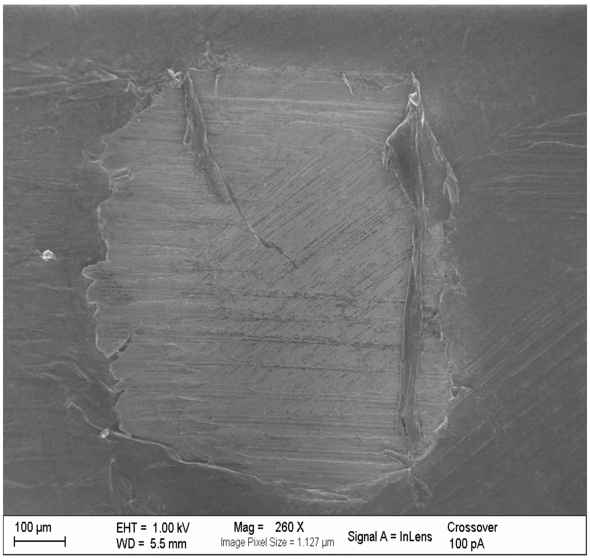



**Figure 11: SEM image of copper reinforced sample cut from the three point bending test specimen.**

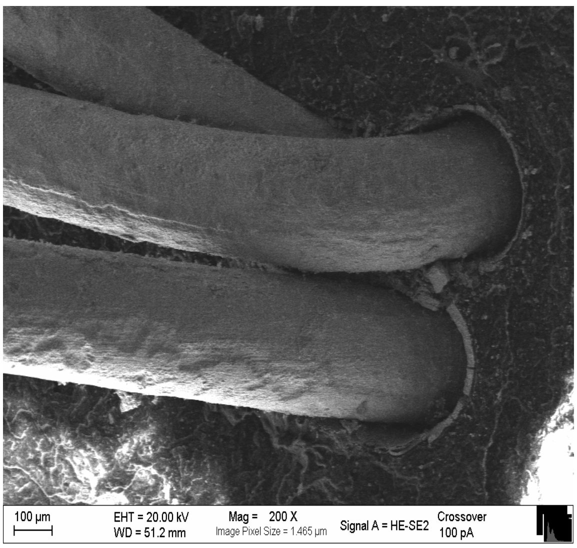



**Figure 12: Fracture site image of steel reinforced specimen.**

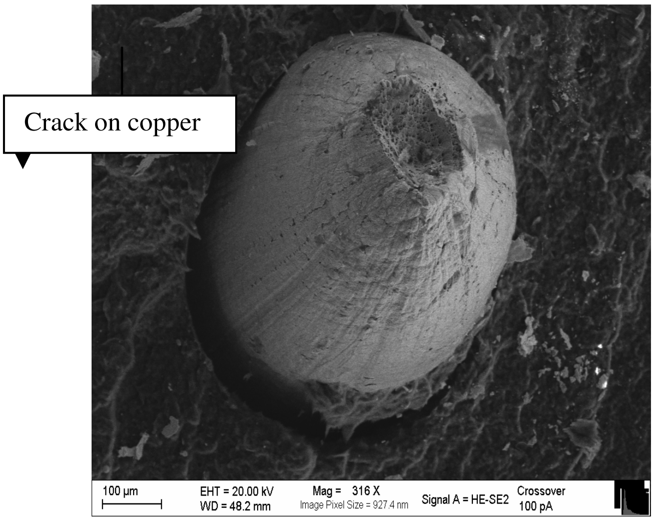



**Figure 13: Fracture site of copper reinforced sample showing cracks on copper reinforcement.**

**Table 4: Comparative mechanical properties of common wind turbine materials and the research materials.**

| Material | E (GPa) | UTS(MPa) |
|---|---|---|
| CFRP(60% fiber)[1] | 142 | 1830 |
| Glass/Polyester ply(50% fiber) with Unidirectional lay up[1] | 38 | 860-900 |
| Pine wood(Along the grain)[2] | 9 | 40 |
| HDPE(Documented value)[2] | 0.8 | 15 |
| HDPE(From research, virgin) | 0.9 | 13 |
| 60% Recycled plastic with steel reinforcement(14% wt) | 0.1 | 18 |
| 60% Recycled plastic with Copper (8% wt) | 0.1 | 15.5 |
| 60% Recycled plastic with Copper (13% wt) | 0.1 | 16.4 |

[1] Adopted from Wind energy Handbook
[2] Adopted from engineering toolbox website

Comparing figure 12 to figure 13, the interfacial bond between the matrix and metal reinforcements seem to suggest that the steel reinforced samples have a better interfacial bond with the plastic compared to the copper samples. This was apparent considering how copper wires would easily slip out of the plastic for example during tensile testing. In addition, since the steel wires were from old tyres, normally they are several wires intertwined; this may have enhanced the metal plastic bond. Moreover, since the steel wires were thinner than the copper wires, they seem to have been easier integrated into the plastic and therefore enhancing the bond. This gets more weight from the higher tensile strength value obtained for the steel reinforced sample compared to the copper reinforced samples.

Figures 12 & 13 show the fracture sites of the reinforced samples and can therefore be used to explain how the specimens failed and how this affected the interfacial bond. From Figure 12, it is evident that the steel wires elongated before failure of the samples. Similarly for copper, there was some elongation of the fiber reinforcements before failure, although to a lesser extent compared to the steel reinforcement. This apparent elongation at the fracture site is therefore the reason for debonding of the plastic matrix and its reinforcements at the fracture sites, since the metals cross section reduced as it elongated to failure leaving a gap between the metal and matrix. It is interesting to note that the copper wires also tended to crack at the point of failure. Overall, the fact that the Steel wires were three thin wires intertwined, it is the opinion of the researcher that this was better reinforcement, since even when fiber pull out or one piece got broken, the others may still provide some support, unlike the copper wires which came in single pieces and therefore when the fiber got broken or pulled out, there would be no further support.

### *3.3 Discussions*

This research aimed at developing a cheap material for construction of wind turbine blades albeit for off grid systems, which at the moment are made mainly from wood in Kenya and other developing countries. Considering values of UTS obtained for reinforced samples and comparing this to values of materials currently used for this application, it is evident that UTS for GFRP is in the range of hundreds of Mega Pascals, but our material ranges in the tens of Mega pascals, wood has UTS in the range of tens of Mega Pascals. For example documented Figures of UTS for pine wood along the grain are 40MPa, which is significantly higher than values obtained for the materials under test, at the concentrations of reinforcement used .Table 4 gives a summary of mechanical properties of materials currently used for construction of wind turbines (small and large) and compares this to the material engineered by this research.

Of interest to note is that the concentrations of reinforcement used were quite low, and perhaps, higher concentrations of reinforcement could raise the UTS further. In addition, the modulus of elasticity E which has implications on the stiffness of a material for the materials made was in the range of between 100 and 120 MPa, for pine wood recorded values are 9 GPa(toolbox, 2014) and that of GFRP is 38GPa. It can be seen that in general, at the given reinforcement concentrations used in these experiments, wood and GFRP are still much stiffer than the materials made and hence still more suitable for the construction of wind turbine blades. However, taking into consideration values of E obtained for the various plastic samples with varying concentrations of recycled plastic, there is still a lot of research that could be done to come up with a suitable material.

The interlaminar shear strength (ILSS) was not significantly changed by addition of reinforcement. Since the material was being developed for wind turbine applications, comparison is made with materials used for similar purposes like GFRP. A study conducted by Putic et. al(Putic et al., 2009) indicates much higher values of ILSS for the GFRP, in the range of between 5.6 – 32.4 Mpa. This therefore means that for whatever application, and with the current reinforcement types and concentrations in our material, GFRP & wood are still superior.

## 4. Conclusions

Thermoplastics offer great advantage over thermosetting plastics for making of composites especially because they are recyclable. Therefore, this research is a step in assessment of the potential uses that recycled thermoplastics can be put to, in order to also establish a sound recycling culture in Sub Saharan Africa (SSA), and putting the recycled waste to a use that could generate economic benefits. However from the SEM images, it is clear that going forward with this research, there will be great need to work on improving the interfacial bond between the plastic and reinforcements.

## 5. Recommendations

Future work could involve changing the reinforcement concentrations and arrangement; perhaps this would improve performance of the material. Further the option of using other reinforcement types such as agricultural processing by products could go a long way in improving performance.

Also from literature especially the research from CWC, it is apparent that plastic waste from different manufacturers has differing properties. This maybe attributable to difference in additives used in processing the plastics before the final product is made. It is therefore recommended that chemical tests could be done in future, to come up with a chemical mix of the plastic with optimum mechanical properties.

From literature it is apparent that Fatigue life is an important factor in gauging the suitability of a material for wind turbine blade making. It had been intended to perform the fatigue test as one of the mechanical tests for the material. This was however hampered by a lack of fatigue testing equipment for plastics within the labs of the respective institutions in which the research was carried out. It is important that future research looking into this field involves determination of fatigue life of the material.

## Acknowledgements

This research work was funded by the National Commission of Science Technology and Innovation (NACOSTI), and the Kenya Nuclear Electricity Board (KNEB). Uppsala University through its International Science Programme (ISP) facilitated the SEM.

## References

ANCONA, D. & MCVEIGH, J. 2001. Wind Turbine - Materials and Manufacturing Fact Sheet.

ASTM 2006. Standard test method for short beam strength of polymer matrix composite materials and their laminates. USA: ASTM International.

ASTM 2008. Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials. USA: ASTM international.

CALLISTER, W. D. 2007. Material Science and Engineering. *An introduction.* Seventh ed. United States: John Wiley & Sons Inc.

CHIANELLI, R. J., J.M.L.REIS, J.L.CARDOSO & P.F.CASTRO 2013. Mechanical Characterization of Sisal Fiber-Reinforced Recycled HDPE Composites. *Materials Research,* 6, 1393-1397.

CWC 1999. Using Recycled Plastics In An Injection Molding Process. USA: CWC.

D.W.I.A 2001. Guided Tour on Wind Energy. Denmark: Danish Wind Industry Association.

KIAEIFAR, A., SAFFARI, M. & KORD, B. 2011. Comparative investigation on Mechanical Properties of Wood Plastic Composites Made of Virgin and Recycled Plastics. *World Applied Sciences,* 14, 735-738.

MISHNAEVSKY, L., FREERE, P., SINHA, R., ACHARYA, P., SHRESTHA, R. & MANANDHAR, P. 2011. Small wind turbines with timber blades for developing countries: Materials choice, development, installation and experiences. *Rnewable Energy,* 36, 2128-2138.

PUTIC, S., BAJCETA, B., VITKOVIC, D., STAMENOVIC, M. & PAVICEVIC, V. 2009. The interlaminar strength of glass fiber polyester composite. *Chemical Industry & Chemical Engineering Quarterly,* 15, 45-48.

TEGEN, S., HAND, M., MAPLES, B., LANTZ, E., SCHWABE, P. & SMITH, A. 2012. 2010 Cost of Wind Energy Review. National Renewable Energy Laboratory.

TOOLBOX, E. 2014. *Modulus of Elasticity - Young Modulus for some common Materials* [Online]. Available: http://www.engineeringtoolbox.com/young-modulus-d_417.html [Accessed 10/2/2014.

UNEP. 2012. Deforestation Costing Kenyan Economy Millions of Dollars Each Year and Increasing Water Shortage Risk. *UNEP NEWS CENTRE* [Online]. Available: www.unep.org/newscentre/Default.aspx?DocumentID=2698&Article=9316&I=en [Accessed 19/12/2013].

WILBURN, D. R. 2011. Wind Energy in the United States and Materials Required for the Land-Based Wind Turbine Industry From 2010 Through 2030. USA: U.S. Department of the Interior U.S. Geological Survey.

# Energy and Exergy Analysis Concepts: Modelling of Olkaria II Geothermal Power Plant in Kenya

**Mr. Nahshon NYAMBANE**[1]
Postgraduate Student

**Dr. Michael J. GATARI**
Lecturer at University of Nairobi, Nairobi, Kenya

**Dr. John G. GITHIRI**
Lecturer at Jomo Kenyatta University of Agriculture and Technology, Juja, Kenya

**Dr. Nicholas O. MARIITA**
Lecturer at Dedan Kimathi University of Technology, Nyeri, Kenya

*[1]Institute of Nuclear Science & Technology, College of Architecture & Engineering, University of Nairobi*

Tel: +254 20 318 262 Ext 483

Mobile Phone: +254 725 717 875
e-mail: nnyambane2@gmail.com

Address: P.O. Box 30197-00100, Nairobi, Kenya

**Abstract:** Condensers of geothermal power plants need to operate at low pressures to ensure optimal use of energy resources. To optimize the steam condensation process cooling water temperature is varied to determine the value that gives a higher condenser efficiency resulting in more power output. Cooling water temperature is dependent on the ambient temperature; therefore, in tropical countries like Kenya, high daytime temperatures affect negatively the cooling efficiency of the cooling towers. The high cooling water temperature increases condenser pressure and exergy loss thus lowering the power output. Our study focused on modelling the cooling system towards lowering the temperature of cooling water in which an absorption chiller was integrated into the system. The relevant energy, exergy balance, and efficiency equations for the Olkaria II (Kenya) geothermal power plant subsystem were derived. Codes were developed from the mathematically derived equations and solved using the Engineering Equation Solver software. By varying the evaporator temperature for a constant refrigerant load temperature; changes in condenser efficiency and turbine output were recorded. Simulation results showed that through adoption of an absorption chiller as the secondary cooling system, the exergy destroyed in the condenser and turbine decreased and an improved power output was observed. The observations were then translated to financial benefits which suggested an increase in annual cash flow. However, further analysis is necessary which should account for current investment costs on the absorption chiller and labour.

**Keyword:** exergy destruction, geothermal, condenser, absorption chiller.

## 1. Introduction

Increased demand for energy and environmental impact due to energy utilization has resulted in calls for a sustainable approach to development and management of energy resources (Rosen and Dincer, 2001). Since energy demand is far much higher than the available resources, the energy conversion systems must be designed to ensure efficient resource utilization as well as minimal exergy losses (Gong & Wall, 1997). In order to improve conversion efficiency of a geothermal power plant, cooling is essential for it increases the heat rejection, raises power output and increases heat to power conversion ratio. For instant in a turbine, conversion efficiency is influenced by the availability of an efficient and effective cooling system. An efficient cooling system lowers the fluid pressure, which contributes to increased vacuum pressure in the condenser. High vacuum pressure leads to increased turbine capacity and overall power plant exergy efficiency.

According to Tesha (2009) the change in condenser pressure is accompanied by a change in power output. His studies revealed that by lowering the condenser pressure from 11.178 kPa to 8.651 kPa an extra power of 45 kW was achieved for a single flash system. Sharma et al. (2011) carried out an exergetic optimization of inlet cooling water temperature of cross flow steam condensers through minimization of exergy destruction. They calculated the optimum inlet cooling water temperature under various operating conditions of the steam condenser. Their aim was to determine the variation of exergy destruction and exergy efficiency at various condenser pressures, different mass flow rates of steam and cooling water under atmospheric temperature. Their findings showed that optimum cooling water temperature decreased with decrease in condenser pressure. Dutta et al. (2013) did a study on the effect of cooling water temperature rise on the efficiency of condenser for a 210 MW thermal power plant. The study was done at fixed condenser pressure, mass flow rate of steam into the condenser, mass flow rate of cooling water, total surface area of cooling tubes and material properties respectively. Their findings show that the condenser efficiency increased with increase in temperature rise of cooling water.

In tropical areas, high air temperature is most of the time an obstacle to the steam condensation process. Condensation process is completed in the condenser, and if it occurs at high temperature the leftover steam increases. This leads to increased condenser pressure that lowers the exergy performance hence decreasing the turbine capacity. Therefore, there is need to ensure improved capacity for heat rejection by adopting systems that work towards increasing the coefficient of performance of the cooling cycle. Acir et al. (2012) investigated the effect of varying dead state temperature on energy and exergy of Cayirhan thermal power plant. The findings showed that varying dead state temperature do not have an effect on energy efficiency (first law efficiency), whereas it has an effect on the exergy efficiency (second law efficiency). The study also revealed that most heat losses occurred in the condenser.

Mehdis and Amir (2012) studied the effect of ambient temperature on the energy and exergy efficiencies of Ramin supercritical power plant in, Iran. They considered the plant at constant and varying condenser pressure respectively. The study revealed that at constant condenser pressure, the energy efficiency of the power plant remained constant as the ambient temperature increased. When the condenser pressure was varied, the energy efficiency decreased with increase in ambient temperature. However, the exergy efficiency of the plant decreased as the ambient temperature increased at both constant and varying condenser pressure with the rate being higher at varying condenser pressure.

One of the systems that have been proved effective in increasing the performance of cooling cycle during hot periods is an absorption chiller. This is an artificial cooling system that uses LiBr as the absorbent and water as the refrigerant. The system works on either a single effect, double effect or multiple effect refrigeration principle. The single effect refrigeration system works under two pressures, the high pressure region and the low pressure region. These pressure differences occur across solution pumps and flow restrictions. The system consists of two flow restrictors, one solution pump and four heat exchangers; absorber, desorber, condenser and evaporator. Solution heat exchanger and refrigerant heat exchanger where incorporate into the system to improve the performance of the system. The refrigerant which is the real working fluid is separated from the absorbent in the desorber then directed to condenser in vapour form. The essence of the absorbent is to treat the refrigerant to a specific condition for a complete cycle continuation.

High pressure occurs in the refrigerant heat exchanger, condenser, desorber and solution heat exchanger while low pressure occurs in the absorber and evaporator. The low pressure in the evaporator, probably far below the atmospheric pressure, makes it easier for the refrigerant molecules to enter the vapour phase at a much lower temperature, enabling the refrigerant to extract more heat from the load into the evaporator thus lowering its temperature further. Kececiler et al. (2000) studied the effect of using low temperature geothermal resource to power a $LiBr/H_2O$ system. His findings showed the system yielded chilled water at a temperature of 4 – 10 $^0$C and this would significantly improve the cooling system for geothermal power plant. Tesha (2009) also studied the effect of incorporating an absorption refrigeration system as an integrated condenser unit in a geothermal power plant. The analysis involved using energy concept to determine the effect on power output through use of an absorption system. The findings obtained showed that by adopting the system an extra 131 KWe was obtained.

## 2. Description of the plant

Olkaria II geothermal power plant is located in the Kenyan part of the East African rift within the Greater Olkaria geothermal area. The plant is 120 km North West of Nairobi and has an installed capacity of 105 MW. It started to produce power in the year 2002 with installed capacity of 70 MW before adding the third turbine in 2010 with generator output of 35 MW. Figure 1 shows the Olkaria plant while Figure 2 shows the schematic representation of Olkaria II plant cycle.

The plant is supplied with steam from 20 production wells which is obtained after separation in the separator. The steam is fed into transmission lines which are connected to steam scrubbers to remove water droplets from the steam. The almost dry steam is then fed into steam expanding turbines coupled with a generator to generate electrical power. The turbine exhaust is directed to the condenser to be cooled thus creating pressure drop. The pressure difference results in enthalpy change between the turbine inlet and outlet which is responsible for the creation of turbine work as shown in Figure 3. The condensed steam flows to the hotwell pumps that deliver the condensate to the cooling towers. A small amount of the condensed steam is re-injected into the ground to maintain the cooling tower volume. The cooled water is then feed to the condenser.

## 3. Methodology

### *3.1 Collection of model parameters*

The parameters, which were considered during data collection, were pressure, mass flow rate and temperature at various state points. These model parameters were collected from actual plant operation log sheets which included the turbine log sheets, auxiliary log sheets and occurrence books. Others were obtained through observation of the field operating conditions while those that could not be directly measured were software estimated. The measured parameters served as inputs to the modelled system for simulation on Engineering Equation Solver (EES).

### *3.2 Absorption chiller model*

In this research the absorption chiller has been modelled to suite the application. The models were based on a simple steady state and the main equations were formulated on the basis of mass and energy balance. Besides the basic thermodynamic principles of mass and energy balance, UA and logarithmic mean temperature difference (LMTD) were used for most of the chiller system except the desorber and absorber which were modelled as adiabatic flash drum for two- phase mixture where the mixture i.e the absorbent and refrigerant are in equilibrium and the exiting vapor in the desorber is pure water.

### *3.3 Code development and Simulation*

For mass, energy, entropy and exergy balances, equations (1 to 3) were used in developing the EES codes based on equation 5. Using the Engineering Equation Solver, mathematical models formulated were simulated to compute the output properties of the system. Iterations were run at varying cooling water temperatures to establish the optimum operating conditions of the hybridized system. Plots for various operating conditions were generated using the EES software. The simulation results for the plant with hybridized cooling system was then compared with the current plant in Olkaria II in terms of exergy destroyed in the turbine(s) and condenser(s), generator power output and exergy efficiencies.

## 4. Thermodynamic analysis

In geothermal power plant modelling three main parameters are considered. They include mass, energy and exergy. For mass and energy balance two important assumption hold, that mass flow into the system is equal to the mass flow out of the system as expressed in,

$$\Sigma(\dot{m})_{in} = \Sigma(\dot{m})_{out} \tag{1}$$

where $\dot{m}$ is the mass flow and the energy into the system is equal to the energy out of the system as expressed in,

$$\Sigma(\dot{m}\cdot \mathrm{h})_{in} = \Sigma(\dot{m}\cdot \mathrm{h})_{out} \tag{2}$$

For a control volume, the exergy balance process is shown in figure 4.

The exergy balance equation for the system in Figure 4 is expressed as,

**Figure 1: Olkaria II geothermal power plant, Kenya.**

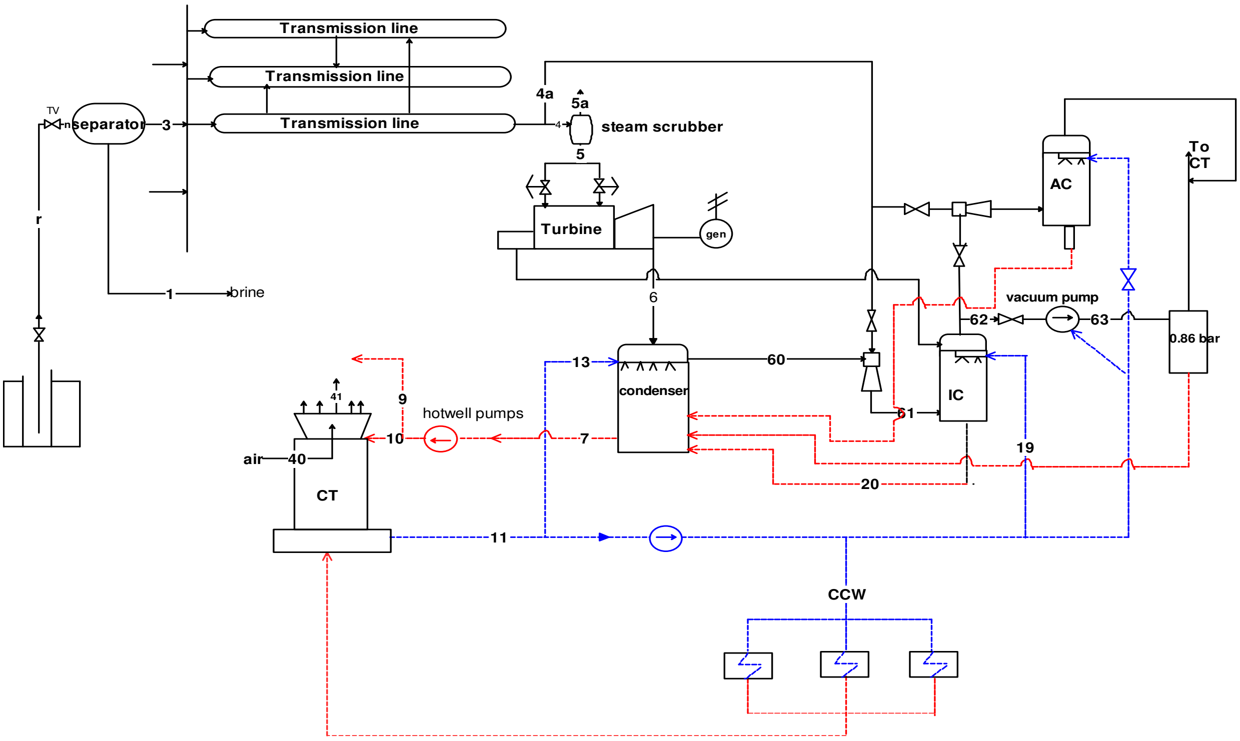



**Figure 2: Schematic description of Olkaria II geothermal power plant.**

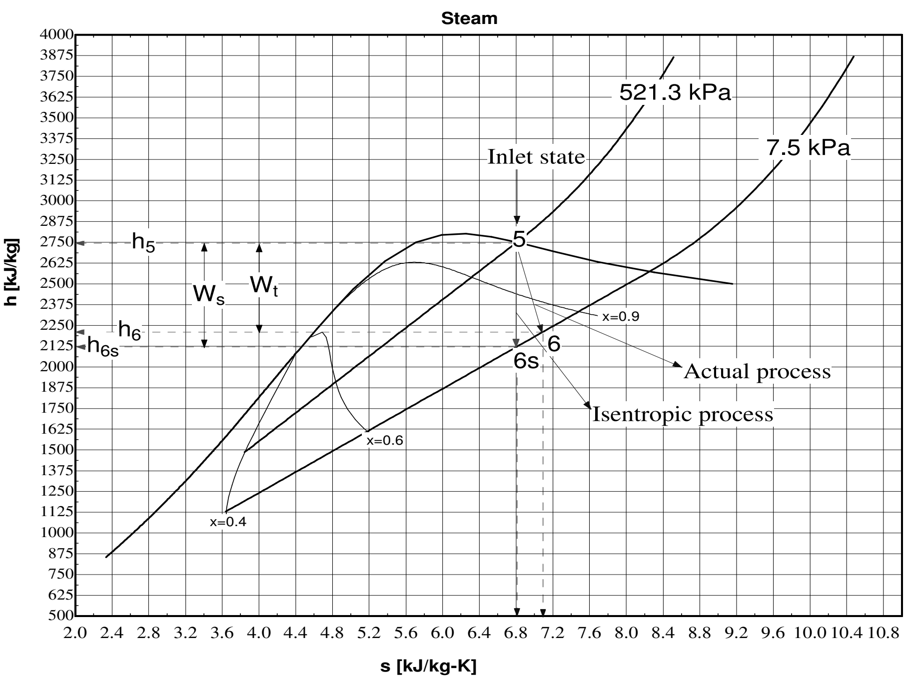



**Figure 3: h-s diagram for turbine operation with inlet and exit pressures of 521.3kPa and 7.5kPa respectively.**

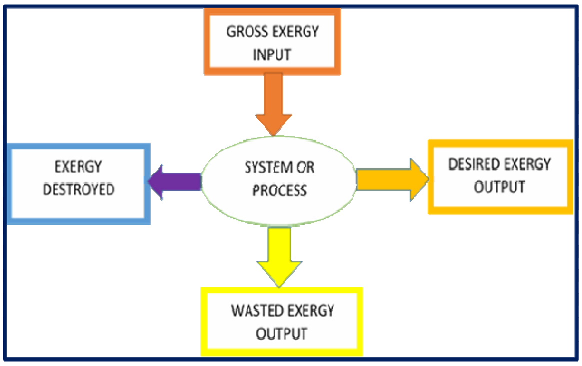



**Figure 4: Illustration of exergy flow through a system.**

$$E_{in} = E_{out} + E_{destroyed} \quad (3)$$

Where,

$$E_{out} = E_{desired} + E_{wasted} \quad (4)$$

The generalized equation for calculation of exergy is as shown in equation 5. The equation forms the basis of EES codes development.

$$E = \dot{m} \cdot [(h - h_o) - T_o(S - S_o)] \quad (5)$$

According to Dincer and Rosen (2007), overall exergetic efficiency of the plant can be expressed as,

$$n_E = \frac{E_{desired}}{E_{in}} \quad (6)$$

where $E_{desired}$ (kW) is the net power output and $E_{in}$ is the total available exergy into the plant.

