4TH INTERNATIONAL SCIENTIFIC CONFERENCE

Energy and Climate Change

Athens - 2011

PROCEEDINGS

Opening

Prof. Theodosios PELEGRINIS

Rector of National and Kapodistrian University of Athens, Hellas

Excellencies, Dear colleagues,

As rector of the oldest Greek university, I cordially welcome you at this old building where our University was initially founded on May 3rd 1837. It is now a museum of our history and you are welcome to visit its halls.

I feel sorry for not been able to be with you today due to an extraordinary meeting of the Senate that takes place at the same time at the central building.

I welcome you to this 4th annual international scientific conference that aims to contribute to the common international effort to build scientific capacity that will allow our societies to confront the Climate Change challenge.

With no doubt, we live in a period of great challenges.

Climate Change, global economic crisis, overpopulation, poverty, starvation, racism, fundamentalism, terrorism, overconcentration in the mega-cities and concentration of the global wealth to very few people, constitutes the gradients of an explosive mixture that threats and dissolves the system and the values of our societies.

The world population has reached the seven billions while millions of people are migrating from your countries in search of a better life and mega cities like Tokyo, London and Istanbul gather population with figures exceeding 35, 20, 15 billions.

We live in a period with tremendous needs in energy demand. There can not be life in those megacities and in our economies without energy and at the same time we have to reduce the green house gas emotions.

In less than a century, we have transformed our economies to almost totally depend by hydrocarbons and in doing so we neglected the environmental repercussions of such use.

We now understand that this is a direct threat for our survival, not for the planet earth. If we destroy the environment where the human life exists we will be vanished the same way dinosaurs were vanished from earth.

The planet earth will continue orbiting around the sun and without the human race on it.

Confronting, the Climate Change challenge continues to be an urgent task even during these period of world economic crisis und social uncertainty. It is a task that we should carry out for our families conscious that no time margins exist for any delays or hesitations.

Of course we are aware of the argument that the rich countries should undertake the cost of this battle and although there is a solid logical ground on it, we should not forget that negative repercussions are more severe for the poor and less developed economies. With no doubt this is a common challenge for all human kind and we have all of us to be committed to confront it through common action.

As scholars and scientists, we have to understand it and work together through research and knowledge transfer to propose the best solutions and practices to our societies.

In this context, I welcome you in this Conference and allow me to congratulate the PROMITHEASnet, the Energy Policy and Development Centre of our University and especially Prof. Dimitrios Mavrakis for their devotion to this effort.

I am pleased to see the continuous expanding of your network and I support your efforts to upgrade it and enhance the bonds of cooperation between Europe, Black Sea and central Asia.

I wish all of you every scientific success in your work and I would be happy to welcome you here next year for the 5th International Conference.

Prof. Dimitrios MAVRAKIS

Director of KEPA

Coordinator of PROMITHEASnet

Excellencies, Dear Colleagues,

It is my honor and pleasure to welcome you to the 4th Annual International Conference on "Energy and Climate Change Policy", organized by PROMITHEASnet under the Aegis of the Russian Chairmanship of BSEC.

The Conference is structured to three (3) Sessions covering Energy, Environment and Renewable Energy Sources.

A total number of ninety (90) abstracts were submitted for presentation. All abstracts were peer-viewed by two members of the Scientific Committee, consisted of Professors of PROMITHEASnet. Thirty nine (39) of them were rejected and eleven (11) of them were re-written, while the remaining fifty one (51) were accepted after revision. Finally a number of twenty seven (27) have been included in the present agenda.

The aforementioned figures reflects both our continuous effort to upgrade the quality of the Conference with a 43% rate of rejection but also the economic uncertainties and difficulties for our colleagues to cover the expenses of their participation, since only 48% of the approved papers will be presented and discussed.

As you know our network, thanks to the support of Prof. Elmira Ramazanova from the Scientific Research Institute of Geotechnological Problems of Oil, Gas and Chemistry of Azerbaijan, publishes the bilingual "Euro-Asian Journal of sustainable energy development policy". We are now in the process of adding its electronic circulation in order to increase its dissemination capacity.

Papers that will be presented in this Conference are welcome for publication after peer –viewed to our Journal.

Further to that our PROMITHEASnet newsletter which is circulated worldwide to almost one hundred seventy (170) countries with more than twenty three thousands (23.000) recipients will be also used to facilitate the dissemination of the book of abstracts and of the papers that will be finally approved for publication.

As we have announced last year, fourteen (14) academic institutions from the broad area of Black Sea and Central Asia participate in the PROMITHEAS – 4, EU-FP7 project. It is a multidimensional effort which under the title *"Knowledge transfer and research needs for preparing mitigation/adaptation policy portfolios"* and in close cooperation with the BSEC countries and the substantial support of the PERMIS of BSEC aims to provide to the governments of the beneficiary countries the opportunity to develop and evaluate policy portfolio mixtures concerning Adaptation and Mitigation.

Thanks to the continuous support of their Excellencies, the Secretary General and Deputy Secretary General, Amb. Leonidas Chrysanthopoulos and Amb. Traian Chebeleu we have established a continuous bi-directional flow of information with all BSEC ministries concerning the produced reports of the project.

In this context, I take the opportunity to express my sincere gratitude to Amb Chrysanthopoulos and the members of PERMIS for their kind and continuous support to our efforts to increase the level and the quality of regional cooperation in the fields of "Energy and Climate Change Policy".

Further to that I would like to announce that next 5th Conference will have a special session devoted to the formation of Adaptation /Mitigation policy mixtures with emphasis on the research outcomes in our region.

We are in the process of defining efficient and coherent policies with other regions like those of Europe and Asia and it is our duty to search and find scientific ways facilitating decision makers to recognize best practices and develop optimum policies.

Indeed we do favor regionally developed multilateral activities based on cooperation between academia and business. It is a tough and difficult task since prerequisites the combination of the appropriate knowledge transfer to local stakeholders and their decision to get involved in an almost unknown and risky area of business.

We have started a systematic effort through the edition of the "Energy View of BSEC Countries" and a number of initiatives that aim to establish a resulting so called "Green Alliance". Apart from initial discussions and acceptance in principle of the proposed cooperation with the market forces the fact of pure results remains as the only reality, at regional level. On the other hand the ongoing discussions on the post – Kyoto mechanisms and the urgent need to develop additional mechanisms and tools to handle global importance phenomena allows us to be optimistic about new synergies in these sectors in the near future.

Ladies and gentlemen,

I cordially welcome to this forth international conference under the hill of Acropolis, in this special place where Athena, the goddess of wisdom has had Parthenon the most famous of her temples and allow me to invite Amb. Chrysanthopoulos to take the floor in his capacity of Secretary General Of the Permanent Secretariat of BSEC and a sincere friend and supporter of the regional scientific cooperation.

Amb. Leonidas CHRYSANTHOPOULOS

Secretary General of PERMIS – BSEC

Ladies and Gentlemen,

I am honoured to have again the opportunity to participate at the *Conference on Energy and Climate Change* and would like to congratulate the network partners and to thank our host, the University of Athens and personally Professor Dimitris Mavrakis for their excellent organization and warm hospitality.

Since it started in 2008, this conference has gained momentum in the scientific, academic and political world and has developed into being one of the best stablished discussion fora in the Black Sea Region for this topic.

We are discussing here two different and still interrelated topics, both of which are of vital importance for the future of our region, our people and the planet itself. Energy and Climate Change. Though one is not the cause or the result of the other, they are both subjects we need to find sustainable solutions for if we want planet Earth to continue to be as hospitable as it has been for the last 15 years. Of course, this is a global challenge. But with this conference we have a regional tool of getting started, here and now, with what we in the Black Sea Region can contribute.

Currently we are facing the first effects of a climate change. To what degree our current lifestyle has contributed to this climate change is still under discussion. Pollution, as a direct result of energy over-consumption, is certainly not good for the present time nor for a sustainable future, but whether this and our industrial use of energy are the main or even only causes of climate change is uncertain. I personally therefore prefer to deal with both of them as independent, yet concurrent, subjects.

We often think about climate change from a perspective that it is our human behaviour that created it in the first place and that it is us who can eventually change it, reverse it and thus control it. Fact is, that our earth has been undergoing climatic changes all through its existence and unti1 today it was always nature which adapted to the changes and not vice-versa. This has resulted in the loss of species as well as in the evolution and creation of new ones and certainly will do so in the future.

The question is not how we can change, stop, or reverse the climate change. It is rather, how we are going to cope with it. How is it going to influence our economic and social life? What are we going to do in order to adapt and re-arrange according to the necessities new and changed environmental conditions will force upon us. And how can we consciously avoid to further contribute to climate change by unsustainable behaviour, also and especially in the energy consuming sector.

This means that we will have to monitor, estimate and forecast how these climate changes will affect nature and what that means for the species living or growing on it. Will there be a desertification - and where? How can we guarantee a sustainable future for those people now living in these areas? There will be migration streams. Where will they be going to and how could we guide them towards a real future? Which species will have to be re-settled or preserved for biodiversity reasons and where and how should this take place? With the reshaping of the surface of this globe new areas will open up like and appear and others will be of less or different importance. Is the ice in the poles going to melt? And if yes, are we going to deal with this suddenly new and additional space? At the moment it can be both, a natural resort or a natural resource.

Energy and climate change have their touchpoints. Energy is a factor which we can influence or control as much as we can control and influence climate change. Our way of living has developed to a style that we cannot forego energy. We cannot do without it because everything we use, eat and do, needs artificial energy to be produced, grown, manufactured, distributed, consumed or just simply function. This has lead to the situation that we attribute more importance
on the exploitation of energy than we do on the sustainability of earth and its passengers.

The Black Sea Region is right in the middle of this challenge. It is a very important geo-strategic energy partner because of its abundant reserves of hydrocarbons, the production of energy from fossil fuels aήd the role of the region as a unique energy transit corridor, bridging the energy routes :from east to west and north to south. At BSEC we have to foster our role as this energy partner, but also to safeguard our region from the negative effects of this energy commerce in order to maintain a hospitable area for its people. We also need to assess and evaluate of how the climate change will affect the face of our region and what influence that might have on our role as energy supplier. And, last not least, we have to keep in mind that this source of income and our role as energy supplier will diminish in the same relation as the resources are drying up. And we need to develop and have alternatives ready for maintaining an economically and socially healthy condition in our

Member States once that point has been reached.

Equally important is the assessment of what the climate change and the decreasing availability of fossil energy will mean to aspects of life such as agriculture, food, housing, clothing, industry, transport, heath, migration, poverty and last not least employment. Problems include the ever growing arid lands, the desertification, the deforestation, the socio-poverty that comes with ecosystem imbalances, the increasing migration of the most unfortunate peoples on the planet, the increasingly greedy consumer society and the overall socially and environmentally irresponsible prevailing model for economic growth. Here it becomes clear that the topics climate change and energy need a cross-sectoral approach both as an intertwined challenge and as independent questions.

Within BSEC we have been approaching these topics in various of our activities.

BSEC contributed for the first time to the **UN Framework Convention on Climate Change** negotiations that took place in Cancun.

The Council of Ministers of Foreign Affairs of BSEC in their meeting in Thessaloniki on 26 November 2010 adopted a **Joint Declaration on Combating Climate Change in the Wider Black Sea Area**. This Joint Declaration has been adopted to set a clear sign of the BSEC common effort to create a sustainable future on our planet for generations to come. The planet can survive without humanity but not vice versa. By imposing pollution taxes, pollution will not disappear. The planet does not function according to our economic strategies. Earth does not accept money to become clean. It is us, the passengers, who must do it, without taking into account economic considerations.

In June 2011, the BSEC Ministers of Foreign Affairs in Bucharest decided that a **Green Energy Development Task Force be established, within the BSEC Working Group** on **Energy.** Human greed has exhausted in a split second of astronomical history, the energy savings of billions of years of energy conservation made by our planet. Consequently we must start immediately operating on our vast daily energy income from the sun, wind, tide and water. And since we cannot produce solar cells and high-tech turbines without oil and since we cannot continue growing petrol on our fields instead of food, it is imperative to give emphasis on research for new technologies and alternatives.

BSEC and UNDP started working on a new joint project entitled **"Introducing Climate Change** in **the Environmental Strategy for the Protection of the Black** Sea", which will be financed by Austria and by the BSEC Project Development Fund. But there is more to be done. For an active monitoring and forecasting of climate change effects as well as for the development of energy alternatives we need an effective information exchange between the BSEC Member States.

BSEC supports regional projects that promote sustainable energy development. The Organization is able to finance projects in renewable energy sources and energy efficiency either through the **BSEC Project Development Fund** or the **BSEC Hellenic Development Fund** which has recently approved six regional projects and will provide to them grants of 400,000 Euros.

As far as training is concerned, BSEC is trying to promote energy conservation practices and it recently co-organized an **Energy Efficiency Workshop** with JICA of Japan and the Turkish energy authorities. In reference to other sectors of ~he economy, BSEC is currently studying ways to suggest to our Member States new economic directions adjusted to the challenges of climate change. For this reason, we are currently implementing in three BSEC countries a pilot project on **Green Economy** with the financial and technical assistance of the German Agency GTZ.

If it comes to the cross-sectoral approach we have just recently started with a Meeting of the Ministers of Agriculture of the 12 BSEC Member States, which adopted a Joint Declaration anticipating closer cooperation among the BSEC Member States for national genetic resources of plants in order to secure biodiversity and thus mitigating the effects of climate change.

Of course, fostering dialogue does not produce results overnight. This can only be done by s cultural transformation that will put the life of earth and its passengers into focus. And we all need towork for this - scientists, politicians, leaders, politicians and we, the people.

Thank you for your attention.

Amb. Vladimir CHKHIKVISHVILI
Ambassador of the Russian Federation in the Hellenic Republic

Dear Ladies and Gentlemen,

On behalf of the Embassy of the Russian Federation in Greece I would like to welcome you to this conference. It is a special pleasure for me due to the current Chairmanship of the Russian Federation in the Organisation of the Black Sea Economic Cooperation.

The problem of interconnection of the energy sector and the climate change is very important and many-sided. It is the solution of this problem, which will define our future on the planet Earth. Therefore it comes as no surprise that this issue is considered very thoroughly in the development strategies of practically all world powers, including Russia. This problem is discussed during many important international meetings. The solution is sought both internationally and bilaterally. In particular, few years ago a seminar on cooperation in the field of renewable energy sources use was organized in the framework of the Russian-Greek scientific and technological cooperation. Currently we are discussing the possibility to organize in Athens next year similar event devoted to energy efficiency and energy saving.

I would like to wish to all participants of the conference to have interesting discussions and fruitful work during the conference, which is guaranteed by the high level of all experts who present here.

Thank you for your attention

Session 1. Energy

The impact of Diesel quality on the Particulate Matter content in the exhaust gases of Diesel cars – Case study: Diesel cars of Korca District, Albania

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Abstract

Air pollution by particulate matter (PM) in Korça District is caused mainly by Diesel cars, which are older than 15 years, and run on Diesel of not-so-good quality compared to EURO 5 standard. In Albania, depending on sulfur content, Diesels are divided into: Diesel D2 [containing 500-2000 ppm S] and Diesel D1 [containing <500 ppm S]. The aim of this research was to examine the vehicle fleet composition and its progress in the last decade in Korça District and to study the dependence of particulate matter contained in the exhaust gases from the Diesel type combusted in Diesel car engines.

Opacity of exhaust gases released during combustion of Diesel at idle conditions was measured from about 220 Diesel cars using the opacimeter which measures the coefficient of opacity expressed in units K (m^{-1}). It was found that the cars which used Diesel D2 type had an average age approximately five years older than the ones that used Diesel D1 type. It resulted that the average value of the coefficient of opacity for cars that were running on Diesel D2 type was 2.64 times higher than the one for cars running on Diesel D1 type and 12.3 times higher than the one for cars that were using Euro 5 type of Diesel with10 ppm sulfur in it. In order to improve the urban air quality not only in Korça, but in all Albanian cities, it is recommended that only Euro 5 type of Diesel be available in all fuel stations in Albania.

Key words: Diesel, K(m^{-1}), PM air pollution.

1. INTRODUCTION

1.1 Vehicle Fleet in Korca

About 80 % of Albanian vehicles run on Diesel. The general trend of vehicle growth for the whole country applies also to the District of Korça. The main increase in the vehicle numbers is caused by private cars (Mulla 2009). In the last decade, as Figure 1 shows, in Korça District, there is noticed an annual increase with about 885 vehicles, out of which there are 673 private cars (passenger cars with 4+1 seats). Vehicle fleet composition shows that private cars and trucks account for 90 % of the total vehicles registered till the year 2010 in Korça District (Figure 2).

Figure 1: Progres of vehicle numbers in Korça District for the period 2000 -2010

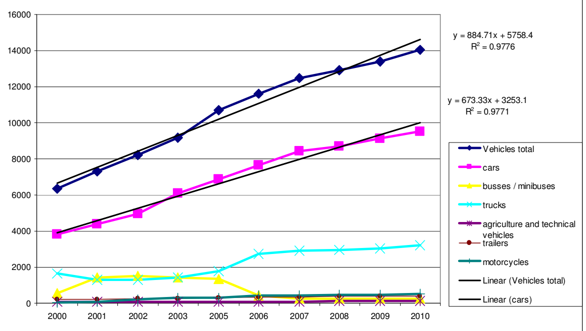
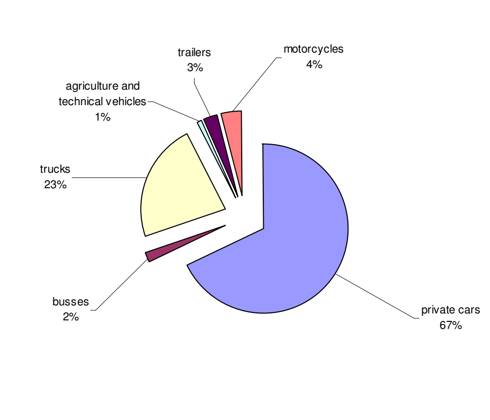
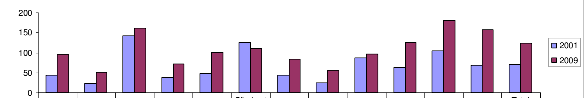


Figure 2: Vehicle Fleet content in Korça District in 2010.
A total of 14032 vehicles.



The vehicle density for Korça District has been under the average of Albania, if the number of vehicles per 1000 inhabitants was to be compared. Nevertheless, from 2001 to 2009 this parameter has increased with 88%, as Figure 3 shows, ranking Korça District the ninth out of twelve Districts in 2009. Source: (MTTPW 2011; INSTAT 2010).

Figure 3: Comparison of the total number of vehicles per 1000 inhabitants in the Albanian Districts
for the period: 2001 - 2009



	Berat	Diber	Durres	Elbasan	Fier	Gjirokaster	Korce	Kukes	Lac	Shkoder	Tirane	Vlore	Total Shqiperia
2001	42.99	23.56	142.8	38.19	46.84	125.68	44.57	24.03	88.47	63.77	104.02	69.03	69.79
2009	95.34	51.05	162.56	71.71	101.79	110.08	83.85	55.06	97.19	125.52	180.31	158.58	124.59

From another research by the corresponding author of this article, the percentage of Albanian families that owned a car in 2009 was 36.10 %. For Korça District this percentage was lower, only 23.28 % of families owned a car (Mulla E. 2010a).

Korça District is situated in the border with Greece and with Macedonia. One of the major highways that connects Albania with Greece (Korça – Kapshtica) passes through this District, thus making the number of vehicles that circulate in the roads of this District much higher than probably the number of vehicles that circulate in other Districts which may have more vehicles of their own than Korça District has. Nevertheless, the traffic counting does not take place in the main highway and in the Korça City's entrance points.

A major problem with the vehicles in Albania is their not being presented annually in the Centers for the Technical Inspection. For Korça District in 2007 only 60.43 % of vehicles (and 65.31 % of cars) were presented for their annual technical inspection and the pollutants testing. For the rest of about 40 % of vehicles and 35 % of cars nothing can be known at present regarding how much they pollute the air. The amnesty of the Government in 2008 and onwards did not seem to yield effective results (MTTPW 2011).

1.2 Diesel quantity consumed in Albania

In Albania, about 85 % of the Diesel quantity consumed in the country comes from import. Up to 2008 the trend of Diesel consumption in Albania was annually increasing to match with the annual increase of vehicle numbers. The effect of financial crisis worldwide was felt even in Albania and a reflection of this is the reduction of the Diesel quantity imported in the following years. Yet from the graph in Figure 1 it can be seen that the effect of the global crisis was not felt in the vehicle fleet growth. It can be said that Albanians would prefer to buy a car and drive less than in previous years now that the fuel prices have very much noticeably increased.

The graph in Figure 4 shows that there has been an annual and steady increase of the Diesel D1 quantity since 2005 and a drastic reduction of the Diesel D2 quantity in 2009. The production of the native Diesel has remained in constant quantity in the last decade (GDC 2011, METE 2011).

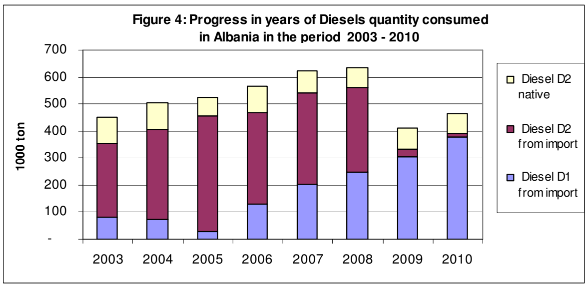


Figure 4: Progress in years of Diesels quantity consumed in Albania in the period 2003 - 2010

At present it is impossible to define the exact Diesel quantity consumed only in Korça District. It is observed that the main fuel providing companies in Albania have their branches in Korça District and their fuel stations are present along each road and highway in this District. Due to vicinity with Greece, there are several fuel providers that import Diesel from Greek refineries. Questionnaires with drivers revealed that a considerable number of Korça District drivers pass the border often to render service to their vehicles in Greece because they want their cars to comply with the requirements of this EU country while they work there and thus maintain the same habit when they return in Albania. They witnessed that fuel quality in Greece is much better than the one in Albania, therefore, according to them, the 30 – 40 km trip is worth it for the well being of their vehicles.

1.3 Air pollutants in Korça

The air quality in Korça is being monitored by the Institute of Public Health. The air pollutants monitored are: Total Suspended Particulates (TSP), PM_{10} (particulate matter less than 10 microns), SO_2 (sulphur dioxide), NO_2 (nitrogen dioxide), and O_3 (ozone). Figure 5 below gives the trend of all these air pollutants' concentrations in the last decade in Korça city. The monitoring station is located in these coordinates: Lat 19°51.100' and Long 41°20.754'. Korça city is situated at the 883 meters above the sea level altitude. (Source of data for compiling the graph on Figure 5: SoE 2001-02; MoEFWA 2010; IPH 2011).

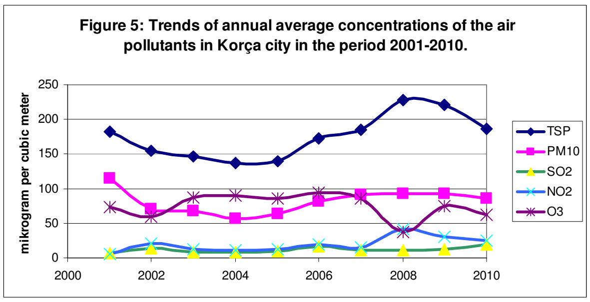


Figure 5: Trends of annual average concentrations of the air pollutants in Korça city in the period 2001-2010.

While SO_2, NO_2 and O_3 respect the Albanian and the EU norms, in the last decade, the most problematic air pollutants in Korça city there have been TSP and PM_{10}. For these two air pollutants a closer observation is carried out. As the graph in Figure 6 shows, the concentrations of TSP have been daily above the Albanian and the EU norm. The concentrations of PM10 have been daily above the EU norm and on 86 % of the days they have been above the Albanian norm too. (Source of data for compiling the graph on Figure 6: IPH 2011).