## 4.1 *Turbine*

The turbine is the most important component in a geothermal power plant. It receives dry steam from the steam scrubber, and then expands it before being exhausted into the condenser. Exergy balance equation for the turbine is given by,

$$E_5 = E_6 + W_t + I_{t-gen} \quad (7)$$

where $W_t$ is the turbine work, $I_{t-gen}$ is the exergy loss in the steam turbine. Exergetic efficiency is expressed as,

$$n_{E,t-gen} = \frac{W_t}{E_5 - E_6} \quad (8)$$

## 4.2 *Condenser*

The exergy balance equation for the condenser is expressed as,

$$E_6 + E_{13} + E_{20} = E_7 + E_{60} + I_{cond} \quad (9)$$

where $I_{cond}$ is the exergy loss in the condenser and the exergetic efficiency is expressed as,

$$n_{E,cond} = \frac{E_{7cw} - E_{13} - E_{20cw}}{E_6 + E_{20,steam} - E_{7,steam}} \quad (10)$$

where subscript cw refers to cooling water.

## 4.3 *Cooling tower*

For the cooling tower the following expression is employed to determine the coefficient of performance (COP)

$$COP = \frac{E_{10} + E_{15} + E_{17} - E_{11}}{W_{fans} + W_{pumps}} \quad (11)$$

where $W_{fans}$ and $W_{pumps}$ is the electric power consumed by the fans and pumps respectively.

## 4.4 *Absorption chiller*

In order to perform estimation of equipment sizing and performance of the absorption chiller, the following assumptions were considered.

i. There is no pressure change except through the flow restrictors and pumps.
ii. The solution pump is adiabatic and is used to maintain the constant solution level in the desorber
iii. The pump is isentropic
iv. There is no jacket heat losses
v. The system is operating in a steady state
vi. Only two pre $E_{desired}$ ssures exist i.e high pressure zone and low pressure zone

For mass balance, each component is treated as a control volume with inlet and outlet of flows. It is considered that the mass flow rate into system is equal to the mass flow rate out of the system,

$$\Sigma \dot{m}_{in} = \Sigma \dot{m}_{out} \quad (12)$$

$$Q = \dot{m}(h_a - h_b) \quad (13)$$

where Q is heat transfer rate, $\dot{m}$ is mass flow rate, $h$ is enthalpy and a and b are state points

For heat exchangers, equation 14is applicable,

$$Q = UA\Delta T_{lm} \quad (14)$$

where

$$\Delta T_{lm} = \frac{(T_{h,1} - T_{c,2}) - (T_{h,2} - T_{c,1})}{\ln\left(\frac{(T_{h,1} - T_{c,2})}{(T_{h,2} - T_{c,1})}\right)} \quad (15)$$

U = coefficient of heat transfer of the material used for the heat exchanger tubes
A = Area of the heat exchanger system
$\Delta T_{lm}$ = Logarithmic Mean Temperature Difference,
where, $h$ and $c$ are referred as hot and cold sides, respectively. The subscript 1 and 2 refer to either end of heat exchanger.

In modelling of absorption refrigeration system both mass and energy balance equations form the basis of other expressions. The subscript numbers in the equation refers to state points in Figure 5. The main equations for the absorption chiller were formulated on the basis of mass and energy balance.

*4.4.1 Absorber*

$$\dot m_{21} = \dot m_{26} + \dot m_{32} \quad (16)$$

$$Q_{abs} = \dot m_{26} h_{26} + \dot m_{32} h_{32} - \dot m_{21} h_{21} = \quad (17)$$
$$\dot m_{14}(h_{15} - h_{14}) = U \cdot A_{abs} \cdot LMTD_{abs}$$

$$LMTD_{abs} = \frac{(T_{26} - T_{15}) - (T_{21} - T_{14})}{\ln\left(\frac{(T_{26} - T_{15})}{(T_{21} - T_{14})}\right)} \quad (18)$$

*4.4.2 Desorber*

$$\dot m_{23} = \dot m_{24} + \dot m_{27} \quad (19)$$

$$Q_d = \dot m_{24} h_{24} + \dot m_{27} h_{27} - \dot m_{23} h_{23} = \quad (20)$$
$$\dot m_1(h_1 - h_2) = U \cdot A_d \cdot LMTD_d$$

$$LMTD_d = \frac{(T_1 - T_{24}) - (T_2 - T_{27})}{\ln\left(\frac{(T_1 - T_{24})}{(T_2 - T_{27})}\right)} \quad (21)$$

*4.4.3 Condenser*

$$\dot m_{27} = \dot m_{28} \quad (22)$$

$$Q_c = \dot m_{27} h_{27} - \dot m_{28} h_{28} =$$
$$\dot m_{16}(h_{17} - h_{16}) = U \cdot A_c \cdot LMTD_c \quad (23)$$

$$LMTD_c = \frac{(T_{28} - T_{16}) - (T_{27} - T_{17})}{\ln\left(\frac{(T_{28} - T_{16})}{(T_{27} - T_{17})}\right)} \quad (24)$$

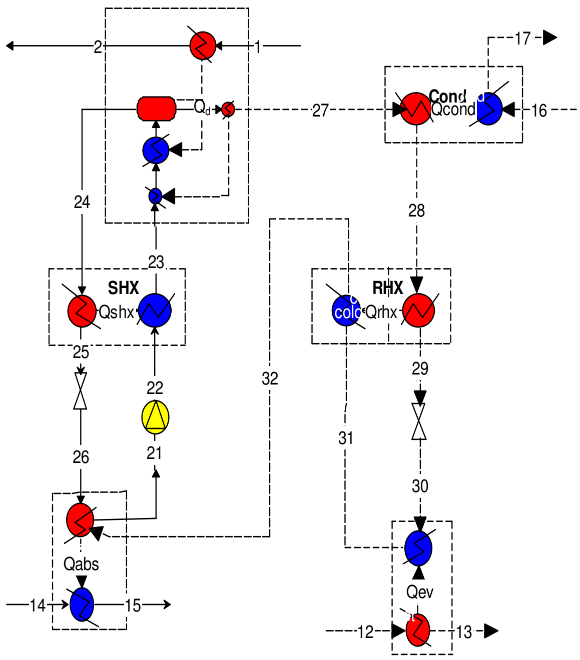



**Figure 5: Schematic diagram of an absorption chiller.**

*4.4.4 Evaporator*

$$\dot m_{30} = \dot m_{31} \quad (25)$$

$$Q_e = \dot m_{31} h_{31} - \dot m_{30} h_{30} = \quad (26)$$
$$\dot m_{12}(h_{12} - h_{13}) = U \cdot A_e \cdot LMTD_e$$

$$LMTD_e = \frac{(T_{12} - T_{31}) - (T_{13} - T_{30})}{\ln\left(\frac{(T_{12} - T_{31})}{(T_{13} - T_{30})}\right)} \quad (27)$$

$$\dot m_{22} = \dot m_{23} = \dot m_{24} = \dot m_{25} \quad (28)$$

*4.4.5 Solution heat exchanger*

$$Q_{shx} = \dot m_{23} h_{23} - \dot m_{22} h_{22} = \quad (29)$$
$$\dot m_{24}(h_{24} - h_{25}) = U \cdot A_{SHX} \cdot LMTD_{SHX}$$

$$LMTD_{SHX} = \frac{(T_{24} - T_{23}) - (T_{25} - T_{22})}{\ln\left(\frac{(T_{24} - T_{23})}{(T_{25} - T_{22})}\right)} \quad (30)$$

*4.4.6 Refrige rant heat exchanger*

$$\dot m_{28} = \dot m_{29} = \dot m_{30} = \dot m_{31} \quad (31)$$

$$Q_{RHX} = \dot m_{28} h_{28} - \dot m_{29} h_{29} = \quad (32)$$
$$\dot m_{30}(h_{32} - h_{31}) = U \cdot A_{RHX} \cdot LMTD_{RHX}$$

$$LMTD_{RHX} = \frac{(T_{28} - T_{32}) - (T_{29} - T_{31})}{\ln\left(\frac{(T_{28} - T_{32})}{(T_{29} - T_{31})}\right)} \quad (33)$$

## 5. Results and Discussions

### *5.1 Simulation results for current power plant*

**Table 1: Parameters at major stages of Olkaria II geothermal power plant.**

| State Point (as shown in Figure 5) | Mass flow rate, (kg/s) | Enthalpy, h (kJ/kg) | Entropy (kJ/kg-K) | Temperature, T ($^oC$) | Exergy, $E_x$ (KW) |
|---|---|---|---|---|---|
| 5 | 70.39 | 2750 | 6.811 | 151.3 | 53239 |
| 6 | 63.35 | 2210 | 7.116 | 44.97 | 8044 |
| 7 | 2372 | 163.3 | 0.5589 | 39 | 5676 |
| 9 | 23.54 | 163.2 | 0.5589 | 39 | 56.27 |
| 10 | 2349 | 163.3 | 0.5589 | 39 | 5615 |
| 11 | 2397 | 104.9 | 0.3670 | 25.0 | 518.7 |
| 12 | 2194 | 104.9 | 0.3669 | 25.0 | 474.8 |
| 13 | 2194 | 104.9 | 0.3673 | 25 | 209.1 |
| 19 | 115.6 | 104.8 | 0.3669 | 25 | 20.39 |
| 20 | 115.6 | 158.7 | 0.5441 | 37.9 | 246.3 |
| 60 | 0.475 | 17 | 0.5602 | 44.97 | -68.57 |

### *5.2 Simulation results for hybrid system*

**Table 2: Parameters at major stages of Olkaria II geothermal power plant with hybrid cooling system.**

| State Point (unit no) | Mass flow rate, $\dot{m}$ (kg/s) | Temperature, T ($^oC$) | Enthalpy, h (kJ/kg) | Entropy, s (kJ/kg-K) | Exergy, $E_x$ (kW) |
|---|---|---|---|---|---|
| 5 | 70.39 | 151.3 | 2750 | 6.811 | 53239 |
| 6 | 63.35 | 41 | 2194 | 7.128 | 6806 |
| 7 | 2372 | 38 | 159.1 | 0.5455 | 5086 |
| 9 | 23.54 | 38 | 159.1 | 0.5455 | 50.48 |
| 10 | 2349 | 38 | 159.1 | 0.5455 | 5031 |
| 11 | 4985 | 25 | 104.8 | 0.367 | 1079 |
| 12 | 2194 | 25 | 104.8 | 0.367 | 474.8 |
| 13 | 2194 | 16 | 67.1 | 0.2387 | 67.76 |
| 14 | 1227 | 25 | 104.9 | 0.2387 | 67.76 |
| 15 | 1227 | 45 | 188.5 | 0.6385 | 5229 |
| 16 | 1361 | 25 | 104.9 | 0.2387 | 67.76 |
| 17 | 1361 | 40 | 167.6 | 0.5722 | 3770 |
| 19 | 115.6 | 25 | 67.18 | 0.2387 | 13.32 |
| 20 | 115.6 | 45 | 188.4 | 0.6385 | 488.5 |
| 60 | 0.475 | 41 | 9.296 | 0.5664 | -73.09 |

Adoption of the hybrid cooling system showed some positive results in terms of power output, condenser and turbine exergy efficiencies, turbine energy efficiency and coefficient of performance of cooling tower. Simulation results showed that by lowering cooling water temperature from $25^0$C to $16^0$C the exergy drop in the turbine increased from 45.2 MW to 46.4 MW resulting in turbine power output increasing from 37.5 MW to 39.1 MW as shown in Table 4. This account for 4.4 % increase in power output. Table 4 also show that the condenser exergy efficiency increased from 63 % to 66 % for a condenser pressure of 5.9 kPa while the coefficient of performance (COP) of the cooling tower increased to 16.9. The exergy destroyed in the turbine decreased by 0.4 MW accounting for 0.75 % of exergy into the turbine while exergy destroyed in the condenser dropped by 0.59 MW accounting for 1.1 % of exergy into the turbine.

**Table 3: Main results of the parameters of an absorption chiller at each state point.**

| State Points (unit no. | Mass flow rate, $\dot{m}$ (kg/s) | Enthalpy, h (kJ/kg) | Temperature, T ($^oC$) | Pressure, P (kPa) |
|---|---|---|---|---|
| 21 | 157 | 76.05 | 35 | 1.228 |
| 22 | 157 | 76.05 | 35 | 9.59 |
| 23 | 157 | 134.9 | 62.6 | 9.59 |
| 24 | 122.2 | 281.8 | 108.8 | 9.59 |
| 25 | 122.2 | 206.1 | 64.1 | 9.59 |
| 26 | 122.2 | 206.1 | 65.1 | 1.228 |
| 27 | 34.85 | 2638 | 74.4 | 9.59 |
| 28 | 34.85 | 188.4 | 45 | 9.59 |
| 29 | 34.85 | 141.6 | 33.8 | 9.59 |
| 30 | 34.85 | 141.6 | 10 | 1.228 |
| 31 | 34.85 | 2519 | 10 | 1.228 |
| 32 | 34.85 | 2566 | 35 | 1.228 |

**Table 4: Comparison of efficiencies between the current geothermal power plant (GPP) and the geothermal power plant with hybridized cooling system (HCS).**

| Subsystem | Desired Exergy for each subsystem (MW) | | Exergy wasted in each subsystem (MW) | | Exergy destroyed in each subsystem (MW) | | Exergetic efficiency of each subsystem (%) | |
|---|---|---|---|---|---|---|---|---|
| | Current GPP | GPP with HCS | Current GPP | GPP with HCS | Current GPP | GPP with HCS | Current GPP | GPP with HCS |
| Turbine | 37.5 | 39.13 | 8.04 | 6.8 | 7.7 | 7.3 | 83.0 | 84.3 |
| Condenser | 5.0 | 4.9 | 0.15 | 0.14 | 2.89 | 2.3 | 63.4 | 65.9 |
| Energy Efficiency of turbine | | | | | | | 19.4 | 20.2 |
| Overall Exergetic efficiency of Plant as a function of steam into transmission lines | | | | | | | 52.4 | 65 |
| Overall Exergetic efficiency of Plant as a function of geo-fluid | | | | | | | 46.6 | 55.6 |

These results clearly show that by lowering the condenser pressure from 6.9 kPa to 5.9 kPa the condenser exergy efficiency increases leading to an additional power output for constant auxiliary power consumption.

Taking the unit price of electricity in Kenya to be 0.07 $/kWh, power gain of 1.5 MW translated to an annual financial gain of 919,800 US $. This was based on an assumption that the cash flow remained constant. Factoring in the operation and maintenance cost (O & M) of 0.00763 US $/kWh (Energy Regulation Commission, 2009), the annual net financial gain amounted to US $ 819,540.

*5.3 Operating graphs for the power plant with hybridized cooling system*

The simulation results show that with an absorption chiller we can achieve a cooling water temperature of 16 $^0C$ for an evaporator temperature of 9 $^0C$ ($\Delta T_{cooling}$). Figure 6 shows the relationship between cooling water temperature and condenser pressure for a constant evaporator temperature. For cooling water temperature of 16 $^0C$ the condenser pressure stands at 5.945 kPa. At this condenser pressure the exergy efficiency of the condenser is found to be 65.9 % as shown in Figure7.

Figure 8 shows the dependency of turbine energy and exergy efficiencies on condenser pressure. An increase in condenser pressure equally leads to a decrease in turbine energy and exergy efficiency. Geothermal power plants strongly depend on the cold end operating conditions where the condenser is the key of the heat exchanger system. The operating conditions of the condenser depend on the cooling system which gives the inlet condition of condenser parameters. One of that parameter is the cooling water temperature which greatly influences the condenser pressure and the power output. A decrease in condenser pressure results in an increase in turbine output power as shown graphically in Figure 9. This observation agrees with the theoretical studies performed. This study explains why the power output decrease during hot months when daytime temperatures are usually very high.

Condensation of steam exiting the turbine is essential for any geothermal power plant. For effective condensation the temperature of water used for cooling should be as low as it can practically be. By improving condensation process, the exergy efficiency of the condenser is improved and this improves the exergy efficiency of the turbine. The sum total of these improvements is depicted by increased overall exergy efficiency of the power plant.

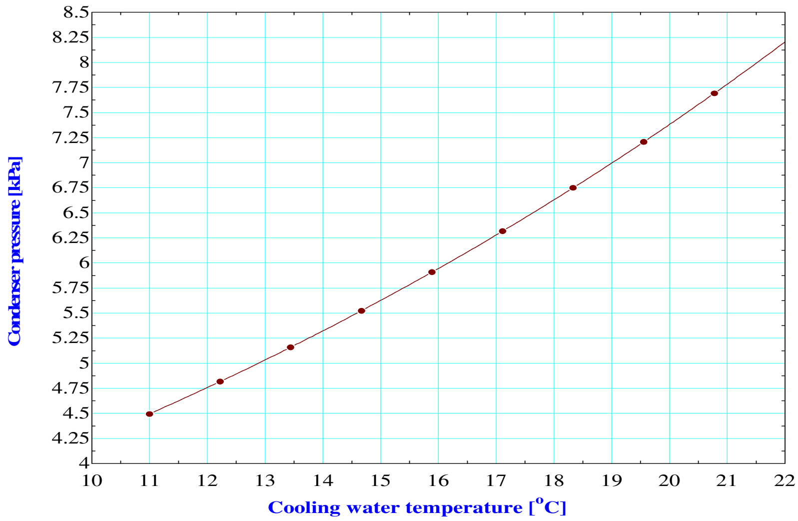



**Figure 6: Relationship between condenser pressure and changes in cooling water temperature.**

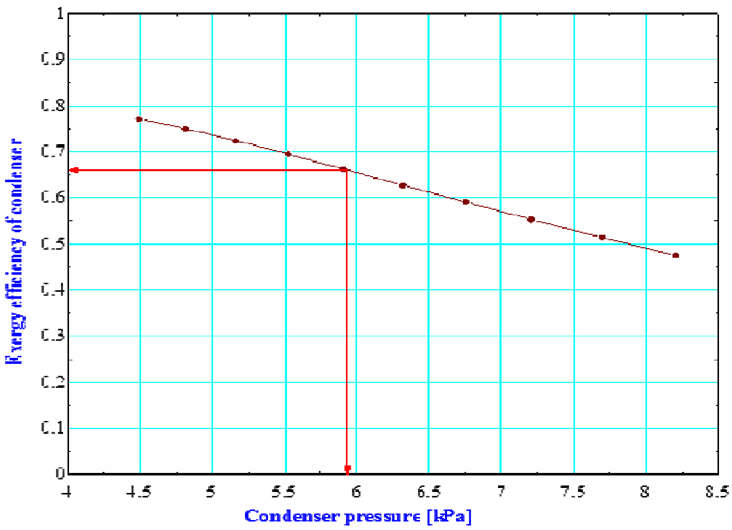



**Figure 7: Relationship between condenser exergy efficiency and changes in condenser pressure.**

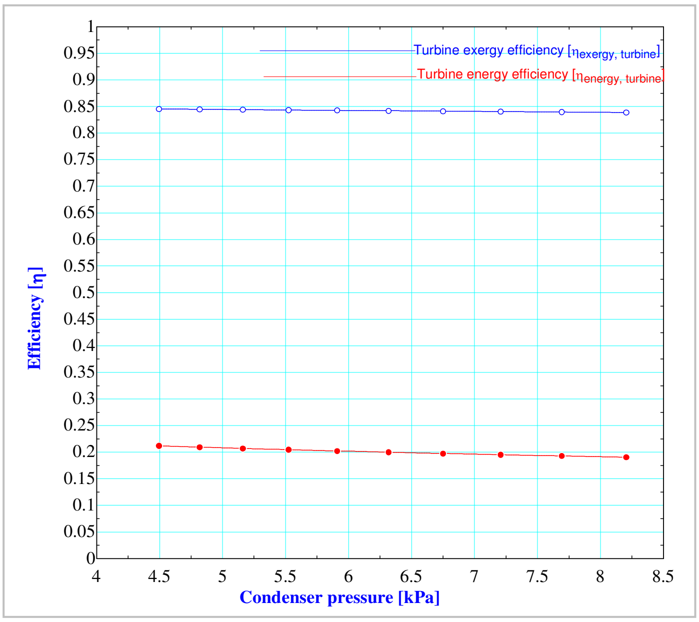



**Figure 8: Relationship between turbine energy and exergy efficiency and changing condensing pressure.**

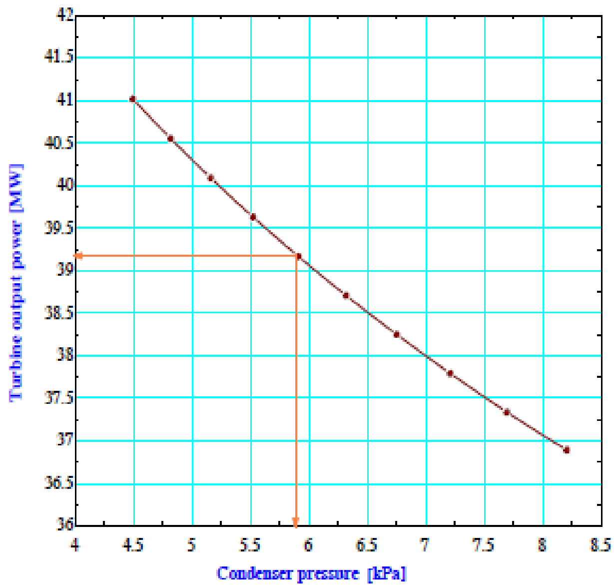



**Figure 9. Relationship between turbine power output and changes in condenser pressure.**

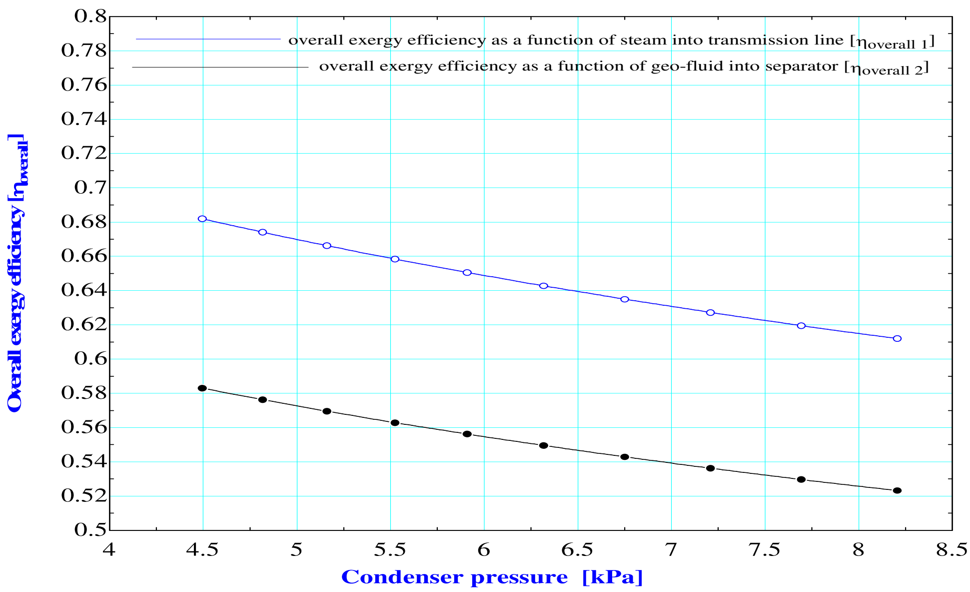



**Figure 10: Graph of overall exergy efficiency against condenser pressure.**

Graphical variations of overall exergy efficiency and condenser pressure are shown in Figure 10.

Figure 11 shows the effect of ambient temperature on energy and exergy efficiency of a geothermal plant. It shows that at variable condenser pressures the exergy and energy efficiency decreased with increase in ambient temperature.

The decrease for energy efficiency was much higher than exergy efficiency for the same temperature range.

From Figure 12, it is noted that at constant condenser pressure and specified cooling water flow rate, increase in cooling water temperature results in a decrease in condenser heat transfer rate. However, for specified cooling water temperature and at constant condenser pressure, heat transfer rate increases as the cooling water flow rate increases.

The graphs above give a picture of the operating conditions of Olkaria II geothermal power plant when subjected to different operating parameters. Results and inferences from the from the Olkaria II plant, can be used to describe other geothermal plants within similar environmental conditions.

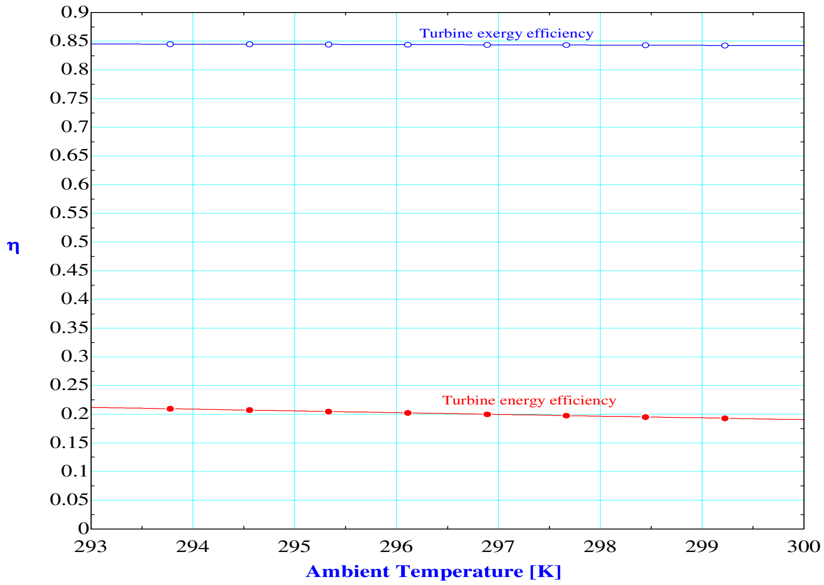



**Figure 11: Effect of ambient temperature on energy and exergy efficiency at variable condenser pressure for a geothermal power plant.**

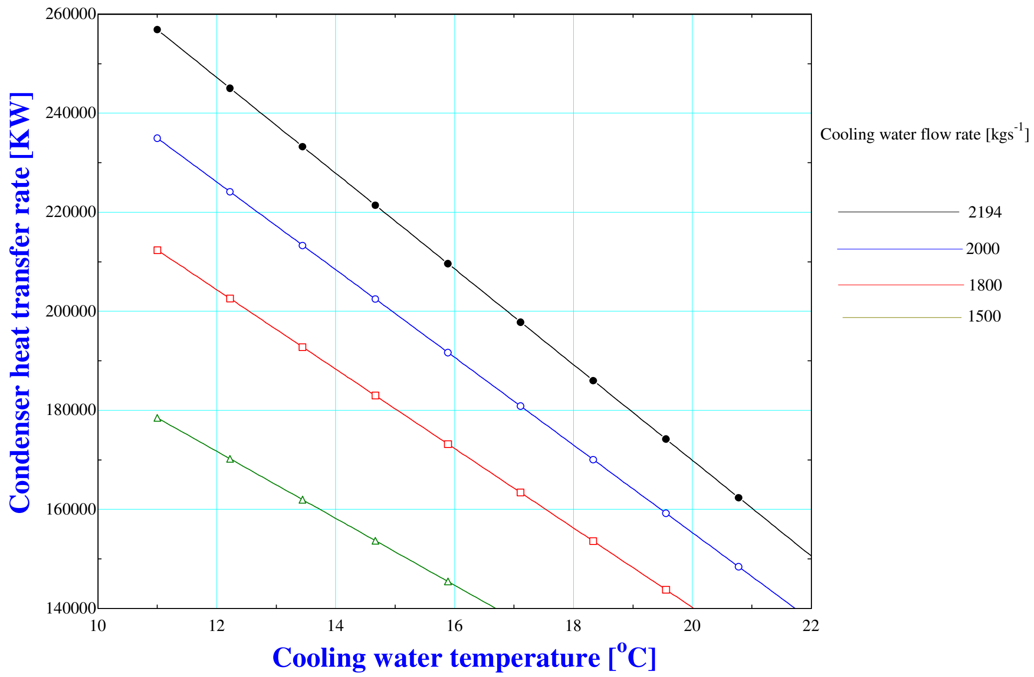



**Figure 12: Condenser heat transfer rate due to cooling water temperature and flow rate changes at constant condenser pressure of 5 kPa**.