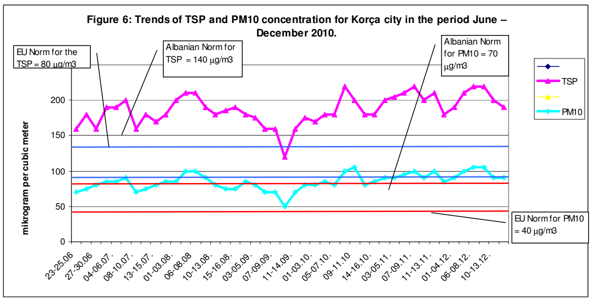


Figure 6: Trends of TSP and PM10 concentration for Korça city in the period June – December 2010.

2. MATERIAL AND METHODS

This research took place in the period: summer – autumn of the year 2009. It is worth mentioning that this is the first time that such a research has been undertaken in Korca District. Because there are not many published data, information on the vehicle numbers and vehicle fleet composition was obtained from various Governmental Institutions, such as Ministry of Public Works, Transport & Telecommunication, Agencies and Directorates as presented in the Bibliography.

The target group of 525 Diesel cars, with which experiments were performed, was comprised of 41 % of cars registered in the Communes and 59 % registered in the City of Korca. The average age of cars at the moment of purchase was 15.5 years and at the moment of testing it was 21 years. As it can be seen from the graph in Figure 7, the distribution of cars according to their production years shows that the majority of cars are produced in the period 1981–1992.

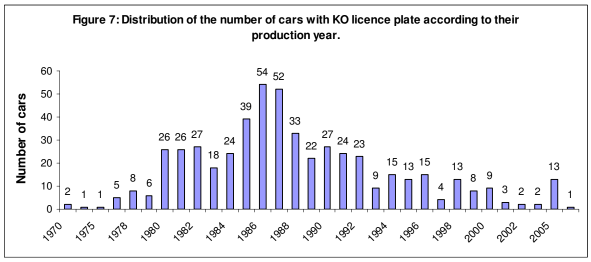


Figure 7: Distribution of the number of cars with KO licence plate according to their production year.

The PM concentration in the exhaust gases was measured from the light weakening after it passes through the mixture of combustion gases in the exhaust pipe, by using the Lambert – Beer equation (Nobutaka 2001, Fifield F. W. and Kealey D, 1983). The experiments were performed at the Center for Technical Inspection of Vehicles in Korça by using the STARGAS 898 Global Diagnostic System opacimeter (Stargas 898, 2005) for the measurement of the coefficient of opacity, K (m^{-1}) which summons the concentration of the particulate matter (PM) contained in the exhaust gases from the diesel combustion in the engine, as well as the dimensions and the nature of these particulates.

$$I / Io = e^{-K L} = e^{-a \cdot c \cdot L}, \quad \text{where} \quad K = a \cdot c$$

a is the concentration of the PM,
c indicates the dimensions and the nature of particulates,
Io is the light intensity when there is no smoke [PM] at all in the exhaust gases,
I is the light intensity when there is smoke [PM] in the exhaust gases,
L is the length of the tube where the measurement of the light intensity is taking place (in meters).

The Coefficient of opacity, K (m^{-1}), and not the real PM concentration in the exhaust gases was measured with this equipment. The higher the K values, the higher the PM concentration in the exhaust gases of cars. The norms of the Coefficient of opacity for Diesel cars, which were in power up to February 2010, are given in Table 1 below:

Table 1: The norms of Coefficient of opacity for Diesel vehicles, in power during the study period.

No.	Year of production	Type of fuel	Diesel Engine	Opacity Coefficient K (m^{-1})
1.	Before 1988	Diesel	Natural intake	4.0
			turbocompression	4.5
2.	1988-1998	Diesel	Natural intake	3.5
			turbocompression	4.0
3.	After 1998	Diesel	Natural intake	2.5
			turbocompression	2.5

3. RESULTS & DISCUSSION

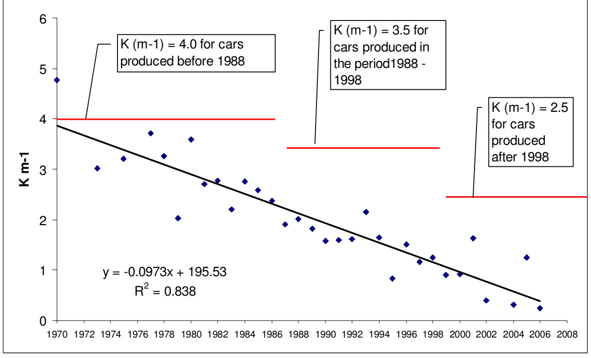
In order to define the overall impact of Diesel quality on the PM emissions of cars in Korca District four main comparisons were made: The impact of cars' age on the PM emission (usually the highest quality of Diesel is used in newer cars), the impact of type of road on the PM emissions (roads in the Communes are in a much worse condition than the City roads therefore the highest quality of Diesel is used in City cars), the impact of Diesel quality on PM emissions of different categories of cars, the impact of car maintenance on PM emissions (taxies usually are better maintained than other private cars, therefore in general they use the highest quality of Diesel).

3.1 The impact of cars' age on the PM emissions

The 525 cars were divided according to their production year and the average values of K (m^{-1}) are presented in the graph of Figure 8. It is obvious that the older the cars, the higher the amount of particulate matter they emit in their exhaust gases. New cars pollute the air much less than old ones and this is in line with the results from a similar study that took place in Tirana (Mulla et al. 2010a).

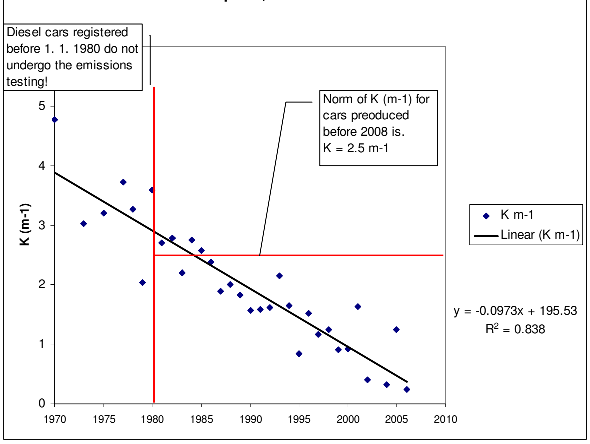
The average values of K (m^{-1}) are compared with the norms which were in power during the study time. It is noticeable that the norms were set too high for each car category and that almost all cars pass the "pollutants' testing".

Figure 8: Variation of the average value of K m-1 for diesel cars, divided by their production year and compared with the norms of K in power up to Feb. 2010.



On the Figure 9 below, the same average values of K (m^{-1}) for the cars of our target group are compared with the new norms, in power from February 2010 (MTTPW, 2010). According to this Guideline, for cars produced before 1980 there is not required an emissions testing, but only a visible inspection of the exhaust gases whether they are black in colour or not. Also the norm of K (m^{-1}) for cars produced in the period 1980-2008 is set at 2.5 m^{-1}, which still is high.

Figure 9: Comparison of average values of K m-1 with the new norms and criteria, according ot the Guideline of the Minister of Transports, No. 2 dt. 11/02/2010



Moreover, it used to be the norm only for the cars produced after 1998, but now it applies to the cars produced in a very wide age range: 28 years apart from one another.

The new norms, by allowing the old cars to circulate without having passed the emissions test, pose an unfair situation to the new cars which pollute less than the old ones, but have to undergo the compulsory emissions test. On the other hand, while Albania aspired to join the European Union (EU) and it is doing a lot of efforts to approximate the legislation, a lot remains to be done in the area of emissions testing because in the EU the cars undergo a procedure that is much different from the one practiced in Albania. Regarding emissions testing, in the EU countries the pollutants are measured in grams per kilometre regardless the cars' production year (ESEU 2011).

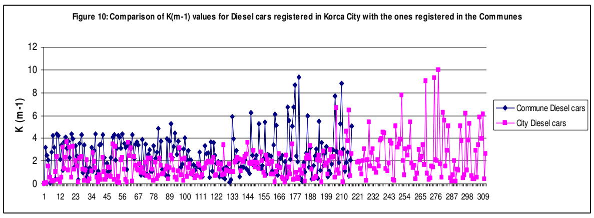
3.2 The impact of the type of road on PM emissions

By surveying the drivers while their cars were undergoing the emissions test, it became clear that the cars of the target group be divided according to the place they are registered. This would enable to see the difference on PM emissions by cars which are driven on asphalted roads (in the cities) with cars which are driven on unpaved roads (in the communes).

The information gathered is presented on Table 2 and it is noticed that cars registered in the Communes are slightly older than the ones registered in the City but the average value of K (m^{-1}) for Commune cars resulted much higher than the one for City cars.

Table 2: Description of the target group of Diesel cars of Korça District according to their place of registration

Registered in	Communes	City
Number of cars tested	217	308
Cars' age at the moment of purchase	16.08	15.07
Cars' age at the day of testing	21.59	20.53
Average value of K (m-1)	2.572	1.83



Moreover, the graphical information given on Figure 10 confirms that, with rare exceptions, the Commune cars pollute the air much more than the City cars.

Survey results showed that the majority of drivers of Commune cars, due to the road conditions on which they drive, do not render a proper service to the cars, they use the cheapest Diesel available in the fuel market and they do not change the air filters often because they perceive it as "not worth it for where the car is driven".

On the contrary, the City cars' drivers in general answered that they take care for their cars. Thus it seems that the type of road in some degree affects the maintenance rendered to a car and indirectly it affects the PM emissions in the exhaust gases of cars.

3.3 The impact of Diesel quality on PM emissions

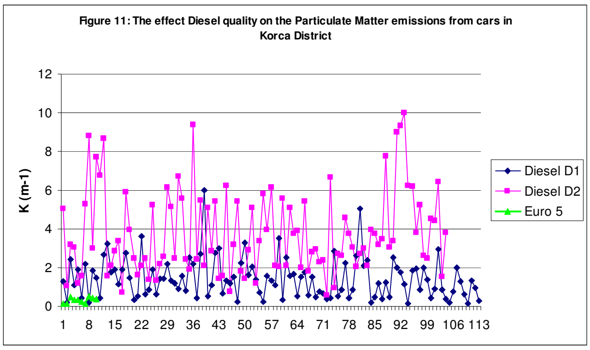
About 220 cars from the target group were divided in two major sub-groups based on the type of fuel they use: Diesel D1 (with less than 500 ppm sulphur in it) and Diesel D2 (with less than 2000 ppm and more than 500 ppm sulphur in it). Even this division confirms the facts mentioned in the two sections above that for old cars which are driven on unpaved roads the Diesel quality used is the cheapest in the market (the worst quality available).

Table 3: Description of the target group of Diesel cars of Korça District according to the type of Diesel they use.

Type of Diesel	Diesel D1	Diesel D2
Number of cars tested	113	104
Registered in the City	69	59
Registered in Communes	44	45
Cars' age at the moment of purchase	12.79	17.13
Cars' age at the day of testing	17.21	22.02
Average value of K (m-1)	1.436	3.788

As information summarised in Table 3 shows, the average age of the cars that use Diesel D2 is about 5 years greater than the one of cars that use Diesel D1 whereas the average value of the coefficient of opacity for the cars that use Diesel D2 is 2.64 times higher than the one for cars that use Diesel D1.

For a small group of cars (Taxi cars that travel on the itinerary Korca – Athens very often) which use Euro 5 type of Diesel bought in Greece, which as another research has shown is of a much better quality than the same type of Diesel traded in Albania (Mulla et. al. 2010b), it is interesting to note that they have approximately the same age at the moment of purchase and a very close age at the moment of testing, but due to the much better Diesel quality that is used by them, their average value of K (m^{-1}) is 4.67 times less than the average K (m^{-1}) which resulted for cars that use Diesel D1 type and 12.3 times less than the average K (m^{-1}) for cars that use Diesel D2 type. The individual results of cars testing based on the type of fuel used in them are presented in Figure 11. It is obvious that the presence of PM in the exhaust gases of all cars that use Euro 5 type of Diesel is the lowest.



3.4 The impact of maintenance on PM emissions

Taxies are obliged by law to undergo emissions testing every 6 months, whereas private cars undergo this testing annually. Due to competition and because of clients' pressure the taxi drivers use better fuel quality than other car drivers. As information summarised in Table 4 and Figure 12 reveals, the PM emissions for taxies have resulted much lower than the PM emissions for private cars. Within the "taxies" category, the PM emissions have resulted lower for city taxies than for commune taxies, and the lowest of all were the PM emissions for Taxies running on Euro 5 Diesel bought in Greece. These taxies use the Greek maintenance services as well. Similar research has confirmed that Commune taxies pollute more than City taxies (Mulla E. F. 2010b; Mulla E. F. 2011).

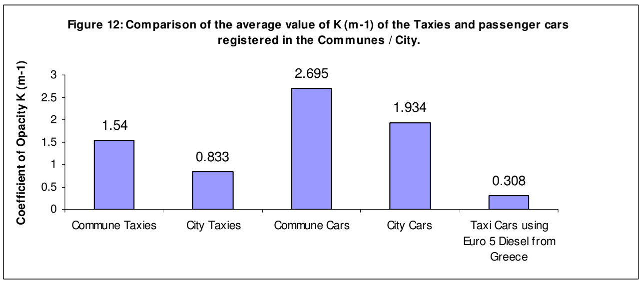


Table 4: Comparison of the K (m^{-1}) of cars with the K (m^{-1}) of the Taxies respectively for Commune and City registered vehicles.

Cars division after:	Taxi cars using Euro 5 Diesel from Greece	Commune Taxies	City Taxies	Commune cars	City cars
Number of cars tested	10	23	29	194	279
Cars' age at the moment of purchase	12.7	12.96	14.38	15.99	15.46
Cars' age at the day of testing	16	18.04	19.86	21.72	20.7
Average value of K (m-1)	0.308	1.54	0.833	2.695	1.934

4. CONCLUSIONS & RECOMMENDATIONS

In conclusion, besides other factors such as cars' age, the type of road where they are driven, the frequency of maintenance, the Diesel quality plays a crucial role on the PM emissions in the exhaust gases of cars.

This research showed that the highest quality of Diesel is being used in relatively newer cars which are driven on paved roads; and also it is being used more in taxies compared to other cars. The Diesel D2 using cars emit much more PM in their exhaust gases' emissions than Diesel D1 using cars. The cars that use Euro 5 type of Diesel pollute the air much less than the former two car categories using respectively Diesel D2 and Diesel D1. These findings about the Diesel quality match the findings about the PM emissions: new cars emit much less PM in the air than old cars; cars that are driven on unpaved roads pollute the air with much more PM than cars which are driven on asphalted roads in the city; taxi cars that are well (and often) maintained emit much less PM in the air than other cars.

Korca City does have an air quality monitoring station which measures the TSP, PM_{10}, SO_2, NO_2, and O_3. In the last decade the TSP and PM_{10} have been continuously above the National and EU norms whereas the other air pollutants have complied with these norms. Therefore, in order to combat the high concentrations of TSP and PM10, which for Korca city are generated in a large scale by road traffic, based on the findings of this research it is recommended that the government takes the following measures:

- fuel stations to provide the Albanian drivers with Euro 5 type of Diesel which meets all EU criteria for this fuel category.

- vehicle fleet renewal. Promotion of purchase of brand new cars should be an ongoing effort by the government, by finding the right economic and fiscal mechanisms in order to increase the preference of Albanians to purchase newer cars than at present.

- road paving especially in communes. Road maintenance in the cities (which already have asphalted roads) and paving roads in the communes is a must in order to reduce PM emissions, not just by avoiding the dust in the air when the cars travel on these types of roads, but mainly by lowering the PM emissions in the exhaust gases by these cars.

- improving the Inspection and Maintenance control of vehicles by making all registered cars undergo the emissions testing at least once a year.

- introduce in Albania the testing procedure that measures the pollutants emitted by cars in the unit "gram of pollutant / km driven" regardless their production year.

It is expected that the implementation of these measures will result in lower PM emissions not only in Korca District but in the whole country as well.

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The concept of clean energy: Scenario development and case study of Bulgaria

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Abstract

Clean energy technologies are making clear progress globally but fossil fuels continue to outpace them. As a target to be achieved the clean energy perspective must be stronger developed in the next 50 years while maintaining the stable balance in the electricity systems. The development of clear path of introducing a clean energy mix for electricity generation is one of the challenges for the Bulgarian energy sector in the coming decades. The Bulgarian power system, public authorities and citizens are facing a diverse and broad set of challenges concerning the implementation of the EU 20-20-20 Energy goals. The need of making the adequate choice of a set of technologies for electricity generation that leave low carbon footprint is acknowledged as a priority goal at the present stage.

The paper discusses the expected path concerning Bulgaria's clean energy future development. The first part of the study examines the adopted policies by other countries and regions as world leaders in the clean energy policies. The implementation of more aggressive clean energy policies is revealed including the removal of fossil fuel subsidies and implementation of transparent, predictable and adaptive incentives for cleaner, more efficient energy options.

The case study of Bulgaria as a new EU member state undertakes a comparative analysis with the long-term policies implemented by other countries. An evaluation of the results of the transitional reform of the energy sector and the problems of the present implementation of the Third Liberalization Package of the EU energy policies is the basis for the revealing of clean energy options for Bulgaria. The development of the Bulgarian clean energy scenario reveals the interrelation between the energy supply options (including the energy efficiency and energy security targets) and the energy demand and consumption trends for sustainable clean energy development.

Keywords

Clean energy concepts, energy efficiency, electricity generation

1. **Clean energy concepts**

The design of policy targets concerning clean energy development across different countries and regions allow the availability of multiple choices of policy approaches to clean energy concepts. For small countries like Bulgaria, there are two main tasks in the process of making the right choice of conceptualization of the future clean energy development:

1) to take part and to comply with the EU clean energy policies and programmes;

2) to take into consideration the experiences and policies of the countries outside the EU due to the fact the energy sector is a basic industry which is highly dependent on the world markets and the energy policies of third countries.

The study introduces the expected path concerning Bulgaria's clean energy future development. The first part of the study examines the adopted policies by the EU as well as third countries and regions, including countries world leaders in the clean energy policies. The world leading economies are searching their path through implementation of more aggressive clean energy policies, including the removal of fossil fuel subsidies and implementation of transparent, predictable and adaptive incentives for cleaner, more efficient energy options.

1.1. Clean Energy policy by the European Union

In order to keep climate change below 2ºC, the European Council reconfirmed in February 2011 the EU objective of reducing greenhouse gas emissions by 80-95% by 2050 compared to 1990, in the context of necessary reductions according to the Intergovernmental Panel on Climate Change. This is in line with the position endorsed by world leaders in the Copenhagen and the Cancun Agreements. These agreements include the commitment to deliver long-term low carbon development strategies. Some EU Member States have already made steps in this direction, or are in the process of doing so, including setting emission reduction objectives for 2050.

According to the World Energy Outlook 2010 the contemporary energy policies have a severe impact on climate change, since energy accounts for 75% of the greenhouse-gas emissions (IEA, 2011). Electricity generation is the sector recognized to be the one with high potential for reducing GHGs. On one hand, the generation of electricity is the largest and fastest growing source of carbon dioxide on the world scale. With 11 gigatonnes (Gt) of CO2 emitted in 2008, electricity generation is the largest CO2 source in the energy sector. With a 65% increase since 1990, it is also the fastest growing CO2 emitter (IEA, 2011).

The Europe 2020 Strategy for smart, sustainable and inclusive growth includes five headline targets that set out where the EU should be in 2020. The EU Member States have committed themselves to reducing greenhouse gas emissions (GHG) by 20%, increasing the share of renewables in the EU's energy mix to 20%, and achieving the 20% energy efficiency target by 2020.

It is important to define a clean energy mix for electricity generation that is in accordance with the low carbon future of the European Union.

The rationale for using a mix of sources rather than a few technologies is to be supported by the following considerations:

a) most technologies do not have sufficient theoretical capacity to supply and satisfy all demand;

b) a mix of technologies is more robust against delivery risks;

c) different technologies can be utilized to a greater extent in those regions where they are most suitable;

d) a diversity of resources also enhances supply security. (EC, 2011)

The EU member states are facing the challenge to optimize the electricity generation according to the goals for decarbonisation. The electricity generating industry has to make a shift of investment towards "clean" energy like nuclear, coal with CCS (carbon capture and storage) and renewables. On the other hand, this shift and the EU ETS in the period after 2012 will become a problem for the citizens and industrial consumers, who will face the higher prices of electricity. Public attitude towards nuclear energy remains rather controversial.

Nevertheless, as the representatives of Eurelectric stated, in a sustainable EU, "the nuclear power should stay in the mix". To achieve this EU Electricity generating companies must invest around €410 billion as needed in the nuclear power sector merely to roughly maintain the current position nuclear energy has in the power mix.

Table 1 CO2 Sectoral reductions (EC, 2011)

GHG reductions compared to 1990	2005	2030	2050

Total	- 7%	- 40 to - 44%	- 79 to - 82%
Sectors			
Power (CO2)	- 7%	- 54 to - 68%	- 93 to - 99%
Industry (CO2)	- 20%	- 34 to - 40%	- 83 to - 87%
Transport (incl. CO2 aviation excl. maritime)	+ 30%	+ 20 to -9%	- 54 to - 67%
Residential and services (CO2)	- 12%	- 37 to - 53%	- 88 to - 91%
Agriculture (non – CO2)	- 20%	- 36 to - 37%	- 42 to - 49%
Other non – CO2 emissions	- 30%	- 72 to - 73%	- 70 to - 78%

As states by the European Commission the electricity will play a central role in the low carbon economy. The EU plans are to eliminate CO2 emissions in the electricity sector by 2050. Decisive part of the energy, used for transportation and heating will be replaced with electricity till 2050. This will lead to raising the share of the electricity consumption in Europe. The historical growth rates of electricity consumption would only have to continue to increase, thanks to continuous improvements due to higher efficiency.

The share of low carbon technologies in the electricity mix is estimated to increase from around 45% today to around 60% in 2020, including through meeting the renewable energy target, to 75 to 80% in 2030, and nearly 100% in 2050.

The electricity systems of the Member States could become more integrated, diverse and secure within the future development of an energy mix, which reflects their specific national needs and circumstances. The integration of renewable energy technologies will have decisive impact in the near future. The expectations are new technologies to become cheaper and thus more competitive over time.

To meet the set of goals of the Energy 2050 Roadmap, further policy development is needed to achieve the decarbonisation targets. The policies will be built on the established EU energy policy and the EU 2020 Strategy.

The development of renewable energy industries and saving energy technologies provides several positive effects. These are mainly referred to the expected increasing in energy self-sufficiency, employment, investment and production. The disadvantages of the renewable energy sources are due to the higher costs related to adjustment in production, grid integration and system operation. Considerable investments in the networks of EU Member states and network integration are required to achieve cohesion of energy markets, continuity of supply and balancing of renewables.

The central role of electricity from renewable sources in the low carbon economy scenario requires more investment in balancing power plants and energy storage. The development of better connectivity between countries and regions is effective at lowering the need for excessive backup generation capacity and balancing cost. The increased inter-regional connectivity creates benefits in sharing of reserves. Transmission capacity between regions is effective at lowering the need for excessive backup generation capacity and balancing costs, allowing the sharing of system resources and reserves. The increased inter-regional connectivity creates benefits in sharing of reserves. Longer-term reserve capacity that needs to be on-line within four hours is assumed able to be shareable between regions, whereas sufficient fast (spinning) reserve is not shared and is provided entirely from resources within each region. Sharing of resources and reserves brings down the backup generation capacity required as reserves and the costs of balancing services by 35-40%, depending on the pathway. In addition to allowing cross-regional sharing of reserves, transmission reduces the impact of demand variability as well as supply variability over the transmission system, and it leverages the negative seasonal correlation between solar and wind production. Differences in daily and seasonal patterns of demand among regions result in lower aggregated demand variability. On a daily and seasonal basis, the ratio of peak demand to minimum demand is reduced. The same mechanism is at work on the supply side. For example, wind output can be highly volatile on a local level, but empirical data for Europe show that volatility dissipates substantially.[1]

The prospects of deepening of the EU energy markets integration makes Bulgaria's accession to the EU energy policies the main pillar of the Bulgarian clean energy development.