## 6. Conclusions and Recommendations

The research presents the effect of varying cooling water temperature on condenser pressure and ultimately power output. The effect of lowering cooling water temperature on condenser pressure and power output has been assessed and the following conclusions can be drawn.

First, by lowering cooling water temperature from 25$^0$C to 16$^0$C the condenser pressure is reduced from 6.9 kPa to 5.9 kPa for unit 3 and this pressure decrease is accompanied with additional power output of 1.5 MW. The idea of lowering cooling water temperature is to ensure that more steam is condensed within the condenser thus creating a higher cooling water temperature difference. The higher temperature difference offered a higher efficiency of the condenser.

Second, the adoption of an absorption refrigeration system as the secondary cooling system minimized the influence of environmental effect on cooling efficiency. With this system cooling water temperature of 16$^0$C was obtained.

At this cooling water temperature exergy destroyed in the condenser and turbine decreased by 0.59 MW and 0.4 MW respectively. Overall exergy efficiency of the plant as a function of steam into transmission line improved by 12.6 %.

There is need to carry out an economic analysis to ascertain the cost of investing in the absorption chiller. This will assist in calculating the payback period which will help the investors to evaluate if the investment is economically feasible.

## Acknowledgements

This study would not have been possible without the equipment support from Kenya Electricity Generating Company (KenGen), and a study and travel grant from National Commission of Science, Technology and Innovations, Kenya and the International Science Programme (ISP), University of Uppsala, Sweden respectively.

## References

Acir, A., Bilgnsoy, A. K., Coskun, H., 2012. "Investigation of varying dead state temperature on energy and exergy efficiencies in thermal power plant". Journal of the energy institute. vol. 85, Issue. 1.

Dincer I., Rosen M. A., 2007. "EXERGY: energy, environment and sustainable development", Elsevier, ISBN: 978-0-08-044529-8, p 454.

Dutta, A., Das, A. K., Chakrabarti, S., 2013. "Study on the effect of cooling water temperature rise on the loss factor and efficiency of a condenser for a 210 MW thermal power plant". International journal of emerging technology and advanced engineering. vol. 3, Issue. 3, p 485-489.

Energy Regulation Commission, 2009. "Least cost power development plan".

Gong, M., Wall, G., 1997. "On exergetics, economics and optimization of technical processes to meet environmental conditions". Conference proceedings of Thermodynamic analysis and improvement of energy systems, Beijing, China, p 453-460.

Kececiler, A., Acar, H., Dogan, A., 2000. "Thermodynamic analysis of the absorption refrigeration system with geothermal energy: an experimental study". Energy Conversion and Management. vol. 41, issue. 1, p 37-48.

Mehdi, S., Amir, V., 2012. "The Effect of Ambient Temperature to Power Plant Efficiency". 2nd International Conference on Mechanical, Production and Automobile Engineering, Singapore April 28-29, p 1-5

Rosen, M., Dincer, I., 2001. "Exergy as the confluence of energy, environment and sustainable development". Internat. J. on Exergy, issue. 1, p 3-13.

Sharma, P., Rajput, SPS., Pandey, M., 2011. "Exergetic optimization of inlet cooling water temperature of cross flow steam condensers". International journal on emerging technologies. vol. 2, Issue. 1, p 144-147

Tesha, 2009. "Absorption refrigeration system as an integrated condenser cooling unit in a geothermal power plant". Proceedings World Geothermal Congress, Bali Indonesia, 25-29 April. p 1-5.

# Investigating the opportunities for wave energy in the Aegean Sea

**George LAVIDAS**[88]
*University of Edinburgh, Institute for Energy Systems, UK*

**Vengatesan VENUGOPAL**
*University of Edinburgh, Institute for Energy Systems, UK*

**Daniel FRIEDRICH**
*University of Edinburgh, Institute for Energy Systems, UK*

**Abstract:** Current circumstances globally, require a diverse mixture of energy sources; each country has to take advantage of its available resources. Renewable energy plays a significant role in the decarbonisation in future markets. One emerging technology that can be utilized by most Mediterranean countries is wave energy. Although estimated resources are not as great as in countries placed at oceanic waters, wave energy still poses a serious alternative energy resource. In order to understand and utilize the full potential and accessibility of wave sites, resource assessments are imperative. Waves are more complex than other renewable resources. Representing the nature of waves changes dramatically from linear to non-linear, increasing the difficulty of the estimated resource. The use of numerical models for predictions and hindcasts, have allowed us to overcome this, although several parameters have to be taken into account. Most importantly, the dissemination of the numerical processes have to be chosen. This paper reports the results obtained from a wave modelling hindcast carried out for the Aegean Sea, using the SWAN numerical model. The aim of this work is to identify any potential wave energy sites in the Aegean Sea, by hindcasting wave parameters and estimating wave power. The results indicate that SWAN performed to a highly satisfactory level in predicting wave conditions.

[88] Corresponding author George Lavidas (g.lavidas@ed.ac.uk)

## 1. Introduction

Seas are an integral component of most Mediterranean countries; people in these areas have been interacting constantly with the nature of waves throughout history. The need for decarbonizing is urgent, and diversifying the energy mix will help to achieve economic growth and reduce its carbon footprint. Several attempts and measures are been taken around the world for a pathway to sustainable development. Specifically legislative themes and proposal from the European Union (EU) and the Kyoto agreement have outlined the fact that becoming independent from fossil fuels will allow economic and environmental sustainability (Parliament 2009; Fischer & Newell 2008; Mathiesen et al. 2011; Hervás Soriano & Mulatero 2011).

Wave resources, apart from naval and fishery activities can be harnessed and utilized to produce clean renewable energy. Wave resource in the greater Mediterranean region and more specifically Greece, are not estimated as high as the ocean exposed EU countries (Cruz 2008)(Athens 2014). However it still poses a significant opportunity for localized distributed energy generation in many of its islands. This will pave the way for penetration of wave energy, in combination with other renewable technologies such as wind and photovoltaic. Thus reducing the cost of oil imports and transfer costs to islands, helping to reach the agreed renewable targets set.

Waves are a versatile resource and their assessment has extended benefits over many sectors, however, in this assessment the focus is on the energy sector. The nature of waves and their connection to the available wind resource increases the difficulty for accurate prediction. A proper detailed assessment of an area will not only provide information for the environment but will help boost potential investments and quantify, in energy terms, the expected energy output.

## 2. Numerical modelling and wave power estimations

The first step to the assessment of energy potential is thorough and detailed resource estimation which is done with the help of Simulating Waves Nearshore (SWAN). SWAN is a third generation implicit, phase average numerical model. SWAN simulates wind generated seas and accounts for many terms that interact and shape the final incoming energy flux. What separates SWAN from other oceanic models (i.e WAM, WaveWatch III), is its ability to resolve the physical interactions that occur in coastal areas. The significant wave height ($H_s$) and periods(peak period $T_p$, mean zero crossing $T_z$) are mostly affected, by non-linear physics such as triad interactions, surf breaking etc. (Komen et al. 1994; Holthuijsen 2007; Delft 2014; Cavaleri et al. 2007).

The modelling of the waves in the greater Mediterranean region has been developed and coupled with the atmospheric model provided by the University of Athens and research studies have demonstrated the calibration and accuracy of the forecasts (Korres et al. 2011; Soukissian & Pospathopoulos 2006). Although these models are accurate to depict the general trends, their accuracy in nearshore locations decreases dramatically and their computational demands are large. On the contrary the computational requirements of SWAN are far less and in combination with the advanced physics that is included the accuracy of results provided for coastal application are verified and widely accepted (Bunney 2011; Akpinar & Kömürcü 2013; Moeini & Etemad-Shahidi 2009; Rogers et al. 2007; Cavaleri & Holthuijsen 1998; Cavaleri et al. 2007)

Currently wave estimations in Greece are being conducted, with the use of large scale numerical models that do not resolve correctly the shallow water terms, operated by the University of Athens/Department of Physics (Athens 2014), the Hellenic Centre for Marine Research (Hellenic Centre for Marine for Research 2014) etc.

Wave devices are expected to be installed in shallow water depths (Waveplam 2009) near coastal areas which provide the opportunity for grid connections. Based on international protocols developed specific processes that have be taken into account before for the assessment of waves (Waveplam 2009; Cradden & Sarantis 2010).

## 3. Model set-up, calibration and validation

In this study, the assessment is conducted for the greater region of the Mediterranean Sea and the Aegean Sea to identify potential locations. Estimations of the available energy for these locations are also presented.

The wave hindcast was perfromed for the year 2010 and the results were compared with buoy data which were acquired at 3-hrs intervals. The data were provided by POSEIDON (Hellenic Centre for Marine for Research 2014), which will help assessing the performance of the model for the region considered. Since the model outputs are satisfactorily validated against the buoy data, the results can be confidently applied to the extended regions where no measurements are available. The numerical model uses several parameters in order to evaluate and simulate waves for this region. One of the most important is the use of atmospheric models, especially wind data. Usually in this region 3-hrs and 6-hrs datasets are utilized. In this hindcast wind data at 1-hr interval available with CFSR/NCEP (NCAR 2014) dataset with spatial resolution ($0.5^o$x$0.5^o$) has been used, due to supporting literature about the effect of temporal and spatial wind resolution (Cavaleri & Bertotti 2006; Cavaleri 2009). Two different set of meshes were generated: a larger mesh for the Mediterranean with spatial resolution 0.1°x0.1° and a nested mesh for the Aegean with resolution 0.025°x0.025°, extracted from the data provided by NOAA and ETOPO1 (NOAA 2014), as seen in Figure 3 Figure 4,respectively. The locations of the buoys are also shown in Figure 4.

Both the Mediterranean and the Aegean Sea are very different from the other European coastlines (e.g. North Sea, Portugal shores, United Kingdom). The alterations in bathymetry and basin type features affect the wave resource. For this reason all physical terms have been optimized to facilitate the areas, based on the rapid and quick changes in bathymetry and physical properties of the area. The terms activated in the SWAN account for all deep water and wind interactions, while the shallow water terms have all been taken into account to provide better nearshore energy estimations, separated in seasons. Finally the JONSWAP spectrum has been considered as appropriate to describe the wave evolution (Hasselmann et al. 1973), which explains in great detail the interactions of wind on local seas leading to the generation of wind dominant seas or "young"-seas, which have distinct wave characteristics and distributions. As JONSWAP spectrum is developed for fetch limited partially developing seas, this has been adapted for the present study in the Aegean Sea.

The model was run with all shallow water parameters active in both the coarse and the nested hindcast. The frequencies and directions were set within 24 bins, 0.01Hz per bin and 15° respectively. The wind applied follow the Janssen expression for exponential growth with a white-capping coefficient of 4.5. Quadruplet interactions are resolved in a semi-implicit way, allowing for additional recalculations per timestep while the bottom friction applied is constant and equal to $0.067\, m^2/s^3$ . Triad interactions for the shallow water regions are fully operational as well as the breaking factor applied in nearshore areas. The computational timestep of the coarse and nested grid were set at 30min, which at both times satisfied the Courant-Friedrich-Levy criterion. Finally the coarse grid offered the boundary and initial condition for the nested, and more resolved Aegean hindcast.

## 4. Results - Assessing the model

The model was run for the year 2010 and the hindcast for three buoys and output points were compared.

In order to quantify the results several statistical indices were utilized and evaluated. These indices include, the correlation coefficient (R), the normalised root mean square errors (RMSE), the bias of the data and the overall performance of the model with the Model Performance Index (MPI) (Komen et al. 1994), both for the coarse and fine hindcast. These indices are helpful when assessing the accuracy of a model, as they will indicate the acceptance level of the model performance and allow drawing conclusions (Korres et al. 2011), regarding the classification of the model. The combination of the aforementioned statistical components will help us detect any short coming and potential improvements for the model. Desirably in the case of assessing large seas the bias should be low, while the R would be over 75%. The indexes compared are significant wave height ($H_s$), Peak period ($T_p$) and average zero crossing period ($T_z$), while the biases should remain low with the average values close to the real wave field.

$$bias = \sum_{i=1}^{N} \frac{1}{N}(X_i - Y_i) \quad \textbf{(1)}$$

$$RMSE = \sqrt{\sum_{i=1}^{N} \frac{1}{N}(X_i - Y_i)^2} \quad \textbf{(2)}$$

$$R = \frac{\sum_{i=1}^{N}((X_i - \overline{X_i})(Y_i - \overline{Y_i})}{\sqrt{\sum_{i=1}^{N}((X_i - \overline{X_i})^2))(\sum_{i=1}^{N}((Y_i - \overline{Y_i})^2))}} \quad \textbf{(3)}$$

$$rms_{changes} = \sqrt{\frac{Y_i^2}{N}} \quad \textbf{(4)}$$

where $X_i$ and $Y_i$ being the corresponding simulated and measured wave quantities, N the number of measurements and $\overline{X_i}$ , $\overline{Y_i}$ the average values of the above mentioned quantities. Desirably the R should be above 75% (0.75) for seas like the Aegean, and the MPI should approximately 1. This way in combination with the bias the accuracy of the hindcast, the accuracy of the hindcast can be accepted or not (Ris et al. 1999).

$$MPI = 1 - \frac{RMSE}{rms_{change}} \quad \textbf{(5)}$$

These data errors have been filtered out and the correlation has been worked out for the portion of the data that was thought to be reliable. The Petrokaravo buoy was found to be having most of the missing datasets. For clarity the full dataset of measurements will be given in Appendix A.

The correlation coefficient (R), between the model and the data, for significant wave height ($H_s$) and the corresponding peak ($T_p$) and average zero-crossing period ($T_z$) listed in the Table 1&2 are found to be above 0.75, which indicated the model performed well. The location of the buoy has a tremendous effect on the predictability of the resource. It can be seen from the available data that both wave period and significant wave height are strongly correlated. The biases are usually negative, leading to underestimations by the model. The bias of the $H_s$ is higher than the periods, this has to be taken into while assessing the resource. Finally the MPI index reveals that the hindcast is performing extremely well, close to 1.0, allowing us the exact representation of the trends thus giving a good resolution of the resource.

The Aegean Sea is mostly dominated by young seas, with high frequency waves, this led to smaller but steeper waves. Current developments show that wave energy converters (WEC's) can be adjusted to specific environments allowing, custom operation for the area, (Vannuchi & Cappietti 2013). This means that for the Aegean and greater Mediterranean Sea, devices operating at high frequency waves and low wave height may be used and increasing the capacity factor of their operation.

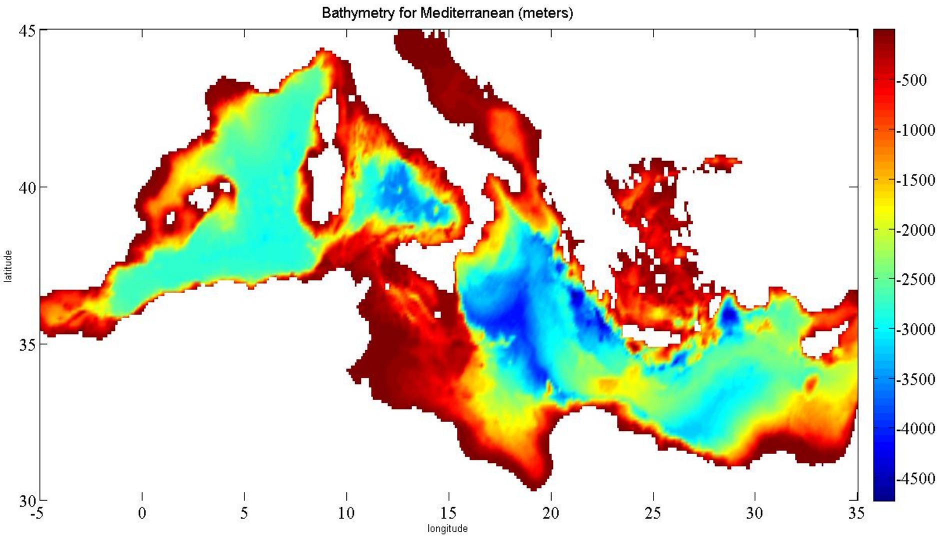



**Figure 3: Mediterranean Sea bathymetry map.**

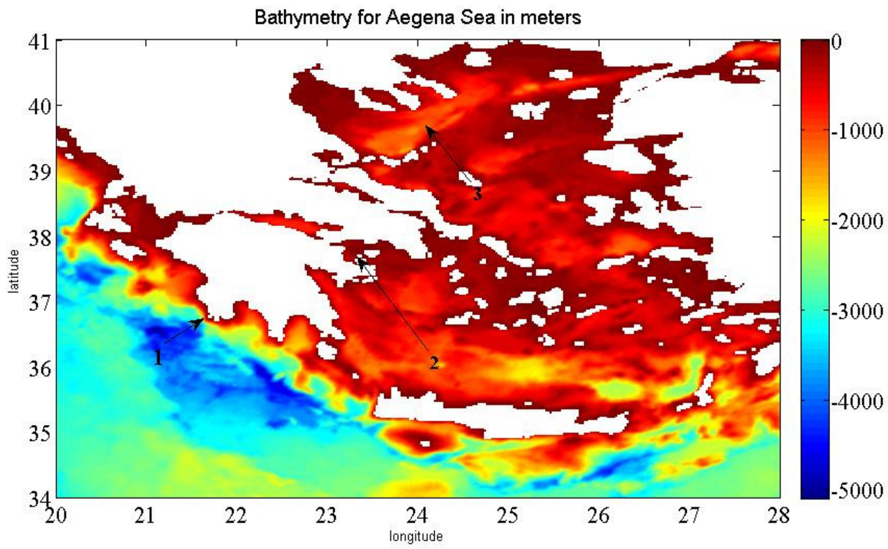



**Figure 4: Bathymetry map of the Aegean Sea (Buoy locations: 1 = Pylos, 2=Petrokaravo, 3 = Athos).**

**Table 7: Significant wave Height indexes ($H_s$) indexes.**

| Buoys $H_s$ | | | |
|---|---|---|---|
| | **Athos** | **Pylos** | **Petrokaravo** |
| **R** | 0.77 | 0.93 | 0.88 |
| **RMSE** | 0.75 | 0.53 | 0.33 |
| **Mean buoy (m)** | 0.81 | 0.99 | 0.55 |
| **Mean SWAN (m)** | 0.39 | 0.66 | 0.29 |
| **Bias (m)** | -0.41 | -0.33 | -0.26 |
| **MPI** | 0.98 | 0.97 | 0.96 |

**Table 8: Peak Period ($T_p$) and Average –Zero crossing Period ($T_z$).**

| Periods $T_p$ and $T_z$ | | | | | | |
|---|---|---|---|---|---|---|
| | Athos | | Pylos | | Petrokaravo | |
| | $T_p$ | $T_z$ | $T_p$ | $T_z$ | $T_p$ | $T_z$ |
| **R** | **0.91** | **0.95** | **0.96** | **0.97** | **0.88** | **0.96** |
| **RMSE** | **2.043** | **1.21** | **1.443** | **0.87** | **2.25** | **0.87** |
| **Mean buoy (Sec)** | **4.59** | **3.75** | **5.59** | **4.23** | **4.35** | **3.23** |
| **Mean SWAN (Sec)** | **4.28** | **3.29** | **5.48** | **4.12** | **4.98** | **3.5** |
| **Bias (Sec)** | **-0.31** | **-0.46** | **-0.11** | **-0.11** | **+0.63** | **+0.27** |
| **MPI** | **0.89** | **0.91** | **0.88** | **0.91** | **0.78** | **0.82** |

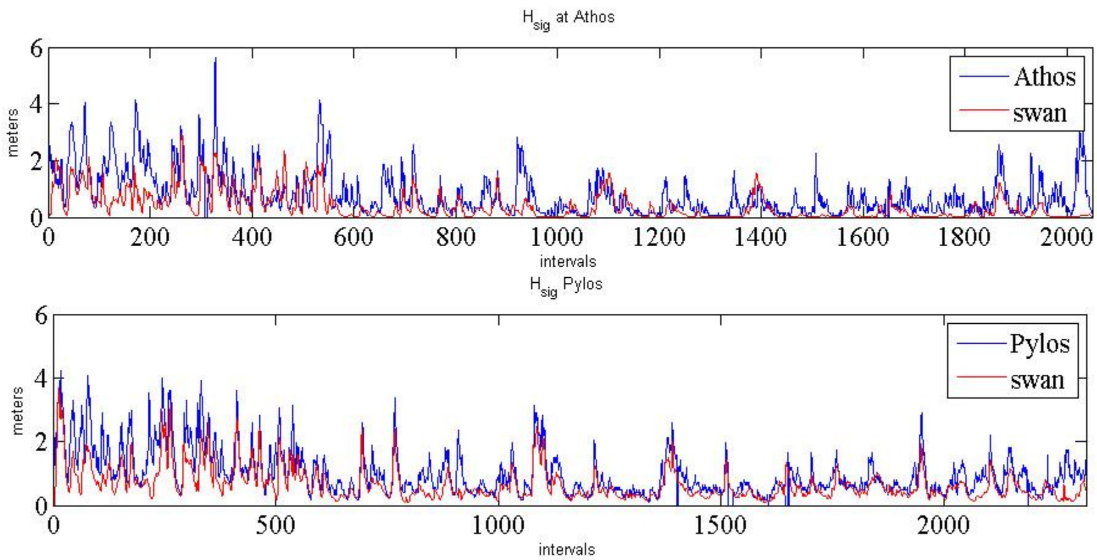



**Figure 5: Significant Wave Height hindcast.**

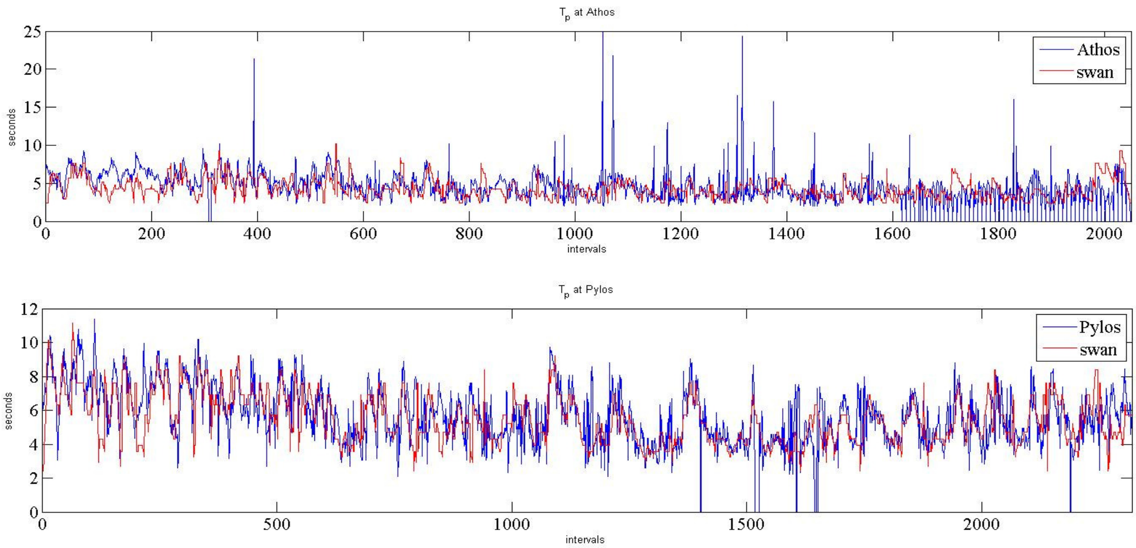



**Figure 6: Peak Period hindcast.**

It should be highlighted that the trend for generation and propagation of waves has been accurately, reproduced allowing to extend the findings to several potential location for energy extraction, even at the complete access of buoys. After the calibration, estimation on the waves results can be extrapolated and presented.

Bearing in mind the calibration and hindcast of the model identifies site of potential energy resources, this will benefit from the further examination and lead to a more detailed numerical assessment with improved factors and data used for an even smaller area.

*Discussion - Opportunities and energy exploitation*

From the numerical evaluation of the area, an overall assessment of the resource can be made and several locations can be identified for further investigation. To assess and estimate the available kW/m the Hs and energy period Te are used.

$$P = \frac{\rho \cdot g^2 \cdot H_s^2 \cdot T_e}{64\pi} \left[ \frac{W}{m} \right] \quad (6)$$

Where g is the gravitational acceleration (m/s$^2$) and ρ is the seawater density equal to 1025 kg/m$^3$, in W/m.

The annual energy at the point of the buoys is shown in Figure 5: Incoming annual wave and mean annual energy at buoy, the amounts of energy that can be extracted by a device, may not be as high as oceanic waters, but poses several advantages. The nature of smaller wave height than oceanic, and the use of tuned WEC's will increase the operational time of the device, due to the absence of extreme events, yielding a potential higher capacity factor over 27-35% (Stoutenburg et al. 2010). This is based on the fact that the survivability of the WEC and operation time is connected to the safety threshold of incoming waves. In absence of extreme waves over 8 meters for example the West coastline of Scotland (Lavidas et al. 2014), leading to lowering the maintenance and operation time, increasing the average life expectancy of the device (~25 years), and allowing a better utilization of the incoming energy flux.

In addition the combined exploitation from offshore wind and waves will provide better reliability for renewable energy generation, while strengthening the system by reducing the reserved capacity connected to renewables (Fusco et al. 2010; Falcão 2010; Lakkoju 1996). This possibility of diversifying the mix will lead to reduce oil usage, especially to the vast complex of islands that inhibit the Aegean Sea.

The seasonal variation of waves alters the nature of the resource. Summer months as shown in Figure 6 have less available resource, while winter months show an increase in availability.

Apart from the wave power resource attained the directionality of waves, will allow a further knowledge concerning the pattern of movement and location that are mostly affected. As seen in Figure 9 and Figure 10 predominately wind seas move from the North part of Greece towards the South, while dominant swells originating from the wider Mediterranean Sea originate from the South West affecting the Ionian and South - South Central areas.

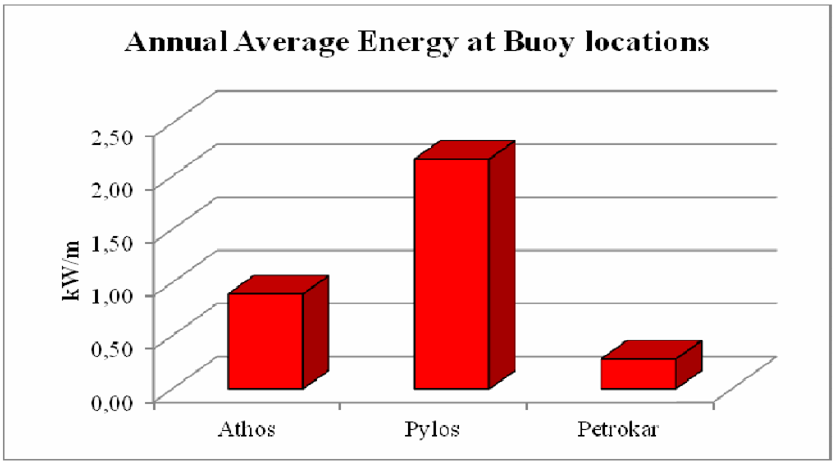



**Figure 7: Incoming annual wave and mean annual energy at buoy.**

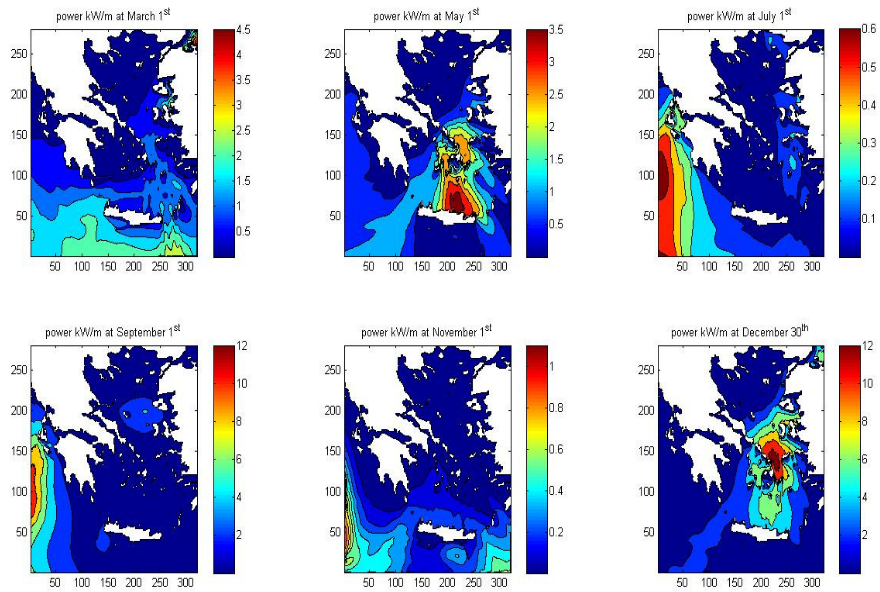



**Figure 8: Seasonal variation of resource and location, in kW/m.**

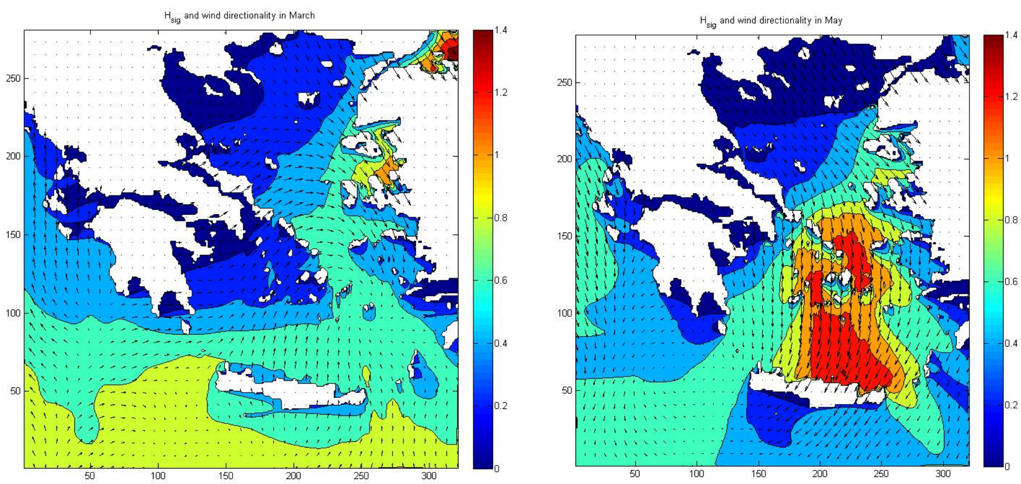



**Figure 9: Wind direction and wave propagation March and May, the vectors show the wind direction while the contoured area displays the $H_s$ in meters.**

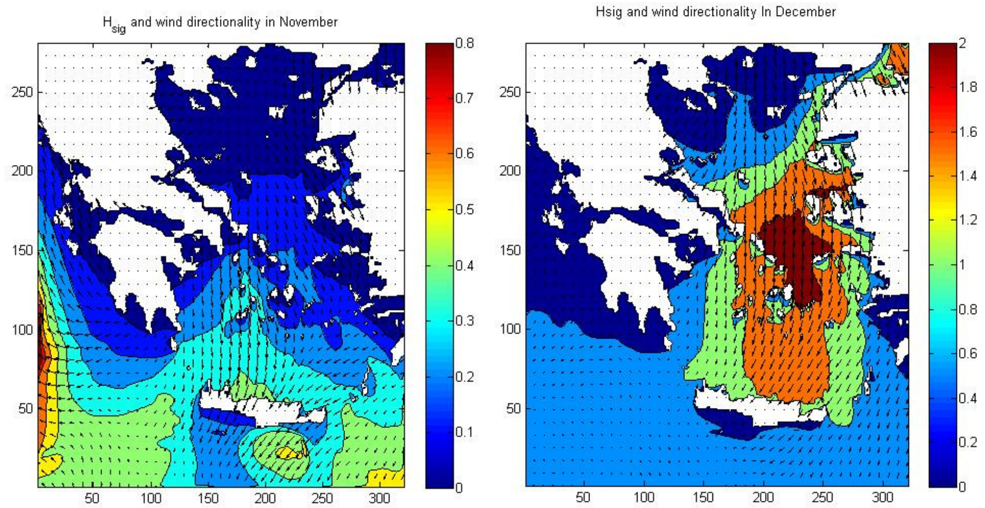



**Figure 10: Wind direction and wave propagation November and December, the vectors show the wind direction while the contoured area displays the $H_s$ in meters.**

Interesting locations that can be explored and utilized for wave related activities, and energy extraction are the Cycladic Island complex, the Central and West Side of Crete (both Northern and Southern coastline part) and the South West part of Peloponnesus. Those waters as shown above are exposed to high resource. In comparison with the North part of the Aegean, this due to its topography acts more like an isolated basin dissipating the wave propagated.

The localised application of wave renewable energy extractor can act as additional opportunity in reducing energy cost in Greek islands and combined with further renewables and other industrial applications (e.g. desalination), can provided significant energy benefits. In absence of buoys the use of numerical simulations can provide insight of many locations and their corresponding environments.

Developing a de-centralized energy production approach will help the reduction of energy cost, while abundant renewable resources will be exploited moving towards the further diversification and de-carbonization of the Greek electricity system. In addition further detailed exploration of the wave resource prompts the economic development of several others activities that may help the local economic development such as tourism, fisheries etc. With knowledge of the wave resource predictions of the weather and weather windows can be applied.

Furthermore developing various energy production alternatives, will lead to construction of significant infrastructure from which the local population can benefit. While the environmental impacts from oil transfer and fossil fuel production will be reduced, benefits of renewable energy have been elaborated in several previous publications (Michalena & Hills 2012; Lund 2006; Fischer & Newell 2008; Krozer 2013; Kaldellis et al. 2013; Mathiesen et al. 2011).

The road to increase renewable energy production and allow increased penetration is a complex matter that requires the exploitation of every resource available, the combination of the major resources that are located in Greece (wind, solar, small hydro) and the addition of innovative productions. These will ultimately lead to the encouragement not only of investments along with job creation further research opportunities (Menegaki 2012). Localized and indigenous production of energy in the islands will strengthen the economic bonds of the renewable market and lead to a better understanding of these technologies, with the scope of increasing the public acceptance of these projects.

Taking into account the connection of Greece with the seas, and its exposure to the wider Mediterranean Sea, increasing awareness for the wave resource available will benefit not only the emerging wave energy industry but several other sectors as mentioned.

## 5. Conclusions

The SWAN wave model has been applied to the Aegean Seas to assess wave power resources. The model has been calibrated and validated against wave buoy data from three different locations within the Aegean Sea. The model was then run for a year and the wave power for the entire Aegean Sea was calculated. The annual wave power estimated form the present model showed that the Athos location has average energy 0.89 kW/m, Pylos location 2.16 kW/m and the Petrokaravo 0.28 kW/m, which agrees well with the values reported in other literature and shows that the model performed well. Although it has to be noted that a more in-depth and seasonal evaluation will reveal that the, corresponding seasonal potential energy values are higher.

Assessing the wave resource is not a trivial task and often requires experience to correctly disseminate results and most importantly to tailor the model to specified areas. Long time series and evaluation can be reproduced with great accuracy. The preceding calibration reveals specific underestimations that exist, although the explanation and presentation of the reasons for those, are beyond the scope of this assessment. Proper use of numerical models, such as SWAN, can give quantitative evaluations of wave energy and provide us with the base for vital energy, economic and planning strategy assessments. Moreover the model can be utilized in areas, with proposed higher wave energy potential, and even with the absence of buoys can deliver a highly accurate for their wave energy assessment.

**Acknowledgements**

The author would like to thank the Hellenic Centre for Marine Research for buoy access, the SWAN development team for maintaining and updating SWAN, NCAP/CFSR for the publically available wind data and the Engineering and Physical Sciences Research Council (EPSRC) for the research grant provided.

**Appendix A**

The time series of the buoy measurements are given below, as mentioned the non-recorded periods have been left out the assessment of the model.

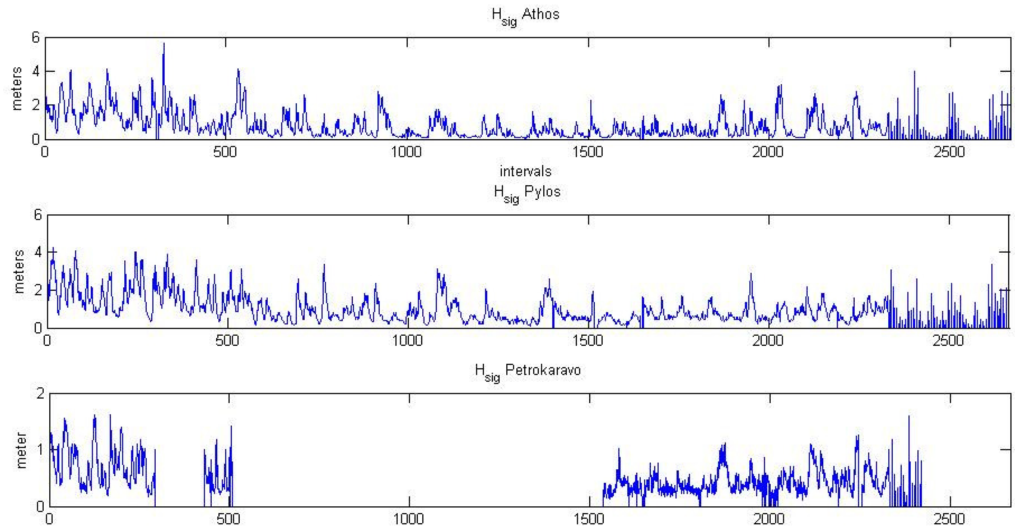



**Figure 11: Buoy data timeseries $H_s$ for 2010.**

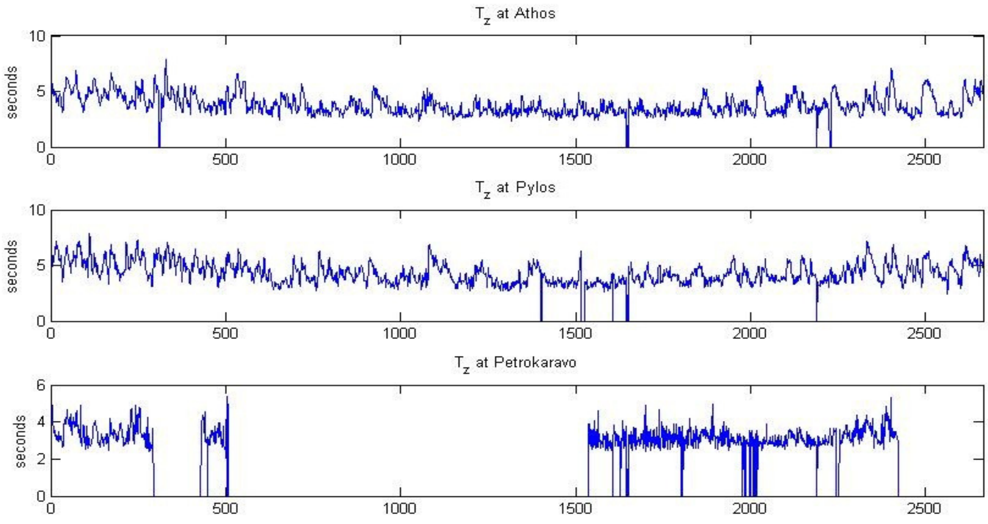



**Figure 12: Buoy data timeseries $T_z$ for 2010.**

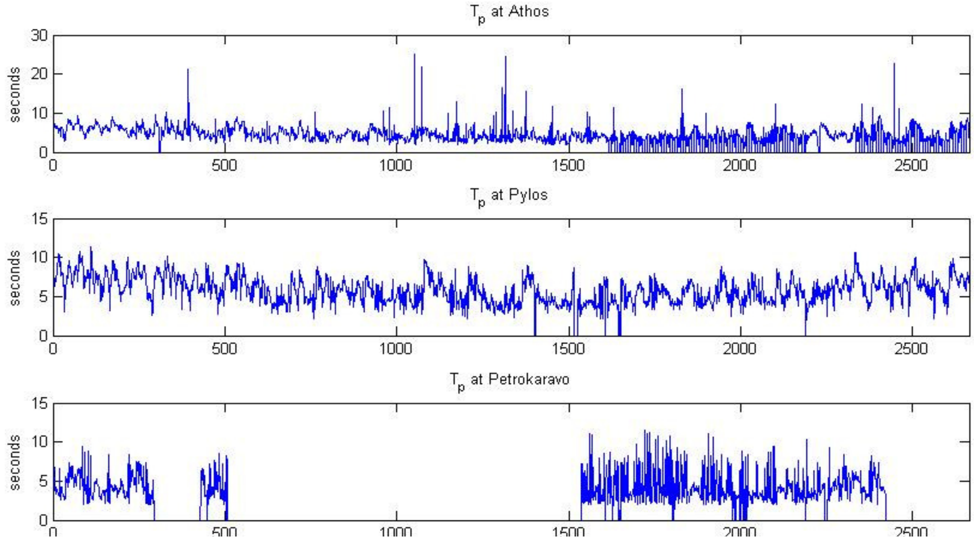



**Figure 13: Buoy data timeseries $T_p$ for 2010.**

## References


Akpinar, A. & Kömürcü, M.İ., 2013. Assessment of wave energy resource of the Black Sea based on 15-year numerical hindcast data. Applied Energy, 101, pp.502–512. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0306261912004461 [Accessed January 24, 2013].

Athens, U., 2014. Wave Forecast by University of Athens. Available at: http://forecast.uoa.gr/wamindx.php.

Bunney, C., 2011. A High Resolution SWAN Model Assessment: North Norfolk to Humber, Available at: www.metoffice.gov.uk.

Cavaleri, L., 2009. Wave Modeling—Missing the Peaks. Journal of Physical Oceanography, 39(11), pp.2757–2778. Available at: http://journals.ametsoc.org/doi/abs/10.1175/2009JPO4067.1 [Accessed December 21, 2013].

Cavaleri, L. et al., 2007. Wave modelling – The state of the art. Progress in Oceanography, 75(4), pp.603–674. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0079661107001206 [Accessed November 15, 2012].

Cavaleri, L. & Bertotti, L., 2006. The improvement of modelled wind and wave fields with increasing resolution. Ocean Engineering, 33(5-6), pp.553–565. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0029801805001782 [Accessed November 16, 2012].

Cavaleri, L. & Holthuijsen, L.H., 1998. Wave modelling in the WISE group. In 5th International Workshop on Wave hindcast and forecast. pp. 498–508.

Cradden, L. & Sarantis, S., 2010. Site Assessment. Deliverable D2.1, MARINA platform, pp.1–28.

Cruz, J., 2008. Ocean Wave Energy: Current Status and Future Perspectives J. Cruz, ed.,

Delft, T., 2014. SWAN scientific documentation Cycle III version 41.01 T. Delft, ed., Delft University of Technology Faculty of Civil Engineering and Geosciences Environmental Fluid Mechanics Section.

Falcão, A.F.D.O., 2010. Wave energy utilization: A review of the technologies. Renewable and Sustainable Energy Reviews, 14(3), pp.899–918. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1364032109002652 [Accessed October 27, 2012].

Fischer, C. & Newell, R.G., 2008. Environmental and technology policies for climate mitigation. Journal of Environmental Economics and Management, 55(2), pp.142–162. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0095069607001064 [Accessed October 30, 2012].

Fusco, F., Nolan, G. & Ringwood, J. V., 2010. Variability reduction through optimal combination of wind/wave resources – An Irish case study. Energy, 35(1), pp.314–325. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0360544209004095 [Accessed November 5, 2012].

Hasselmann, K. et al., 1973. Measurements of Wind-Wave Growth and Swell Decay during the Joint North Sea Wave Project (JONSWAP) D. H. Institut, ed., Hamburg.

Hellenic Centre for Marine for Research, H., 2014. Monitoring, Forecasting System Oceanographic information for the Greek Seas (POSEIDON). Available at: http://www.poseidon.hcmr.gr/.

Hervás Soriano, F. & Mulatero, F., 2011. EU Research and Innovation (R&I) in renewable energies: The role of the Strategic Energy Technology Plan (SET-Plan). Energy Policy, 39(6), pp.3582–3590. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0301421511002485 [Accessed November 5, 2012].

Holthuijsen, L.H., 2007. Waves in oceanic and coastal waters, Cambridge University Press. Available at: http://www.cambridge.org/gb/academic/subjects/earth-and-environmental-science/oceanography-and-marine-science/waves-oceanic-and-coastal-waters?format=PB.

Kaldellis, J.K. et al., 2013. Comparing recent views of public attitude on wind energy, photovoltaic and small hydro applications. Renewable Energy, 52, pp.197–208. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0960148112006908 [Accessed January 18, 2013].

Komen, G.J. et al., 1994. Dynamics and Modelling of Ocean waves, Cambridge University Press. Available at: www.cambridge.org/9780521470476.

Korres, G. et al., 2011. A 2-year intercomparison of the WAM-Cycle4 and the WAVEWATCH-III wave models implemented within the Mediterranean Sea. Science, Mediterranean Marine.

Krozer, Y., 2013. Cost and benefit of renewable energy in the European Union. Renewable Energy, 50, pp.68–73. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0960148112003643 [Accessed October 30, 2012].

Lakkoju, V.N.M.R., 1996. Combined power generation with wind and ocean waves. Renewable Energy, 9(1-4), pp.870–874. Available at: http://linkinghub.elsevier.com/retrieve/pii/0960148196884187.

Lavidas, G. et al., 2014. Wave energy assessment and wind correlation for the North region of Scotland, hindcast resource and calibration, investigating for improvements of physical model for adaptation to temporal correlation. In ASME 2014 33rd International Conference on Ocean, Offshore and Arctic Engineering, OMAE2014, June 8-13, San Francisco, California, USA. pp. 1–11.

Lund, H., 2006. Large-scale integration of optimal combinations of PV, wind and wave power into the electricity supply. Renewable Energy, 31(4), pp.503–515. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0960148105000893 [Accessed November 9, 2012].

Mathiesen, B.V., Lund, H. & Karlsson, K., 2011. 100% Renewable energy systems, climate mitigation and economic growth. Applied Energy, 88(2), pp.488–501. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0306261910000644 [Accessed October 29, 2012].

Menegaki, A.N., 2012. A social marketing mix for renewable energy in Europe based on consumer stated preference surveys. Renewable Energy, 39(1), pp.30–39. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0960148111005015 [Accessed October 29, 2012].

Moeini, M.H. & Etemad-Shahidi, A., 2009. Wave Parameter Hindcasting in a Lake Using the SWAN Model. , 16(2), pp.156–164.

NCAR, 2014. NCAR/CISL Research data archive. Available at: https://rda.ucar.edu/index.html?hash=data_user&action=showsignedin.

NOAA, N.G.D.C., 2014. Grid exctraction ETOPO1. Available at: http://maps.ngdc.noaa.gov/viewers/wcs-client/.

Parliament, E., 2009. The European Parliament. Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources amending and subsequently repealing directives 2001/77/ec and 2003/30/ec.,

Ris, R.C., Holthuijsen, L.H. & Booij, N., 1999. A third-generation wave model for coastal regions: 2.Verification. , 104, pp.7667–7681.

Rogers, W.E. et al., 2007. Forecasting and hindcasting waves with the SWAN model in the Southern California Bight. Coastal Engineering, 54(1), pp.1–15. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0378383906000937 [Accessed January 14, 2014].

Soukissian, T.. & Pospathopoulos, A.M., 2006. The Errors-in-Variables approach for the validation of the WAM wave model in the Aegean Sea. Science, Mediterranean Marine, 7(1), pp.47–62.

Stoutenburg, E.D., Jenkins, N. & Jacobson, M.Z., 2010. Power output variations of co-located offshore wind turbines and wave energy converters in California. Renewable Energy, 35(12), pp.2781–2791. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0960148110002004 [Accessed May 22, 2013].

Vannuchi, V. & Cappietti, L., 2013. OMAE2013-10183 Wave Energy estimation in four Italian nearshore areas. In ASME 2013 32nd International Conference on Ocean, Offshore and Arctic Engineering, OMAE2013, June 9-14, Nantes,France. pp. 1–7.

Waveplam, 2009. Methodology for Site Selection (D3.1). Intelligent Energy Europe, (November), pp.1–35.

Michalena, E. & Hills, J.M., 2012. Renewable energy issues and implementation of European energy policy: The missing generation? Energy Policy, 45, pp.201–216. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0301421512001383 [Accessed November 5, 2012].

# Ecological risks and opportunities of Eucalyptus planting (Case study in the framework of the GIZ-German-Madagascan Environmental program) - Preliminary results

**Laura PRILL** [1]
MSc. Student Wood Science and Technology, University of Hamburg

**Prof Dr. Michael KÖHL**
Head of the Institute for World forestry

**Dr. Daniel PLUGGE**
Scientist at the Institute for World forestry
Tel: +49 (0)1748172864
email: laura.prill@studium.uni-hamburg.de
[1]Address: Laura Prill, Kleiner Schäferkamp 19, 20357 Hamburg, Germany

**Abstract:** Forest plantations on prior degraded land have globally been declared as an option to address the world's increasing demand for renewable energy resources. One of the most widely used fast-growing species in this context is eucalyptus, currently covering approximately 20 million hectares worldwide. This area is expected to increase due to population growth and urbanization trends, especially in developing countries where wood energy will continue to be the dominating energy source. Adding to this, this development is further driven by an increasing demand for renewable energy sources in developed countries.

Growing biomass for rural energy purposes in highly productive energy forests can contribute to the preservation of natural forests, its biodiversity and the mitigation of climate change. For this purpose some 7.000ha of former degraded land have been afforested in the north of Madagascar with eucalyptus to supply the Antsiranana region with sustainable wood energy (charcoal). Despite the manifold opportunities cultivating eucalyptus has often been associated with environmental and ecological impacts that negatively affect environmental sustainability of afforestation projects. The present study therefore aims to analyze ecological risks and opportunities of eucalyptus in projects for promoting renewable energy resources in rural areas. For this purpose impacts on soil properties and biodiversity of eucalyptus plantations in Madagascar are analyzed. Special regard is given to the temporal and spatial scale of these impacts. The results allow the formulation of recommendations for policy makers and practitioners to assure the environmental sustainability of renewable energy programs with eucalyptus in the future.

## 1. Introduction

Forest plantations on prior degraded land have globally been declared as an option to address the world's increasing demand for renewable energy resources. One of the most widely planted fast-growing species in this context is Eucalyptus, currently covering approximately 20 million hectares worldwide (git-forestry 2009). This area is expected to increase due to population growth and urbanization trends, especially in developing countries where wood energy will continue to be the dominating energy source. Adding to this, this development is further driven by an increasing demand for renewable energy sources in developed countries.

Growing biomass for rural energy purposes in highly productive energy forests can contribute to the preservation of natural forests and its biodiversity by taking pressure from these ecosystems, which at the same time helps in the mitigation of climate change (FAO 2006a). For this purpose, some 7.000ha of former degraded savannah have been afforested with Eucalyptus to supply the Antsiranana region in the North of Madagascar with sustainable wood energy (charcoal). In a community-based approach the charcoal is produced and sold by local famers to secure the future energy supply of the Diana region and reduce deforestation, which is one of the major ecological concerns in Madagascar. For further information on the community-based afforestation project see GREEN-Mad (2007) and Miranda *et al.* (2010). If appropriately planned and managed, exotic forest plantations - including eucalypts - may also have the ability to provide further ecosystem services such as the rehabilitation of degraded land and the regeneration of biodiversity (Bauhus *et al.* 2010; FAO 2006a). Despite the manifold opportunities, cultivating Eucalyptus has often been associated with environmental and ecological impacts that negatively affect environmental sustainability of afforestation projects. Accusations being made contained the suppression of biodiversity, an intense water-consumption and an excessive nutrient uptake leading to soil impoverishment. Although, many of these critics have been restricted to certain areas and unsustainable management systems, for the production of sustainable charcoal ecological risks need to be identified and unfavourable impacts avoided. Beyond that there is a rising recognition that management systems should further enhance the provision of ecological services of plantations (Brockerhoff *et al.* 2012). Regarding the continuous global loss of forest area and biodiversity on the one hand and the expanding land area covered with Eucalyptus on the other hand such aspects nowadays become even more important. Based on a case study in Madagascar the present study therefore aims to analyse ecological risks and opportunities of planting Eucalyptus in projects for promoting renewable energy resources in rural areas. For reaching the overall aim, impacts on floristic biodiversity and soil properties of Eucalyptus camaldulensis plantations and adjacent savannahs were analysed. Special regard was given to the temporal and spatial scale of these impacts. The present paper summarizes first results of the biodiversity assessment.

The study was carried out, financed and facilitated in the frame of the GIZ Sector Project to Combat Desertification and the "German Madagscan Environmental Program" (PGM-E) of the "Gesellschaft für Internationale Zusammenarbeit" (GIZ) and in cooperation with the University of Hamburg. The implementation of the Charbon-Vert project (former GREEN-Mad) and the field work of the study in 2014 were realized with the help of ECO Consult.

## 2. Methods

*Study area*

The research area, belonging to the villages Ankitsaka, Mandrosomiadana and Saharenana Bas, was located in the Diana region in the North of Madagascar in the district Antsiranana II between 25 and 40km south of the city of Antsiranana. Elevations of the plantation sites around Ankitsaka (ANK) and Mandrosomiadana (MAN) are approximately 83m and 93m, respectively. The afforested areas surrounding Saharenana Bas (SHB) which is located in mountainous area show varying elevations between 200m and 300m. Mean annual rainfall of the Antsiranana II district is approximately 1.100mm (GREEN-Mad 2007). Soils of the study area are mainly ferruginous. Investigated areas around the villages Ankitsaka and Mandrosomiadana were adjacent and relatively similar in terms of soil properties whereas the sites adjacent to the village Saharenana Bas showed clear differences. The texture in the Saharenana Bas region is mainly composed of sand (~90%) and to a much fewer extent of silt and clay (3 and 6%) whereas the texture in Ankitsaka and Mandrosomiadana shows a relatively low sand content (~52%) and an elevated clay content (>30%).