[1] Roadmap 2050 – A practical guide to a prosperous, low carbon Europe

1.2. United States Clean Energy Standard

In his recent State of the Union address, President Obama proposed a Clean Energy Standard (CES) to require that 80 percent of the nation's electricity come from clean energy technologies by 2035. The Senate Energy and Natural Resources (ENR) Committee now faces a threshold question of what the general policy goals for the electric sector are and whether a CES would most effectively achieve them. Until the proposal of President Obama the discussions were on how to promote green energy. This action will change the policies direction from "green" to "clean" energy. There are many questions concerning the new CES are still open (Bingaman, 2011). The increasing amounts of clean electricity can lead to a variety of benefits, such as the reduction of greenhouse gases and other emissions, as well as an increase in domestic manufacturing of associated technologies. In contrast, opponents have claimed that a federal electricity mandate, depending on its design, could pick winners and losers among competing technologies and serve as a tax that may cause a wealth transfer from those regions of the country lacking compliant resources (Bingaman, 2011).

The US Congress has debated Renewable Portfolio and Renewable Electricity Standards (RES) for the past decade. During the 111th Congress, the ENR Committee included a 15 percent by 2021 RES in S. 1462, the American Clean Energy Leadership Act of 2009. The policy of the U.S. during the last decade was primary focused on enhancing the competitiveness of renewable technologies in order to allow them to become economically competitive. Other proposals in Congress have focused on diversification of power generation in order to enhance energy security. If "clean" energy were defined as renewable and nuclear energy only, then the United States would currently be obtaining 30 percent of its electricity from clean sources. If efficient natural gas (i.e. combined cycle) were included as well – and awarded "half credits" in accordance with the President's CES proposal – the United States would currently be obtaining 40 percent of its electricity from clean sources (Bingaman, 2011).

Table 2: Average Carbon Dioxide Emission Intensity by Generation Type, 2009, tCO2/MWh

Coal	Oil	Natural gas	Nuclear	Hydroelectric	Other renewables
0.99	0.95	0.44	0	0	0

Source: **The Hamilton project**, 2011

1.2.1. What resources should qualify as "clean energy?"

One of the debated questions concerning the new standard is what resources should qualify as clean energy. According to the proposal of the World Resource Institute, as one of the debating interest groups, in order to qualify a technology as "clean", the performance of the technology should be compared to an objective benchmark established by statute or by the implementing agency. A list of qualifying technologies or classes of technologies would then be identified that clearly meet or exceed the benchmark. The benchmark should be written in order to qualify existing, well-understood technologies expeditiously but also to maintain flexibility to incorporate new innovative technologies as they are commercialized.[2] The same metrics and methods used to establish technology eligibility can also be employed to determine how many credits are generated from certain technologies. (World Resource Institute, 2011)

"Clean" implies an absence of emissions, but if emitting technologies are included in a CES then a benchmark is required to define eligibility. If a benchmark defining the average emissions rates of a technology or class of technologies is the basis of its eligibility, it can be calculated in two primary ways:

1. Based on the emissions produced in the combustion phase solely;
2. Based on a lifecycle analysis (LCA) of the emissions from the technology and any necessary associated fuel production. The boundary for a complete LCA typically includes six stages, five of which are important in this context:
    a. Materials extraction
    b. Production (i.e. of the fuel)
    c. Distribution (i.e. through pipelines or by tanker)
    d. Use, in this case combustion
    e. Disposal/End of life.

Emissions from the manufacturing of the equipment itself could potentially be included, but that phase tends to be relatively insignificant for combustion technologies.

Taking into consideration only combustion emissions ignores major emissions sources in upstream stages of power generation, and would

[2] To do this, the implementing agency would both assess a set of current technologies to develop a qualified list and also set up a procedure for listing new technologies on a regular cycle and/or as petitioned for a new technology. The implementing agency should draw on relevant expertise to develop and maintain the lists of qualifying technologies and their emissions rates, making full use of the most current scientific data.

lead to reduced benefits from the program. If an LCA approach is used to establish default emissions rates for particular technologies and fuel classes, then they should be periodically updated to ensure that they reflect current science.

”Clean energy” implies energy whose generation does not emit pollutants, and several classes of pollutants could be considered, including greenhouse gas emissions, local air pollutants, and water pollutants. At least three options are available to address the scope of emissions considered in determining eligibility and crediting as a clean source:

1) Consider GHG pollution only for eligibility and crediting: In the interest of administrative feasibility, the scope of pollutants to consider in the performance benchmark could be restricted to greenhouse gases only.
2) Consider GHG pollution only for (partial) crediting purposes, but include eligibility criteria that consider other pollutants, for restricting certain other technologies that emit amounts of other pollutants that would endanger human health. For example, the implementing agency could be permitted to disallow certain types of technologies during the qualification process if they pose severe environmental hazard that would undermine the purpose of the Clean Energy Standard;
3) Consider average emissions rates for all pollutants (GHG, SOx, NOx, particulates, water, etc.) for both eligibility and (partial) crediting. This would require either a weighting of the emissions rates of various pollutants to develop a combined index, or the worst rate could be used.

Emission rates for qualifying a given technology (or technology class) should be periodically re-assessed based on improvements in technologies so that the technology is not being penalized/credited based on old data (World Resource Institute, 2011).

As an example the World Resource Institute presents the U.S. Experience and approach during the decision making process concerning the design of the new standard.

In 2010 the U.S. domestic electricity generation was comprised of about 20 percent from nuclear power plants, 10 percent from renewable energy power plants (hydropower, wind solar, geothermal and biomass), 25 percent from natural gas power plants, and 45 percent from coal power plants.

Many of the biggest costs of energy are hidden. Today, American consumers purchase electricity from markets that do not internalize the true costs of energy extraction and production. In fact, there are many hidden costs associated with pollution for example:

1) air pollutants are known to be harmful to human health;
2) thermal energy production stresses the quality and quantity of fresh water supplies;
3) climate-change related impacts to public health and the environment have already been considered in the U.S. (World resource institute, 2011).

If clean energy were defined as renewable and nuclear energy only, then the United States would currently be obtaining 30 percent of its electricity from clean sources. If efficient natural gas (i.e. combined cycle) were included as well – and awarded “half credits” in accordance with the President’s CES proposal – the United States would currently be obtaining 40 percent of its electricity from clean sources (Bingaman, 2011).

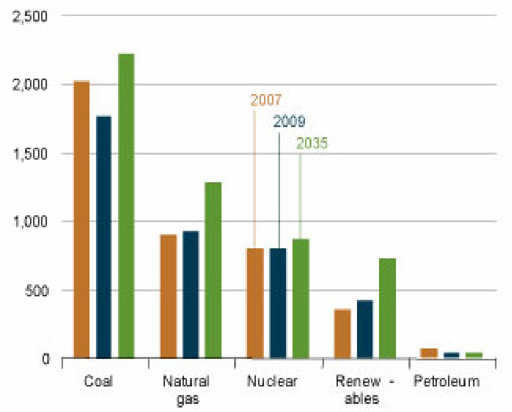

Figure 1 Electricity generation by fuel 2007, 2009, 2035

Source: EIA, 2011

The EIA reference scenario, in its 2011 Annual Energy Outlook, projects that overall electric generation will increase by about 20 percent between 2010 and 2035. The majority of new capacity is expected to come from natural gas power plants. Natural gas is expected to maintain its 25 percent share of overall electricity generation throughout this period. Renewable power is expected to grow to a 14 percent share of the generation mix.

Nuclear is expected to add capacity but decrease slightly in its overall share of the generation mix to 17 percent in 2035. Events in Japan may affect that potential growth in capacity. Generation from coal is expected to increase overall but decrease to a 42 percent share of the generation mix. The most commonly used fuel for electricity production in the U.S. is coal. According to the Energy Information Administration (EIA) in 2010 nearly 45% of the electricity used coal. Figure 2 clearly specifies the percentage of the different technologies, used for electricity production in the U.S. Second after coal ranks generation of electricity from natural gas. 20% of the US electricity is generated by natural gas fired power plants, followed by nuclear and hydro energy. In the projected scenario of EIA in 2035, electricity production from coal will maintain its leading position within the energy mix. The expected decrease in electricity, produced from coal is around 2 percent from 45% in 2011 to 43% in 2035. EIA expects a growth of generation, using as a primary energy source natural gas. This is conditioned by a sense of predictability in gas prices, and because the predictability of capital spending for new power plants through the investment period. Another factor is the relatively low level of greenhouse gases for the electricity generated by natural gas fired power plants (Figure 1).

In the AEO2011 Reference case, capacity additions from 2010 to 2035 total 223 gigawatts, including new plants built not only in the power sector but also by end-use generators. About 80 percent of the capacity added in the period is natural-gas-fired, due to higher construction costs for other capacity types and uncertain prospects for possible future limitations on GHG emissions (IAE, 2011).

The debate on the new CES is still ongoing. The expectations are that the electric utilities should interact strong with the producers of clean energy. A CES would require electric utilities to purchase a minimum amount of clean energy as a percentage of the total electricity they deliver annually. While what would qualify as “clean energy” has yet to be defined by Congress, a CES could include renewables and nuclear, as well as natural gas and fossil fuel generation equipped with carbon capture and storage technology.

The development of the concept of "clean energy" in the U.S. leads in the long term to lower greenhouse gas emissions, lower electricity prices, diversification of supply and stimulate the development of high technologies in the production of electricity. On the other hand the CES will have positive impact on the GHGs on the world scale. The United Stated is the second larger producer of electricity from coal after China in the world. The USA is the major consumer of natural gas for the purpose of power generation on the world scale (Table 3). These facts underline the importance of the development of a CES (Clean energy standard) as a policy towards climate change mitigation.

Table 3 United States electricity production from fossil fuels - TWh

Coal	2133 TWh
Oil	58 TWh
Natural gas	911 TWh
Source: IEA, 2010	

2. The clean energy concepts of Bulgaria

Since 2007 Bulgaria is a fullfleged member of the European Union. Bulgaria is taking part in the energy policy decision making proces of the EU. Bulgaria has adopted a long term policies that imply from the decisions taken on the European level since the preaccession period. The main priorities are policies towards lowering the negative efects of the climate change, energy efficiency, diversification of energy supply and better integration of the energy markets.

On the first of June 2011 the National Parliament of Bulgaria voted for the new Bulgarian Energy Strategy up to 2020. The principles for sustainable development of the energy sector have been cleary stated. The main policies in the energy sector are divided in two:

2.1.Demand side oriented policies

Bulgaria faces the chalenge to optimise its energy consumption profile. In 2010 consumption per head reached an estimated 2,900 kg oil equivalent, compared with 1,665 kg oil equivalent in Romania and 3,746 kg oil equivalent in Slovakia. Overall energy consumption has increased only moderately in recent years, despite strong economic growth, owing in part to gradual improvements in energy efficiency. Nevertheless, there is substantial scope for enhanced energy efficiency. Bulgaria's energy intensity, in terms of tonnes oil equivalent (toe) per US$1,000 of GDP at purchasing power parity (PPP), is much higher than the rates in Western Europe. According to Eurostat data, Bulgaria is the most energy intensive country in the EU.

There are significant differences in total energy intensity within the EU-27 Member States, with the highest values in Bulgaria, Estonia and Slovakia – due to the presence of large energy intensive industries like steel and cement industries (Eurostat, 2009).

The newly adopted Energy Strategy of the country till 2020 expects Bulgaria’s energy intensity to fall markedly over the forecast period (2011 - 2020). To achieve this Bulgaria will develop strong policy towards energy efficiency. The main priorities of the energy efficiency policy of the country till 2020 are:

1) Achieving the full potential for energy savings within the building and transport sector;
2) Strengthening the competitiveness of industry through improved efficiency, including through the introduction of stricter standards and better labelling of appliances and devices and implementation of schemes for energy management (energy audits, plans, energy managers and others);
3)Increasing the efficiency of energy supply by raising energy efficiency along the supply chain.

Bulgaria aims to reduce by 50% of the energy intensity of GDP by 2020. The implementation of the upcoming approval of the Energy Strategy of Republic of Bulgaria 2020 measures and policies to increase energy efficiency is to result in improvement of energy efficiency by approximately 25%, or savings of more than 5 mln.toe primary energy compared with the baseline for development in 2020 (Bulgarian Ministry of economy, energy and tourism, 2011).There is a clear trend of growth of the electricity consumption by the households in Bulgaria. Households consume around 10,4 TWh or 36.3% of the total consumption in the country. Higher levels of household income may lead to higher energy consumption by residential consumers. The electricity prices for housholds are growing but they are still the lowest in the European Union. The higly subsidised electricity price for household custemers is one of the major barriers for implementation of the Energy Efficiency Action Plan. The households are not attracted to lower their energy intensity. The lack of information support by the governmental institutions is a problem for the development of sustainable policies towards achieving energy efficiency. There is a lack of information for programs and granting opportunities.

Table 4: Electricity consumption in t. toe

	2007	**2008**	**2009**
Households	806	867	886
Industrial consumers	876	936	725

(NSI, 2010)

Industrial energy consumers and the public sector have a relatively high share of around 18.23 TWh or 63.7% of the consumption in the country (SEWRC, 2010). Energy consumption will continue to be driven by the industrial sector, especially energy-intensive branches such as metallurgy, chemical industry and non-ferros metal industry. The products of these companies are compatative on the world markets so day have to energy efficient.

The GHGs emissions policies are expected to be the driver of the changes in the energy sector of Bulgaria in the coming years. Power generation plants and district heating are the main source and emit more than 25 million tons of CO_2 annually by 2009 the amount of emissions emitted from coal plants only has 19.8 million tonnes of CO_2. These energy companies are required to participate in the European emission trading scheme. In the next ETS period from 2013 all electricity generating companie have to buy the emissions they need. The expectations are that this will lead to an increase of the electricity prices. This will encourage the consumers to implement energy efficiency improvement mesures.

2.2.Supply side oriented policies

Bulgaria has substantial coal reserves and is a net exporter of electricity. The usage of coal reserves and electricity production from coal are being expanded in recent years by the EU-mandated closure of reactors at the Bulgaria's Kozlodui nuclear-power plant. This has caused a delay in compliance with the EU targets. Development of clean energy option for the electricity generation will have clear impact on the GHGs emissions. Coal has the highest share of gross domestic energy consumption, accounting for more than one-third of the total (an estimated 38% in 2009), followed by oil (with an estimated 24% in 2010), nuclear energy (21% in 2010, down from an average of 25% in 2002-06) and natural gas (15%). Nearly all domestic coal output is used for electricity generation.

Diversification of the electricity generating mix through policies towards introducing a renewable and clean energy will be in the scope of political programs in the next 30 years in Bulgaria. Looking at Bulgaria's energy mix over the forecast period, the government hopes to develop a cleaner mix through adding substantial nuclear capacity and promoting the development of renewables projects. We expect that some progress within the renewables sector could be achieved soon, though some regulatory hurdles may hold this up to somje extent. Bulgaria is not especially keen to increase the use of natural gas for electricity generation significantly, given its dependence on imports from Russia.

The "greenness" of the country's energy mix may be harmed by continuing large-scale use of coal until Bulgaria's domestic supply of coal is largely depleted. The development of renewable energy was really strong in the last four years. The country is to achieve 16 percent of the end energy consumption from renewable energy in the year 2020. During the negotiations of the renewables target on EU level, Bulgaria has negotiated higher targets than Great Britain, Slovakia, the Czech

Republic, Hungary, Poland, Holland and other memeber states. The excessive development of wind and photovoltaic electricity generation in the recent years leaded to two major problems. The first was that the renewable electricity generation was strongly subsidesed by feed-in tariff. So far 1738 MW 3634 MW photovoltaic and wind projects are in preliminary stage, a final contract or put into service. All consumers are paying their part of the feed-in tariff. This has lead to higher prices of electricity and has become a problem of rising prices for all types of consumers.The energy poverty has been growing as a new issue of concern due to the fact that 21.8% of the population or 1,657,000 people live below the poverty line (NSI, 2011).

The second problem for the development of renewable energy in Bulgaria is the bad condition of the national power grid and the unsufficient investments in network infrastructure development. The national grid has failed to make possible the connection to the grid for all investors who want to realize their PV or wind projects. These facts have brought to the adoption of a new law on renewable energy. The new law was introduced in May 2011.The subsidies for the renewable energy sector were cut and new feed-in tariffs were introduced.The overall impact of the changes introduced on the energy prices is still uncertain having in mind the stagnating structure of the energy mix of Bulgaria so far.

3. Concluding remarks and discussion

Bulgaria is developing a clean energy concept that is in accordance with the EU long term energy sector development. The idea of integrating measures towards lowering the energy intensity of the end energy consumption and developing an electricity generating mix that will be affordable for the consumers is a long term goal for the future of the Bulgarian energy sector. The cut of the renewable Feed-in tariffs and the plans to develop the nuclear power project “Belene” are clear signals that Bulgaria will include a broader set of technologies in its future electricity generation mix.

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“Gradual transition between the Kruja – Garovo and Ionian zones and location of carbonate hydrocarbon prospects”

Prof. E. PRENJASI, Polytechnical University of Tirana, Albania

-full paper not submitted-

Development of Republic of Srpska's Electric Power Sector

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Abstract

Nowadays, energy is a subject of interest to, not only energy experts, but also a wider range of intellectual circles. Considering these facts, as well as the importance of electric power sector for Republic of Srpska, this energy sector is presented in the paper. Energy potentials which are available to the Republic of Srpska are respectable, in terms of its size and requirements for electricity, accordingly electric power sector and energy sector in general are defined as bearers of economic development. Hydropower potential is the most important and it is available in amount of 10.000 GWh/yr, that is only used in percentage of around 30%. Therefore it is production based on renewable energy sources, with aim of environmental protection. Investments in expanding, reconstruction and modernization of transmission and distribution network aim to decrease losses, hence they should lead to more rational consumption of electricity and increase energy efficiency. Requirement for planning of measures and actions in energy consumption brought to development of so called sectoral "end-use" models.These are simple mathematical models, with detailed structural analysis of all consumption sectors and their sub-sectors. Starting point is the analysis of useful energy consumption, i.e. energy services, which they primarily predict. Therefore these models are suitable for prediction of energy consumption in developing countries. The software tool is MAED, developed by IAEA (International Atomic Energy Agency based in Vienna). For the application of a model such as MAED, high-quality energy balance of at least one, starting year, is strictly required.
Key words: Strategy, energetics, electrical-energy.

1. Introduction

Considering the complex organization and functioning of BiH, it is important to emphasize that, based on constitutional order, energy sector is under the authority of the entities, and therefore, all legislation in the field of energy is in line with the constitutional jurisdiction and Republic of Srpska Government is responsible for the implementation of energy policy in Republic of Srpska.
Total need for energy in Republic of Srpska is met by consumption of coal, liquid fuels, gaseous fuels, hydropower and firewood. In the period from 2000 to 2010, final energy consumption in Republic of Srpska grew with an average annual rate of 3%. Electricity, liquid fuels and firewood are the most important forms of energy supply to end consumers. Total energy consumption in Republic of Srpska is ensured by own production and partly from imports (crude oil and natural gas). Certain amounts of energy, primarily in the form of coal, electricity and liquid fuels, are exported. Own supply of total primary energy has increased from about 70% in 2000 to 75.9% in 2010.
One of the most important part of the energy sector is certainly the electric power sector. The main objective in the electricity sector of all countries, including Republic of Srpska, is to ensure continuous and quality supply of all consumers of electricity at market-established and acceptable prices, satisfying the principles of environmental protection and sustainable development. Depending on which activity is performed, electric power sector can be divided in:

- Manufacturing activity
- Transmission activity
- Distribution activity
- Supply as a separate activity

All these activities are organized within Republic of Srpska, i.e. at entity level, with the exception of the transmission activity that is performed by the joint venture company at state level. This activity is conveyed by agreement from the entity level to a joint venture company.

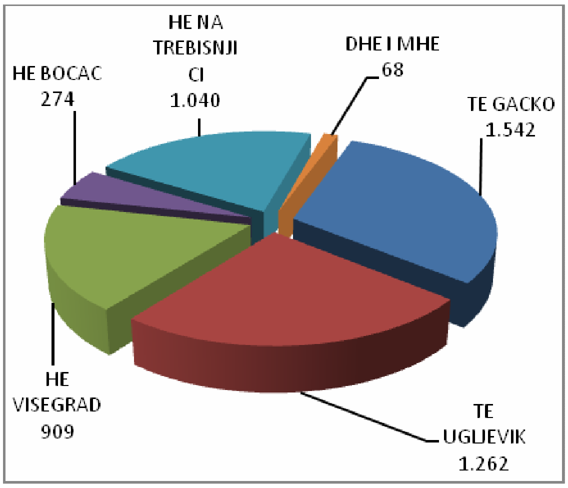
2. Current situation in the electric power sector

Analysis of current situation and characteristics of electric power sector of Republic of Srpska represents the starting point for understanding the future electricity needs, possibilities and options to meet the needs, defining objectives and measures for achieving the development goals of Republic of Srpska's electric power sector.

2.1 Electricity generation

Electricity generation in Republic of Srpska in 2010 was 6174 GWh. It is based on production in the thermal power plants on domestic coal and generate about 55% and hydropower plants that generate about 45% of electricity. Security of supply is high due to the use of domestic sources of primary energy. Electricity generation is currently greater than its consumption. For that reason, about 25 - 35% of the total electricity production is exported to other markets.
Total available capacity of hydropower plants, including small hydropower plants, is about 736 MW, and installed capacity of thermal power plants is 600 MW.
The available capacity at thermal power plant threshold is about 500 MW with an expected annual production of about 3000 GWh, while the expected annual production in the hydropower plants is from 2500 to 3000 GWh, depending on the hydrological situation.

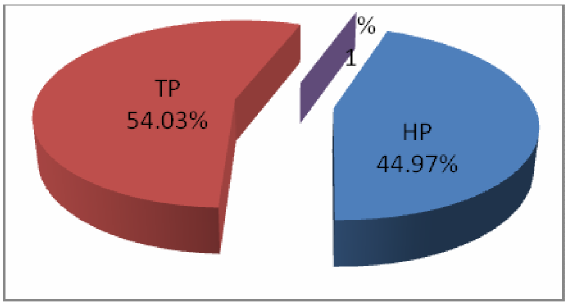
Figure1. Planned electricity generation in certain facilities



Source: Energy Development Plan for Republic of Srpska to 2030

Thermal power plants have been in operation for 25 years and revitalization is needed to extend the lifespan, improving the technical and economic characteristics and meeting the provisions of environmental regulations, while the lifespan of hydropower plants is from 40 to 25 years.