Most of the natural land cover surrounding the villages ANK, MAN and SHB is savannah resulting from earlier deforestation driven by agricultural activities and fuel wood production. The north-eastern part of the plantation sites in Saharenana Bas adjoins patches of natural forest. Some crop cultivation especially of rice is practiced around all villages, however, the reforested savannah sites were not appropriate for crop cultivation.

*Plantation establishment and management*

Most of the 21 investigated different-aged and -managed Eucalyptus camaldulensis plantations were afforested on former degraded savannah within the community-based Project GREEN-Mad ("Gestion Rationnelle de l'Energie et de l'Evironnement à Madagascar", now Charbon Vert) which started in 1994/5 to supply the Antsiranana region with sustainable charcoal. Few plantations were directly converted from pistachio- or rice plantations due to unsuccessful cultivation; nevertheless, most of the area was not used prior to plantation establishment. The oldest investigated plantations were established during the years 1997/8, the youngest in 2009. The program suggests a spacing of 3x3m resulting in 1.111trees/ha. Planting and management as well as the carbonization process are conducted by the local plantation owners and in help of the community. Following the first harvest after 7 years farmers usually apply rotation periods of 5 or less years (for more information see GREEN-Mad 2007). Natural woody vegetation is usually conserved during site preparation and harvest. Nevertheless, farmers are responsible for all silvicultural decisions including the realization of thinning.

*Site selection*

Plantations studied were chosen based on various site characteristics including a minimum size of one hectare. All studied tree stands were located next to a savannah site and at least 50m away from other plantation edges, forests, roads etc. to avoid side effects. A total of 21 transects, all in Eucalyptus camaldulensis monocultures, were sampled within the three villages - 12 in Ankitsaka, 5 in Mandrosomiadana and 4 in Saharenana Bas. Total ages of the investigated plantations ranged from 5 to 17 with exploitation intensities between 0 (never harvested) and 2. Soil samplings were limited to seven tree stands planted in 1997, 1998, 2001 and 2009.

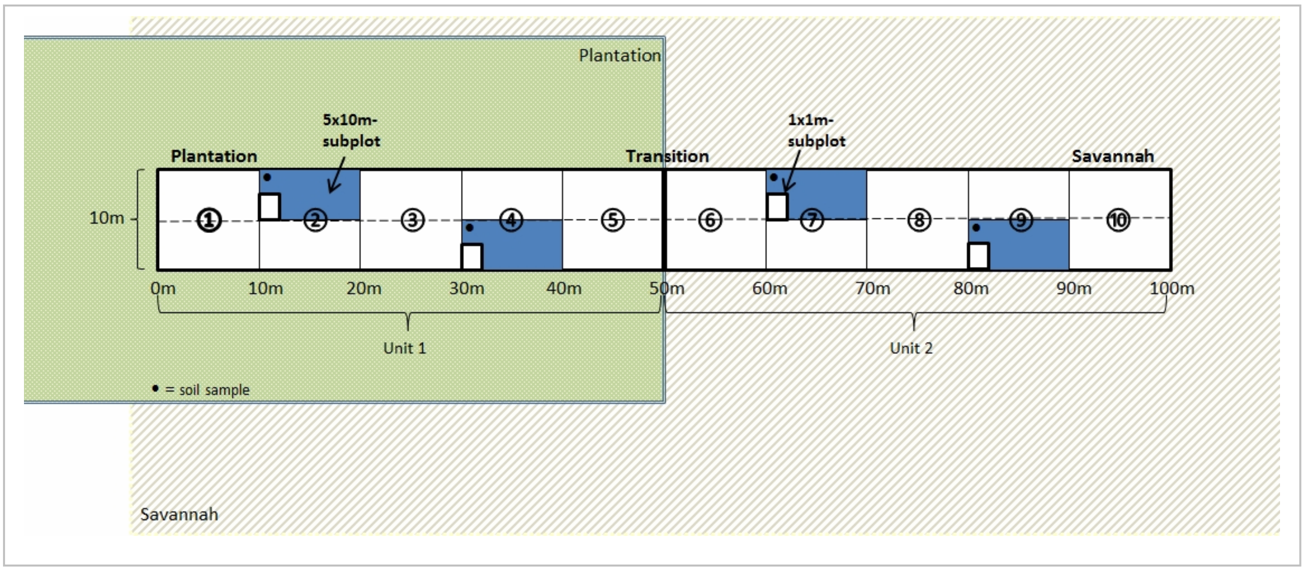



**Figure 14: Sample unit design (transect).**

*Data collection*

Data were recorded in 10mx100m-sample units (0,1ha) that were implemented on the transition from a plantation to its adjacent savannah and covered 500m² of both ecosystems, transect see figure 1. The transect orientation was predetermined by the planting direction of a plantation. However, plantations were only considered with a planting direction facing the savannah.

Number and species of woody shrubs and trees (> 0,5m) were collected within the whole transects. Positions of plants, defined by the distance between the tree/brush and the transect grid which resulted in x- and y- coordinates, were recorded for all woody plants (including eucalypts) with a minimum height of 1,30m (commonly used for measuring the diameter at breast height (DBH)). This allowed for later analyses of the spatial aspect. A biomass inventory (DBH, height) of Eucalyptus trees and woody undergrowth exceeding a height of 1,30m was performed in four 5x10m-subplots that were located within each transect. Non-woody ground vegetation (grass and herb species) was determined and counted using 1x1m-subplots. Data holding information on stand characteristics including the total age were available at ECO Consult. However, information on the plantation history such as the exploitation intensity or the current age was collected during interviews with the plantation owner or the president of a community.

Soil samples were taken in all subplots for later analyses at the laboratory of the FoFiFa Pédélogie in Antananarivo. Several interviews with local plantation owners and non-owners were additionally realized to verify further impacts of the monocultures on environmental aspects. Soil and interview results are not presented in the context of this paper.

## 3. Biodiversity analyses

*Floristic diversity*

Floristic diversity of the plantations was assessed by calculating the parameters species richness, plant frequency and the Shannon Diversity Index of woody plants and ground vegetation. Species richness was defined as the number of species and plant frequency as the absolute number of plants present. The plant frequency and the Shannon Diversity Index was calculated for woody plants only.

The Shannon Diversity Index (H') is defined as follows:

$$H' = -\sum_{i}^{R} p_i \cdot \ln p_i \; with \; p_i = \frac{N_i}{N}$$

where R is the species richness (number of species) and $p_i$ is the proportion of individuals belonging to the species i in relation to the total number of individuals of all species. The Shannon Diversity Index is sensitive to a dominance of a few species. High values express a high diversity meaning that there are many species with an even abundance.

Based on the sample unit design the results calculated for the plantations were compared to those of the savannahs by using mean values for each region (s. below) and parameter. Calculated parameters and indices were analysed with respect to the plantation age and the applied management (exploitation intensity). The implementation of the sample unit on the transition of a plantation and savannah and the localization of woody plants allowed for a spatial analysis. For this purpose, each transect was divided into 10 sub-squares (10x10m, see figure 1).

*Statistical analyses*

Differences between the plantation and savannah results for each biodiversity parameter were tested for significance by applying a t-test. A correlation analyses was performed to verify the (linear) relationship between stand characteristics (total age and exploitation intensity) and biodiversity parameters or index (species richness, plant frequency and Shannon-Index). The calculated multiple correlation coefficients were tested for significance with an analysis of variance.

*Classification of data*

Based on the similarity between the two adjacent sites around the villages Ankitsaka and Mandrosomiadana, data of the corresponding plantations were grouped together. Results from Saharenana Bas were regarded separately. For analyses of the plantation parameters stands with the same characteristics were grouped together within each regions. Applied age classes for the stands in Ankitsaka were 5, 8-9 and 13-15. Due to the low number of investigated stands in Saharenana Bas each age represented one age class.

## 4. Results

*Stand characteristics*

DBH and height varied with current plantation ages between 2 and 15cm and 3 and 12m, respectively. Planting density varied between 100 to 1.120 trees/ha among all stands. However, the fact that the sample units were implemented on the edges of the plantations might have caused lower values compared to an inventory inside the tree stand. Among the 21 investigated E. camaldulensis stands were 5 uncoppiced stands and 10 and 6 that have been harvested once or twice, respectively.

***Biodiversity results***

*Statistical Analyses*

Differences in the calculated parameters species richness (for woody- and ground species), plant frequency and Shannon-Diversity between savannah and plantation sites were not significant in both investigated regions. Based on the correlation analyses, there was further no clear and significant linear relation found between the parameter total age (and exploitation intensity) and all three biodiversity parameters.

*Species Richness*

Species richness for woody species was generally relatively low throughout the 21 investigated sites with an average of 4 and 6 species per transect unit in the plantation and savannah, respectively. Species richness varied from 0 to 9 species per stand in plantations and from 1 to 12 in the adjacent savannahs. In total 46 woody species were recorded in all sample units. In plantations 26 woody species were identified and 39 in the adjacent savannahs. More than half of the woody species found in the savannah were also present in the single-tree stands, among them the most frequent savannah species. Three species were exclusively found in the undergrowth of plantations whereas 16 were apparent in the savannah but not in the Eucalyptus stands. 11 ground species were only found in plantations whereas 16 were exclusively found in savannahs. The dominating grass in all tree and savannah sites were Heteropogon Contortus.

*Species Richness in Ankitsaka and Mandrosomiadana*

In total 37 woody species were recorded in the Ankitsaka-Mandrosomiadana-region. 21 species were found in the undergrowth of the Eucalyptus stands and 30 in the adjacent savannah sites. With 5 woody species on average, absolute species richness per transect unit was marginally higher in the savannahs than in the plantations. However, this difference resulted in only two species. 65% of the investigated sites around the two villages showed the trend of a higher number of woody species in the savannahs. Species richness of ground vegetation was nearly the same with both mean values resulting in five species per unit. 38% of the studied sites in this region had higher ground species richness and in 31% of the sites ground vegetation species richness was the same in plantation and savannah sites.

*Species Richness in Saharenana Bas*

In Saharenana Bas species richness was generally higher than in the Ankistaka-Mandrosomiadana-region. A total of 21 tree or shrub species were recorded throughout the four investigated sites. 13 were found in the E. camaldulensis stands and 17 in the adjacent savannah ecosystems. All of the investigated stands had lower woody species richness than the adjacent savannah sites. On average the plantations showed 6 and the savannah sites 8 species per 500m²-unit. Ground species richness in plantations was higher (in 75%) compared to those of the neighbouring savannah.

*Plant frequency*

Undergrowth density in the ANK-MAN-region varied between 0 and 1.980 woody plants per hectare and between 20 and 2.200 in the adjacent savannah sites. On average there were approximately 100 trees or shrubs/ha less in the E. camaldulensis stands, resulting in a mean plant frequency of 374 species/ha, than in the savannah sites. 65% of the investigated stands showed higher values in the savannah.

Plant density in the Saharenana Bas region was generally higher compared to the ANK-MAN-region ranging between 1.360-5.520 in the eucalypt stands and 1.100-2.320 plants per hectare in the savannah. Mean plant frequency in the Eucalyptus stands (3255 plants/ha) was higher than in adjacent savannah ecosystems (1.739 plants/ha). 75% of the investigated transects showed this trend.

*Biodiversity according to Shannon Index*

Biodiversity assessed by the Shannon Diversity Index showed higher mean values for the savannah sites (1,08) than for the plantations (0,82) around ANK and MAN. Consequently, in 65% of the investigated stands species diversity was higher in the adjacent savannahs. In SHB biodiversity results indicated a higher diversity for the savannah sites (1,30) next to the E. camadulensis monocultures than for the tree stands (0,92). 75% of the investigated sites in this region showed this trend.

***Influence of plantation parameters on biodiversity***

As indicated by the results, the corresponding standard deviations (not presented) and the statistical analyses diversity results varied widely among plantations even with the same characteristics (i.e. total age, exploitation intensity).

*Exploitation intensity*

The highest mean species richness (4 woody and 5 ground species) occurred in uncoppiced stands. However, in comparison to the coppiced sites of ANK/MAN the differences were only of one species for both plant types. Variations between stands harvested once and twice were negligible. In the Saharenana Bas-region the plantation that was harvested twice showed a higher species richness (8 woody species) than stands harvested only once (5 woody species). Ground richness decreased from 9 species in uncoppiced stands to 6 species in the tree stand that was harvested twice.

Plant frequency of woody undergrowth decreased in both regions with higher exploitation intensities.

Biodiversity calculated by the Shannon Diversity Index was slightly lower for stands that were coppiced once (0,75) than for uncoppiced stands (0,87) in the Ankitsaka-Mandrosomiadana-region. However, stands that were already harvested twice showed nearly the same mean diversity (0,86) than the uncoppiced stands. Species diversity for coppiced stands decreased if one categorized stands into uncoppiced (0,87) and coppiced stands (0,80) regardless of the number of harvests. In Saharenana Bas the stand that was harvested twice showed the highest Shannon diversity value (1,52).

*Plantation age*

In Anitsaka and Mandrosomiadana highest mean species richness (6 species), highest undergrowth density (1.293plants/ha) and highest Shannon Diversity (0,85) was calculated for stands of the age class 8-9. The Shannon-results were, however, relatively homogenous in all age classes. Mean ground species richness was relatively homogenous throughout the different age classes. In Saharenana Bas-region woody species richness and the Shannon Diversity increased with older plantations from 4 species and a Shannon Index of 0,46 in the 13-year old stand to 8 species and a Shannon Index of 1,52 in the 17-year old stand. Ground species richness decreased from 9 to 6 species. Plant frequency was highest in the 16-year old stands.

*Spatial variations*

In the Ankitsaka-Mandrosomiadana-region woody species richness generally decreased in both ecosystems with approximation towards the transition of plantation and savannah. Highest values were recorded within a 20-40m distance to the transition in each unit. However, species richness decreased again from 40m on towards the inside of the plantation and savannah. Similar trends were found for sites around Saharenana Bas.

## 5. Discussion

With only 5 woody species per transect unit on average and rather low Shannon Diversity Indices biodiversity in the two investigated regions was relatively low and showed how degraded the land became in the past. Based on the presented results the savannah sites around both villages appeared to be slightly richer in woody species. This trend was observed in 71% of the investigated sites. However, general differences between savannah and plantation resulted in only 2 woody species per site on average around ANK-MAN and in only 3 species around SHB. With the rather low biodiversity in the investigated area those differences might appear quite high, although no significant differences were found. Diversity measured by the Shannon Diversity Index indicated comparable results in both regions. This is in accordance with the results of Tyynelä (2001) who investigated species diversity in Eucalyptus camaldulensis woodlots and miombo woodland in Northeastern Zimbabwe. Nevertheless, contrary results in Eucalyptus plantations to those of the present study were found by Loumeto and Huttel (1997). They investigated the understorey vegetation in Eucalyptus hybrids plantations on savannah soils in Congo and recorded higher species richness beneath the exotic plantations. Species richness in the Congo study was also higher for the region with clay soils which is in contrast to the present results where species richness on clayey-sandy soils in the Ankitsaka-Mandrosomiadana-region were lower than on sandy soils around Saharenana Bas. Those differences highlight the importance of area specific research.

Mean species richness of ground species was the same for plantations and savannahs in Ankitsaka- Mandrosomiadana. Those results are supported by Tyynelä who also recorded no differences in the mean number of grass species per sample plot between the investigated woodlots and woodland. As for the woody species richness results of investigated sites surrounding Saharenana Bas indicated higher ground species richness than those surrounding the other villages. With a higher number of ground species in 75% of studied stands species richness of grass and herbs in SHB tended to be higher beneath the eucalypts than in the adjacent savannah. This suggests a catalysing effect of the plantations on ground species. This is also supported with respect to the 11 ground species exclusively found beneath eucalypts and indicates equally sufficient light conditions.

In accordance with the present results in Ankitsaka Tyynelä also recorded a higher density of woody plants in the savannah sites. Despite this, plant frequency results for woody plants in Saharenana Bas-region were higher in the plantations than in the adjacent savannah. Plant density was generally clearly elevated to that in Ankitsaka. However, plant frequency should only be assessed in consideration of the biodiversity results calculated by the Shannon Index as this parameter respects the dominance of single (or only a few) species. The general observed differences between the two investigated sites around Saharenana Bas and Ankistaka-Madnrosomiadana might be due to different environmental conditions such as the location in a mountainous area and differences in soil properties.

As shown by the statistical analyses, there was a large variation between tree stands within the same characteristic groups (total age and exploitation intensity). Undergrowth density decreased in coppiced stands in both regions. This is in contrast to the results of Senbeta (2002). Further results for the effect of harvesting were not consistent in the two investigated areas. Results of the SHB-sites suggested an increase of diversity and species richness with higher exploitation intensity for woody plants whereas stands around Ankitsaka/Mandrosomiadana showed a slight decrease. Bone *et al.* (1997) also reported an elevated number of species and Shannon Diversity for the coppiced E. camaldulensis stands. Species richness, plant frequency and diversity results for different-aged stands did not indicate a regular pattern around ANK/MAN. However, the studied sites around SHB showed a trend of increasing diversity of woody undergrowth with older plantations. This is supported by the result found by Loumeto and Huttel (1997).

Although stand density might be higher inside the tree stands than on the investigated edges the intended spacing of 3x3m was only observed in one plantation in Saharenana Bas. This low stocking might be an explanation for the general low response of undergrowth diversity to alterations in stand characteristics. Consequently, alterations in light conditions might have been rather low.

As mentioned above differences between the two investigated areas could be explained by the varying environmental conditions. Those also include the proximity to the natural forest that can play a key role in biodiversity regeneration and might increase the chance to enhance plant diversity. Bernhard-Reversat (2001) for example found that the total number of species decreased with increasing distance between plantations and natural forest edges in a study in Congo. In the present study a minimum distance of 50m from other ecosystems or land uses were chosen to avoid any of these effects. In any case, enhancing biodiversity in plantations is based on the availability of seed sources (Senbeta *et al.* 2002). This is closely related to seed dispersal but might be challenging in a surrounding ecosystem that is inferior in terms of species diversity. Further research in this context is needed for the specific case of Madagascar.

## 6. Conclusion and outlook

The investigated Eucalyptus plantations in the Diana Region of Madagascar were primary established to reduce the pressure on natural forests and to supply the Antsiranana region with sustainable charcoal. By this means, the monocultures indirectly preserve natural forests and its biodiversity and generate household incomes for the rural population. Although the presented results indicated a slight trend towards lower species richness and diversity for woody species in plantations than adjacent savannah sites, the Eucalyptus stands in North-Madagascar were able to provide habitat for more than half of the indigenous species which were at the same time the most frequent ones found in the savannah ecosystem. Regarding that the plantations also contained some plant species that were not found elsewhere and that differences between the two ecosystems were not significant, the assertion that

Eucalyptus plantations might suppress undergrowth could not be supported in the studied area. However, investigated plantations did not provide the possibility to increase woody species diversity. In consideration of the expanding area covered with eucalypts (and exotic species plantations in general) there is hence a reasonable need to intensify silvicultural activities that catalyze the provision of ecosystem services such as the provision of biodiversity. Consequently, to reduce the risk of diversity loss and enhance the opportunity to provide habitat for native undergrowth beneath eucalypts the objective of enhancing biodiversity should be included in future programs established to produce energy wood and other wood products. In this regard, multi-species plantations should be favored at best containing some native species as their interaction with the environment (including other plants and animals) is generally better adapted than those of exotic species (Brockerhoff 2013). However, further research in the specific case is needed.

Further analyses will focus on the development of species composition and structure beneath the plantations in comparison to the adjacent savannah- and references sites. In addition, parameters such as planting density, current age and soil properties will be included.

## References


Bauhus, J., Van der Meer, P.J., Kanninen, M., 2010. “Ecosystem Goods and Services from Plantation Forests”, Earthscan publishing for a sustainable future, London.

Bernhardt-Reversat, F., 2005. “Effect of exotic tree plantations on plant diversity and biological soil fertility in the Congo savanna: with special reference to eucalypts”. Center for International Forestry Research, Bogor, Indonesia.

Bone, R., Lawrence, M., Magombo, Z., 1997. “The effect of a Eucalyptus camaldulensis (Dehn) plantation on native woodland recovery on Ulumba Mountain, southern Malawi”. Forestry Ecology and Management. Issue 99, p 83–99.

Brockerhoff E.G, Jactel, .H, Parrotta, J.A., Ferraz, S.F.B. 2013. “Role of eucalypt and other planted forests in biodiversity conservation and the provision of biodiversity-related ecosystem services”. Forest Ecology and Management. Issue 301, p 43-50.

FAO, 2006a. “Responsible management of planted forests: voluntary guidelines”. Planted Forests and Trees Working Paper 37.

FAO, 2006b. “Madagascar – Country Pasture/Forage Resource Profiles”.

GIT-FORESTRY, 2009. Cultivated eucalypts forest global map. Available at: http://git-forestry.com/Global_Eucalyptus_Map.htm

GREEN Mad, ECO Consult, 2007. Available only in French. “Le reboisement villageois individual – strategies, techniques et impacts de GREEN-Mad dans la région d’Antsiranana Madagascar”.

Loumeto, J.J., Huttel, C., 1997. “Understory vegetation in fast-growing tree plantations on savanna soils in Congo”. Forestry Ecology and Management. Issue 99, p 65–81

Miranda R.C, Sepp S, Ceccon E, Mann S, Singh B. 2010. “Sustainable Production of Commercial Woodfuels: Lessons and Guidance from Two Strategie”. Energy Sector Management Assistance Program (ESMAP). The World Bank Group.

Senbeta, F., Teketay, D., Näslund, B., 2002. “Native woody species regeneration in exotic tree plantations at Munessa-Shashemene Forest, southern Ethiopia”. New Forests. Issue 24, p 131–145.

Tyynelä, T.M., 2001. “Species diversity in Eucalyptus camaldulensis woodlots and miombo woodland in Northeastern Zimbabwe”. New Forests. Isuue 22, p 239-257.

# Projects

# U.S. Approaches and Actions on Climate Change by Mr. David J. LIPPEAT

**Economic Councelor of the U.S.A. Embassy in the Hellenic Republic**

## Introduction

I'm delighted to be here at this important event and appreciate the opportunity to speak with you on the U.S. commitment to address climate change. I'd like to thank the event sponsors for the invitation to be here.

## U.S. Climate Views

- The Obama Administration is firmly committed to the fight against climate change, and President Obama and Secretary of State Kerry have made climate change a priority at home and internationally.
- As the State Department's Special Envoy for Climate Change, Todd Stern, said a year ago in London: "We can see that climate impacts are already large, are very likely to increase significantly, and have the potential to be fundamentally disruptive to our world and the world of our children and grandchildren."
- The United States has backed its commitment with many domestic and international actions

## U.S. Initiatives on Climate Change

For example, in June 2013, President Obama introduced a comprehensive Climate Action Plan. This plan affirmed the U.S. commitment to:

- Cut carbon pollution in the United States that allow us to meet our UN Framework Convention on Climate Change target of reducing U.S. GHG emissions in the range of 17% below 2005 levels by 2020;
- Lead international efforts to address climate change; and
- Prepare the United States for the impacts of climate change.

## U.S. Domestic Actions under the President's Climate Action Plan

I will outline the first two components of the plan today. The Administration has taken many domestic actions to reduce carbon pollution in the United States.

- During President Obama's first term, the Administration made investments to double renewable electricity generation by 2020. The Administration also enacted regulations to nearly double the fuel economy of cars and light trucks by 2025.
- Also, new energy efficiency standards in the United States for appliances and other equipment, combined with standards set in 2009, are expected to reduce $CO_2$ emissions by at least 3 billion tons cumulatively through 2030.
- The United States is also implementing a comprehensive methane strategy to reduce emissions from landfills, oil and gas production and distribution, and agriculture. Methane emission reductions could be up to 90 million metric tons of $CO_2$ equivalent by 2020.
- Finally, in June 2014, the U.S. Environmental Protection Agency proposed strong draft carbon standards for existing power plants. With these standards in place, power sector emissions are projected to be about 26% below 2005 levels by 2020.

## U.S. International Efforts

On the international front, the United States is leading efforts under the UN Framework Convention on Climate Change to reach a new agreement in December 2015. We are also working through other bilateral and multilateral partnerships.

UNFCCC

- A new international agreement can guide global efforts to respond to climate change in the post-2020 era. These negotiations are scheduled to conclude in Paris in December of 2015, under the UN Framework Convention on Climate Change (the UNFCCC).
- The United States believes we have a significant opportunity in Paris to conclude a new agreement that is ambitious, effective, and inclusive of all countries, particularly the largest greenhouse gas emitters.
- It will be important to include both developed and major developing countries in a future agreement. If major developing countries do not cut their emissions, it will be impossible to reduce emissions sufficiently to address the climate problem.
- The U.S. government organized a "Major Economies Forum" of countries that generate about 80% of global greenhouse gas emissions. Through these meetings, the U.S. is urging major economies, including China, India, and Brazil, to commit to actions to cut emissions in a manner that is transparent and accountable.

Other U.S. International Efforts

We also work with international partners in other multilateral settings:

- Bilateral Partnerships. We are working with bilateral partners who are prepared to make a difference. The President and Secretary Kerry have initiated partnerships with key players, including China and India, to promote cooperation on clean energy, sustainable forestry, and adaptation and resilience to climate change.

- Climate and Clean Air Coalition on Short Lived Climate Pollutants (CCAC): In 2012, the United States, UNEP and six country partners, launched the Climate and Clean Air Coalition on Short Lived Climate Pollutants (CCAC) to address pollutants, like methane, black carbon, and HFCs, that have significant warming impact in the short term. This coalition now includes some 41 country partners and 52 non-state partners.

- Montreal Protocol: As well, the United States has worked to build support among other nations for a phase-down of HFCs under the Montreal Protocol on Substances that Deplete the Ozone Layer. Roughly 110 countries have signed on to our call for an amendment to the Protocol, which could reduce the production and use of HFCs and eliminate the equivalent of 90 billion tons of carbon dioxide by 2050.

- Arctic Council: The Arctic Council has already begun to address the impacts of climate change in the Arctic. When the United States assumes the Council's two-year chairmanship in May 2015, we will work to heighten its efforts on climate change.

- Mitigation Finance. The United States has increased its international finance to help developing countries mitigate and adapt to climate change, providing $7.5 billion in total "Fast Start" climate finance from 2010 to 2012. We are working with other donors to collectively mobilize $100 billion per year by 2020 from all sources, public and private, in the context of meaningful and transparent mitigation by developing countries.

- Executive Order on Climate-Resilient International Development. Finally, on September 23, 2014, President Obama announced an Executive Order on Climate-Resilient International Development, requiring U. S. government agencies to factor climate considerations systematically into the U.S. government's international development work.

**Climate Reporting and Assessments**

- To inform our actions, the U.S. also publishes frequent climate reports, such as the 2014 U.S. Climate Action Report, fulfilling UNFCCC reporting requirements on progress in combating climate change, and the 3rd National Climate Assessment in May 2014.

In conclusion, the United States is working broadly through a range of ambitious domestic and international actions, and through research, to step up and meet our climate responsibilities.

We have a moral obligation to act on behalf of future generations. As President Obama said in 2013, climate change represents one of the major challenges of the 21st century, but as a nation of innovators, the United States can and will meet this challenge in a way that advances our economy, our environment, and public health all at the same time. We stand ready to do our part both domestically and with our many international partner around the globe. Thank you very much.

## *SUSTAINABLE ENERGY PLANNING*

# COOPENERGY

### At a Glance

**Title**: Regional and local public authorities cooperating in sustainable energy planning through effective multi-level governance models

**Funding mechanism:** Intelligent Energy Europe Programme of the European Union

**Total Cost:** 1.635.768,00 €

**EC Contribution:** 1.226.826,00 €

**Duration:** 36 months

**Start Date:** 1/4/2013

**Consortium:** 12 partners from 9 countries

**Project Coordinator:** Regional Council Rhone-Alpes (France)

**Project Web Site:** http://www.coopenergy.eu/

**Key Words:** sustainable energy planning, regional and local public authorities, multi-level governance

### The Challenge

COOPENERGY is a three-year European funded project (co-funded through the Intelligent Energy Europe Programme) aiming to help regional (county) and local public authorities develop joint action plans by using Multi-Level Governance agreements. These agreements could range from informal meetings to more robust partnerships and Memoranda of Understanding (MoUs) and will ensure regional and local authorities are working together to the greatest effect to deliver on the EU 20/20/20 targets.

By developing and delivering these Sustainable Energy Action Plans (SEAPs) in partnership, public authorities can avoid duplication, cut inefficiencies and share resources effectively to help their residents and communities make the transition to a low carbon society and economy.

The project brings together twelve partners from nine countries from across the European Union to work with local authorities in their regions to share good practice and create mutually beneficial Sustainable Energy Action Plans (SEAPs).

### Project Objectives

The overall project objective is to contribute to the EU 2020 targets on energy efficiency and renewable energy sources. The specific project objectives are:

1. **Identifying and learning** from the good practice of others who have successfully collaborated on sustainable energy planning. An interactive online good practice database will be produced with examples from across Europe
2. **Developing and testing** local Multi-Level Governance agreements to show how public authorities can work in partnership to deliver results
3. **Implementing and evaluating** joint actions and solutions to demonstrate success
4. **Celebrating success, sharing experience and transferring learning** within the partnership and across Europe
5. **Promoting key European policies (such as the Covenant of Mayors)** that can help

public authorities plan sustainable energy projects and actions in partnership

## Methodology

The main goal of COOPENERGY is to foster the development of collaboration models in sustainable energy planning between the regional and local public authorities to lead the transition towards low carbon communities and regions. COOPENERGY aims to mobilize eight (8) regional public authorities to work hand in hand with the local authorities and demonstrate their collaboration by developing Multi-Level Governance (MLG) models that support the creation of mutually beneficial Sustainable Energy Action Plans (SEAP) and the development of high impact actions in energy planning for the successful implementation of SEAPs.

Good practice MLG models in sustainable energy planning have been identified through a European survey. At this purpose, IEFE-Bocconi University developed an online questionnaire in collaboration with all COOPENERGY partners, which has been disseminated to more than 250 local authorities across EU 28 countries. The European survey has enabled to collect more than 150 collaborative examples, out of which 60 were selected as best case models, documented by IEFE Bocconi and Fedarene and made available in a searchable repository on the project website.

The learning from the European survey is now being used by partners to develop robust MLG models for the review of regional SEAPs and development of coordinated sustainable energy planning actions. More practical help will be given through a number of technical workshops aimed at strengthening the capacity of public authorities in sustainable energy planning. The models will be transferable across European regions and designed to promote long term collaboration and partnership working.

Learning from COOPENERGY will be shared through bilateral exchanges with regions outside the project area and through an interactive cooperation platform that will be widely promoted. A targeted communications strategy will ensure not only that outcomes are shared as widely as possible, but also to illicit feedback from other partners and regions to further develop the outputs of the project.

## Expected Results

The expected results of the project are:

- Identify and promote transferable models of effective collaboration in sustainable energy planning between local and regional public authorities and facilitate their cooperation establishing multi-level governance models in sustainable energy planning.
- Demonstrate joint actions in the partner regions involving both the regional and local authorities and providing support for the successful implementation of SEAPS.
- Support knowledge transfer and replication of effective collaboration models to other European regions. Beneficiary Regions will participate in bi-lateral transfer activities and commit to implementing collaborative models. Five regional authorities will adhere to CoM as Coordinator. In total twenty (20) Regions will promote MLG models in European level events
- Promote European policies and the use of European instruments and programs (e.g. ELENA, EEEF) and their integration in SEAPs.

| Project Partners | |
|---|---|
| Regional Council Rhone-Alpes | FR (France) |
| Rhonalpenergie-Environnement | FR (France) |
| Agenzia Regionale per l'Energia della Liguria SPA | IT (Italy) |
| Malopolska Agencja Energii I Srodowiska Sp. Z o o | PL (Poland) |
| Ente Vasco de la Energía | ES (Spain) |
| Norrbottens energikontor AB | SE (Sweden) |
| European Federation of Agencies and Regions for Energy and Environment | BE (Belgium) |
| Metropolregion Rhein-Neckar GmbH | DE (Germany) |
| Energetická agentura Zlínského kraje, o.p.s. | CZ (Czech Republic) |
| Kent County Council | UK (United Kingdom) |
| Università Commerciale Luigi Bocconi - IEFE | IT (Italy) |

*STI COOPERATION*

# INCONET EAP

**AT A GLANCE**

**Title**: STI International Cooperation Network for Eastern Partnership Countries

**Funding mechanism:** Coordination and support actions (Supporting) FP7

**FP7, Funding Scheme**

**Total Cost:** 3.284.808 €

**EC Contribution:** 2.999.950 €

**Duration:** 36 months

**Start Date:** 1/9/2013

**Consortium:** 19 partners from 16 countries

**Scientific Coordinator:** Centre for Regional & International STI Studies & Support (Greece)|www.ceriss.eu

**Project Web Site:** http://www.inco-eap.net

**Key Words:** climate change, energy, health, EU-EaP policy dialogue, EU innovation platforms, analytical evidence, promotion of Horizon 2020

## BACKGROUND

The "STI International Cooperation Network for Eastern Partnership countries - IncoNet EaP" project is dedicated to the promotion of the bi-regional policy dialogue in STI between the EU Member States (and countries Associated to FP7) and the Eastern Partnership (EaP) countries, aiming at the identification of priorities for action, especially, in three Societal Challenges (SC) of particular importance for the two regions (Climate Change, Energy and Health), as well as on the promotion of Innovation. In doing that, the project will benefit from the interaction with the recently established "EU – EaP Panel on Research and Innovation" that provided a new impetus to the EU – EaP STI cooperation.

## WHAT WE DO:

A. With the aim to support the bi-regional STI policy dialogue for joint agenda setting and definition of research priorities in three Societal Challenges (Climate Change, Energy, Health), the project already:

- implements pilot actions such as twinning grants to promote comprehensive approaches and to reduce fragmentation;
- organizes Policy Stakeholders Conferences in the target countries to address the three SC as well as horizontal STI policy issues;
- implements STI Policy Mix Peer Reviews in two EaP countries (Georgia, Armenia), as well as mentoring activities for key research institutes in all the EaP countries;
- prepares studies, i.e. an STI cooperation barometer, a bibliometric analysis, a feasibility study for ERANETS, etc.
- prepares recommendations for a future cooperation strategy involving policy makers and representatives of the research communities in both regions.

B. In order to promote Innovation in the target countries and to create synergies with the relevant stakeholders in the EU, the project already:

- stimulates the establishment of specific links between entities in EaP and the European Technology Platforms;
- enhances the cooperation of the EaP countries with the Enterprise Europe Network (EEN) and explores the extension of the European Innovation TrendChart to EaP Countries;

- implements capacity building actions in research and innovation, such as trainings and seminars.

C. With the aim to promote H2020 in the EaP countries and to increase the participation of researchers from EaP in the Framework Programme, the project already:

- organizes awareness campaigns and trainings of the National Contact Point (NCP) structures, as well as Info Days on H2020 in all the EaP countries;
- implements a grant scheme for the participation of EaP researchers to Brokerage events in the EU.

The project envisages a considerable number of dissemination activities (including promotion of key deliverables of joint EU-EaP projects) and in particular will focus on making the results widely visible to all relevant stakeholders for a better exploitation and implementation.

## EXPECTED IMPACT

The IncoNet EaP project is expected to:

- identify needs in STI to be jointly addressed by providing a flexible format for the STI policy dialogue between the EU and EaP, paving the way for an enhanced STI cooperation;
- mobilize a considerable number of STI stakeholders in the target countries from the broader STI sphere, such as policy makers, representatives of sectorial Ministries/Agencies dealing with the three Societal Challenges, representatives of Innovation-related structures such as platforms, clusters, agencies etc.;
- address through various structural activities, both at policy-support and research-support level, the Societal Challenges of mutual concern, namely Climate Change, Energy and Health;
- increase the level of cooperation of the entire "research to innovation chain" by developing and/or strengthening the partnerships for Innovation;
- increase the participation of researchers from the EaP countries in H2020.

The project constitutes the bridge between the 7th Framework Programme for Research, Technological Development and Demonstration and the new Research and Innovation Programme for 2014-2020, Horizon 2020. It also embraces other Community policies and instruments (such as ENPI and its follow-up ENI) as well as additional international initiatives such as those promoted by UNDP, UNECE, UNEP, World Bank, etc. in order to identify complementarities and synergies among the relevant instruments.

| PROJECT PARTNERS | |
|---|---|
| Centre for Social Innovation (Administrative Coordinator) | ZSI (Austria) |
| Centre for Regional and International STI Studies and Support (Scientific Coordinator) | CeRISS (Greece) |
| Deutsches Zentrum fuer Luft- und Raumfahrt | DLR (Germany) |
| Regional Centre for Information and Scientific Development Ltd | RCISD (Hungary) |
| Agenzia per la Promozione della Ricerca Europea | APRE (Italy) |
| Sihtasutus Eesti Teadusagentuur | ETAg (Estonia) |
| Centre National de la Recherche Scientifique | CNRS (France) |
| Centrul Proiecte Internationale | CIP (Moldova) |
| Instytut Podstawowych Problemow Techniki Polskiej Akademii Nauk | IPPT-PAN (Poland) |
| Sociedade Portuguesa de Inovação, Consultadoria Empresarial e Fomento da Inovação, S.A. | SPI (Portugal) |
| The Scientific and Technological Research Council of Turkey | TUBITAK (Turkey) |
| International Center for Black Sea Studies | ICBSS (Greece) |
| United Nations University, Vice Rectorate in Europe | UNU (Germany) |
| National Academy of Sciences of the Republic of Armenia | NAS RA (Armenia) |
| Presidium of Azerbaijan National Academy of Sciences | ANAS (Azerbaijan) |
| Belarusian Institute of System Analysis and Information Support of Scientific and Technical Sphere | BelISA (Belarus) |
| Shota Rustaveli National Science Foundation | SRNSF (Georgia) |
| The Centre for Scientific and Technical Information and Innovation Promotion of Ukranie | UKRTECHINFORM (Ukraine) |
| Kharkov Technologies, Business Incubator | KT (Ukraine) |

Connecting SMEs for a green economy

## At a Glance

**Title:** Accelerating progress towards the Green Economy - A best practice platform to support the transition towards a green economy

**Funding mechanism:** Coordination and support actions (Coordinating) FP7

**FP7, Funding Scheme**

**Total Cost:** 1,086,959.40€

**EC Contribution:** 999,968.00€

**Duration:** 36 months

**Start Date:** 01/06/2013

**Consortium:**
6 partners from 5 countries

**Project Coordinator:** University of York, UK

**Project Web Site:**
http://www.greeneconet.eu/
GREENECONET

**Key Words:** SMEs, green economy, knowledge exchange platform, green business practices, eco innovation, barriers & enablers.

## The Challenge

Current high-level dialogues in the field of green economy argue that for achieving the transition to green economic pathways, the joint engagement of not only the public but also the private sector needs to be employed. Indeed the private sector and especially small and medium sized enterprises (SMEs), forming the backbone of EU economy, can be key contributors to creating green economy pathways, through investing in technologies and infrastructure, products and services that can drive change and innovation. In EU level the Green Action Plan for SMEs sets out a series of objectives and lists actions within the framework of the Multiannual Financial Framework 2014-2020. Such actions include investigating opportunities for business resource efficiency and access to green markets. On the one hand, many SMEs and corporate actors have introduced innovative green solutions and/or have developed revolutionary organisational, behavioral and technological approaches to the problem of sustainability and human well-being. Yet, on the other hand, a large part of the business communities face difficulties to follow the same pace. Important constraining factors are: the lack of resources (financial/time/staff resources), lack of technical skills and capacity, along with the lack of access to appropriate information (e.g. through IT).

The overarching ambition of GreenEcoNet is to support SMEs to overcome barriers encountered and enable their transition to green economy pathways.

## Project Objectives

Main objectives of the project is to fill the gap between research and SMEs, to strengthen the dialogues within the private sector (SME to SME across member states) and between SMEs and EU and Member State policy makers on the subject of green economy best practice and more in specific on enablers and on how to address and overcome soft and hard barriers. The dialogues will take place under the form of events, such as workshops and conferences but also through publications, and the creation of tools and instruments, i.e. the **GreenEcoNet online platform** aimed at developing an exchange knowledge network of best practices involving the 'best in class' private enterprises, the wider business community and research institutions and ultimately at becoming the reference platform for green economy best practice for businesses and in particular for SMEs. Key objectives of the platform are to:

1. Showcase real life case studies and green solutions from SMEs across Europe that have successfully gone 'green';
2. Assist the replication of these success stories by providing on demand technical expertise, and in particular technical answers to the requests for support highlighted either through forums or through one to one dialogue or by channeling questions to relevant research institutions and groups of experts outside the consortium. Ultimate aim is to create a matching mechanism among green solution 'providers' and interested green solution 'adopters' SMEs;
3. Create a library of tools and guidance for the assessment of business sustainability and the cost-effectiveness of the green solutions employed (from the planning to the implementation and monitoring stages);
4. Trigger and maintain discussion forums and news updates tailored for smaller businesses, such as funding opportunities and information of the application process.

## METHODOLOGY

The project builds upon participatory networking and exchange, thus sound stakeholder engagement is key to the success of the project. Both online and offline (i.e. Thematic Workshops and Annual Conferences) instruments are employed for the support of information exchange on green economy opportunities.

**Online GreenEcoNet Platform:** The purpose of GreenEconet Platform is to connect and engage a global community of stakeholders on the subject of the green economy in order to accelerate the transition to green economy pathways.

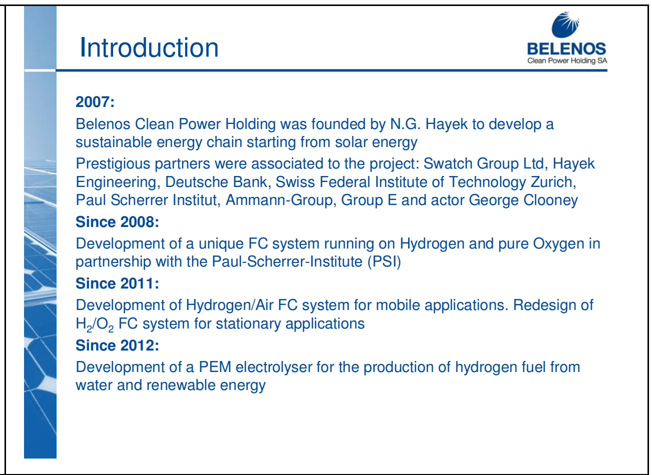
The platform offers: **(a)** an updated collection of case studies describing success stories of SMEs. The collection is accessible to all stakeholders and

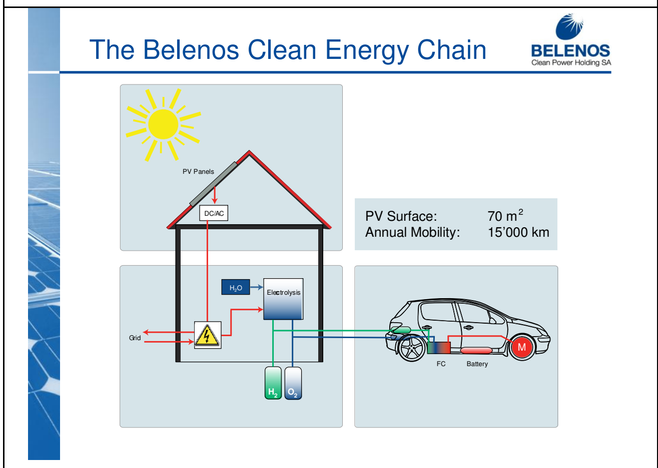
registered stakeholders are able to receive periodic updates on specific categories; **(b)** tools that support the monitoring and evaluation of the performance of the green business solution and guidance to allow SMEs assessing resource efficiency performance of their business activity; **(c)** discussion forums and news updates.

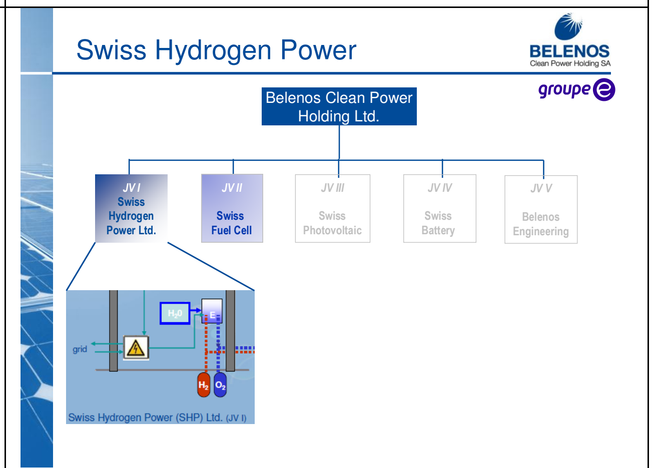
| PROJECT PARTNERS | COUNTRY |
|---|---|
| University of York | UK |
| University of Piraeus Research Center | GR |
| Centre for European Policy Studies | BE |
| Joint Implementation Network | NL |
| Green Economy Coalition | UK |
| Ecologic Institute | DE |

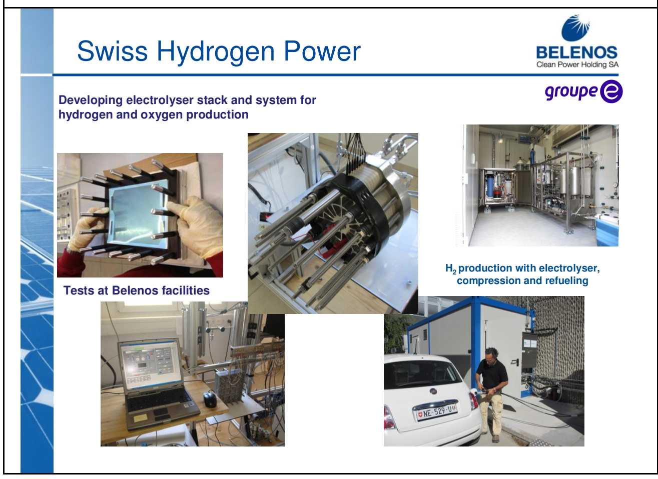
# Belenos activities in the field of green energy and its storage

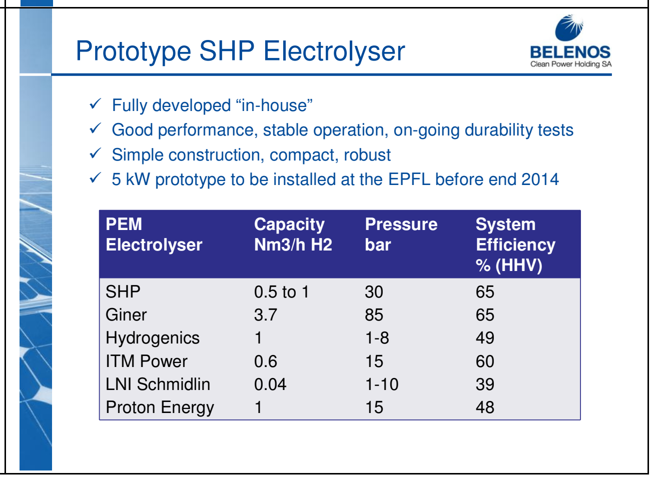
by
**Dr. Elli VARKARAKI**
Belenos Clean Power Holding Ltd.

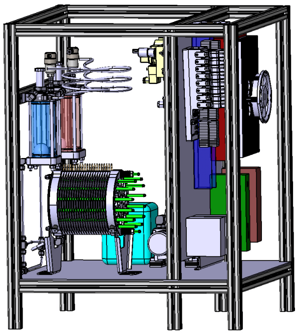




| PEM Electrolyser | Capacity Nm3/h H2 | Pressure bar | System Efficiency % (HHV) |
|---|---|---|---|
| SHP | 0.5 to 1 | 30 | 65 |
| Giner | 3.7 | 85 | 65 |
| Hydrogenics | 1 | 1-8 | 49 |
| ITM Power | 0.6 | 15 | 60 |
| LNI Schmidlin | 0.04 | 1-10 | 39 |
| Proton Energy | 1 | 15 | 48 |

## Prototype SHP Electrolyser

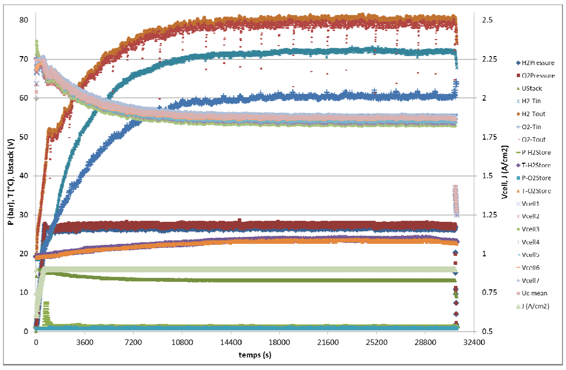
BELENOS Clean Power Holding SA



| Technical Specifications | |
|---|---|
| Production: | up to 1000 NL/h $H_2$<br>up to 500 NL/h $O_2$ |
| Pressure: | 30 bar |
| Power: | 5 kW |
| Cabinet: (LxWxH) | 80x80x100 cm |
| Stack efficiency: 75% | |
| System efficiency: 65% (estimated) | |

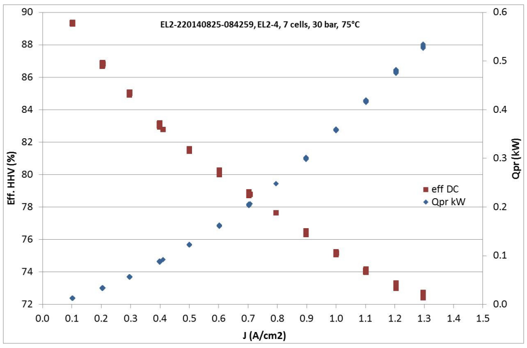
## Prototype SHP Electrolyser

BELENOS Clean Power Holding SA




## Prototype SHP Electrolyser

BELENOS Clean Power Holding SA




## Fuel Cell mobility tests

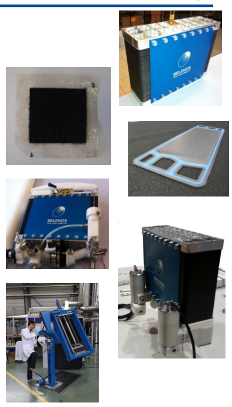
BELENOS Clean Power Holding SA



## Belenos Fuel Cell System

BELENOS Clean Power Holding SA

- ✓ Proprietary design of fuel cell stack and FC system
- ✓ Development of low cost PEM membrane with excellent durability in collaboration with PSI
- ✓ Bipolar plate development with leading supplier for stationary FC systems
- ✓ Integrated system components for improved performance and reduced cost
- ✓ Production capacity for 1MW/month available



## Advantages $H_2/O_2$ FC over $H_2$/Air FC

BELENOS Clean Power Holding SA

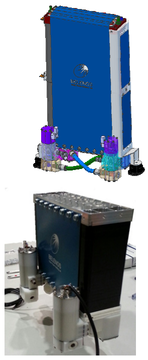
Higher system efficiency
- 60 .. 70% with $H_2/O_2$ vs. 45 .. 55% with $H_2$/Air

Significantly lower cost
- Power density (W/cm² active area) is twice as high at same efficiency
- 80% of FC cost is active area cost (bipolar plates and MEA)

Better reliability
- Very simple system
- Very few moving parts

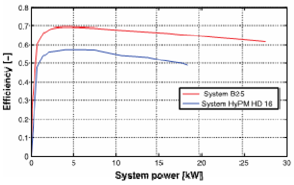
Fast start-up
- Full power achievable within a few seconds
- No startup-time and -energy for air compressor required

Independent from ambient air conditions
- Operation at high altitudes possible
- Operation at any ambient temperature and humidity possible
- No degradation due to air pollution

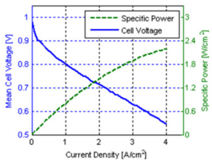


## FC system efficiency

BELENOS Clean Power Holding SA




Belenos $H_2/O_2$ FC System efficiency compared to Hydrogenics HyPM HD 16, one of the most efficient systems on the market




This performance can be reached due to a very high cell efficiency and extremely low parasitic losses

(U/I curve measured with 6 cell stack with 200 cm² active area at 3.5 $bar_{abs}$ and 75 °C)

## Hybrid - fuel cell/battery - EV

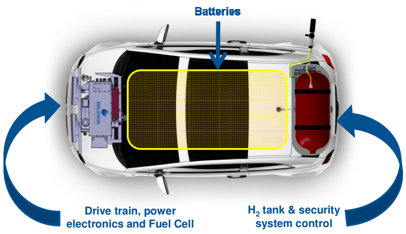
BELENOS Clean Power Holding SA

- The fuel cell system doubles the range of the vehicle.
- The fuel cell could also drive the vehicle when the HV battery is empty (with limited power).

| | Mass | Power | Chemical Energy | Electrical Energy | Range (NEDC) | Filling Time |
|---|---|---|---|---|---|---|
| HV Battery | 210 kg | 60 kW | 31kWh | 26 kWh (124 Wh/kg) | 200 km | 10 h |
| FC system | 125 kg | 10 kW | 55 kWh | 26 kWh (208 Wh/kg) | 200 km | 2 min |

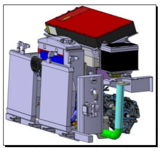
## Electric FIAT 500 with FC range extender

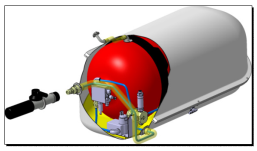
BELENOS Clean Power Holding SA




**Fuel Cell (FC) system information:**

| | |
|---|---|
| •Emissions | = 0 |
| •Electric power/peak | = 20/60 kW |
| •Battery capacity | = 26 kWh |
| •Battery weight | = 210 kg |
| •Hydrogen capacity | = 1.7 kg |
| •Fuel Cell power | = 10 kW |
| •Battery driving range | = 200 km |
| •$H_2$ driving range | = 200 km |
| •Total Range | = 400 km |
| •Curb Weight | = 1300 kg |
| •Number of seats | = 4 |





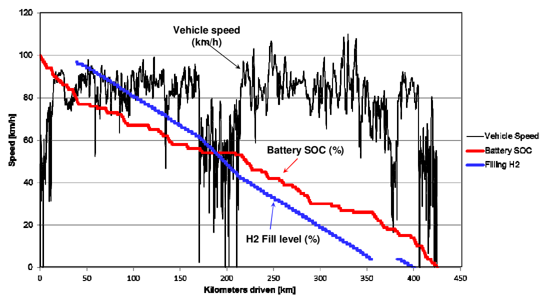
## Test drive : Top range record

BELENOS Clean Power Holding SA

Date & Time: 20 Oct., 2013 | Distance: 425km | Battery used: 100%

Test Driver: M. Vögeli | Max Speed: 110km/h | Hydrogen used: 97%

Avg Speed: 73km/h




## FIAT 500 Statistics

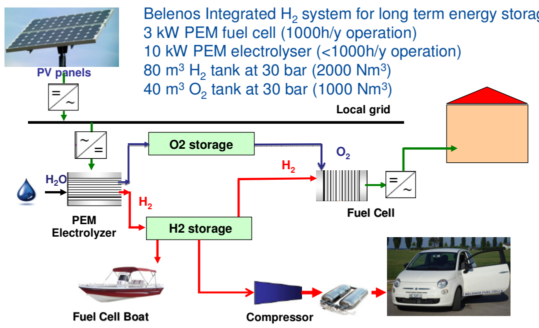
BELENOS Clean Power Holding SA

| What | Value |
|---|---|
| Distance | 40 120 km |
| Average speed | 49 km/h |
| Drivetrain consumption | 194 Wh/km |
| Vehicle ON time | 815 h (1 year) |
| Average power demand | 9.5 kW |
| Battery full cycles | 205 |
| Fuel cell ON time | 400 h (49% of vehicle ON time) |
| Fuel cell average power | 6 kW (including DC/DC) |
| H2 full filling | 105 |
| Number of FC starts | 1200 |
| Average efficiency H2 tank to DC bus (including Stack, BoP, Purges, DC/DC) | 41 % |

## PV-H2 integration in micro-grids

BELENOS Clean Power Holding SA

Belenos Integrated $H_2$ system for long term energy storage
3 kW PEM fuel cell (1000h/y operation)
10 kW PEM electrolyser (<1000h/y operation)
80 m³ $H_2$ tank at 30 bar (2000 Nm³)
40 m³ $O_2$ tank at 30 bar (1000 Nm³)




Heat recovery option for co-generation!