Figure 2. Structure of electricity generation

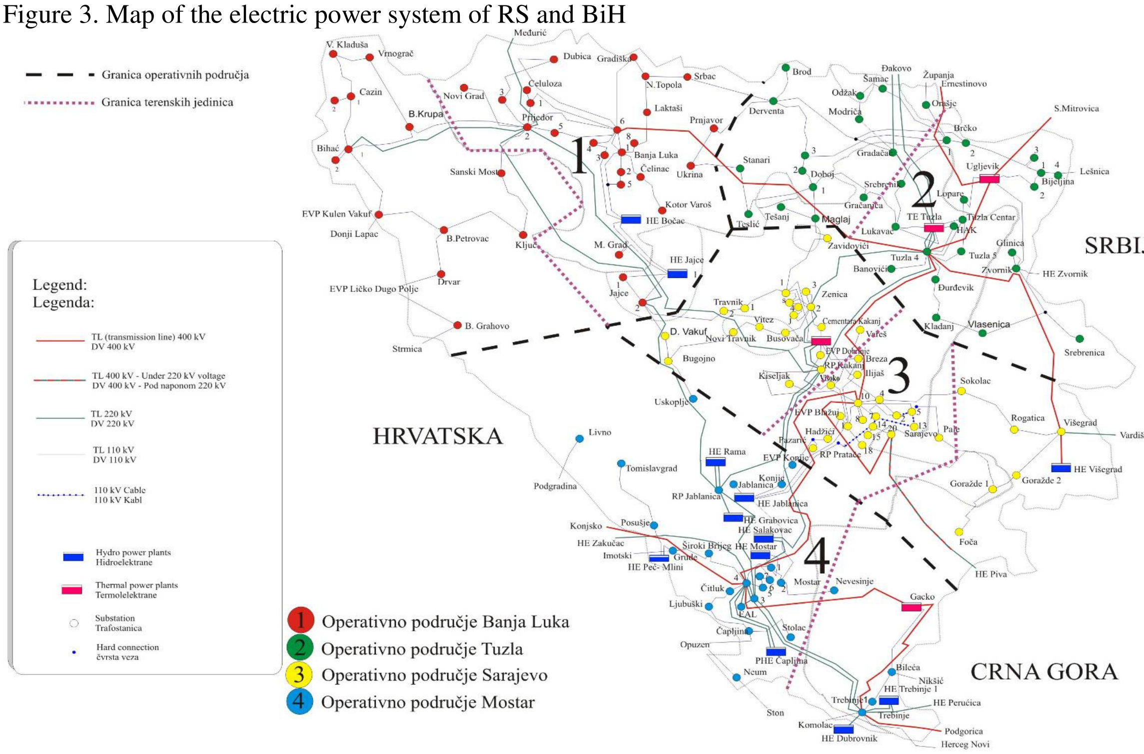


Source: Energy Development Plan for Republic of Srpska to 2030

2.2 Transmission of electricity

Transmission activity in Bosnia and Herzegovina is performed by transmission company whose shareholders are Republic of Srpska Government with 41.11% of shares and Federation of BiH with 58.89% of shares. Transmission network consists of lines of 400 kV, 220 kV and 110 kV voltage level, figure 4. Total length of transmission lines within the electric power system of Republic of Srpska is 2395 km, or about 38% of the total length of transmission lines within Bosnia and Herzegovina. About 2/3 of the interconnection lines to neighboring electric power systems is located in Republic of Srpska. Network of the highest voltage level is built on the territory of BiH and is connected to the neighboring power systems in Serbia, Montenegro and Croatia.

Figure 3. Map of the electric power system of RS and BiH



The power of 400 kV transmission lines is very high and loaded under 30% of the maximum allowed value, which allows in the future further increase in the transfer by that network, and the connection of large thermal units on the existing infrastructure.
Statistical indicators on the availability of transmission network and all transformers within BiH, and thus the RS, in 2010 show satisfactory reliability and amount to 97.71%.

2.3 Electricity distribution

Electricity distribution is organized into five independent distribution system operators - elektrodistribucije (Figure 4). In 2010, total gross electricity consumption was 3760 GWh. Republic of Srpska has about 510,000 electricity consumers.

Figure 4.Organisation of electricity distribution in Republic of Srpska

Indicators of continuity of electricity supply within the territory of Republic of Srpska are worse than common values in European systems. Indicators of quality of commercial services are in many cases in line with European practices.
Losses and non-registered electricity consumption are one of the biggest problems of the distribution network operators in Republic of Srpska, and in the previous period distribution losses were about 17%. It is important to emphasize that distribution losses tend to decline slightly.
Structure of electricity consumption in Republic is very unfavorable and, at this time, about 56% of electricity is consumed by households, while other consumption and industry consume about 17%.

3. Potential for development of RS electric power sector

In electricity generation, thermal and hydro power plants play a dominant role. Primary energy sources are coal and hydropower with the possibility of using renewable energy sources.

The estimated coal reserves at the mine Gacko and Ugljevik, where the existing thermal power plants are located, amount to 450 million tons. It should be noted that coal exploitation is also performed in mines Stanari and Miljevina. Total balance coal reserves in Republic of Srpska amount to 684 million tons and total reserves 578 million tons.

Total technically usable hydropower potential in Republic of Srpska is about 3.200 MW of installed capacity or 9500 GWh of expected annual electricity generation, out of which about 2500 GWh/yr is utilized. As for biomass, forests cover about 40% of the total area of BiH, out of which 53% is in the territory of Republic of Srpska, so the total theoretical biomass potential in Republic of Srpska is estimated between 31.08 and 46.24 PJ. The largest part (59%) relates to the biomass suitable for combustion and 39% to the biomass suitable for production of biogas from municipal waste, livestock and crops for energy purposes.

The northern part of Republic of Srpska has significant geothermal potential. Geothermal water of average temperature of 100 ° C (80-150 ° C) is expected in reservoirs. Thermal water is now used primarily for the spa purposes and it is not used for energy purposes.

Some areas of Republic of Srpska are also suitable for use of wind energy for electricity generation. Most promising area for the construction of wind turbines is south-eastern part of Republic of Srpska. Theoretically exploitable wind potential is estimated at 640 MW of installed capacity with an expected production of 1200 GWh per year. In Republic of Srpska, wind is currently not used for energy purposes.

Preliminary analysis show that Republic of Srpska has a considerable potential for using solar energy. The lowest solar potential is available in the northern regions from 1.25 to 1.3 MWh/m2 of total solar energy. The intensity increases by lowering to the South (1.50 to 1.55 MWh/m2). The main possible form of usage of solar energy is space and hot water heating.

4. RS Electric Power Sector Development Strategy

4.1 Economic growth and development of Republic of Srpska

In relatively short time and with a number of adverse circumstances, the results in development are achieved enabling, together with the available natural and human resources, favorable position of Republic of Srpska in the future development, with the ultimate goal to reach the level of economic development that would allow EU accession in the next decade.

Low level of utilization of natural resources, particularly energy and mineral, agricultural land and forest reserves, proximity to roads leading into central Europe provide a good basis for accelerated growth.

Nowadays, the available capacity for electricity generation and capacity for supply of other types of energy are such that far exceed domestic needs, and they are guarantee, but also imperative for the development of other economic sectors, particularly processing industry.

International (IMF) and local analysis show that Republic of Srpska has the conditions and could, in the next decade and longer, achieve above-average growth dynamics in order to become an equal partner in EU integration. Starting from the above mentioned, two scenarios of the gross domestic product growth are defined, as follows in the following table 1.

Republic of Srpska has to maintain relatively high growth rates, in average 4.2% in the twenty-year period.

4.2 Objectives of RS energy development

The overall objectives of Republic of Srpska's energy development are to:

- provide sufficient quantities of energy and a sufficient level of security of supply for the economy and citizens of the RS at reasonable prices,
- increase the efficiency of production, transportation and transmission, distribution and consumption of energy, especially in construction industry,
- create conditions for the availability and even use of networked energy (electricity and gas) throughout the geographical area of Republic of Srpska,
- ensure the development of energy sector in terms of restrictions on CO2 emissions, combined with increased energy efficiency and increased use of renewable energy sources,
- align the legislation with the EU acquis

4.3 Scenarios of Republic of Srpska's energy development

RS Energy Development Strategy considers three growth scenarios in which two scenarios of gross domestic product (GDP) growth by 2030 are elaborated- high and low GDP growth. Scenarios that are considered are:

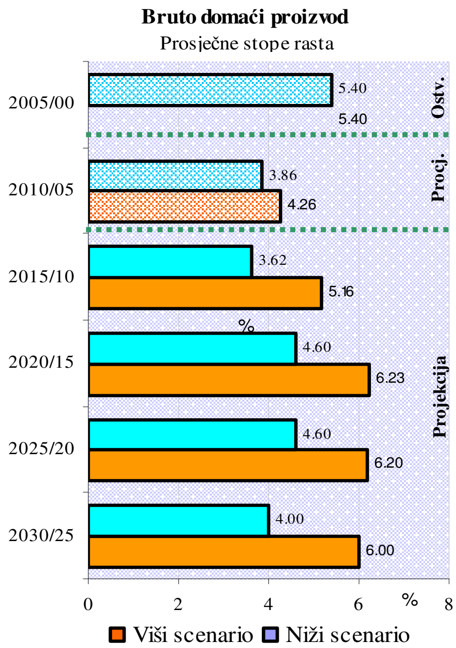
S1 - High GDP growth - fundamental feature of this scenario is rapid growth of gross domestic product (desirable scenario of economic development), the application of conventional technology without active government measures

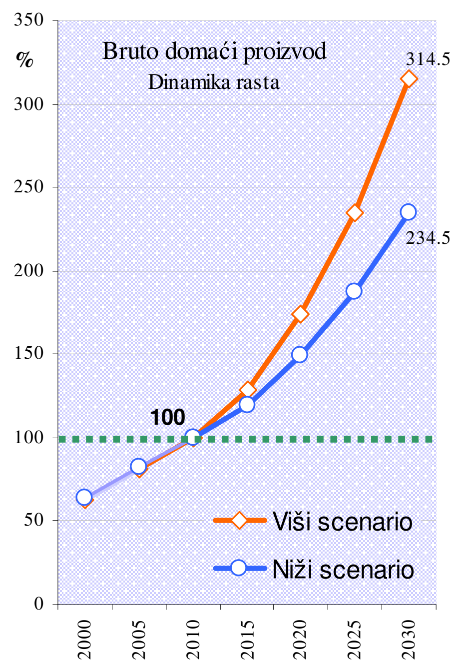
S2 - High GDP growth with measures - fundamental feature of this scenario is rapid growth of gross domestic product together with the implementation of energy efficiency measures and promoting the usage of renewable energy sources

S3 - Low GDP growth - fundamental feature of this scenario is slow growth of gross domestic product and the application of conventional technology without active government measures.

Table 1. Gross domestic product in the period 2010 - 2030 - growth scenarios

	Realized		Estimate		Projection			
	2005./00.	2008./05.	2009.	2010.	2015./10.	2020./15.	2025./20.	2030./25.
High GDP growth	5,40	6,10	- 0,80	4,00	5,16	6,23	6,20	6,00
Low GDP growth	5,40	6,10	- 0,80	2,00	3,62	4,60	4,60	4,00





Growth index (%)

	2000.	2005.	2010.	2015.	2020.	2025.	2030.
High GDP	62,4	81,2	100	128,6	173,9	235,0	314,5
Low GDP	63,6	82,7	100	119,5	149,6	187,3	234,5

Source: Energy Development Plan for Republic of Srpska to 2030

4.4 Electric Power Sector Development

4.4.1 Electricity consumption

The need for planning of measures and actions in energy consumption has led to the development of so-called sectoral „end-use“ models. These are simple mathematical models, with detailed structural analysis of consumption by all sectors and their sub-sectors. The starting point is analysis of useful energy consumption, so-called energy service, which they primarily predict. Structural „end-use“ models can be applied to the analysis of one base year and do not require a consistent historical time series, as required in the econometric models. For that reason, these models are suitable for predicting the energy consumption in transition and developing countries. It is a software tool MAED, developed by IAEA (International Atomic Energy Agency based in Vienna).
Total electricity consumption at the transmission network will increase from 3760 GWh in 2010 to 5680 to 6540 GWh in 2030, depending on the scenario in which the process will unfold.
By the end of this period, increase in system load factor is expected from current 55% to about 64%. Increase in load factor is the result of certain changes and activities in the system.

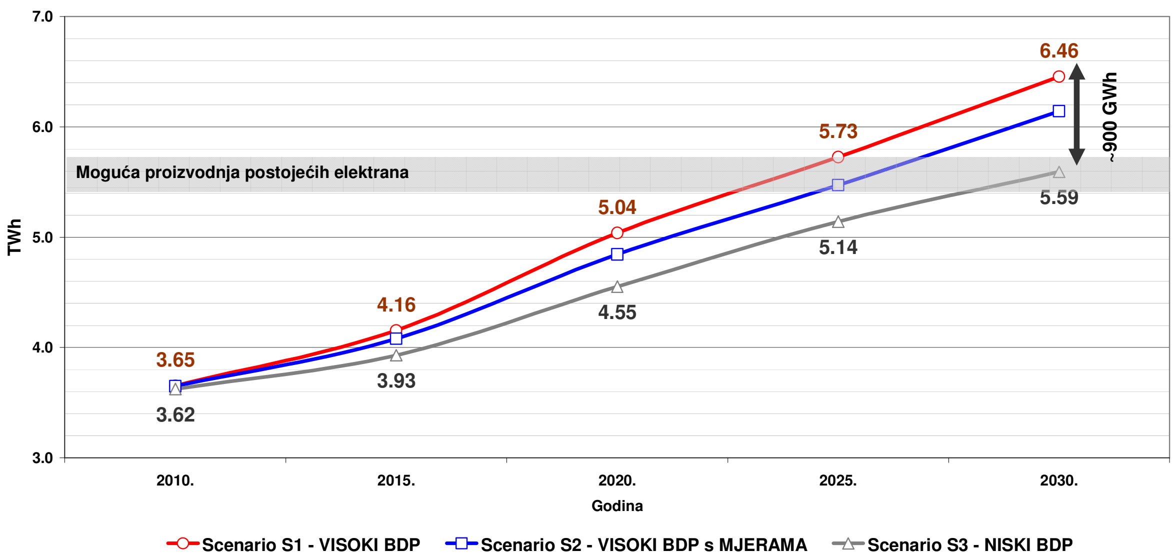
4.4.2 Development of electricity generation

Planning criteria and methodology for drafting long-term plan for electricity generation is based on the standard methodology with the least cost (LCP, Least Cost Planning), which is widely accepted by international organizations. Processing model WASP (Wien Automatic System Planning) was used, as a computer tool for long-term planning of power plants construction.
The essence of long-term planning of power plants construction is in finding the optimal expansion plan for the production system over a period of typically 20-30 years, defining constraints. The optimum is based on a minimum total discount costs, and the main goal is to meet the needs for energy in the RS, focusing on potential for electricity export.
Very important fact for the optimization of Republic of Srpska's electric power system is the fact that it is a small system with two coal-fired power plants whose installed capacity is relatively large compared to the peak system load. The current load factor is very low, about 55%, and therefore it can be concluded that there is a need for peak power in the system.
Development of RS electric power system is seen in terms of market development with the possibility of selling electricity to neighboring markets. Market is currently not regulated, i.e. there is no exchange of electricity and contracts are awarded by tender or direct negotiations.
Limiting factor for all systems in the region, including BiH and RS systems, is the future uncertainty concerning reduction of greenhouse gas emissions.Systems in which production is based on a fossil fuel power plants will be more affected and limited by future obligations and will have to change the orientation towards “cleaner” sources of primary energy or “cleaner” technologies. BiH, and thus RS, has no quantified obligation related to reduction of greenhouse gas emissions. In the period 2020/2025 projected lifespan of existing power plants expires. It is possible to revitalize and extend their lifespan for additional 15 years or phasing out with the simultaneous construction of new / replacement units at the same locations. All existing hydropower plants will be in operation by the end of the reference period with appropriate interventions to revitalize the electro-mechanical plants and buildings.
RS Government has awarded several concessions for construction of power plants of total capacity of about 380 MW and expected annual production of 2400 GWh (TPP Stanari, HP KotorVaroš, HPP Ulog, HPP Krupa, HPP Banja Luka Niska), and a number of concessions for construction of small hydropower plants of total capacity over 210 MW and expected annual production of 650 GWh.Concessions are awarded in various stages of implementation. Entering the TPP Stanari and HPP Ulog production plant is expected in 2015/2016, while the implementation of other projects is practically at a standstill.
In the future, it is necessary to develop projects for usage of energy potential of watercourses in RS. Location of objects that are considered as candidates for construction by 2030 are as follows:

- hydropower system Upper Drina (HPP BukBijela, HPP Foča, HPP Sutjeska, HPP Paunci - construction expected in the period 2015/2020)
- Upper Horizons project (HPP Dabar, HPP Nevesinje and HPP Bileća with HPP Dubrovnik II - construction expected by 2020/2030)
- Implementation of the Middle Drina project (HPP Tegare, HPP Rogačica and HPP Dubravica)

Two existing locations of thermal power plants for which two developmet options are considered are retained. These options are consistent with the objective of limited increase of carbon dioxide emissions, i.e. maintaining the power generation and coal at its current level or their limited increase.

Figure 6. Total electricity consumption at the transmission network by 2030 for the three growth scenarios



Source: Energy Development Plan for Republic of Srpska to 2030

Option 1: Termination of TPP Gacko 1 and TPP Ugljevik 2020/2025 and construction of new/replacement units

- Construction of 300 MW unit at TPP Gacko,
- Construction of 400 MW unit at TPP Ugljevik
- Application of modern technological solution,
- Increasing the level of efficiency (> 40%)
- Increasing the power of existing locations
- Increase in electricity generation
- Reduction of specific emissions of carbon dioxide
- Relatively high investment (EUR 950 million)

Option 2: Extension of lifespan of TPP Gacko 1 and TPP Ugljevik 1 by 2035/2036

- Retention of existing solutions
- Limited power increase
- Retention or a slight increase in electricity generation
- Limited ability to increase the level of efficiency (up to 35%)
- Retention of carbon dioxide emissions
- Lower investment
- Expected higher cost of operation and maintenance

In urban areas, the application of highly efficient gas cogeneration is expected. Interesting locations for gas cogeneration are Banja Luka, Prijedor and Doboj as greater consumption concentration centers in RS with district heating systems already developed. Prerequisites for the implementation of gas cogenerations are regulated electricity market, district heating sector and development of pipeline network. Entering the gas cogeneration plants is expected in the period 2015/2020.

Depending on electricity consumption scenario, scenarios for development of renewable energy sources and options to extend the lifespan of existing power plants, the total investment in construction of new and rehabilitation of existing power plants by 2030 are estimated as follows:

- Investments range from 2.5 to 3.66 billion EUR (excluding investment in mine development)
- In almost all scenarios TPP-HP Banja Luka on natural gas is built with total investment about EUR 150 million
- Investment in large HPP provided the implementation of all three systems amounts to 1.8 and 2.2 billion euros
- In case of intensive development of renewable energy sources (i.e. the introduction of strong incentives for their development), investment in this segment reach the amount of almost EUR 1 billion (scenario with measures)

Together with expected entry into plant TPP Stanari by 2015, electricity generation in RS will significantly increase. This will affect the ability to increase the export of electricity. At the same time, carbon dioxide emissions will significantly increase.

For selected scenarios for construction of power plants (i.e. scenarios S1-REF, S2-REF and S3-REF) at the end of the reference period carbon dioxide emissions from electricity generation activities will increase from current about 3.0 million tons to 4.5 million tons (export options included). Total demand for coal for electricity generation by 2030 is estimated to about 140 million tons.Demand for natural gas is estimated at 2.4 to 3.3 billion m^3.

"Screening" analysis provides a simplified picture of the competitiveness of the power plants candidates for the construction (and / or rehabilitation) starting from the installed power of the plants, investment, operation and maintenance costs, fuel costs, life expectancy and selected discount rate.
The analysis is simplified because it takes into account the total costs of each candidate power plant, but not the characteristics of the system / market where the plant fits. The analysis is static and does not take into account the need for covering consumption/demand for electricity, but only estimates the average cost of production during the lifespan of the power plant for desired sale of electricity.
The expected price increase has been calculated based on the weighted average of the present structure of electricity generation in the region and is around 13 EUR / MWh compared to the case without having obligation to CO_2. It is important to emphasize that, besides the cost of emission permits, future market will be limited in terms of total amount of emission permits for all sectors involved in the emission permits trading.
The introduction of additional obligations for emissions, i.e. increasing the costs of electricity generation from fossil fuel power plants to some extent weakens the position of the coal power plants, but they remain competitive at the market. Position of gas thermal power plants is better, as expected due to the lower specific emission of carbon dioxide per produced unit of electricity.

4.4.3 Development of electricity transmission

Electricity consumption in RS is forecasted to reach over the observed period by 2030 the value of 5675 GWh to 6539 GWh depending on the scenario observed, while the peak load by 2030 will reach 1012 MW to 1166 MW, which represents an increase of 226 MW, i.e. 380 MW, compared to the highest peak load recorded in 2008 (786 MW).
Based on these data, it can be preliminarily concluded that relatively small increase in load compared to current situation means that, in terms of meeting the domestic consumption, the transmission network in RS generally needs to be reinforced to 110 kV, together with appropriate maintenance and rehabilitation of existing network.
Transmission network development plan must comply with the Grid Code of BiH and the market rules for the use of electricity transmission network. Investment and development plan must ensure the future security of supply to consumers in RS and BiH, and market activities.
Given the position of RS and BiH in the south-eastern european area, an appropriate development of the RS and BiH network help develop the electricity market within the region.

Grid Code includes standards of planning, with the following criteria:

- planned transmission network must be designed to allow contracted and planned electricity transmission, based on rule 3 UCTE,
- planned configuration must be based on economic criteria,
- transmission network must be dimensioned in accordance with (n-1) criteria,
- transmission network must be planned so that the static and transient stability is not threatened, nor the voltage profile in the network.

Similar planning criteria are used throughout Europe, but the relationship between economic, technical and (n-1) criteria has not been clarified. Open issue is how to treat the investment required from the technical point of view, but unjustified from an economic point of view.
The most important impact of opening of electricity market is a phenomenon of much uncertainty in the planning process. The most important uncertainties are taken into account when planning a multi-scenario analysis, in a manner that scenarios (hypotheses) are set depending on the uncertainties.
The most important uncertainties in RS and BiH that affect the transmission network planning process are:

- location of new power plants and schedule of their engagement, taking into account hydrological conditions,
- load increase, shape of annual curve of load duration, and impact of the market prices on consumption,
- organization of markets within the Energy Community, unknown market transactions and use of interconnection lines,
- long-term availability of power lines and transformers.

Technical criteria for planning the transmission network are defined by BiH Grid Code and the basic criteria is (n-1).
Transmission network in Republic of Srpska should be planned taking into account the different modes (including summer regimes characterized by low engagement of hydropower plants), transit network scenarios in BiH Electric Power Utilities, as well as at the market of Southeast Europe, and planned disconnection of a line or transformer after which follows random outage of the other branch (criteria n-1-1). At the same time, the economic side of the problem should be taken into account and the economy should not be excluding factor for the network reinforcement.

In the future, ElektroprenosBiH has to ensure connection of all plants and new customers, in accordance with the (n-1) criteria defined in Grid Code. Strategic orientation in planning RS transmission network development is:

- further development of 400 kV network primarily including the construction of TS 400/220/110 Prijedor 2 and line 400 kV Banja Luka 6 - Prijedor 2, and connection of these substations to a junction point in 400 kV network of BiH or Croatia (Zagreb-Tumbri or Obrovac) in order to ensure double supply at 400 kV network,
- HPP Višegrad connection to the network 400 kV by construction of a new line 400 kV from HPP Višegrad to HPP BukBijela or 400 kV junction point Vardište, or TPP Pljevlja in Montenegro
- construction of a new line 400 kV TPP Gacko- HPP BukBijela (in case of construction of Gacko 2)
- installation of compensation devices in the network (restrictors) for rehabilitation of occasionally excessive voltage caused by low-loaded 400 kV and 220 kV lines
- stagnation of 220 kV network development and normal maintenance until further notice
- construction of new and rehabilitation of existing 110 kV lines, including lines required for connection of new HPPs and wind turbines and lines required for connection of new TS 110/x kV
- inclusion of new objects in the spatial plans in order to create the conditions for their construction when there is a need and to provide the necessary financial resources.

Table 2. Forecast of growth in electricity demand and peak load

Year	Scenario					
	S1 – High GDP		S2 – High GDP with measures		S3 – Low GDP	
	W (GWh)	P_{max} (MW)	W (GWh)	P_{max} (MW)	W (GWh)	P_{max} (MW)
2010.	3652,8	712	3649,1	711	3622,8	706
2015.	4156,3	791	4079,3	776	3929,7	748
2020.	5038,8	928	4843,4	892	4551,1	838
2025.	5767,4	1029	5513,2	983	5183,3	925
2030.	6538,9	1166	6224,9	1110	5675,3	1012

Source: Energy Development Plan for Republic of Srpska to 2030

4.4.4.Development of electricity distribution

Distribution network is part of the electric power system, which serves to bring electricity from transmission networks and power plants connected to the distribution network to customers connected to the distribution network.

Distribution network planning represents geographical, technical and economic analysis of different solutions of providing reliable and cost-effective services to network users. The purpose of planning of distribution network development is appropriate sizing for reliable operation and maintenance of parameters of electricity quality in accordance with the standards and coordinated action with transmission network and connected facilities of distribution network users. In accordance with demarcation of ownership of power system facilities, the following elements are included in the plan of distribution activity development: 35 kV lines, substations 35/10 (20) kV, lines 10 (20) kV, substations MV / LV, low voltage lines and management systems, measurements and communication.

According to the General conditions of delivery and supply of electricity, the quality of services consists of three parts:

- continuity of electricity supply,
- quality of commercial services and
- voltage quality.

Rules and obligations to register data on quality of services, their recording, publishing and submission to RCERS are established.

While planning the development of complex system, such as electricity distribution, it is necessary to plan the continuous modernization and gradual replacement of some equipment with new and modern one, as well as installation of modern equipment that contributes to more reliable operation of distribution network and quality of supply of its users.

This primarily refers to long-term strategic projects; reducing electricity and power losses, reduction of illicit consumption by reconstruction of connectors and relocation of measuring points, automation and remote network control, installation of electronic electricity meters and enabling remote reading and consumption control etc.

The main recommendations for the development of electricity distribution are:

- Gradual transition to direct transformation 110/10 (20) kV
- Gradual elimination of 35 kV voltage level
- Gradual replacement of voltage level of 10 kV by 20 kV
- In non-urban networks to use low-power transformers (50 kVA and less)
- Installation of a number of simplified TS 10 (20) / 0.4 kV small
- Equipping of distribution dispatching centres for automated and remote control
- Recommendations to reduce losses and non-registered electricity consumption
- Strategy of replacement of meters for certain categories of customers

By 2020, increased investment in the reconstruction of existing network and meters replacement is planned. For that reason, in this period investments are estimated to be almost 50% higher than after 2020. According to types of objects in the distribution network, most of the investment goes to a secondary medium voltage network (54%), then the low voltage network (30%), and the rest goes to the primary medium voltage network and management systems, measurements and communication.

Outlining the reasons for investment shows that the largest part of it is caused by transformation MV / LV construction and reconstruction of low voltage network (55%) as well as reconstruction of existing distribution network facilities (36%). A significant part of the costs goes to the replacement of existing meters by modern digital ones with the possibility of remote reading and control of consumption.

Assuming a mass replacement of 2/3 meters by 2020, which is in line with EU objective of 80%, the investment reaches 8% of total investments in distribution.

5. Conclusion

Data presented, as well as planned investments in energy, especially in the electric power sector, using considerable resources, confirm the orientation of Republic of Srpska for energy sector in the future to be a carrier of general social development.

Together with this task, certainly no less important role for the electric power sector is to ensure for all consumers in Republic of Srpska continuous and regular supply of electricity. In the future, Republic of Srpska will pay special attention to the use of renewable energy sources and energy efficiency. In this way, it will contribute to the environmental protection and solving the global issue of greenhouse gases.

Republic of Srpska has no investment potential for the realization of these significant projects. For that reason, realization of these projects requires significant participation of foreign investors. When it comes to attracting foreign investment, the priority are international companies in the field of energy, i.e. electric power sector.This primarily refers to larger facilities in the field of thermal power as well as renewable energy.

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Braking energy recovery in public transport: Trends and opportunities

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Abstract

During the last decade, public transport companies have increased their efforts to reduce CO_2 emissions and improve the energy efficiency of their infrastructures and rolling stock. In the latter field, technologies aiming at recovering braking energy have improved and are now evolving from prototypes to products. Potential energy savings are significant and range from 15% to 30% of the total traction energy.

This paper presents the latest research results in the field of braking energy recovery for light rail vehicles and shares the vision of public transport companies for these technologies. The structure of this publication is the following. First, three types of energy recovery applications are considered: mobile storage applications, stationary storage applications and stationary "back to the grid" applications. A comparison of the main technologies developed for these applications (batteries, supercapacitors, flywheels and reversible substations) is then provided with a presentation of their maturity and deployment stage. Finally, a case study of the Brussels metro network considering a storage system is presented with a cost-benefits analysis.

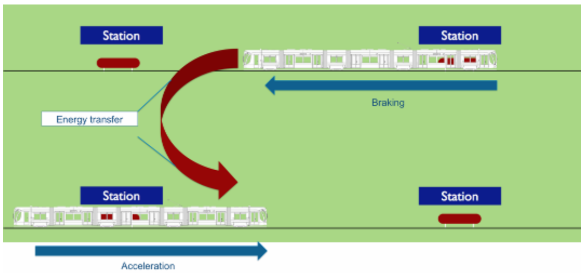
The research done for this publication is produced in the frame of an INTERREG NWE IVB European project called *Ticket to Kyoto*[3], which aims at reducing CO_2 emissions for public transport. The project combines the expertise of five public transport companies (Bielefeld, Brussels, Manchester, Paris, and Rotterdam) who are investing in tram and metro braking energy recovery devices.

Keywords

Public transport, supercapacitors, flywheels, reversible substations, braking energy recovery, power grid management

Introduction

Urban rail vehicles are propelled by electric motors. In the case of a tram, electricity is generally supplied by an overhead line (also called "catenary") through the pantograph. In the case of a metro train, the electricity is supplied by a third rail running all along the track. Both overhead lines and third rails are fed in electricity by substations placed along the tracks. Most recent rail vehicles have the ability to regenerate the braking energy into electrical energy. In that case, the electric motor can be configured to recover the mechanical energy produced by the vehicle inertia (kinetic energy) and works then as a generator producing electricity. In these vehicles, while a small portion of this kinetic energy can be reused to power vehicles auxiliaries, the remaining energy can be sent back to the network and hence recovered only if a vehicle is accelerating nearby. In this case, the accelerating vehicle takes advantage of this energy transfer. If it is not the case, the network voltage increases due to the energy excess and this extra energy has to be burnt in braking resistors. This principle is shown on the figure below. In a metro network, these energy transfers between vehicles usually amount to 20-30% of the total consumption.



Despite the fact that spontaneous energy transfers occur between vehicles, significant energy losses occur because of a lack of simultaneity: no vehicle is receptive (accelerating) when another is braking. To avoid these energy losses, reduce the overall energy consumption and the emissions (CO_2, variospollutants) generated by the energy production, solutions are being been developed and tested in different conditions and contexts. This paper presents such braking energy recovery solutions and illustrates a concrete case study for Brussels metro.

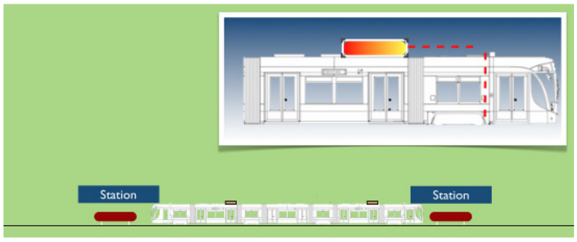
Braking energy recovery applications

Braking energy recovery applications can be classified in three families:

- → Mobile storage applications
- → Stationary storage applications
- → Stationary "back to the grid" applications

Mobile storage applications

Mobile storage applications consist of onboard energy storage systems (ESS) usually located on the vehicle roof. Every system works independently and the recovered energy is directly sent to the storage system placed on the vehicle When the vehicle accelerates, energy is used in priority from the ESS to propel the vehicle. This principle is illustrated in the figure below.



<u>Benefits</u>

- → High efficiency due to reduced overhead line losses, the storage being located on the vehicle
- → Possibility to operate the vehicle without overhead lines on certain sections of the route (urbanistic integration)
- → Voltage stabilization by mitigating voltage sags[4]
- → Reduction of the peak power demand by averaging loads over a period of time
- → Potential down-sizing of the onboard braking resistors

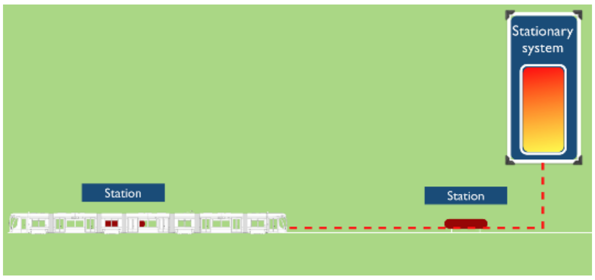
<u>Drawbacks</u>

- → Retrofitting of old vehicles (space availability and weight constraints)
- → Placement of one ESS per vehicle (increase in the costs)
- → Standstill of the vehicle for implementation, maintenance and repair
- → High safety constraints due to passengers onboard

Stationary storage applications

[4] A voltage sag is a temporary drop below a certain threshold of the nominal voltage level

Stationary (wayside) storage applications consist of one or several energy storage systems (ESS) placed along the tracks. These devices recover the exceeding energy when no other vehicle is receptive meanwhile.



Benefits

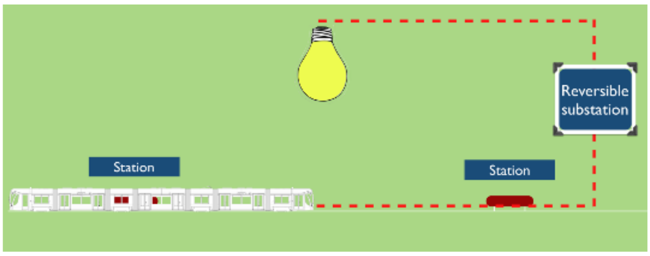
- → System can be used by all vehicles running on the line
- → Voltage stabilization by mitigating voltage sags
- → Reduction of the peak power demand by averaging loads over a period of time
- → Reduction of the number of traction substations or possibility to add vehicles without upgrading the electrical network
- → Reduction of the waste heat, which avoids warming tunnels and stations
- → Potential down-sizing of the line-side braking resistors
- → Lower safety constraints in comparison with onboard systems
- → Implementation, maintenance and repair do not affect operations (switch off mode)

Drawbacks

- → Fine-tuned analysis for sizing the systems and for choosing the right locations
- → Less efficient system due to overhead line losses increasing with the distance of the vehicle
- → If undersized, some energy may still be lost in the braking resistors
- → Place availability in the substations or along the line
- → No opportunity for catenary-free operations

Stationary "back to the grid" applications

The main difference with the previous applications is that "back to the grid" applications do not store the recovered energy but send it to the main electrical grid for other consumers such as lighting, escalators, administrative and technical buildings or potentially sold back to the energy provider.



Benefits

- → Can be used by all vehicles running on the line
- → Very energy efficient due to fewer transformation losses than in storage applications
- → Compared to storage applications, reduction of the waste heat, which avoids warming tunnels and stations
- → Potential down-sizing of the line-side braking resistors
- → Lower safety constraints in comparison with onboard systems
- → Implementation, maintenance and repair do not affect operations (switch off mode)

Drawbacks

- → Fine-tuned analysis for choosing the right locations
- → Place availability in the substations or along the line
- → No opportunity for catenary-free operations
- → No voltage stabilization and reduction of the peak power demand due to the lack of energy buffer (no storage)
- → No reduction in the number of traction substations

Technology overview

Different technologies are envisioned for braking energy recovery applications:

- → Batteries
- → Supercapacitors
- → Flywheels
- → Reversible substations

For each technology, a short technical description is given as well as a list of implementations in the public transport sector. A comprehensive description of all these technologies is to be found on the Ticket to Kyoto Website in the deliverables section [i, ii]

Batteries

In the context of energy recovery, batteries act as an energy storage system (ESS) by storing energy through an electrochemical reaction. Batteries are found in a large range of sizes and power ratings and most of them work on the same principle: between two different materials (electrodes) immersed in an electrolyte solution, a potential difference occurs.

Battery-based implementations are found in different cities both in mobile and stationary applications:

- → NiMH batteries onboard of ALSTOM Citadis Tram operating in Nice (France)
- → NiMH Gigacell batteries onboard of KAWASAKI catenary-free tram in Sapporo (Japan)
- → Lithium-Ion batteries onboard of KINKI SHARYO catenary-free tram in Charlotte (USA)
- → KAWASAKI Gigacell Battery Power System (BPS) for stationary purpose

Supercapacitors

Supercapacitors are electrochemical storage devices that operate like large versions of common electrical capacitors where energy is stored in an electrostatic field by means of charge separation. In contrast to batteries that are charged and discharged through an internal chemical reaction, in a supercapacitor, the energy is stored as a charge or concentration of electrons on the surface of a material [iii] and no chemical reaction occurs.

Supercapacitors, which are also called “ultracapacitors” or “electrochemical double layer capacitors (ELDC)”, are not a new concept since scientists have studied the electrical charge in the interface between a metal and an electrolyte since the 19th century. NEC produced the first commercially successful double-layer capacitor under the name of “supercapacitor” in 1971. These devices were designed for memory back-up in low power applications due to the high internal resistance of the first models. Nowadays several companies produce supercapacitors at commercial level in several countries [iv]. They bridge the gap between conventional capacitors and batteries. They can store 10 to 100 times more energy than conventional capacitors and can deliver around 10 times higher power than most batteries of equivalent size [v].

Supercapacitors-based implementations are found in different cities both in *mobile applications*:

- → BOMBARDIER Mitrac energy saver currently in use in light rail vehicles in Mannheim (Germany)
- → SIEMENS Sitras Mobile Energy Storage currently in use light rail vehicles in Lisbon (Portugal)
- → ALSTOM Steem system in use onboard of a Citadis tram on tram line T3 in Paris
- → CAF ACR system currently in use in light rail vehicles in Sevilla and Granada (Spain)

and *stationary applications*:

- → SIEMENS Sitras Static Energy Storage to be placed along light rail or metro tracks for energy recovery and voltage stabilization purposes. This system has been installed in many cities including Cologne, Madrid and Peking
- → BOMBARDIER EnergGstor wayside energy storage system currently at a prototype stage
- → ADETEL Neo Green Power system recently installed in the metro network in Lyon (France)
- → WOOJIN stationary system currently in use on the Seoul metro network (Korea)

Flywheels

A flywheel is a rotating disc spinning around an axis used for storing energy mechanically in the form of kinetic energy. The flywheel works by accelerating a rotor to a very high speed and maintaining the energy in the system as rotational energy. Flywheels can be used to produce high power peaks. Flywheels systems for stationary applications have been implemented on various networks:

- → PILLER PowerBridge system is currently in use in Rennes, Hamburg and Hannover
- → KINETIC TRACTION GTR System has been successfully tested in New York

Reversible substations/Inverters

A substation consists in an electricity distribution system where voltage is transformed from high to low voltage (and vice-versa) using transformers. As it is more efficient to transmit electricity over long distances at very high voltages, the function of a substation is to reduce the voltage from transmission level to values suitable for local distribution. Substations provide current only in one direction and are not able to absorb energy generated by other sources. A reversible substation consists in allowing the system to act in both ways. The quantity of energy a public transport network is able to absorb is mainly conditioned by the probability of trains braking and accelerating simultaneously [vi]. This absorption phenomenon is called the receptivity of the line. The target of a DC reversible substation is to improve the power line receptivity, in order to regenerate almost completely the trains braking energy.

Reversible substations systems are not widely used in the transport sector but some recent projects have blossomed:

- → SIEMENS Thyristor-controlled inverter (TCI) system is in use in the Zugspitzbahn in Garmisch-Partenkirsch
- → ALSTOM Hesop system has been tested in La Rochelle and is currently tested in Paris
- → INGETEAM system has been installed on the metro network of Bilbao

Market analysis

Based on the technologies overview of the previous section, key elements can be addressed regarding the market for energy recovery systems:

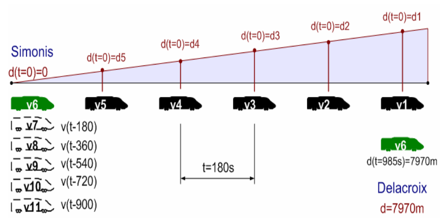
→ Braking energy recovery technologies have recently become a priority for the industry and most suppliers are investing in R&D in this field.
→ Different technologies are competing on the same segment with no clear leading technology. Each technology has advantages and drawbacks that will depend on each situation and context.
→ Mobile and stationary systems aim at reducing the overall consumption of tram/metro networks but mobile systems can also allow catenary-free operations. These different applications will obviously coexist in the future.
→ The solutions developed by the manufacturers must be adapted to every transport network. This requires the use of powerful simulation tools for designing the right system. Suppliers have invested significantly in these tools and will continue their efforts.
→ Despite the high number of suppliers competing in that market, only very limited systems have yet been implemented in the public transport field. The reason is that most systems are still at the prototype stage, which makes it difficult for transport operators to take investment decisions due to the lack of experience feedback and uncertainties about the return on investment.
→ Costs shall decrease when market expands due to technological improvements and elements costs reduction.

Case study

To show the potential savings in terms of energy consumption and emissions mitigations, this article presents a case study of the Brussels metro network considering the implementation of supercapacitors-based energy storage systems (ESS) to be placed along the line.

The analysis was applied to former line 2 of the Brussels metro network. This line has now been extended and forms a circle line around the city centre. However, energy savings simulations have been carried out before this extension when the line had a total length of around 8 km with 14 stops and was fed by 9 unidirectional substations. Metro trains are mode of 5 cars and each car has a tare weight of 30.400 kg and a capacity of 223 passengers (counting on 4 persons/m2), for a total weight of 45.100 kg when fully loaded. The auxiliaries' consumption is set at 20kW per metro car.

Simulation results
A simulation tool has been developed to simulate the whole metro line and the energy exchange between vehicles had to be accounted for. It is modelled in the way that the total distance of the route is covered by a vehicle (vehicle 6, in green as shown on below) that starts from the first stop (d=0) at t=0. At that moment, there are already 5 vehicles running ahead with a time span of 180s. The distance between them depends on the driving cycle. Every 180s after t=0, one vehicle starts the cycle from the first station. Thus, the network is populated with vehicles while vehicle 6 is covering the route. with a time span of respectively 240s and 600s.



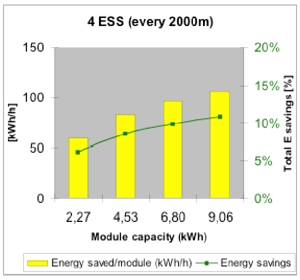
Four alternative module configurations have been configured with an energy content ranging from 2.26 kWh to 9.06 kWh. Given the high frequencies of metro lines, significant energy exchanges occur between vehicles thanks to regenerative braking strategies but a portion of this kinetic energy cannot be recuperated and has to be dissipated in heat in the braking resistors. As a result, the use of energy storage solutions can still strongly contribute to energy savings and efficiency. In the case of a stationary application, one way to evaluate the benefits of the ESS is to measure the energy saved per module every hour. In general, the energy saved per module increases with its size but a higher number of ESSs on the line decreases the amount of energy saved by each module.

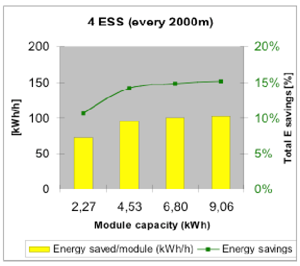
Small-size configuration	Large-size configuration
Cells: C=1500F, V_{max}= 2.7 V.	Cells: C=3000F, V_{max}= 2.7V.
Configuration: 10 strings x 232 cells in series	Configuration: 15 strings x 232 cells in series

Usable energy: **2,26 kWh**	Usable energy: **6,79 kWh**
Max Voltage: 580 V	Max Voltage: 580 V
Cells weight: 742 kg	Cells weight: 1914 kg
Medium-size configuration	**Extra large-size configuration**
Cells: C=3000F, V_{max}= 2.7V.	Cells: C=3000F, V_{max}= 2.7V.
Configuration: 10 strings x 232 cells in series	Configuration: 20 strings x 232 cells in series
Usable energy: **4,53 kWh**	Usable energy: **9,06 kWh**
Max Voltage: 580 V	Max Voltage: 580 V
Cells weight: 1275 kg	Cells weight: 2552 kg

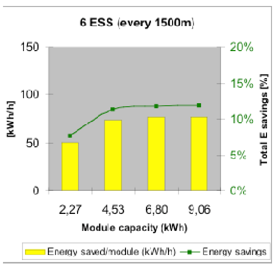
Simulations have proved that at least 1 ESS every 2000 m is required and the distribution of 1 ESS every 1500 m also seems fair. The graphs below show the results obtained when 4 ESSs and 6 ESSs installed along the line, this for different module configurations and both at peak time and off-peak time. Simulation results show total savings ranging from 30kWh/h up to 150kWh/h. It must be mentioned that simulations only consider the traffic in one direction and do not take into account the potential energy exchanges between vehicles running in the opposite direction. As a result, simulation results could be slightly overestimated, especially during peak time. Regarding the module size in the case where ESSs modules are spread every 2000m or 1500m, the small (2.27 kWh) or medium size (4,53 kWh) modules seem the best compromise [vii, viii].

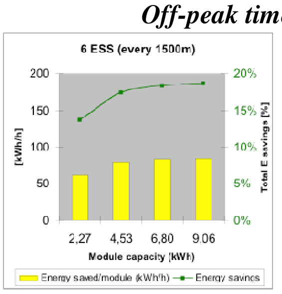
Peak time ***Off-peak time***





Peak time ***Off-peak time***



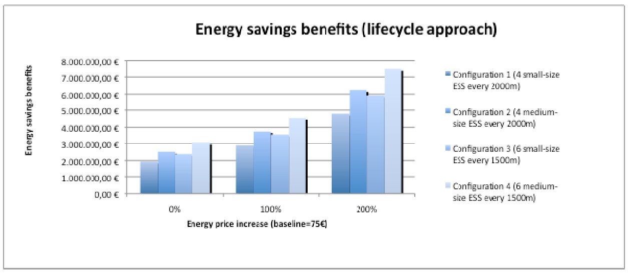


Expected annual energy savings

The annual energy savings of the selected scenarios are given in the table below and take into account the operating hours calculated split between peak and off-peak times and their respective savings.

Configuration	Total installed energy [kWh]	Total savings in one year (kWh)
Configuration 1	9,06	**1 817 203**
Configuration 2	18,13	**2 364 408**
Configuration 3	13,59	**2 237 978**
Configuration 4	27,19	**2 858 459**

The economic benefits of installing supercapacitors-based energy recovery systems are shown on the graph below. These calculations consider a baseline energy price of 75€/MWh and various price increases over time. Expected benefits during the lifecycle of 15 years range from 2.000.000€ up to more than 7.000.000€.

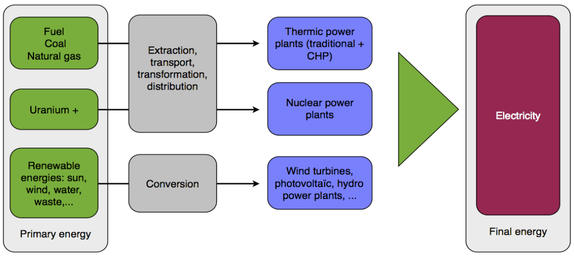


Expected emissions mitigations

Electric vehicles are more environmentally friendly than fuel-powered vehicles but the production of electricity is not emission-free. A considerable variation in terms of emissions due to the production of electricity is observed since a wide range of energy sources are used, often depending on local conditions. In order to measure the total emissions of an electrically powered rail vehicle, a well-to-wheel analysis must be developed.

Direct emissions (tank-to-wheel) are associated to the use of the vehicle itself. In the case of an electric rail-guided vehicle, there are no direct emissions, as the transformation of electricity into propulsion power does not engender pollutants. This is the main advantage compared to fuel-powered vehicles that are responsible for a large amount of pollutants locally.

Indirect emissions (well-to-tank) are those related to the extraction and transportation of the raw materials (primary energy) for the energy generation and the distribution on the electrical network as shown on the graph below.