+ car option
15 kW electrolyser
350-700 bar storage

BELENOS Clean Power Holding SA

**Thank you for your attention!**

## *CLIMATE CHANGE*

# CIRCLE-2

**AT A GLANCE**

**Title**: **Is current decision making "adapted to internalize adaptation" into policy making? /ADAPT-MED**

***CIRCLE-2, Adaptation to Climate Change from a natural and social science perspective: Water in coastal Mediterranean areas***

**Total Cost: 424 333.6 €**

**FUNDER organisations**:
Ministry for Ecology, Sustainable Development and Energy (MEDDE), FR
Foundation for Science and Technology, Portugal (FCT), PT
Mariolopoulos-Kanaginis Foundation for the Environmental Sciences (MKF),GR
Partners' own funding

**Duration:** 24 months

**Start Date:** 1/12/2013

**Consortium:** 5 partners from 3 countries

**Project Coordinator:** ACTeon, France

**Project Web Site:** http://circle-2.wix.com/adapt-med

**Key Words:** Adaptation, perception, decision-making, policy exercise, adaptation strategy, impacts, societal challenges

## THE CHALLENGE

The topic "Water and Adaptation to Climate Change from a natural and social science perspective in coastal Mediterranean areas" highlights the role and importance of water for human life, nature and the economy as well as the societal challenges emerging from climate change (CC) to protect our water resources and ecosystem services. In the last decade, many assessments of the impacts of global and climate change in the coastal zones have been undertaken. However, such assessments have rarely been connected to decision making on adaption strategies, often because of the uncertainties associated to CC impacts strategies. Although generic methods to inform decision making (e.g. the robust decision making) exist, they have rarely been set up at regional and local scale. In addition, adaptation being trans-sectorial, there is a need to better demonstrate how such measures can be taken within the existing regulation on development, risk prevention and land use planning. In this context, ADAPT-MED questions: Is current Decision Making (DM) "adapted to internalize adaptation" into policy making?

## PROJECT OBJECTIVES

ADAPT-MED focuses **on the main factors that affect the capacity of DM to effectively internalise adaptation to CC**, negatively and positively and aims to derive recommendations for adapting components of DM so that adaptation can be better considered for in today's DM. ADAPT-MED will investigate three key components of DM:

- The **policy instruments** in place (regulation, financing, voluntary agreements, etc.) – and their capacity to account for CC vulnerability and adaptation to CC ;
- The **decision making processes** – and the capacity of the current policy governance to "give space" to adaptation issues in a context of uncertainty;
- The **main players of decision making processes** who have **individual understanding, perceptions and values** on "adaptation" and who (as individuals) clearly influence policy (political) decisions to: 1) consider adaptation as a policy issue *per se*; 2) develop an adaptation strategy for a given

territory or sector; or 3) systematically internalise adaptation in existing instruments and policies relevant to other policy domains (agriculture, water, land use, urban development, environment).

## METHODOLOGY

ADAPT- MED will concentrate on **3 research sites:** Ria de Aveiro coastal lagoon (Portugal), Provences-Alpes-Côte d'Azur (France) and selected Northeastern coasts of Crete (Greece)(all regions affected by increased urbanization and likely to be diversely affected by CC).

A **knowledge database** will be built for the 3 sites. Its development builds on the collection of existing data, research results and studies relevant to each research site complemented by dedicated stakeholder interviews that help gathering gray literature and stakeholder knowledge. The information is structured and stored in database/Geographic Information System.

Current practice of adaptation in these regions will be investigated using **semi-structured interviews** with experts and decision makers at different scales and its relation to other regulatory mechanisms on land use planning and risk prevention.

The perceptions and values of decision makers and stakeholders towards adaptation to CC will be explored with the use of an **online survey**.

Desirable adaptation measures will be examined as well as the way they can be mainstreamed/ integrated within current policy, DM and regulatory mechanisms through the organisation of an **interactive policy exercise** with groups of decision makers and stakeholders targeting to develop adaptation "strategies".

The way changes in understanding, perceptions and values can result in changes in CC adaptation decisions will be examined by a **post policy exercise survey.**

## EXPECTED RESULTS

The project is expected to produce a breakthrough in the field of DM related to sustainable development, risk prevention and adaptation to climate and global change by:

- Better **linking vulnerability assessment with DM**, notably taking advantage of approaches such as the robust DM presented by Lempert and Schlessinger (2010). Indeed, although this method is conceptually recognized as having great potential for long term environmental DM, there is a lack of "real case" applications in the scientific litterature;
- Focusing on **DM**, both in terms of formalised or informal processes and decision makers considered as individuals whose perceptions and values are expected to significantly incluence the way CC adaptation is made operational and effectively put in policy practice;

It is expected that ADAPT-MED research will in the medium term contribute to:

- The identification of (governance, institutional and DM) **constraints** in the internalisation of adaptation in existing policies or the development of specific adaptation strategies as well as **practical options for removing these constraints**; change in understanding, perception and values of decision and policy makers on CC adaptation;
- **Raise awareness** and **stakeholders involvement** in CC adaptation in coastal areas in the 3 partner countries and the Mediterranean Region, as a key to the development and implementation of effective CC adaptation strategies and actions.

| PROJECT PARTNERS | |
|---|---|
| ACTeon, Environment Research and Consultancy | FR (France) |
| BRGM Bureau de Recherches Géologiques et Minières | FR (France) |
| Universidade de Aveiro/University of Aveiro/ UAVR (CESAM) | PT (Portugal) |
| ISCTE-Instituto Universitário de Lisboa, Business Research Unit/ ISCTE-IUL | PT (Portugal) |
| National and Kapodistrian University of Athens / UoA | GR (Greece) |

*CLIMATE CHANGE*

# EUROPEAN CCS DEMONSTRATION PROJECT NETWORK

**AT A GLANCE**

**Title**: Support to the European CCS Demonstration Project Network (CCS – PNS)

**Funding mechanism:** Coordination and support actions (Supporting) FP7

**FP7, Funding Scheme**

**Total Cost:** 3,670,745.2 € (estimated eligible – whole duration)

**EC Contribution:** 82 % (maximum financial contribution – whole duration)

**Duration:** 48 months

**Start Date:** 21/3/2012

**Consortium:** 4 partners from 4 countries

**Project Coordinator:** Global CCS Institute EMEA (Belgium)

**Project Web Site:** http://ccsnetwork.eu/

**Key Words:** climate change, network, knowledge exchange, CCS, demonstration

## THE CHALLENGE

The European Carbon Capture and Storage (CCS) Demonstration Project Network (the Network) was established in 2009, to support and accelerate large-scale CCS projects across the continent in a safe and commercially viable way. As part of an initiative of the European Commission, the intention of the Network has been to establish a community of leading CCS demonstration projects. This world-first knowledge sharing Network brings together leading CCS project operators and proponents to exchange both technical data and hold workshops on specific topics for mutual benefit. By sharing experiences this community of projects helps de-risk project proposals and reduce their costs, seeking to achieve the wide deployment of successful, safe and economically viable CCS.

## PROJECT OBJECTIVES

The Network is aiming to facilitate knowledge sharing amongst projects by addressing key topics that will enable CCS project deployment. The Network provides added value to European projects by:

- Facilitating the identification of good practices, lessons learnt and recommendations with respect to large-scale CCS demonstration and enabling knowledge sharing amongst projects.
- Providing a common EU identity to Network Members.
- Leveraging experience gained from projects and the evidence generated by them, in order to build public confidence about the feasibility and safety of CCS.
- Promoting CCS, EU leadership and cooperation potential to third parties/countries.

## METHODOLOGY

The organisation of the project to support the implementation of the project objectives includes distribution of work in four packages:

**Work Package 1: Project Management** *Beneficiaries:* Global CCS Institute

**Work Package 2: Secretariat** *Beneficiaries:* Global CCS Institute

**Work Package 3: Knowledge Sharing** *Beneficiaries:* Global CCS Institute, SINTEF, IFPEN, and TNO

**Work Package 4: Information Technology** *Beneficiaries:* Global CCS Institute

## PROJECT ACTIVITIES

- Provide overall project management and ensure work packages provide agreed deliverable on time and on budget. Ensure that the project is adequately staffed with team members with relevant skills and experience.
- Support to Steering Committee (the body that guides the activities of the Network and the preparation and publication of information produced) and Advisory Forum (the consultative body in the annual agenda-setting process of the Network) as well as support to Network members.
- Gather and analyse internal Network information towards the creation of knowledge sharing products.
- Facilitate knowledge sharing within the Network and beyond.
- Hosting and maintenance of Network and Member's public websites, Network private website, web platforms and events, email list management tools and Network event registration tools.

## EXPECTED RESULTS

The Sleipner Project captures and stores around 1 million tonnes of $CO_2$ per annum from its light oil and gas field. If all of the other member projects were developed, the Network would have an installed clean electricity generating capacity of 1,450 $MW_e$. If fully developed, in total the Network members would permanently store nearly 9 million tonnes of $CO_2$ per year (2013 data).

The Network is in a strong position to engage in co-ordinated actions to promote public awareness for CCS. Moreover, commitment to knowledge sharing has identified best practices, lessons learnt and recommendations, thus providing significant aid towards the deployment of large-scale CCS projects in Europe.

| PROJECT SECRETARIAT PARTNERS | |
|---|---|
| Global CCS Institute EMEA | BE (Belgium) |
| SINTEF | NO (Norway) |
| IFP Energies Nouvelles (IFPEN) | FR (France) |
| TNO | NL (The Netherlands) |

**Member Projects' Partners:** Endesa, Ciuden, Foster Wheeler, 2Co Ltd, National Grid, Enel, E.On Benelux, GDF Suez, TAQA, Statoil, Exxon Mobil, Total, The Crown Estate

## At a Glance

**Title:** Mobilizing and transferring knowledge on post-2012 climate policy implications

**Funding mechanism:** Coordination and support actions (Coordinating) FP7

**FP7, Funding Scheme**

**Total Cost:** 1,233,885.71€

**EC Contribution:** 998,147.00€

**Duration:** 36 months

**Start Date:** 01/05/2013

**Consortium:**
7 partners from 7 countries

**Project Coordinator:** Joint Implementation Network, The Netherlands

**Project Web Site:** http://www.polimp.eu/ POLIMP

**Key Words:** climate policy, negotiations, low emission economy, implications for business, knowledge gaps.

## The Challenge

It is acknowledged that much information is already available for climate policy stakeholders but the way the information is presented is often difficult to access, not in the right format or otherwise of limited use for stakeholders. POLIMP aims at identifying, where knowledge gaps exist, of what future international climate policy directions may look like and what these imply for policy and decision makers internationally and within the EU. The overarching motivation of POLIMP is to facilitate exchange and transfer of information about climate policy and its implications among the policymakers, market actors and general society within the EU. This will be done by identifying where knowledge gaps exist and how these gaps can be filled.

## Project Objectives

POLIMP objective is to facilitate a process to identify, for different policy and decision making levels, knowledge gaps about implications of possible directions of international climate policies. Subsequently, it will cover these gaps with knowledge packages derived from a broad range of existing reports, research and climate policy decisions at, e.g., EU and UNFCCC levels.

The aim is to provide stakeholders with better insights on implications of possible international climate policy directions; so that they can take more informed decisions with reduced uncertainties and mitigated risks. Through that, POLIMP can enhance the implementation of the EU climate targets, strengthen the EU climate policy information and its effects and increase stakeholders' understanding of the consequences
of current and future international climate regimes.More analytically, the core objectives of the project are:

**1.** Identification of knowledge gaps on the implications for EU stakeholders of possible directions of climate policy making during the second commitment period of the Kyoto Protocol and, after that, as a result of negotiations under the "Durban Platform".

**2.** Collection and synthesize knowledge of possible climate policy directions and their implications in terms of: governance (centralized multilateral or scope for decentralized, bilateral climate actions), applicability of all current policy mechanisms in climate agreements, such as market based mechanisms (ETS, CDM, JI, DOs etc), embedding of climate change priorities in countries' national economic, environmental and social priorities in NAMAs, Low Emission Development Strategies, National Adaptation Plans, and potential for and support of international low emission and climate resilient technology transfer within different sectors (energy, transport, industry, land use and forestry).

**3.** With these information packages, support policy and decision makers in taking well informed decisions, thereby reducing uncertainties and mitigating the risk that decisions are taken against poorly-understood climate policy contexts, and build awareness among the society as a whole of costs and opportunities of future climate policies.

**4.** Track down links between the outcome of the UNFCCC negotiations and EU-level and domestic policy actions in selected country-parties and explore how different UNFCCC climate policy directions would impact these policy actions;

**5.** Facilitate communication among various research components and knowledge dissemination among various stakeholder groups.

## Methodology

POLIMP approach is based on an extensive two-way stakeholder consultation process. POLIMP will collect and process information on future climate policy trends and impacts in an integrated manner for exchange with decision makers at different levels. Instead of exchanging information about climate change mitigation, adaptation, technology transfer, etc., through separate channels, POLIMP will integrate these information flows into balanced information packages to support decision makers.

POLIMP will first identify what information about climate policy making and its implications is needed, then collect this information from various different sources and offer it to stakeholders in desired packages, in intuitively easy formats and clear language. With these information packages, which will be communicated through series of workshops, climate policy associated stakeholders will be better able to extract key policy conclusions. These activities will be facilitated

| Project Partners | |
|---|---|
| STICHTING JOINT IMPLEMENTATION NETWORK | NL |
| CENTRE FOR EUROPEAN POLICY STUDIES | BE |
| UNIVERSITY OF PIRAEUS RESEARCH CENTER | GR |
| UNIVERSITAET GRAZ | AT |
| ECOLOGIC INSTITUT gemeinnützige GmbH | DE |
| CLIMATE STRATEGIES LBG | GB |
| FUNDACJA NAUKOWA INSTYTUT BADAN STRUKTURALNYCH | PL |

# Economic valuation of energy-wood plantations in Northern-Madagascar

**Gernot GAUGER**,

University of Hamburg

**Prof. Dr. Michael KÖHL**,

Institute for World Forestry, University of Hamburg

**Dr. Daniel PLUGGE**,

Institute for World Forestry, University of Hamburg

With contribution of GIZ, Deutsche Gesellschaft für Internationale Zusammenarbeit and ELD, the Economics of Land Degradation initiative.

**Abstract:** In Madagascar 85% of the total energy is gained by fuel-wood and charcoal. This share is foreseen to increase due to urbanization trends and population growth. The high demand for charcoal exceeds the growth rate of natural forests, leading to an intensive, non-sustainable and often illegal exploitation. To address these issues the German Gesellschaft für Internationale Zusammenarbeit (GIZ) together with the Malagasy "Ministère de l'Energie et des Mines" (MEM) started the project GREEN-Mad (nowadays Charbon Vert) in 1996. The approach includes the afforestation of degraded land with fast growing eucalypt species and ameliorated charcoal production. It focuses on the promotion and modernization of the usage of renewable energy sources in rural areas and comprises all elements of the value chain. Local villagers and farmers were included in the process by handing over the management and the revenues of the plantations. Alongside this cooperation a robust database was set up during the project and is analysed in this study. The analysis is based on a cost of action versus benefits of action approach. This incorporates a comparison of the costs and benefits implied with the afforestation activities as well as the costs and benefits of unsustainable forest usage. The aim of this analysis is to estimate the economic viability of such an afforestation approach for local communities and for protecting natural resources. The results serve as an example for the potential benefits from adopting sustainable land management practices and give advice to decision-makers worldwide to take appropriate measures for ensuring better rural development through the promotion of renewable energy sources.

## 1. Introduction

The Charbon Vert project focuses on areas in northern Madagascar, more precisely the districts Antsiranana I and Antsiranana II which belong to the Diana region.

The participatory design of the project includes different actions. The fundamental action is the planning of the plantings and providing financial and knowledge support to the planters. Other important actions are to take place in the educational sector. Knowledge about afforestation, thinning and natural regeneration as well as management indicators are part of this. The third big action of the project is the amelioration of the local charcoal kilns and private coal ovens.

At the beginning a scheme consisting of three stages with a total of nine steps is set up to prepare all the elements of the project.

The first stage is to create awareness about the project and mobilize potential participants in a four step scheme which is foreseen to take three months working time. The first step is an information campaign which is organized on municipal level presenting and explaining the Charbon Vert project and the benefits of the afforestation. Steps two and three are about guaranteeing support from the municipalities for the project and identifying interested parties and assistants. Interested parties fill out forms with personal data and information about potential plantation areas. Step four is to build groups for the afforestation ("Groupements des Adhérents au Reboisement") abbreviated as GAR. These groups are managing the technical support and social organization and in general oversee the realization of the afforestation campaign. Main working areas for the GAR are legal contracting and work flow management for the workers taking part.

The second stage is about the education, planning and realization in the steps five to seven. The timeframe for this stage is eight months. Step five organizes the training of the members of the GAR to be able to develop realistic and coherent planning for the afforestation. Steps six and seven are about the planning and implementing of the tree farms and afforestation plan. The GAR is directly supported by project specialists from Charbon Vert.

The third stage is about self-responsible work of the GAR with internal and external rating of the quality of work. The target of this stage is to create autonomy in decision making and addressing problems and ways of dealing with them.

For any land use option, e.g. afforestation in this case, a crucial point is to have legal and secured tenure rights to defined parts of land. This is a very important factor for the motivation of the farmers of the plantation to be able to receive clear tenure rights.

The beginning of the thesis comes with an overall introduction deeper into the topic of energy-wood plantations and the special properties of Eucalyptus, in particular the subspecies of Eucalyptus camaldulensis. In this context the terms of energy wood, fuel wood and wood fuel have to be differentiated. In general energy wood and fuel wood are two terms for one concern. While fuel wood more refers to the product to be achieved from it, which are energy sources like firewood, charcoal, chips, sheets, pellets and sawdust, the term energy wood more refers to the specific energy potential of wood that is varying among the different wood species. Fuel wood in this case is the term for the above described products that are specified as fuels.

After describing the circumstances and foundations of the project more detailed it is part of this thesis to describe the methodology that is used to analyse the existing, and by this thesis newly developed, data, before the obtained results are critically discussed under different perspectives.

*Eucalyptus camaldulensis*

Eucalyptus camaldulensis is a species of the genus eucalyptus which contains around 800 species. Eucalyptus has its origin in Australia and Indonesia. The most used vernacular names for E. camaldulensis are River red gum and Murray red gum. River red gum originates from Australia and is found from the Northern Territory to Victoria thus covering an area from tropical to temperate climate zones. Nowadays Eucalyptus camaldulensis is found in many tropical and subtropical countries as one of the world`s most widely planted species in arid and semi-arid lands. Since 1900 it has been planted in Africa and has become the most common tree in woodlots, shelter belts and fuelwood plots. Trees of Eucalyptus camaldulensis may reach up to 50 meters in height and 2 meters in diameter while heights of 20 meters and 1 meter in diameter are common. The species grows under a wide range of climatic conditions with an annual rainfall ranging from 250mm to 2500mm. However, the trees may grow on saline waterlogged soils as well. In Africa the best annual rainfall conditions observed are from 700mm to 1200mm as there is about 1200mm rainfall per year in Antsiranana. Under favorable conditions yields of up to 70m³ per hectare and year are possible. In drier tropical areas the yields vary from 2 to 10m³/ha/a [cp. LOUPPE 2008]. The recorded yields in the project area are around 6m³/ha/a.

*Preparation of the plantation sites*

The main preparation activity is ploughing to make the planting of the trees possible. Mechanized ploughing is favored above manual ploughing, using a combination of tractor and plough. A deeper penetration comes with mechanized ploughing which opens the soil for water intrusion, simplifies the planting and is sometimes decisive for the success of the planting if the upper layers of the soil are already dried out. The gaps between the ploughing fugues support the proposed planting matrix. It can be achieved easier by keeping the correct distance from furrow to furrow. Compared with manual techniques this method has a higher demand for management to effectively use the machines on different sites. Extreme sites may be difficult to handle as the tractor may only deal with slopes up to 20% and working time and effectiveness rapidly decreases.

Another key factor that comes with mechanized ploughing is the aligned costs. These are higher than for manual ploughing and in average sum up to 283.000 Ariary per hectare which equals around 86€ including operating costs, repairing and drivers wages. The costs can add up to more than half of the total cost for the plantation.

*Plant production*

The breeding of the seedlings is another important task. Productive and reliable tree nurseries are decisive for the project's success. The first aspect is to discover the right location. It should be near to the selected plantation site while at the same time coping with the water demand of the tree nursery. To protect the seedlings from animals the site has to be fenced.

As the building and of a tree nursery and the breeding of the seedlings requires deepened knowledge the local farmers are supported by the GAR and Charbon Vert in the beginning enabling them to supervise the breeding independently later on. Operating the nurseries requires at least one full-time job which the participating farmers delegate amongst them. Activities comprise plant protection, pest control, weeding, watering, replanting, repotting and reparation of the fences.

Charbon Vert supports the villagers and famers with thematic coaching adapted to existing precognitions, as well as with supplies like

watering cans, plant bags, barrows, seeds and pesticides.
The costs for the plant production sum up to 59.100 Ariary per hectare or 18,20€.

*Planting*

The planting of the seedlings has to take place after the beginning of the rainy season, when the water saturation of the soil is high enough. The most critical part of the whole planting process is the transport from the tree nursery to the plantation site. The loss during the transport or as a result of the transport may reach 5% - 10%. Therefore the transport circumstances have to be optimized. The plants have to be irrigated before the transport and are best delivered shadowed while heat accumulation under the covering has to be avoided.

Baskets and spades are the main tools for the planting. The planting itself is self-organized by the farmers.

The planting of the seedlings costs about 20 Ariary of working cost per tree, that is 22.220 Ariary or 6,84€ per hectare. The cost for the transport form the tree nursery to the planting site depends on the distance in each case but an average cost of 10.000 Ariary or 3,08€ for the plants for one hectare has been calculated.

The payment for the planting is the biggest part of costs the farmers have to afford on their own.

## 2. Development and operating of the plantations

Key to the whole program is the sustainable use of the plantations. For the monitoring and generation of reliable databases it is requested to collect specific data like the harvested amount of biomass which is needed to calculate growth rates. This information is also required to estimate the development of the plantations.

The costs for the maintenance of the plantation average 30.000 Ariary or 9,24€ per hectare.

Since burning sites for the preparation of any kind of planting still is a key concept in Malagasy agriculture the protection form fire is important. Adding to this, Charbon Vert supports the farmers with knowledge that makes the event of an uncontrolled fire less likely.

As another important part for the operating aspect it has to be ensured, that the tree nurseries are kept productive for future planting actions.

Adding to the above mentioned costs there are 54.450 Ariary or 16,77€ for the technical support per hectare and 42.030 Ariary or 12,94€ for diverse other material needed for the plantation per hectare.

## 3. Local charcoal market

In the districts of Antsiranana I and Antsiranana II the livelihood of about 1900 people directly depends on the production, transportation and trading of charcoal. The annual demand for charcoal in the districts was calculated to be about 12000 tons with a value of around three billion Ariary (3*109) which equals 1,2 million Euro.

The supply chain for charcoal is differentiated into several jobs. From the plantation owners to illegal forest users and charcoal burners as well as local and regional transporters and wholesale, intermediate and retail traders.

Another positive effect of Charbon Vert is that more of these people are pushed into legality of their work by reducing or abandoning the use of illegal forest resources.

*Charcoal cost and price structure*

The popular way to sell charcoal in retail trade in Madagascar is in form of 12 kg bags. The price for such a bag was about 3000 Ariary which equals about 252 Ar/kg in 2007. Interestingly these prices do not seem to change while circumstances of wood and charcoal change. For example prices are constant even if the raw material for the charcoal may be of different quality or the distance of transport differs. It can be extracted from these facts that prices are held constant by changing profit margins of the traders.
The data presented in the following is typical for wood and charcoal from the formal sector, in this case from the afforested Charbon Vert sites. Other data is hardly collectible because there is no incentive for actors from the informal sector to provide business data since the wood may even be illegal. The prices display an annual median price which has been identified in the researches.

In this price structure it is assumed that the farmers organize the carbonization on their own. Considering this a price of 45,8 Ar/kg is ascertained. Another 15,8 Ar/kg are calculated for the local transport and an average of 4,2 Ar/kg is spent as expenditures and dividends to the municipality. These costs sum up to a total of 65,8 Ar/kg for the farmer. Fees for the operating licence could in this case not be raised because of a lack of transparency in the fee calculation.

Intermediate traders or collectors pay 145,8 Ar/kg which leaves a profit of 80 Ar/kg for the farmer by subtracting the former calculated cost of 65,8 Ar/kg.

The regional transport costs 25 Ar/kg while the resale price at specialist retailers in the city is 232 Ar/kg. This leaves an intermediate profit of 61,2 Ar/kg. Depending on the organization of the collecting and transport of charcoal this benefit

may even be split between collectors and wholesale trades. Anyways these relations differ in particular and do not show any regularity.
In the end a total profit of 20 Ar/kg is left for the retail traders in the city by subtracting the 232 Ar/kg from the 252 Ar/kg mentioned at the beginning.

*Cost and price structure analysis*

By analyzing the explored data interesting discoveries can be made. In comparison to the final sale price the profit for the farmer is relatively small totaling 32% considering that the majority of risks like the loss during the carbonization are carried by them.

The charcoal collectors have a big amount of the total profit of the branch while carrying only a small risk. In some cases they may even build an oligopoly and determine another purchase price from the farmers.

As the farmers carry out the work to produce the wood and the associated risks for the charcoal production it would be preferable to increase the profit margins for the foresters. Better organization amongst the farmers can strengthen their position towards the charcoal collectors and creating new sales places like rural markets create new possibilities. Another possibility is to avoid the collectors and sell the charcoal to wholesale or citizens directly in urban areas. This will even amount to higher profit but in most of the cases investments are to be made like buying a car or truck.