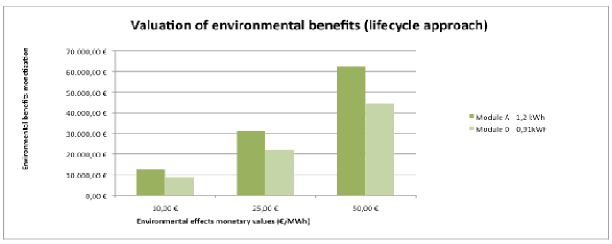
Indirect emissions are directly proportional to the energy consumption of the assessed vehicle as they are measured by the energy consumption multiplied by emission factors that include all pollutants of the electricity production mix.

The metro network in Brussels is exclusively supplied in electricity by the ELECTRABEL facilities. As a result, indirect emissions may be extrapolated from the environmental figures of the ELECTRABEL electricity production facilities.

The annual emissions mitigations due to the installation of ESS along the metro line are computed for the four configurations and show, among others, CO_2 emissions reductions between 400 and 670 tons.

Classification	Emission type	ELECTRABEL production mix emissions in 2007 (mg/kWh)	Emissions avoided with configuration 1 (kg)	Emissions avoided with configuration 2 (kg)	Emissions avoided with configuration 3 (kg)	Emissions avoided with configuration 4 (kg)
Global Warming	CO_2	233.136,00	**423.655,62**	**551.228,79**	**521.753,35**	**666.409,78**
	CH_4	4,00	**7,27**	**9,46**	**8,95**	**11,43**
	N_2O	1,59	**2,89**	**3,76**	**3,56**	**4,54**
Human health / Ecosystems	VOC	3,91	**7,11**	**9,24**	**8,75**	**11,18**
	CO	19,78	**35,94**	**46,77**	**44,27**	**56,54**
	PM10	5,42	**9,85**	**12,82**	**12,13**	**15,49**
	NO_x	234,16	**425,52**	**553,65**	**524,05**	**669,34**
	SO_2	234,45	**426,04**	**554,34**	**524,69**	**670,17**

These emissions can be monetarily valuated. The calculated external cost of one MWh produced by the Electrabel facilities in 2007 was estimated to 10€, considering a value of 25€ per ton of CO_2 emitted. However the price of a CO_2 ton is expected to increase significantly in the future.
The expected environmental benefits expressed in monetary terms are shown on the graph below and range from around 10.000€ up to more than 60.000€ in the case of higher CO_2 emissions value [ix,x].



Conclusion

Braking energy recovery technologies such as batteries, supercapacitors, flywheels and reversible substations were presented in this paper. Considering that the cost of energy is more than likely to follow the upward trend of the previous years and that the environmental concerns will be strengthened, investing in energy recovery applications seems a promising way for transport operators to limit their energy consumption and reduce their operational costs.

The assessment of the installation of supercapacitors-based energy recovery applications along metro line 2 in Brussels presented in this paper has revealed that significant benefits can be expected, both in terms of financial gains but also by a strong reduction of the environmental effects linked to the production of electricity.

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“A Decision Support System for Smart Grid Energy Management”

Ms. A. SERGAKI, Technical University of Crete, Greece

-full paper not submitted-

A statistical approach to the prediction of the hotel stock's energy performance

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Abstract: The issue of evaluating possible strategies for improving the building stock's energy performance is crucial, if the effort and resources invested in renovation and upgrading measures are to be utilized in an efficient way. This applies particularly to non-residential buildings, hotels being a group both of importance and of interest. In a bottom – up approach data related to the energy and environmental performance of buildings were gathered within a frame of a field study, along with information related to occupancy levels, indoor environmental quality and management procedures. The results of this study, and also of similar studies carried out and published over the last years; provide interesting in depth insides to the energy and environmental performance of specific hotels, or fairly limited groups of hotel buildings.

At the same time, and in a top – down approach, data were obtained from the Hellenic National Statistical Service, as well as from the Tourism Organization and Hotel Chambers. These data provide a reliable background in order to elaborate statistically sound mean and median values for the energy performance of various hotel groups. The idea of a "typical" hotel and its respective performance remains, however, vague and has to be linked to the aforementioned bottom – up approach. This was attempted by means of a control of the parameters determining the buildings' energy performance, of the groups' main features and of the statistical control of the variation, deviation and robustness of the data examined. Correlations and possible association between these factors will be further investigated and the results will be presented in this paper.

Keywords: hotels, energy efficiency, typical model building, bottom – up and top-down approach

1. Introduction

Ever since the oil crisis in 1973, it has been realized that a large percentage of energy consumed in buildings for their heating, cooling, and lightning is directly to the way in which the buildings are designed (Maciel et al., 2007; Isaac and Van Vuuren, 2009; Karkanias et al., 2010). At the same time, it was also realized that the densely built urban environment creates a microclimate on its own, affecting energy's balance. The architectural approach improves both energy efficiency and indoor environmental quality, and consequently the quality of life of the inhabitants, by exploiting the building's design and structure as such (Karkanias et al., 2010).
In an evolutionary process since the early 1970s, a series of technologies, which are at the meantime considered to be "green" technologies, has been embodied in the building's design, utilizing solar energy, natural building's shell and the ground, in order to achieve lightning, heating, and cooling with a minimum conventional energy consumption (Papadopoulos, 2007). In this sense, it is important to mention the way the European legislation defines the concept of bioclimatic architecture.

2. European Union and Greek Legislative Framework

In order to promote and support energy conservation at the building sector, European Union (EU) has issued directives to enforce more environmentally friendly building policies by its Member States. The most related directive for sustainable building was the 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the Energy Performance of Buildings (EPBD). The transposition date was in January 2006 with a grace period until January 2009. A further step related to sustainable building was on the Directive 2006/32/EC on the energy-use efficiency and energy services. The main aim is to make the end-use of energy more economic and efficient, by establishing incentives and legal frameworks that prevent efficient end-use of energy, and to create conditions for the development and promotion of a market for energy services.
The general target for EU is to adopt and achieve an energy saving target of 9% by 2016. Moreover, with the Directive 2002/91/EC Member States were forced to develop energy auditing systems for all final consumers in order to promote energy end-use. The most recent action of the EU towards sustainability at the building sector is the Directive COM/2008/0780 final – COD 2008/0223. The recast of EPBD clarifies certain provisions; minimum energy performance requirements, certifications, inspections and finally develops a framework for higher market uptake of low- or zero-energy and carbon buildings. Member States should apply a methodology, at national or regional level of energy performance of buildings' calculation on the basis of the general framework (Article 3).
Apart from the aforementioned directives, the harmonisation with the Greek legislation complied with the Law 3661 'Measures for the reduction of energy consumption in buildings' (Official Journal of the Government of the Hellenic Republic, FEK 89/19 May 2008) and the Regulation of Buildings Energy Performance (KENAK). The only legislative measure pending implementation is the Presidential Decree for the enactment of Energy Auditors.

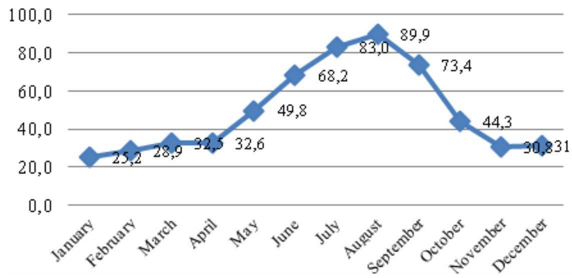


Figure 1. Seasonality of the Greek Tourism Sector

Greek Law 3661/2008 with the new regulation on energy efficiency of buildings (KENAK) sets a framework of regular inspections requirements in heating, cooling, air conditioning and lighting systems and at the building in general. However, there is still a gap of know-how at their implementation to the public use buildings, such as hotels.

3. The Greek Hotel Sector

Greek tourism is among the most dynamic branches within the services' sector. According to Association of Greek Tourism Enterprises (SETE, 2011) tourism contributed 15.3% to the Greek Gross Domestic Product (GDP) and 17,9% to employment. During the following years, despite the worldwide economic crisis, tourism in Greece is expected to develop with an annual growth rate of 4.4% / year (WTTC, 2010).
As Greece is on the way to transform itself to an upmarket tourism destination, the need for an increase in high quality, resort accommodation becomes apparent. Specifically, hotels represent 0,82% of the Greek building stock with more than 9,000 hotels, with 763,407 rooms, in operation (SETE,2001). Most of the hotels are 2-star hotels with low budget infrastructure. Therefore, a strategic plan for spatial development is needed in order to achieve a balanced touristic growth and high quality tourism facilities development. Furthermore, and aiming at the improvement of the existing infrastructure, the lengthening of the operational season and the improvement of alternative forms of tourism, a series of structural, financial and administrative measures were adopted by the State. With respect to the aforementioned role of

sustainability, the measures are based on the EU's encouragement towards the improvement of the environmental performance of services and products. Concerning these new approaches elaborated by the EU, in order to improve the energy performance of the tourism sector, one cannot fail to underline the voluntary environmental quality labelling schemes.

If energy demand is analyzed with respect to its time variation, it is obvious that the peak values are recorded in the summer season, due to the use of air-conditioning for space cooling, a fact that is enhanced by the seasonal character of Greek tourism.

An in depth investigation on present energy uses of the sector is presented aiming to highlight the potential and the importance of a master plan for the implementation of an energy renovation strategy in order to lead the hotel industry to a sustainable touristic development road by improving the quality of its facilities and its services.

The aim of this paper is to provide comparison bottom-up building physics stock models in order to analyze the hotel sector energy outputs and inputs. After placing bottom-up hotel physics stock models we can provide conclusions about energy use at the hotel sector.

4. Top-down and Bottom-up Modelling Approaches

The methodologies and the underlying techniques available for modelling at the hotel sector and generally at the building sector have been a topic of discussion to a plethora of articles (Kavgic et al., 2010). The two fundamental classes of modelling are usually used to predict and analyze various aspects of the overall building stock energy use performance.

4.1. Bottom – up approach

Bottom-up models have been widely used within energy analysis and planning. Models of this type are fully detailed and describe a number of specific energy technologies with both technical and economic parameters. Both present and future technologies are often included, which means that these models include a description of the change in parameters as, e.g. fuel substitution options based on knowledge of the stage of development of new technologies (Kavgic et al., 2010). Bottom-up models in this indirectly way describe changes in parameters which in top-down models would be fuel substitution elasticities. Models based on the bottom-up approach can be either optimisation or simulation models.

Additionally, bottom-up models include energy demand divided into end use demands, e.g. heating, lighting, ventilation, process, rather than divided into energy types. The latter remark reflects the view that developments in energy demand tend to depend more on the different purposes for which energy is made use of than on the specific energy type and the characteristics related to this type including the energy price.

Bottom-up models of hotel energy demand are typically based on vintage models of a large number of end use technologies (Jacobsen, 1998).

4.2. Top-down approach

Top-down modelling approach works at an aggregated level. The econometric top-down models are primary based on energy use in relationship to variables such as the existence of air-conditioning systems, restaurants, pool, seasonality etc. A top-down method implies that energy demand is determined by relative prices, income or production and exogenous energy efficiency. This energy efficiency is quantified from bottom-up calculations that are aggregated to the level of the macroeconomic model (Jacobsen, 1998).

4.3. Model comparison

A simple comparison between those models can lead to very different results. The difference between the approaches and the consequences for costs has been treated in depth (Jacobsen, 1998; Kavgic et al., 2010; Tuladhar et al., 2009). As argued by Hourcade and Robinson (1996), both top-down and bottom-up models can be optimistic or pessimistic on costs. Bottom-up models tend to be optimistic on the technical cost, while top-down models are often more negative on this issue. Top-down models can be either optimistic or pessimistic regarding the existence of double dividends. The effect of double dividend in a top-down model could produce costs that are negative and in this way the top-down model could be more optimistic than some bottom-up models. The relative advantages of the two approaches for analyses in different fields could be summarised at the following table.

Table 1. Advantages of bottom – up and top-down modelling approaches (Jacobsen, 1998).

Bottom-up	Top-down
▪ regulation and detailed energy planning; ▪ restructuring of	▪ Energy taxes; ▪ effect of different economic scenarios on energy and

energy supply sector; ▪ using standards for housing insulation or electric appliances; and ▪ project the technological development in order to quantify the aggregated development in energy efficiency.	environment; ▪ macroeconomic consequences of changes in the energy system; and ▪ general equilibrium effects.

5. Bottom-up Approach

The hotel distribution across Greece is studied by means of 3 independent parameters: the climate zone, the region (official regional administrative division) and the official geographic area division of the country. The data are supplied through the Hellenic Chamber of Hotels, concerning the year 2010 and were processed using Excel and SPSS 17 software. According to the results, almost half of the hotels (49%) are located in the climate zone A, characterized by mild, sunny weather conditions and high temperatures throughout the year, with only 2% in zone D. Respectively, the region of South Aegean accumulates the 20% of the hotels, followed by Crete (16%) and Central Macedonia (12%).
At the same time, the 40% of the Greek hotels are situated in the Aegean islands and Crete, while the geographic area of Macedonia meets the 16%. Both the region and area of Thrace has the minor percentage of hotel infrastructure. The results are presented in the following table (table 2).

Table 2. Hotel distribution across Greece according to: (a) climate zone, (b) region and (c) geographic area.

(a)

Climate zone	N	Percentage (%)
A	4766	48.8%
B	2887	29.5%
C	1949	19.9%
D	169	1.7%
Total	9771	100.0%

(b)

Region	N	Percentage (%)
Epirus	342	3.5%
Thessalia	596	6.1%
East Macedonia & Thrace	379	3.9%
Crete	1550	15.9%
Central Macedonia	1164	11.9%
Western Makedonia	126	1.3%
Northern Aegean	407	4.2%
South Aegean	1987	20.3%
Ionian Islands	912	9.3%
Central Greece	547	5.6%
Attiki	886	9.1%
Western Greece	269	2.8%
Peloponnisos	606	6.2%
Total	**9771**	**100.0%**

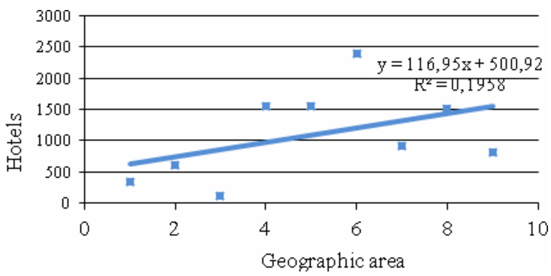
(c)

Geographic area	N	Percentage (%)
Epirus	342	3.5%
Thessalia	596	6.1%
Thrace	109	1.1%
Crete	1550	15.9%
Macedonia	1560	16.0%
Aegean Islands & Dodekanese & Cyclades	2394	24.5%
Ionian Islands	912	9.3%
Central Greece	1509	15.4%
Peloponnisos	799	8.2%
Total	9771	100.0%

In an effort to study and quantify the relation between the hotel location and the 3 aforementioned division types, the Pearson correlation coefficient is estimated for the available data. It is proven that the hotel site is strongly correlated to the climate zone (R^2= 99%, statistical significance at the 0.01 level), though there is no statistical significant correlation between the site and either the region (R^2= 13%), or the geographic area (R^2=44%). Furthermore, a linear regression model is fitted in order to examine and express the relation of the hotel frequency and the allocation. The hotel distribution is successfully expressed by the parameter of the climate zone (coefficient of determination r^2=98%) and poorly by the geographical area (coefficient of determination r^2=19%). The linear regression models fit is presented in Figure 2.
Hence, the evaluation of the results suggest the considerable association between the development of lodging infrastructure and the climate conditions,

meanwhile the impact of division using administrative criteria is proven insignificant to hotel allocation.
In that sense, and after using the data provided by means of the top down approach to obtain the necessary background on the hotel buildings' features, the bottom up approach will be used to provide the necessary insight to the buildings' energy performance and its impact on the feasibility and viability of energy conservation measures in the branch.

Figure 2. Linear regression models of the hotel distribution in relation to geographical area



6. On The Energy Performance of Hotel Buildings

A further set of data used for this paper is derived from a survey carried out by the authors and LHTEE on the energy use in 93 Greek hotels. The study focused on energy and environmental performance of the hotels. Within this line of approach information were gathered on the conditions of the hotel buildings' envelopes and HVAC installations as well as on the hotels' operations. The former included energy and water consumption, while the latter average monthly occupancy levels, operational patterns and conditions on indoor environmental quality, including thermal comfort, indoor air quality and lighting. The data were collected by means of a questionnaire according to standard procedures foreseen by energy management practices for hotels and public buildings (Papadopoulos et al., 2005, Boemi et al., 2009). The questionnaire was completed within the frame of a series of in-situ visits of LHTEE's researchers in 2008 and 2009.
The data base set up in this way is a tool that supports (a) the study the constructional and operational features of existing lodgings services and hotels and (b) the elaboration of interventions and improvement measures, leading to the reduction of consumption and the rational use of energy and also to the use of new and innovative technologies in this sector. Some of the most important findings of the survey are presented briefly in the following paragraph.

6.1. Results of the survey

The survey included audits of 93 hotels, which were picked out without any designed parameter. Audited hotels are placed in urban areas or close to major cities. Most of the hotels are placed in the Region of Central Macedonia (58% in the prefecture of Thessaloniki and 26% in Halkidiki) and were: 1% 1-star hotel, 20% are 2-stars, 22 are 3-stars, 25 are 4-stars and 24 are 5-stars and LUX hotels. That allocation indicates a balance between hotel classes.
From the hotels audited, 55% were built before 1980, 30% were constructed between 1980 and 2000 and 15% were built after 2000. Therefore, for reasons of age alone, there should be a pressing necessity for the majority of the buildings to adopt energy conservation measures.
According to the survey's findings, most hotel units, both seasonally and annually operating, were renovated to some extent after 2000. This fact is quite encouraging for the attitude of the branch, as it shows that hoteliers are trying to reduce their energy consumption. The results, however, do not always live up to the expectations.
Electricity consumption for the most hotel units varies around 300 kWh/m^2 month for rural hotels and over 400 kWh/m^2 for urban hotels. The former value is equal to the hotel case that is in accordance with the published literature. The following diagrams are representative samples for hotel in rural and urban areas.
Considering the results produced by the audit with the statistical values provided by other studies (Santamouris et al., 1995, Daskalaki et al., 2004, Gaglia et al., 20007) they can be regarded as fairly typical for the climatic zone, the administrative and the geographic region considered. In that sense they can be used as an input for the top-down analysis of the hotel sector as such.

7. Conclusions

The lack of validated and verified data on the energy behaviour and performance of significant building groups leads to the necessity to approximate these figures by means of statistical processes. However, no statistical approximation can be safe when it is not based on a verified top-down analysis of the sample considered and bottom-up configuration of the boundary conditions, based on real data.
The hotel sector is of vital importance for the Greek

economy, so is its energy performance for the building sector. The lack of data lead us to the adoption of a combination of top-down and bottom-up approach, in order to produce a viable strategic plan for the improvement of the hotels' energy and environmental performance. The first results validate this approach, which is currently being allied on the full sample of the hotel buildings studied.

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Title: Impact of Energy Taxation in Electroproduction from Natural Gas units on the Greek Electricity Market

Abstract

This paper aims to analyze the impact of the imposition of the fuel consumption tax imposed by the Greek Government on the electricity produced by natural gas plants. This new fiscal measure is applied since 1st of September 2011 and the early results show its influence on the electricity market. The paper examines the marginal system price for September 2011 compared to previous months in order to capture the effect of the imposition of this measure. In order to have a better comparison of the effect of the tax, the load conditions over the last year has been compared to those of September 2011 in order to identify the months with similar or comparable load conditions. The paper examined the impact of the tax on the marginal prices during peak and base demand hours as long as the impact on the electricity trade (imports/exports), share of the fuels in the electricity mix and share of internal electricity production in total consumed energy. Although the tax has been applied very recently, there is a increasing opposition from market participants and the regulatory authority that the fiscal benefits to be expected from this measure are less than expected. Although, the target of this paper is not to provide the macroeconomic effect of the imposition of this tax, important changes in the electricity market and the share of the different fuels can provide indication on medium term-impacts. The paper aims to provide evidence in the discussion over the suitability of this measure towards meeting fiscal targets as well as affecting the electricity market on its own.

Keywords: Energy Taxation, Electricity Market, Natural Gas

Introduction

The Greek electricity Market in the last years is phasing important changes either through its further liberalization or through the influence of the economic crisis in its operation. Since 30/09/2011 the Greek Electricity Market operation is split in a) Day Ahead Schedule (DAS) Market and b) Imbalance Settlement, entering a new phase towards its further integration into the European “target model”. The DAS market is dominant in money transactions (> 90%), but since its implementation it has led to important changes, such as the decrease of the System Marginal Price in the first months of its implementation. This has allowed private Load Representatives to gain market in consumption from the Public Power Corporation (PPC), leading to decrease in the electricity tariffs for specific categories of electricity customers. .However, it had also negative effects, such as the widening of the debt needed to be covered in order to pay the Renewables Production through feeding tariffs. Moreover, it has created space for “arbitrage”, through the quite important difference between the DAS system marginal price and the imbalance marginal price.

The above situation had led the Regulatory Authority of Energy (RAE) to impose charges for non compliance, aiming not to leave space for producers and consumers for speculation and gaming in the Greek electricity market and to improve its further stability. At the same period, the Greek economy is phasing its worst economic crisis since the last 50 years, arising mainly due to its increasing debt. Towards raising new loans, the Greek Government has been committed in imposing sharp fiscal measures all over the economy in order to decrease its deficit. In the electricity market, it has been decided to implement special consumption taxation in electroproduction form natural gas, a decision that raised questions over its suitability. Similar policies have been introduced in other markets providing interesting outputs (Voorspools and D’haeseleer, 2007; Vehmas et. al., 1999; Szargut and Stanek,, 2008). The Greek Electricity sector has been identified as a crucial sector for imposing energy and environmental policies (Dagoumas et. al., 2007), but its examination under the running economic crisis in Greece leaves space for further research. This paper is the first to provide results from the consequences of the implementation of this tax in the electricity market. By providing also results from the last year, this influence can be more easily understood. The paper provides results on the influence on the system marginal price, on the electroproduction mix and on the behaviour of the importers and exporters.

Natural Gas Pricing

A critical issue when examining the effect of an energy tax in natural gas is how the natural gas pricing takes place. If its price is very low an energy tax can create different results when its price is very high. Natural gas pricing over the last decade has been based on oil pricing and the majority of long-term gas contracts have been based on this relationship. However recent trends and research (Stern and Rogers , 2011) have raised the question the rationale of the continuing linkage of prices in long term natural gas contracts to those of oil products. Natural Gas import pricing in Greece seems, as most European markets, to move steadily from oil-linked pricing to hub-based pricing. Natural gas pricing for electroproduction is further depending on volume and demand curves of gas units. Since 01 September 2011, a special Consumption Tax (SCT) is imposed on electroproduction from natural gas units, equal to: 1.5 Euro/GJ (=5.4 Euros/MWh).This leads to an increase in the fuel cost of gas units by about 10-18 Euros/MWh, considering efficiencies in the range 33-60% (Open Cycle – Closed Cycle Gas turbines) and the relevant VAT. Considering the variable costs of units consists of the fuel cost and the O&M cost, which are usually constant or slightly increasing with generation, the change in fuel cost leads to almost identical change in the variable cost, as can be seen in figure 1.

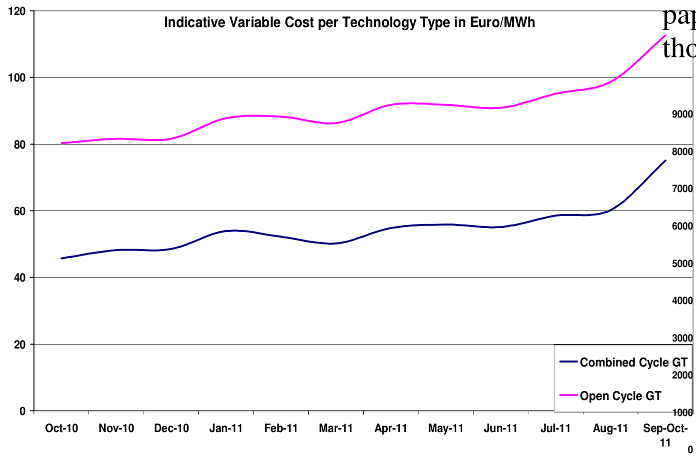

Figure1: Indicative variable cost of natural gas units per technology type in €/MWh.

Special Gas Consumption Tax influence in System Marginal Price

The imposition of this tax has led important increase of marginal gas price for peak times as can be seen in Figure 2, which shows the marginal gas price in the period October 2010-August 2011 and the period September-mid October 2011, when this tax was implemented. This figure shows also its difference.

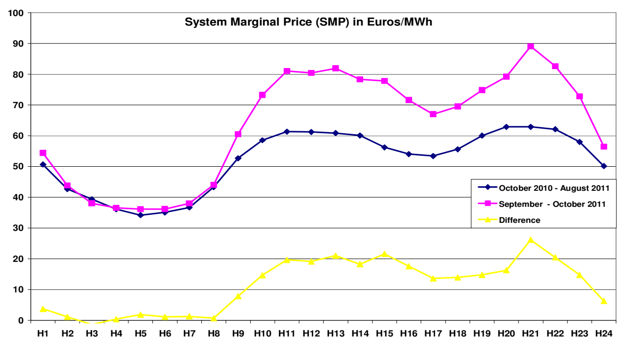

Figure2: System marginal price for periods October 2010-August 2011 and September-mid October 2011 in €/MWh.

Considering that in order to compare the marginal price among two periods, similar conditions have to be considered. One of them is the load demand, which as shown in Figure 3, shows that the load demand in June 2011 and September 2011 where almost identical. Considering also that the gas pricing in those months where similar, the paper focused on comparing the outputs of those months.

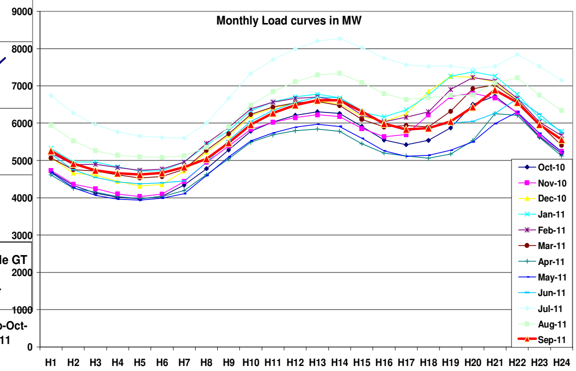

Figure3: Monthly Load Curves in MW.

Figure 4 shows the marginal gas price for each month in the last in the period October 2010-October 2011, where a direct comparison of each month can be done. June 2011 and September 2011 shows significant differences in Marginal Prices for peak hours, even up to 20 €/MWh for few hours.

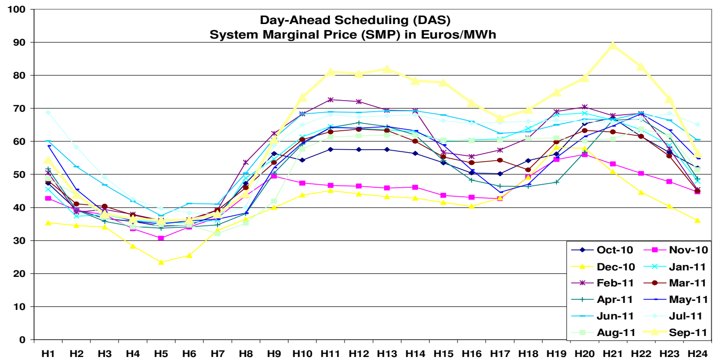

Figure4: System marginal price for each month in last year in €/MWh.

Special Gas Consumption Tax influence in Electroproduction mix

The imposition of the natural gas tax has led to a small decrease in the electric mix, as natural gas share has been decreased, covered mainly through the increase in lignite production, as shown in Figures 5&6. The current trends show that imports has not been increased yet, as would have been expected. A higher price in the Greek electricity Market creates place for gains for importing cheaper electricity from neighbouring countries. The fact this increase has not yet been reported in real market, has directed this paper towards examining the behaviour of importers and exporters of electricity.

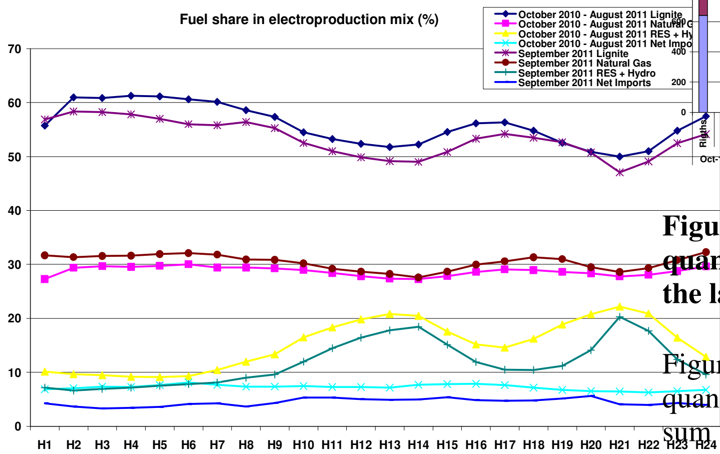

Figure5: Fuel share in electroproduction mix for periods October 2010-August 2011 and September 2011 in %

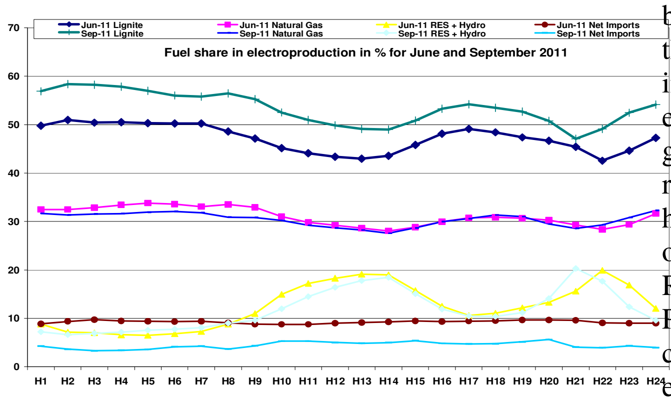

Figure6: Fuel share in electroproduction mix in June and September 2011 in %

Special Gas Consumption Tax influence in interconnections trade

The imposition of the natural gas tax has not yet changes the behaviour of importers and exporters as can be seen in Figures 7-8. Figures 7 show the quantities scheduled in DAS (yellow bar) compared to the sum of Long-term (purple) and Daily (claret bar) Rights. For all Months importers tend to use a quantity slightly more than their Long-Term Rights, as they are forced to do due to the existence of relevant charges in case they don't use them.

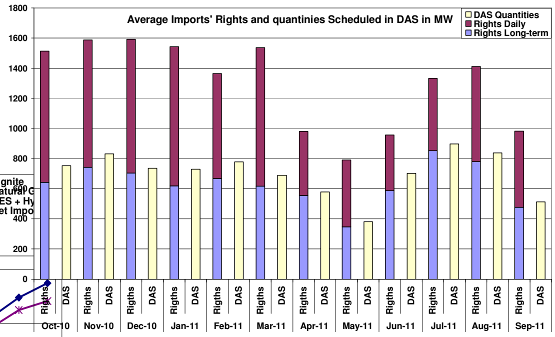

Figure8: Average Imports' Rights and quantities scheduled in DAS in MW over the last year

Figure 8 show the percentage of the quantities scheduled in DAS compared to the sum of Long-term and Daily Rights. For all Months importers tend to use a similar percentage. However it is expected that importers will take the price signal through this increase in System Marginal Price and in the next months will change their behaviour, towards using the majority of their Rights. This is expected to lead in an increase of their share in the electroproduction mix by replacing natural gas electroproduction. A continuation of this research will clarify if those outcomes will happen, which will then justify the reaction of several agents in the markets, such as the Regulatory Authority of energy and the Producers, which claim that this fiscal policy can lead to perverse outcomes for the Greek economy.

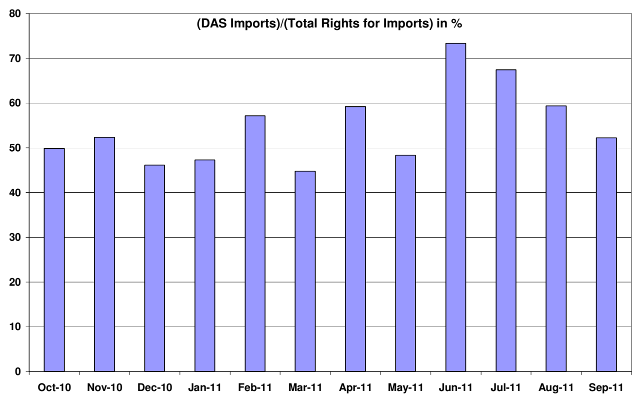

Figure8: Share of quantities scheduled in DAS for Imports in Total Rights for Imports in % over the last year

Conclusions

The implementation of Day Ahead Schedule and the further Code developments, such as the charges of non-compliance has led to: decrease initially in System Marginal Price with relevant Increase in Exports initially, Increase of share on private Load representatives and decrease of PPC' share, leading to a new status with increasing competition in consumers' tariffs and more stable trade in interconnections. The Aim of the Greek Government to raise money towards decreasing its deficit and financing Renewables has led to the imposition a tax in electroproduction from natural gas units. This decision has raised questions over its suitability. Natural Gas Pricing for electroproduction is related, a) internally to the volume and demand curve and b) internationally to evolution of oil products markets and gas hub-based pricing, and therefore any energy tax on natural gas has to consider internal and international conditions.

The implementation of Special Consumption Tax in Gas units led to increase of System Marginal Price 10-20euros/MWh for most of the hours, about 8euros/MWh in average for each hour. But, yet no significant change in the electric mix has been reported, as natural Gas production remains at same levels and the behaviour of Exporters/Importers has not changed. However, it is expected that the Importers will take the price signal of the increase in system Marginal Price and will start use the majority of their Imports' Rights, leading to increase in imports and decrease in natural gas electroproduction. The research will continue towards examining the influence of the tax in the next months and therefore judging over its suitability.

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Session 2. Environment

Pressure Swing Adsorption as an Efficient Tool for the Separation of Carbon Dioxide from Flue Gases

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Abstract

An important option for the abatement of carbon dioxide emissions is the removal of CO_2 from flue gases. This technique, known as post-combustion capture, can be realized by various methods already used in other applications. One of these methods is pressure swing adsorption (PSA), which was specifically mentioned in the IPCC Special Report as a promising emerging technology. Mathematical modelling and simulation provide a reliable and inexpensive tool to analyse the various PSA configurations that might yield high-purity CO_2. The paper presents such an approach, together with the relevant equilibrium and kinetic data and the results of extensive PSA simulations. The simulations were carried out for a three-column installation packed with zeolite molecular sieves 13X. The principal objective of the simulations was to demonstrate the practical feasibility of the proposed PSA configuration. The main result of the study is the modification of the PSA process used in the purification of flue gases by the introduction of purge with the CO_2-rich stream.

Keywords: flue gas, CO_2 abatement, pressure swing adsorption

1. Introduction

A promising technique for the removal of carbon dioxide from gas streams is pressure swing adsorption (PSA), which was specifically mentioned in the IPCC Special Report (Metz et al., 2005) as an interesting emerging option when applied to flue gases (Kikkinides et al., 1993, Na et al., 2001, Chou and Chen, 2004). However, a key problem in the design and optimization of this process is a judicious selection of a suitable adsorbent which, on the one hand, would exhibit a high CO_2 adsorption capacity and, on the other, would be selective in terms of CO_2/N_2 separations. Therefore, the present study was at first focused on the choice of an appropriate adsorbent from a range of commercially available materials, based on extensive experimental assessment of their adsorptive properties. Then, for an adsorbent thus selected, simulations were performed for a three-column PSA installation using a model developed and verified elsewhere (Tanczyk et al., 2010). The simulations led to a number of interesting conclusions. It was found, among others, that the three-column system can yield a highly concentrated stream of carbon dioxide, with an almost complete recovery of this species.

2. Adsorption isotherms for carbon dioxide and nitrogen

The initial screening of adsorbents that might potentially be used in CO_2/N_2 separations was done for five commercially available materials: three activated carbons (BA-10, GAC CECA and Norit Vapure 612) and two zeolite molecular sieves (Molsiv 13X and Grace 13X). The equilibrium experiments were carried out using an Intelligent Gravimetric Analyser (Hiden Isochema) shown schematically in Fig.1.

The experimental CO_2 and N_2 adsorption isotherms for the five adsorbents at 20^oC are shown in Figs.2 and 3.

Based on the isotherms thus measured selectivity coefficients were calculated using the following formula

$$\alpha_{CO_2/N_2} = \frac{q^*_{CO_2} / q^*_{N_2}}{y_{CO_2} / y_{N_2}} \qquad (1)$$

Obviously, for non-linear isotherms these coefficients strongly depend on partial pressures of the two species (Warmuzinski and Sodzawiczny, 1999), Fig.4.

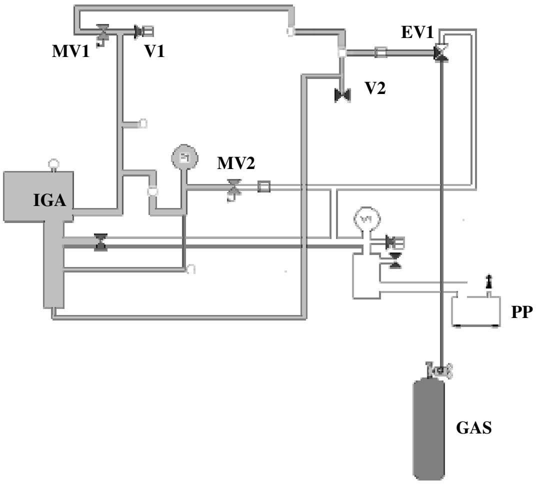

Fig.1. Schematic representation of the measurement system (IGA – gravimetric analyser, PP – vacuum pump, GAS – gas cylinder, MV1- inlet valve, MV2 – outlet valve, EV1 – three-way valve, V1 – safety valve, V2 – inlet valve for ambient air)

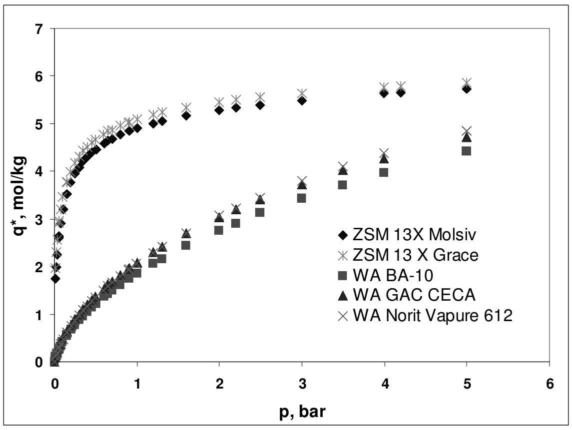

Fig.2. Experimental adsorption isotherms for CO_2 at 20°C

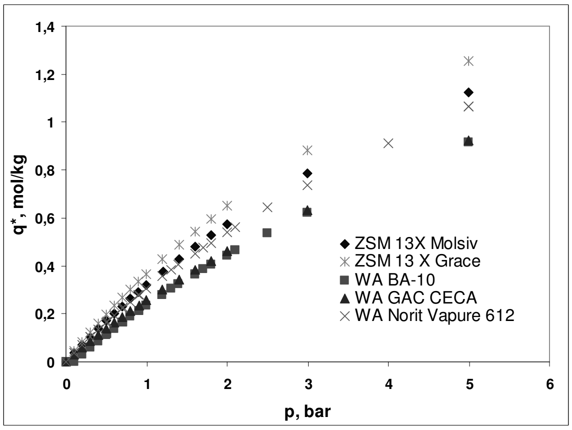

Fig.3. Experimental adsorption isotherms for N_2 at 20°C

As the experiments reveal (cf. figures 2, 3 and 4), ZMS Grace 13X is superior to the other adsorbents in terms of both adsorption capacity and selectivity. Consequently, it is this adsorbent that was selected for the detailed investigation of both equilibria and kinetics of CO_2 and N_2 adsorption.

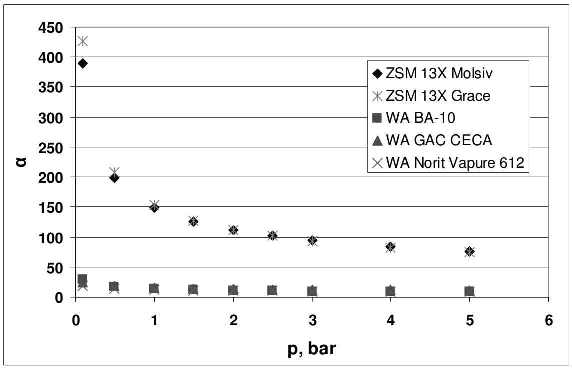

Fig.4. CO_2/N_2 selectivities for the five adsorbents at 20°C

Adsorption equilibria were measured at 20, 40, 60 and 80°C, over a pressure range of 0-5 bar (Figs.5 and 6).

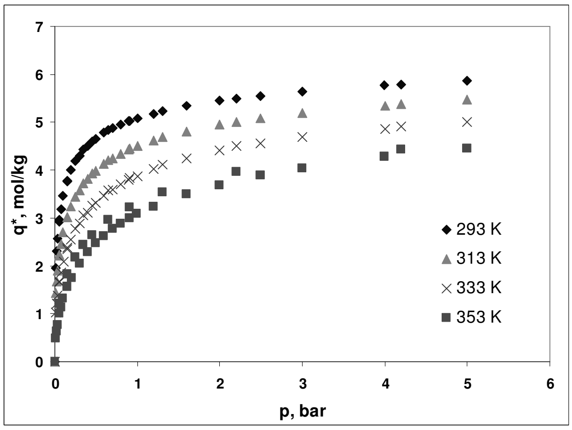

Fig.5. Experimental equilibria for CO_2 over ZMS 13X (Grace)

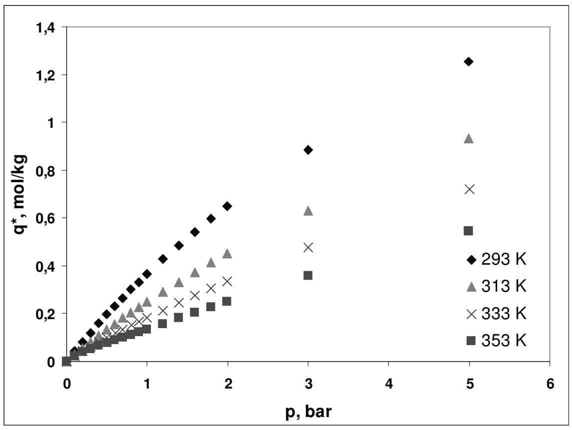

Fig.6. Experimental equilibria for N_2 over ZMS 13X (Grace)

The equilibrium data were then correlated using the Langmuir-Freundlich equation

$$q_i^* = q_{si} \frac{b_i \, p_i^{n_i}}{1 + b_i \, p_i^{n_i}} \tag{2}$$

3. The kinetics of adsorption

Every single point of an adsorption isotherm is measured as an uptake curve which shows the temporal approach to equilibrium. Such a curve makes it possible to determine mass transfer rate in the adsorbent pores provided certain experimental conditions are met.

The kinetics of mass transport within the pores can be quantified using diffusional time constants. For the systems analysed (i.e., CO_2 and N_2 over ZMS 13X Grace) these constants remain almost unchanged with pressure. Therefore, in simulation calculations their averaged values were used. Also, the difference between the values of this parameter for CO_2 and N_2 is only minor and is less than one order of magnitude. Hence, it is assumed that the adsorptive separation of carbon dioxide and nitrogen is controlled by their equilibrium properties rather than by the rate at which the two species move within the tortuous pores of the adsorbent.

The values of the diffusional time constants for the adsorption of CO_2 and N_2 on ZMS 13X (Grace) averaged over pressure are given in Table 1.

Table 1. Diffusional time constants for CO_2 and N_2 over ZMS 13X (Grace)

Gas	**D/r^2, s^{-1}**			
	20 °C	**40 °C**	**60 °C**	**80 °C**
CO_2	$9.06 \cdot 10^{-4}$	$1.07 \cdot 10^{-3}$	$1.33 \cdot 10^{-3}$	$1.59 \cdot 10^{-3}$
N_2	$4.08 \cdot 10^{-3}$	$4.79 \cdot 10^{-3}$	$4.65 \cdot 10^{-3}$	$4.86 \cdot 10^{-3}$

4. Mathematical model of the process

The main components of a dry flue gas include carbon dioxide, nitrogen and oxygen. Due to a low separation selectivity of nitrogen vs. oxygen and large adsorption capacity for CO_2 on many carbon and zeolite adsorbents, N_2 and O_2 are treated as a single component. The problem is thus reduced to the separation of CO_2 and N_2, which yields a stream of pure nitrogen and a stream of gas enriched in carbon dioxide. Based on the available literature and our own experimental and theoretical studies it is assumed that the sequence of steps in such a process can be as follows: feed with the flue gas, cocurrent depressurisation, purge with CO_2-rich stream, countercurrent depressurisation, vacuum regeneration, and, finally, pressurisation with the feed (cocurrent) or with a fraction of the N_2 stream (countercurrent). The feed, purge and vacuum regeneration steps are carried out at a constant pressure. During the other steps the pressure either increases or decreases. The direction of the cocurrent flow is the same as that of the flow during the adsorption (feed) step, while the countercurrent flow takes place in the opposite direction. It is further assumed that the process is realised in a PSA installation consisting of 2-4 columns, and the columns are packed with zeolite molecular sieves (ZMS 13X). Although the process itself is non-isothermal, thermal equilibrium prevails between the gas and the solid phase. Plug flow with axial dispersion is assumed, pressure drop over the adsorbent bed is negligible and the fluid phase is modelled as an ideal gas.

The details of the model are given in Tanczyk et al., 2010. The model was validated based on extensive experiments carried out in a two-column PSA laboratory installation for the separation of CO_2 and N_2 mixtures (Tanczyk et al., 2010).

5. Simulation studies

In conventional PSA cycles an increase in CO_2 content in the enriched gas relative to the concentration of carbon dioxide in the feed gas is 20-80%. Thus, if the initial CO_2 concentration in the flue gas is 15%, its concentrations in the enriched product are, roughly, between 18% and 27%. These are rather small numbers, despite using vacuum regeneration of the adsorbent bed. As has already been pointed out, a means to raise the content of carbon dioxide in the product is the purge with a portion of the enriched gas. The results of the numerical simulations for such a modified cycle (cf. Table 2) are shown in this chapter.

Table 2. PSA cycle in the three-bed installation. F – feed, D – depressurisation, P – pressurisation, Pu – purge, R – regeneration (vacuum), ↑ – cocurrent flow, ↓ – countercurrent flow

Column / **Stage**	**1**	**2**	**3**
1	F↑	D↑ Pu↑	D↓ R↓ P↓
2	D↓ R↓ P↓	F↑	D↑ Pu↑
3	D↑ Pu↑	D↓ R↓ P↓	F↑

A binary CO_2/N_2 mixture (15%/85%) is separated in a three-column PSA installation (the addition of a third column leads to an almost continuous flow of the gaseous stream through the system). It is assumed that a small fraction of pure nitrogen is passed through the column undergoing vacuum regeneration to enhance the regeneration of the adsorbent. Nitrogen flow rate in this step along with the flow rate of the CO_2-enriched stream in the purge step were the only parameters varied in the calculations. The feed gas had a pressure of 1.1 bar and a temperature of 80ºC; the duration of the feed step was 120 s. The pressure during vacuum regeneration was 0.1 bar. The dimensions of the columns were the same as those in the experimental PSA system (Tanczyk et al., 2010). The performance of the installation was assessed in terms of the CO_2 content in the enriched gas and the recovery of carbon dioxide. The effect of the gas flow rate during purge and vacuum regeneration on these two parameters is shown in Figs.7 and 8.