*Cost-Benefit-Analysis*

In the following the data that was observed and expected by the project will be analyzed. Therefore three different points of view will be taken into consideration to expose different qualities of the benefits and costs. The first part will be a classical cost-benefit analysis determining the costs and benefits for the project as a whole. In the second part the data will be adjusted to determine the costs and benefits from the farmers' point of view taking different conditions of the charcoal supply chain into account. Part three will analyse the project with a "with project" versus "without project" approach.

Values are all displayed in the Malagasy currency Ariary (Ar). For the conversion to Euro (€) the annual average for 2014 of 3247,15Ar/€ is taken. The first calculated value is the net present value (NPV). The NPV is the discounted sum of all cash inflows and cash outflows at an interest rate reflecting the risk of a project. It is a method for valuing capital investments. In general if the NPV is positive it is worth investing and not worth investing if it is negative [cp. MEGGINSON 2009].

To create comparability the NPV is calculated for two different interest rates of 8% and 10%.

The NPV calculated with an 8% and 10% interest rate are:

$$NPV(i = 8\%) = 409.959Ar = 126.52€ \quad (1)$$

$$NPV(i = 10\%) = 218.300Ar = 67.23€ \quad (2)$$

Multiplied by the whole project area of 6700ha the overall NPV's sum up to:

$$NPV(i = 8\%) \times 6700 = 2.746.722.778\,\text{Ar} = 845.887,25€$$
(3)

$$NVP(i = 10\%) \times 6700 = 1.462.612.763Ar = 450.429,69€$$
(4)

These total NPV's can be interpreted as the amount of money that would have to be invested at an 8% or 10% interest rate today to create the same revenue.

As both of the values are positive, the investment is considered as worthy in both cases.

For a more precise valuation the return of investment (ROI) is calculated. The ROI is a tool to relate the profit of a project to the total investments made to achieve that profit [cp. FRIEDLOB 1996]. To determine the ROI the total cost of 2.029.910Ar is calculated and then divided from the respective NPV.

$$ROI(i = 8\%) = \frac{NPV(i = 8\%)}{2.029.910Ar} = \frac{409.959Ar}{2.029.910Ar} = 20,19\%$$
(5)

$$ROI(i = 10\%) = \frac{NPV(i = 10\%)}{2.029.910Ar} = \frac{218.300Ar}{2.029.910Ar} = 10,75\%$$
(6)

The third calculated value is the benefit-cost ratio (B/C ratio). It sets a statement about the profitability of the project and can be interpreted as each Ariary spent in the project will achieve a benefit in the height of the B/C ratio[cp. TAPLIN 2005]. To calculate the B/C ratio the discounted benefit and discounted cost is needed.

$$\frac{B}{C} ratio(i = 8\%) = \frac{1.429.671Ar}{1.019.713Ar} = 1,4020 = 140,20\% \quad (7)$$

$$\frac{B}{C} ratio(i = 10\%) = \frac{1.131.739Ar}{913.439Ar} = 1,2390 = 123,90\% \quad (8)$$

The last calculated value for this part is the internal rate of return (IRR). The internal rate of return is the particular interest rate where discounted costs and discounted benefits show alignment. An investment is considered as profitable when the IRR is bigger than the interest rate used in the calculation [cp. HEESEN 2012].

$$IRR = 13\% \quad (9)$$

The second part is about the costs and benefits from the farmers' point of view. Different scenarios are chosen to create sound statements. In one scenario the price for a kilogram of charcoal is 252Ar, which is the market price in Diego, and 1600Ar per unit of pole wood. The second scenario is created with the market prices selling the charcoal and pole wood at the plantation site with revenue of 145,8Ar per kilogram charcoal and 1000Ar per unit pole wood.

NPV for 8% and 10% interest rate:

$$NPV(i=8\%)=932.208Ar=287{,}85€ \quad (10)$$

$$NPV(i=10\%)=725.560Ar=223{,}45€ \quad (11)$$

For the whole project area (6700ha):

$$NPV(i=8\%)\times 6700=6.245.795.438Ar=1.923.469{,}95€$$
(12)

$$NVP(i=10\%)\times 6700=4.861.253.969Ar=1.497.083{,}28€$$
(13)

The total cost to determine the ROI is 1.417.478Ar:

$$ROI(i=8\%)=\frac{NVP(i=8\%)}{1.417.478Ar}=\frac{932.208Ar}{1.417.478Ar}=65.76\%$$
(14)

$$ROI(i=10\%)=\frac{NVP(i=10\%)}{1.417.478Ar}=\frac{725.560Ar}{1.417.478Ar}=51.19\%$$
(15)

$$B/C\ ratio(i=8\%)=\frac{1.429.671Ar}{497.464Ar}=2{,}8739=287{,}39\%$$
(16)

$$B/C\ ratio(i=10\%)=\frac{1.131.739Ar}{406.179Ar}=2{,}7863=278{,}63\%$$
(17)

$$IRR=53\% \quad (18)$$

Besides the above mentioned changed revenue per kilogram charcoal and per unit pole wood, the selling on the site comes with a change in the cost structure. The transport cost per bag of charcoal decreases from 492Ar to 192Ar due to the regional transport cost of 300Ar per bag disappearing.

$$NPV(i=8\%)=668.469Ar=205{,}86€ \quad (19)$$

$$NVP(i=10\%)=516.782Ar=159{,}15€ \quad (20)$$

For the whole project area:

$$NVP(i=8\%)\times 6700=4.478.744.409Ar=1.379.284{,}73€$$
(21)

$$NPV(i=10\%)\times 6700=3.462.442.115Ar=1.066.301.87€$$
(22)

The total cost to determine the ROI is 1.135.238Ar:

$$ROI(i=8\%)=\frac{NPV(i=8\%)}{1.135.238Ar}=\frac{668.469Ar}{1.135.238Ar}=58{,}88\%$$
(23)

$$ROI(i=10\%)=\frac{NPV(i=10\%)}{1.135.238Ar}=\frac{516.782Ar}{1.135.238Ar}=45{,}52\%$$
(24)

$$B/C\ ratio(i=8\%)=\frac{1.076.078Ar}{407.609Ar}=2{,}6400=264{,}00\%$$
(25)

$$B/C\ ratio(i=10\%)=\frac{851.832Ar}{335.050Ar}=2{,}5424=254{,}24\%$$
(26)

$$IRR=45\% \quad (27)$$

For the "with project" versus "without project" approach the chosen method is to create a calculation for the damage cost avoided. Therefore the $CO_2$ sequestered by the project is calculated.

$$\frac{192m^3\times 0{,}7\times 0{,}725\times 0{,}5\times 3{,}6663=178{,}622t\ CO_2/ha}{27a}$$
(28)

$$\frac{178{,}622\div 27a=6{,}616t\ CO_2/ha}{a} \quad (29)$$

With the so called "back-loading" resolution decided by the EU-Commission in early 2014 the overall number of allowed $CO_2$-Certificates to be traded were reduced by 900 million until 2019-2020 [EUROPEAN COMMISSION 2012]. This increased the price for $CO_2$-Certificates. Taking the data from the stock market the average price, from 1.Febuary 2014 to 30.September 2014, for one ton of $CO_2$ is 5,89€.

$$6{,}616t\ \frac{CO_2/ha}{a}\times 5{,}89€=\frac{38{,}9682€/ha}{a}=126.535{,}7Ar$$
(30)

$$NPV(i=8\%)=1.793.651Ar=552{,}38€ \quad (31)$$

$$NPV(i=10\%)=1.387.142Ar=427{,}19€ \quad (32)$$

For the whole project area:

$$NPV(i=8\%)\times 6700=12.017.459.241Ar=3.700.925{,}19€$$
(33)

$$NPV(i=10\%)\times 6700=9.292.849.267Ar=2.862.155{,}82€$$
(34)

$$IRR=37\% \quad (35)$$

As the last part of this section the average annual surplus per capita is calculated from the total surplus (Income – costs) and then compared to the GDP per capita (GDPPC) of Madagascar. The GDPPC equals 354€ [IMF 2014] and is taken from the International Monetary Fund (IMF). This turns out in the following values displaying the percentage of the income to the GDPPC

$$Scenario1=20\%, Scenario2=25\%, Scenario3=16\%, Scenario4=49\%$$
(36)

The data that is built up in the in this section is analyzed critically in the following section.

*Results*

The economic analysis of the first scenario reflecting the project with all the participating parties shows that it performs well overall. With an internal rate of return of 13% it would still be profitable if the interest rate would rise from 8% to 10%. The assumption of a 10% interest rate on the other hand does definitely decrease the viability of the project, nearly halving the NPV and ROI compared to an 8% interest rate. Having the NPV calculated for the total project area of 6700ha gives a good outlook on how good the project can totally perform with 845.887€ for a 8% interest rate or 450.430€ for a 10% interest rate. Both of the B/C ratios would be considered as inviting for investors. Looking at the second scenario a major shift is recognized. What could have been expected because a big part of the investment costs was eliminated turns out very positive anyway. Total NPV's of 1.923.470€ for 8% interest rate and 1.497.083€ for 10% interest rate are stand-alone statements from the farmers point of view. Outstanding B/C ratios of 287% and 279% underline this. Interestingly the impact of the interest rates is smaller in this scenario due to smaller start off investments.

While the IRR develops over the full time of the project in scenario one, in scenario two the final IRR of 53% is almost reached after the first rotation after seven years (IRR in scenario one after 7 years: 2% ; IRR after 7 year in scenario two: 50%).

In scenario three the reduction of income is about 25%. As the costs decrease by 20% as well the total reduction of efficiency is at around 5%. For the worst commonly expectable scenario this does not seem too bad. Total NPV's of 1.379.285€ for 8% interest rate and 1.066.302€ for 10% interest rate are still decent. Even if the monetary efficiency decreases by around 5%, the IRR decreases by 8% to 45% in total. Putting this into context, assuming that scenario two is just very strong, the B/C ratios of 264% and 254% still promise good revenues.

While scenario two and three changed the perspective to the farmers' one, the "with project" versus "without project approach turns it back to the economy as a whole. For the further understanding the exact method will be explained. As the biomass from the plantations will be converted to charcoal to be burned it is self suggesting, that suspicion about the long-term sequestration of $CO_2$ will be uttered. This is where the thought of damage prevention comes into play. The $CO_2$ from the plantations may not be sequestered for long itself, but it is assumable, that the same amount of sequestered $CO_2$ may therefore "survive" on another site. The charcoal from the projects plantations can thus be interpreted as a substitute. Taking this to account the scenario without the project is said to emit the amount of $CO_2$ sequestered by the projects plantations. As the degraded acreages are suspected not to have other accountable incomes, they end up only costing in this calculation. This might seem exaggerated, but in actual fact the degraded soils would neither be able to sequestrate nor to balance the $CO_2$ household. Actually degraded soils lose their soil organic carbon (SOC) and thereby emit $CO_2$ [WMO 2005]. Though the calculation understates this fact due to lack of data, the results created without are already remarkable.

With NPV's for the total project area of 3.700.925€ at 8% interest rate and 2.862.156€ at 10% interest rate the value enhancement is between 4,5 to 6,5 times compared to scenario one. The previous IRR of 13% rises by 24% to 37% which underlines the effect on the determined effectivity.

*Discussion*

The analysis showed, that from an economical point of view, the project is worth being undertaken in every of the chosen scenarios. Even if the avoided cost method does not directly favor anyone monetarily, it prevents damage to society as a whole and directly increases the viability of the project for decision-making which can be derived from this particular case.

Beside the direct effect of the damage avoided indicated in this analysis it has to be considered that the avoided damage also relieves the pressure on the natural forests, being a habitat for plenty endemic species and consisting of endemic species itself, which has a value for society and mankind as a whole. Even though this value is difficult to assess it should be considered to be very high due to its uniqueness. Part of it could though be determined by a cost-benefit analysis using travel cost methods.

Planting eucalyptus plantations has always been discussed critically. General concerns are [cp. REJMÁNEK 2011]:

- Excessive use of water and groundwater
- Suppression of ground vegetation that may result in erosion
- Fire hazard
- Poor wildlife value

The total annual evapotranspiration of E. camaldulensis in the equatorial zone averages up to 1150mm [cp. NAMBIAR 1998]. With the assumed 1200mm/m²/a precipitation for the plantation areas, this points out that the water usage will strongly increase at the sites but a critical change in groundwater has not yet been detected.

Suppression of ground vegetation has been detected in recent surveys. Due to the small biodiversity on the sites prior to planting this can be interpreted either way. In general the used planting matrix seems to not influence the common vegetation in undergrowth as bad as other close structured eucalyptus plantations would do.

Taking fire hazard serious in populations of E. camaldulensis is important. As the species lacks of fire protective lignotubers it is essential to clear the produced litter from the plantations frequently [cp. POORE 1985]. Actually creating awareness and a change in mind about fire hazards and interest for farmers to protect their plantations may have decreased fire impact in the region. If so, this is an achievement from educational methods and not from the plantations itself.

As the savannah vegetation is slightly influenced by the plantations and no species have been recorded to occupy the new ecological niche this point can be interpreted as negative.

*Conclusion*

The global pressure on natural resources is growing due to higher demand for energy and energetic material especially in developing countries. To address the problems arising from this the demand for highly effective and simultaneously sustainable programs and developments is huge. To find mechanisms on a large scale that are free from criticism and contrary beliefs to some parts, tends to be very difficult. The integrative design of the Charbon Vert project sustainably creates awareness of new challenges the local people have to deal with. Sustainability hereby is an important part of the coaching. The fact that the project decreases the pressure on a unique biodiversity is a very special part towards the whole consideration. Even if the project would be less productive it could be considered as worth undertaking under this aspect. In reality there is no reason to believe in a decreasing productivity of the project at the current state. Instead the chances for improvements of the project are numerous not only including different monetary chances, like ameliorated charcoal piles and improved stoves, but also combined chances, when talking about possible tax layers on non-certified charcoal that would lead to improved income and increased political righteousness by the decimation of illegal acts. Besides those aspects the educational aspect and building of local authorities are the important social benefits while one social chance is the attraction of people working in the informal sector and guiding them into legality.

Sustainability plays an important role in the education at the University of Hamburg and especially in Wood Science and Technology. With this background the negative aspects of a monoculture could be decreased by adding other tree species leading to better biodiversity and increased cultural and economic value.

In the end the water use intensity should not be forgotten but the productivity of eucalyptus should be taken into consideration because it makes the relative decrease in pressure on the unique biodiversity even bigger.

## References

1. Louppe, D. et Al.: Plant Resources of Tropical Africa 7(1): Timbers 1 – Prota Foundation, Backhuys Publishers, CTA, Wageningen 2008
2. Megginson, W., Smart, S.: Introduction to Corporate Finance; page 335 – South-Western, a part of Cengage Learning, Mason 2009
3. Friedlob, G., Plewa, F.: Understanding Return of Investment; page 6 – Wiley & Sons, Inc, New York 1996
4. Taplin, J. et Al.: Cost-benefit Analysis and Evolutionary Computing: Optimal Scheduling of Interactive Road Projects; page 155 – Edward Elgar Publishing Limited, Cheltenham 2005
5. Heesen, B.: Investment for practitioners; page 58f – Springer Gabler, Wiesbaden 2012
6. European Commission: Commission Staff Working Document Proportionate Impact Assessment; page 20 – Brussels 2012
7. International Monetary Fund: World Economic Outlook Database 2014, Internet: http://www.imf.org/external/pubs/ft/weo/2014/01/weodata/weoseladv.aspx?a=&c=674&s=NGDPDPC. Retrieved 02.10.2014
8. World Meteorological Organization: Climate and Land Degradation; page 27 – Geneva 2005
9. Rejmánek, M., Richardson, D.: Encyclopedia of Biological Invasions; page 203ff – Berkeley and Los Angeles: University of California 2011
10. Nambiar, E., Cossalter, C., Tiarks, A.: Site Management and Productivity in Tropical Plantation Forests; page 16 – CIFOR Workshop, Pietermaritzburg 1998
11. Poore, M., Fries, C.: The ecological effects of eucalyptus; page 20 - FAO Paper, Rome 1985

# Funding Projects in Greece

**by**

**Konstantinos VENETSANOS**
National Bank of Greece S.A.

**7th International Scientific Conference on Energy and Climate Change**

**FUNDING PROJECTS IN GREECE**

**NATIONAL BANK OF GREECE S.A.**

**Konstantinos Venetsanos**
**Project Finance Division**

**Athens, 10 October 2014**

**The risk profile of projects has changed due to:**

- Decrease in project revenues due to the economic crisis,
- Unable to form reliable forecasts,
- Debt crisis has serious impact on government obligations (expropriations, VAT refunds, payments of compensation, etc.).

## New terms of funding

- Banks' requirements have become more conservative,
- Increased investor participation (from 20% to 40% -50% of project budget),
- Shorter loan tenors (Mini Perm),
- Cash Sweep mechanisms,
- Increased guarantees and securities (government and / or corporate),
- Increased margins as a result of the increase of funding costs for the Banks.

## Critical factors for the banking sector

- Upgrade creditworthiness Greek banks,
- Positive GDP growth rates,
- Reduced growth rate of non-performing loans.

## Infrastructure projects in Greece

Significant to the economic activity are Infrastructure Projects

- New technology Thermal Power Plants reducing $CO_2$ emission
- New motorways that reduce travel time and distance
  - Successful projects' restart in December 2013,
  - Accelerated payment procedures (expropriation, VAT refunds, payments of compensation, etc..),
  - Multiplier effects on the economy, particularly at regional level,
  - Increase confidence of foreign investors and banks to participate in new projects.

## Waste management projects

- NBG is involved in the financing of almost all waste managed projects in Greece,

| Western Macedonia | tpa | 120,000 | Total cost | € 45 mio |
|---|---|---|---|---|
| Serres | tpa | 60,000 | » | € 33 mio |
| Ilia | tpa | 63,000 | » | € 37 mio |
| Financial needs for all of them ≈ € 60 mio | | | | |

## Financing renewable energy projects

*NBG Group data as at 31/12/2013*

| (amounts in millions. €) | Power (MW) | Cost of investment | Approved lending |
|---|---|---|---|
| Photovoltaic Parks | 100 | 258 | 200 |
| Windfarms | 931 | 1.228 | 698 |
| Small Hydro Plants | 31 | 52 | 37 |
| Biogas | 23 | 35 | 18 |
| **Total** | **1.085** | **1.573** | **953** |

7

## Public Private Partnership (PPP) Projects

- NBG is actively financing :
  - Mainly in the field of waste management - schools - telematics
    - During the second quarter of 2014, contracts were signed for two PPP schools (22 schools in total) in Attica (participation and program JESSICA),
    - Telematics Project (signed 30/6/2014).
  - Increased participation of EIB after successful recapitalization of Greek Banks

*These projects contribute to environmental sustainability*

8

### PPPs challenges

| CHALLENGES | ACTIONS |
|---|---|
| • Increase in cost of risk for private investors,<br>• Increase in financial cost of the project due to pricing of credit risk by banks,<br>• Available funds need to be directed towards creditworthy projects,<br>• Requirements for binding banking letters of support. | • Encouraging competition between the private entities,<br>• participation of EIB,<br>• Increase in Equity requirements,<br>• Club Deals (syndicated loans),<br>• Escape clauses,<br>• Renegotiation clauses. |

The relatively small size of the Greek PPPs is an advantage in the current situation

9

### European programme JESSICA

- Joint European Support relating to Sustainable Investment in Urban Areas,
- Initiative of the European Commission (DG Regional Policy) in cooperation with the EIB in order to promote sustainable investment in urban areas,
- The financing of urban development is through the "conversion of subsidies" to a funding mechanism "refundable grants",
- The initiative provides for the establishment of Urban Development Funds (UDF), which will be responsible for implementing the program through the JESSICA Holding Fund,
- To Holding Fund is a fund of funds, managed by the EIB, which is established for the investment of resources in Urban Development Funds,

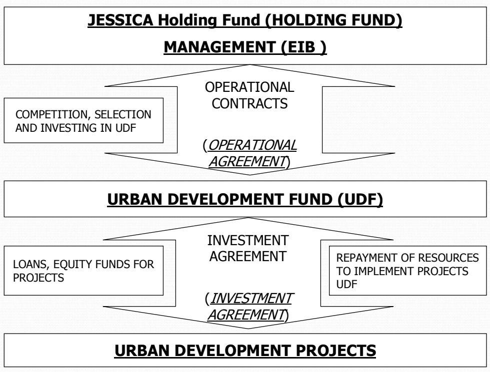
10

### European programme JESSICA

- Enhanced mobility of capital for urban development and PPP focusing on sustainability and environmental friendly solutions,
- Incorporating the experience of international financial institutions such as the EIB,
- NBG participates in the programme acting as Manager of Urban Development (UDF) for the regions of Attica, Western Greece, Ionian Islands, as well as projects of the Operational Programme "Environment and Sustainable Development" (EPPERAA),

11

### JESSICA 'S STRUCTURE IMPLEMENTATION




12

**European programme JESSICA**

**Indicative areas of interest :**

- Urban infrastructure (parking facilities and green areas),
- Urban rejuvenation (refurbishment of buildings),
- Public Networks (transport, water, sanitation, energy),
- Health / education (hospitals, rehabilitation centers, etc.).

13

**An example of project within the scope of Jessica:**

**Municipality of *Alexandroupolis' Energy Saving Project***

Regarding the contribution of Jessica for the implementation of energy saving project, Municipality of Alexandroupolis is willing to realise the following project in the context of Jessica initiative.

- Project budget of € 2,33 million
  - Installing photovoltaic cells in 16 schools for producing electricity from RES,
  - Replacing 2,028 lighting street lighting system throughout the city of Alexandroupolis type LED luminaires,
  - 7 Supply of electric vehicles for use by the municipal services,
- Phase 1 for eligibility has been completed.

14

*Thank you !*

**NATIONAL BANK OF GREECE SA**
**Project Finance Division**
**128-132 Athinon Avenue, GR104 42**
**Tel. : +30210 51 81 384**
**Fax : +30210 51 81 400**
**Email: kvenetsan@nbg.gr**

15

*Executive Sustainability Training*

# SUPER

## At a Glance

**Title**: **SU**stainability **P**olicy and practice: An **E**xecutive **R**e-training program (SUPER)

**Funding mechanism: Attendance Fees; Sponsors**

**Duration:** From one or more 1-week seminars to a full Master program

**Start Date:** June 2015 (see website)

**Consortium:** Run by a 13-member Board

**Project Coordinator:** NTUA (GR)

**Project Web Site:** http://super.chemeng.ntua.gr/

**Key Words:** sustainability; policy; practice; executive; re-training; Greek islands

## Scope & Objectives

1. Providing Leadership: "Sustainability" is on the agenda. It is becoming an integral part of the long-term planning of both developed and newly developing economies. New approaches for incorporating "sustainable" strategies are emerging from both government policy and business practices. Learning about, and applying, the best of these will give a competitive and early advantage to those who adopt and incorporate them. Also, sustainability enhances the financial performance of companies. It will be these leaders in business and government and community that will lead us all into a sustainable future.

2. Educating for Action: Faculty from the National Technical University of Athens (NTUA), Greece, in collaboration with a group of distinguished international experts, are offering a focused executive course of study that will bring together business managers, policy makers and leaders from the government, non-government and business communities, and prepare them to work together to align business, government and community policy and practice toward creating a more sustainable future.

3. Following a New Concept: This unique executive level graduate program will provide nine weeks of intensive study over a two year period. For three weeks each summer, over two consecutive years, participants will engage in a course of study that will culminate in an Executive Masters of Science Degree in Sustainability Policy and Practice.

4. Combining Business & Pleasure: Each summer's course of study will take place at a selected Greek venue, typically a Greek island, where the learning will be integrated with issues related to the study site. This design will afford the students and the host site the opportunity to experience real-world challenges and explore and apply solutions to those challenges. Each summer segment will consist of three courses and incorporate a project related to the courses and specifically designed for the benefit of the venue.

## Methodology

**1. Description of Program:** The program will consist of a total of nine courses, to be offered in 3 consecutive summers, with each course delivered each week, over six days (Monday – Saturday). Additional time will be allowed for project work. The 3 courses in each of the summer sessions will be aligned to issues of sustainability that are important to the venue. Two weekend discussion groups and a resolution session at the close of each of the summer programs will connect the course learning to the sustainability issues that are specific to the venue. Group projects may be allowed to be completed virtually after the summer session ends.

Students are able to take any one, two of all three of the one-week courses offered each year, i.e., take courses according to their specific interests or all courses towards a degree, which will require a minimum of three summer teaching periods plus the project during the first two summer sessions.

**2. Learning in Living Laboratories: Islands:** An experimental design often requires the study of independent or dependent variables unaffected by factors not included in the experimental design. In the case of an experiment on some environmental issue in the real world, it is often difficult to isolate the problem from surrounding parameters. One way to accomplish this feat is to test the experiment on an *island*.

## PROGRAM CONTENTS

**1. The Three Themes of Sustainability:**

(A) Definition, Policy and Strategy: 1. Industrial Ecology; 2. Business Strategy; 3. Corporate Reporting and Metrics ;

(B) Energy and Climate Change: 1. Energy Management; 2. Energy, Environment and Economics; 3. Carbon Management & Climate Change.

(C) Critical Resource Management and Restoration: 1. Water, Air & Soil Policy and Management; 2. Integrated Sustainable Communities; 3. Environment and Economics.

9. **Applied Learning: Executive Projects:** Projects, where participating executives can practice on the course contents, may be as follows: i) STRATEGIC THINKING: Develop a strategy that will identify existing or newly developed local business models that might operate competitively while being sustainable. Local businesses may be able to adopt the strategy, allowing the students to measure results in future years. ii) ACTION ORIENTED: Develop and apply changes to local utility policy and practices that can make it operate more efficiently, cleaner, carbon neutral, etc….iii) INTEGRATED SOLUTIONS: Develop a policy and practice model for more efficient use of local resources, e.g., replenishment of water, while serving the needs of the local culture.

| BOARD MEMBERS | **Country** |
|---|---|
| ***Program Directors*** | |
| **Koukios, Emmanuel**: Director of the Organic Tech Lab, NTUA | Greece |
| **Nassos, George**: Principal, George P. Nassos & Associates, Inc. | United States |
| ***Members*** | |
| **Angelidaki, Irini**: Department of Environmental Engineering, Technical University, Copenhagen | Denmark |
| **Agrafiotis, Demosthenes**: Professor Emeritus of Sociology, National School of Public Health, Athens | Greece |
| **Assimacopoulos, Dionysis**; Professor of Environmental and Energy Management, School of Chemical Engineering, NTUA | Greece |
| **Economidis, Ioannis**: PhD, former European Commission Senior Officer, DG Research, KBBE (Knowledge-Based BioEconomy) Program, Brussels | Belgium |
| **Langert, Bob**: Senior Vice President for Corporate Responsibility, McDonald's Company | United States |
| **Meissen, Ronald**: Senior Director Sustainability, Baxter International Inc. | United States |
| **Monteleone, Massimo**: Professor of Agronomy; Director, STAR AgroEnergy Project, University of Foggia | Italy |
| **Moropoulou, Antonia**: Professor of Material Science & Engineering, School of Chemical Engineering, NTUA | Greece |
| **Pallios, Vassilis**: PhD, Vice President, Business Mobility Solutions, GLOBO PLC | Greece |
| **Rakos, Christian**: PhD, President, European Pellet Industries Association, Vienna | Austria |
| **Samartzis, Jimmy**: Managing Director, Global Environmental Affairs and Sustainability, United Airlines | United States |