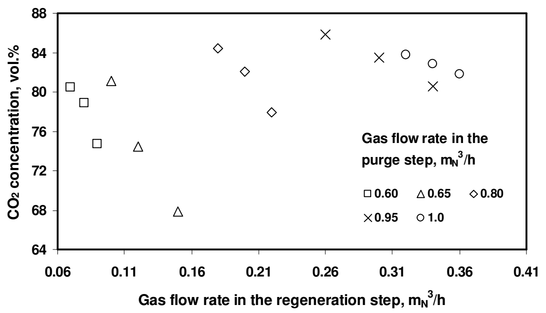

Fig.7. Effect of the gas flow rate during the purge with CO_2-rich stream on CO_2 product concentration

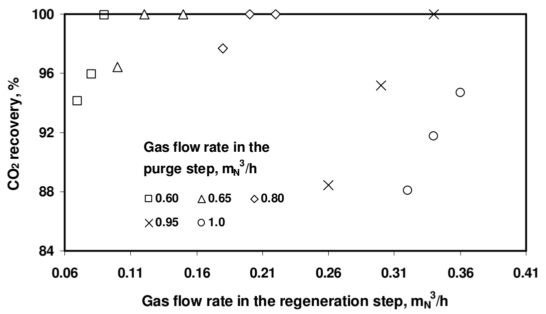

Fig.8. Effect of the gas flow rate during the purge with CO_2-rich stream on CO_2 recovery

As can be seen, the PSA process can enrich the 15% CO_2/85% N_2 mixture to a level of over 80% of CO_2, with a full (100%) recovery of this species. Such an efficiency can be achieved by a suitable selection of flow rates during purge with the enriched gas and vacuum regeneration. For a three-column PSA installation the maximum CO_2 content (82%) corresponds to flow rates of 0.8 and 0.2 m_N^3/h, respectively.

The mathematical model used in the simulations was successfully validated based on CO_2/N_2 separation experiments in a two-column laboratory PSA installation (Tanczyk et al., 2010). The relative discrepancy between the model predictions and experimental data were, in the majority of cases, less than 10%. Therefore, the model provides a useful tool for the analysis and optimisation of the adsorptive separation of carbon dioxide from flue gases. It has to be remembered, however, that the quality of the model strongly depends on the numerical values of the relevant equilibrium and kinetic parameters which, preferably, should be determined experimentally for each individual adsorbate - adsorbent system, as shown in Sections 2 and 3 of this paper.

Nomenclature

- b - coefficient of the Langmuir-Freundlich isotherm, $1/bar^n$
- D - coefficient of diffusion in the adsorbent pellet, m^2/s
- D/r^2 - diffusional time constant, 1/s
- i - CO_2 or N_2
- n - coefficient of the Langmuir-Freundlich isotherm
- p - pressure, bar
- q^* - adsorbed phase concentration in the pellet at equilibrium, mol/kg
- q_s - equilibrium adsorbed phase concentration at $p \to \infty$, mol/kg
- r - pore radius, m
- y - mole fraction in the gas phase
- α - selectivity

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Global commitments, Kypreos

How to write action plans for mitigation and adaptation by implementing the BSEC 2010 Thessaloniki Declaration on combating Climate

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Abstract

The Thessaloniki Declaration provides BSEC countries with a balanced and comprehensive commitment for action and cooperation in the realm of climate change. It's now crucial to lay down strategies and action plans that implement it. This paper explores the possible adoption of mixed mitigation and adaptation plans in the region at several geopolitical levels, suggesting guidelines for their effectiveness from an economic, social, environmental and political point of view.

At a broad regional level, common but differentiated responsibilities can lead to a MOSAIC configuration, with complementary roles and commitments (as suggested in Piana et al., 2009), which – at national level – could take the legal form of NAMAs (Nationally Appropriate Mitigation Actions as defined by the Cancún Agreements) and National Adaptation Strategies.

At sub-national and local level, action plans should federate the public and the private sector, as well as the civil society, to promote packages of policies and measures that can gain economic and social traction (Piana, 2011; King Baudoin Foundation, 2010).

The approach of the paper is typical of science-for-policy where political objectives are offered technical tools and options for implementation, while referring to science as for the urgency of both mitigation and adaptation.The outcome is a group of guidelines for policymakers in order to effectively combat climate change in line with the Declaration.

Keywords
Mitigation and adaptation policy mix, post-2012 policy regimes, science-for-policy approach.

Under the Greek Presidency in 2010, the Black Sea Economic Cooperation (BSEC) Organization approved in Thessaloniki a key Declaration on Combating Climate Change in the wider Black Sea area. Keeping into account the different interests in place, including the participation of both UNFCCC Annex I and non-Annex I countries, the Declaration is a major achievement, supporting the global and regional processes in coping with climate change. In this paper we explore the main messages of the Declaration in order to obtain and originally develop guidelines for laying down national, sectoral and local Action plan.

1. The four key messages of the Thessaloniki Declaration (TD)

The Declaration is a 3-page policy statement full of insights and broad judgements, possibly inserted after long negotiations and improvements. In reconstructing its key messages, we operate across the words of the text, without respecting the textual order, trying to grasp lines of thought which, albeit not necessarily referring to some specific Party, offer suggestions for Action Plans.

The first key message we see in the Declaration is a strong support for multi-level governance. The UNFCCC process is directly mentioned and "The Ministers… [c]ommit themselves, within this framework, to contributing to the success of the United

Nations Framework Convention on Climate Change negotiations, […] [r]ecognizing that the Black Sea area is vulnerable to many negative impacts of climate change and therefore our countries should work towards a binding international agreement on climate change".

This Declaration, expressed on the 26th November, could arguably contribute to the success of the Cancún COP of December, where a long text (from LCA-AWG) was approved.

This large building block of the wider Cancún Agreements explicitly calls in art. 7 for "…the need to engage a broad range of stakeholders at global, regional, national and local levels, be they government, including subnational and local government, private business or civil society, including youth and persons with disability, and that gender equality and the effective participation of women and indigenous peoples are important for effective action on all aspects of climate change".

And the Declaration moves exactly in the same direction when it underlines the importance of a regional approach, including cooperation and sharing of best practices and experiences, while stressing the BSEC role as a leader.

The Declaration requires and supports the establishments of projects, shared plans and initiatives. In so doing, it opens the way to Action plans from different stakeholders and at different level of governance. There is no monopolization of action – the States are given a key role, while explicitly praising civil society (and "their extensive expertise and know how") and setting "the framework for attracting public and private investment in all sectors that can contribute to [the TD] vision".

In the second place, the Declaration stands for Green growth to foster welfare. In a moment where the human and non-human welfare is under attack from many sides, it's very relevant that the Declaration states the general goal as "to secure a future of welfare" through Green growth, entrepreneurship, investment, employment. Far from being a constraint or an enemy to growth, green policies should be conducive to a wider improvement of the functioning of society, prompting profitability, investment, employment, effective demand.

In the debate whether technology or changes in lifestyles are more relevant for achieving sustainability, the Declaration mentions (reasonably!) both. There is no technological silver bullet that allows one specific sector "to save the world" leaving the rest of the economy "as it is now". On the contrary, change has to be comprehensive and to embrace many sectors and practices.

Conversely, without the fastest and widest adoption of new technologies and habits, the transformation will not be achievable.

At the basis of such processes, "forward-looking approaches" are required. We feel that it is a very near formulation to the "Innovative economic policies" that we have been advocating for some years.

In a book (Piana et al., 2009), we proposed more than twenty "economic policies aimed at mitigation of climate change [...] designed to be:

1. realistic, i.e. based on appropriate understanding of conditions, constraints, motivation, and behaviors;
2. dynamic, i.e. providing guidance for a number of steps over time, leveraging on pre-existing conditions and pioneers to give them a quantum leap, then follow up and reach quantifiable targets;
3. self-propelling, i.e. building on their own success to put in motion a positive self-feedback that allows them, even when started at low scale, to quickly ramp up;
4. non-linear, i.e. serving as a leverage or a buffer in the complex relationships between economic activities and emissions, on the one side, and climate change and its impact, on another side;
5. adequate to the context of XXI century, with its mix of globalization and local identities;
6. environmentally effective in reaching wide, deep, lasting, and irreversible results, both in terms of GHG emissions and of environmental quality at large;
7. socially sustainable, defending the interests and generating gains for all (or most) social groups;
8. politically sustainable, boosting consensus for politicians who adopt them;
9. independent from each other, in the sense that they can stand up on their own feet and merits,
10. capable of generating synergies when and if adopted together or in a sequence;
11. integrable in wider mitigation policy packages, which will also comprehend more directly scientific, technological, social, and political measures.

Indeed, these policies are based on a richer set of behavioral assumptions about firms, markets, consumers, and government, which include deep heterogeneity across them, the use of bounded rational rules, inputs from psychology and sociology.

They are evolutionary policies, which we might define as policies a) acting on a articulated present (considered as the result of dynamics having modified a past state) and b) capable of (appropriately) nurturing and strengthening (or weakening, suffocating, reversing) the dynamics in act and of launching, sustaining, and leading to success new ones" (p. 35-36).

Instead of framing climate change mitigation as a cost, we feel it is a huge opportunity for innovation, profits, business growth, employment, wages and improvement of real quality of life. As we stated in the peer-reviewed awarded paper on "Exploring Economic and Political Drivers for the Introduction of Innovative Mitigation Policies": "If mitigation is mainly seen as a cost, then the issue shifts back and forth from 'keeping the cost low' by unambitious goals to 'who has to pay these costs' and how to verify that 'you really paid'. The fact that the costs of inaction are much higher than mitigation is crucial, but too often overlooked…At the same time, connecting mitigation with the large benefits of low-emission economy for innovative sectors, for green jobs, quality of life, and a host of domestic constituencies will be valuable to rate radical cuts in emissions not only as feasible but highly desirable" (p. 422, Piana V. 2011b).

Carbon taxes and cap-and-trade systems largely fail to generate green growth, a burden to the economy as they are perceived. Indeed, they risk to be contrasted by the same people that are more vulnerable to climate change effects, as recent analyses and stakeholders consideration have suggested (King Baudouin Foundation, 2010).

Feed-in tariffs and other tools have on the contrary already demonstrated that it is possible to nurture green firms, jobs and eco-neighbourhoods.

In the third place, the Declaration indicates the main building blocs for action:

- Clean and secure energy (renewables)
- Resource efficiency
- Climate resilence.

It underlines that it necessary:

- to connect climate change with environmental and social concerns (sustainable development)
- to integrate mitigation and adaptation
- to contrast both disasters and slow on-going degradation through adaptation.

It's easy to hear here the echo of many false dychotomies that heated debates oppose renewables to efficienty, the climate and the sustainability perspective, mitigation vs. adaptation, the abrupt and irreversible climate change vs. other dynamics.
The Declaration makes an admirable job in connecting the dots and allowing cohesion.

In the fourth place, the Declaration calls for a full policy cycle:

1. Ecological awareness;
2. Leadership;
3. Investment;
4. Best practices;
5. Sharing experiences;
6. Macroeconomic results in welfare, employment, growth;
7. Political majority.

The cycle can begin also in other points, but all elements are important and interconnected, to assure that the effective "greening of politics and policies" takes place, providing clear rewards to the politicians, firms and organizations that embrace it.

2. Action plans at national level

National Action plan for mitigation and adaptation should:

- embrace the Declaration;
- demonstrate leadership;
- connect goals;
- generate opportunities;
- promote change;
- map key territorial assets;
- foster incentives for partnerships.

In so doing they would begin to implement the Declaration, avoiding false dychotomies, providing a full policy cycle.
In practice, it is possible that the names and the scope of such Action plan might vary across countries and temporal circumstances. The Ministry that takes the initiative can be authorised to cope with only some of the fields required or having a particular, additional, aim. The balance between different measures and components can be extremely different across instruments.
However, it's important to use any occasion to connect pieces of the puzzle and suggest (pieces) of ambitious national plans that: build on historical and current stregths and that lead to the intentional repositioning in the world system (Piana, 2006). If green growth has to gain the forefront in the development path of countries, then it should take into account the much larger ambitions of the nation.
In this vein, we proposed in 2009 a MOSAIC strategy in five steps:

1. to highlight a shared vision of the future for the world (the "mosaic");
2. to identify a good number of "roles" (the "plugs") to fulfill the vision;
3. for each role, to specify a list of quantitative commitments (the "colors");
4. each country to freely choose one role - at least - for itself;
5. the international community to support the efforts of each country in a gradual and appropriate way.

In this way, the UNFCCC principle of "common but differentiated responsibilities" could be interpreted not merely as a quantitative difference but in a more fundamental way: as in a mosaic, where the overall picture emerge from "plugs colored in different ways", put in a specific order and composition

In each country, leaders would interpret self-perceived identity and national pride in order to choose a suitable role for their countries, whereas the execution of commitments linked to them would be constantly monitored internally and externally, also to support efforts and provide correcting actions if commitments face difficulties in being carried out.

By undertaking a role, a country signals to domestic and foreign investors a crucial component of its strategic direction, which helps coordination of decentralized decisions.

Conversely, by orchestrating the mosaic, BSEC could exert a subtle leadership role. It should be underlined that, after the disappointment in Copenhagen and the directions after Cancún, the composition of the MOSAIC would mostly come from a bottom-up perspective[5].
The Declaration, moreover, puts a strong emphasis in many points to sharing experiences. This could be operationalised in a structured way by adopting our BENCHCLUB policy, described in the same book, and that, intriguely, was independently chosen by a University team in Novi Sad (Serbia) as the most suitable policy to be implemented there.

"Until now, the international debate has been largely dominated by setting goals, but how to reach them has to some extent been left to technology and finance, which, albeit crucial, are ingredients and not aims in themselves. You should know where to spend and which technology to adopt, but even more it's important to realize how to act, what to avoid, which law article was effective and which other was easily circumvented, which tool worked and why, etc.

Learning at the micro-scale, with on-site visits, forums of discussion, cross-country mixed groups government / business / NGOs, are crucial for a wide diffusion of a means of implementing mitigation with large co-benefits.

Countries should decide to establish and join a "club" where to "benchmark" the methods, the efforts and the achievements of mitigation policies as well as of an history of good results in decoupling GDP and emissions. Benchmark is a proven business strategy aimed at establishing areas of comparison across a selected number of organizations, where qualitative and quantitative performance is assessed. Intelligent imitation, adaptation and appropriate experimentation of followers will give them a path forward to the performance of the leaders.
In our context, benchmark is an explicit framework of cross-border assessment and learning along the following steps:

1. choosing partners and areas of comparison
2. assessing quantitative performance and singling out best practices
3. understanding the reasons for performance and the case history of best practices, e.g. in terms of emissions, employment, green growth
4. separating what can be transfered from what is totally idiosyncratic
5. experimenting with the transfer (imitation / adaptation) of what is positive and de-learning of what is negative
6. mixing proven "recipes" with new ideas
7. mainstreaming the experimentation
8. opening up the benchmark exercise to new areas and further partners.

Benchmarking builds a lot of technical experties and cumulates capacities, skills and routines in organizations of the different countries. Thus, it has a prevalent behind-the-scene technical nature, but the kick-off of benchmarking clubs of nations offer politicians a highly visible way to communicate commitment and international friendship, and over time it should be punctuated by events for highlighting reports, justifying new laws, show-casing results.
Conversely, benchmarking can begin informally, led by NGOs and networks, attract the attention of media and politicians to get official endorsement and support" (p. 229-230, Piana et al.).

Benchclubs should be established and supported by the national or regional level, because this would provide a strong architecture, with rewards for cooperating partners, small levies on entities that do not participate, large visibility for success cases.

More in general, national plans should describe the architecture and the incentives for sectoral and local (more detailed) plans.

3. Action plans at sectoral level

3.1. The Declaration explicitly mention energy as the main sector to work upon, because of the importance of energy production and use in emissions and sustainable development.

Meanwhile it is worth noting that secure energy affordable for all is not an easy goal but the result of intentional policies both from an economic and a technological point of view.

The huge potential for RES, estimated and supported in excellent papers presented in previous edition of PROMITHEASnet conferences (among others: Kasselouri B. et al., 2010; Martinopoulos G., 2010) has to be reaped through effective policies. A careful mix

[5] In our original proposals, we exlored 8 different roles and the respective commitments:

a) countries undertaking drastic cuts in emissions;
b) countries heavily investing in R&D for radical and incremental innovations;
c) countries proposing high-dignity low-carbon lifestyles;
d) countries quickly adopting new low-carbon technologies and lifestyles;
e) countries extensively adopting and diffusing cheap green technologies and new lifestyles;
f) countries making a sustainable transition out of poverty;
g) countries protecting unique ecosystems; and
h) countries in transition out of their dependence on fossil-fuel exports.

However, the qualification should now be country-driven and self-tailored.

of different mitigation and energy policies can be optimal from a larger set of criteria (Konidari P. and Mavrakis D., 2007).

Within such mix, Feed-In Tariffs have demonstrated their effectiveness in boosting quickly a massive private investment. To cope with rising FIT costs and allow for 100% RES, we recently proposed a non-linear Feed-In Tariffs scheme (Piana, 2010).

A slight modification of the time profile of the project-wide FiT levels over the years can dramatically improve the economic sustainability of supporting large shares – and even a target of 100% - for renewable energies (RE) in the energy mix, while preserving price competitiveness in an environment with widespread poverty.

In developed countries, FiT have initially spread the premium for RE over a large fossil fuel base by charging consumers a very affordable monthly increase . Final consumers pay for the FiT, not the public budget. The Governments don't need to subsidise FiT from the national budget, which, in turn, offers Transparency, Longevity, and Certainty (TLC) to investors.

However, when the share of RE is not negligible anymore, the cost of energy to final consumers goes up, until it approaches the high RE prices when the RE share is close to 100%.

The reactions of households and industrial users of energy can be so strong that the governments might be under pressure to contribute with injections from the public budget. But this public support may be judged as expensive in certain political environments and remains under the disturbances provoked by macro-economic circumstances. Some government can decide to stop the experiment, sharply reduce the FiT, leading to a crisis in the RE market. Spain and Italy may be seen as an outstanding example of such a dynamics.

In several developing countries, FiT face important challenges, if not supported from abroad, because widespread poverty makes the price of energy highly relevant for family budget and can be raised only with difficulties.

These conditions, as well as the decision to support entrepreneurial activities (which require energy and oil, as for plants and cars), might lead certain governments to subsidise energy prices. Accordingly, the relatively small fossil fuel base cannot be taxed to raise the amount necessary for FiT (as this money would come from the budget, not from consumers), because the consumers would not afford rate increases.

This does not prevent FiT to be feasible: they need to be adapted to the circumstances. In some more advanced developing countries, the initial phase of diffusion of RE can yet be launched, as the per capita GDP, the income distribution and the government policies would accomodate the changes.

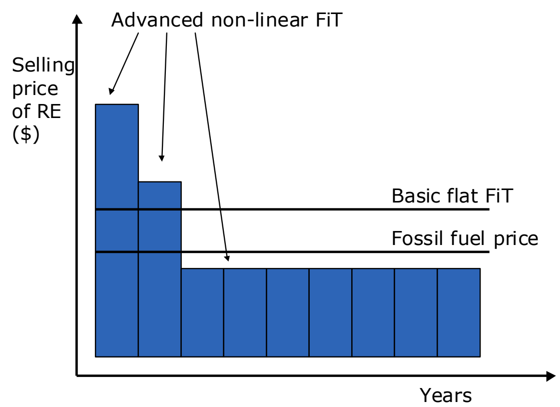
But more generally, RE have a time profile for costs so different from fossil fuels that it is possible for a slight modification of the basic flat FiT scheme to cope with all the abovementioned challenges.

RE costs are concentrated in the beginning, while sharply falling afterwards. If an Advanced Tariff scheme replicates this profile, it's possible to obtain several advantages.

Vis-à-vis fossil fuels, renewable energies have a larger upfront investment per MW of installed capacity but exhibit dramatically lower Maintenance & Operations costs, approaching zero, since their "fuel" is free.

After the RE investment has been paid off with a generous profit margin, (almost) all turnover is converted to profits. By skimming part of these profits to give a stronger boost in the first years, one can obtain a RE project that, with respect with the basic flat-rate original one, has the same NPV (net present value) but a shorter payback period and a lower-than-fossil-fuel selling price for all the subsequent years. The investor would continue to undertake the project, as the NPV is the same, and the shorter payback period would even make the him better off.

A graphical scheme showing the time profile of selling prices of RE, including the incentives given by the FiT, is the following:



This Advanced Feed-in Tariff scheme is non-linear over time for each funded project:

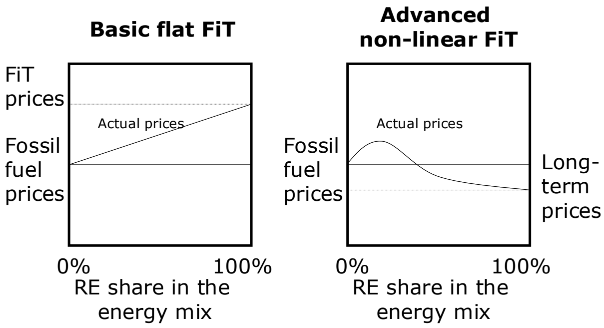
- in the first years, it heavily subsidises the RE project;
- it declines to an intermediate level after the first years;
- it eventually reaches a low level of price, with no subsidy required.

The first two phases quickly repay the investment made and provide a generous profit for investor (e.g. the Independent Power Producer). The third phase keeps the prices of energy produced by that plant under the fossil fuel ones, so as to outcompete them.

Cheaper RE production - sold when the investment has already been profitably paid off - will be very appreciated by utilities, government, final consumers.

This project-wise time profile is great for the investor (who obtains a shorter payback period, which in turn mitigates uncertainties and risks, such as inflation, currency fluctuations, etc.). But it is even greater at the macro-scale, when many projects beginning in different years are funded.

The Advanced scheme has a significantly lower total cost when many projects are funded over time, as older projects contribute to finance the younger ones. This allows for funding the achievement of a high share of renewable energies – even 100% - over the total mix. The costs of different levels of RES penetration under standard and advanced FiT is shown in the following picture:



In standard flat FiT, the actual price of energy is a weighted average of fossil fuel and RE premium prices, with weights equal to the respective share in the energy mix. At high RE shares, the actual prices approaches the RE premium prices.

With this advanced non-linear time profile of FiT, a high bump at the beginning is compensated with (project-wise) lower-than-fossil-fuel prices. Overtime all "old" projects reach this low level, thus asymptotically the actual price of 100% renewable will reach the same level .

This is particularly important in fast rising emerging countries, if they choose to power all growth with renewable energies, because soon the RE share will be large in the total energy mix. With this Advanced scheme RE outcompete fossil fuel, so at a certain future date (e.g. during a business cycle downturn) fossil fuels can be phased out, leaving a 100% RE energy model. This makes the economy not only resilient to fluctuations in fossil fuels world prices and supply difficulties but also price competitive when those shocks occur.

3.2. Albeit energy is a large sources of emission, it is not the only sector that should have an Action plan. They should cover all main GHG emitting sectors, such as:

- Energy
- Transport
- Building
- Final goods
- Industrial processes
- Waste.

Agriculture and forestry are very relevant both for mitigation and adaption.

On transport, we elaborated a 4-stages scenario for the taking off of electric mobility (Piana, 2011d), while stressing, among others, the following factors:

1. Social and economic drivers for diffusion;
2. Priority given to professional logistics (e.g. Taxis);
3. Territorial differentiation (e.g. small islands, peri-urban areas,…);
4. Integration RES production and electric mobility.

As for forestry, we explored policy options to mainstream the sector in mitigation and adaptation plans (Piana V., 2011a).

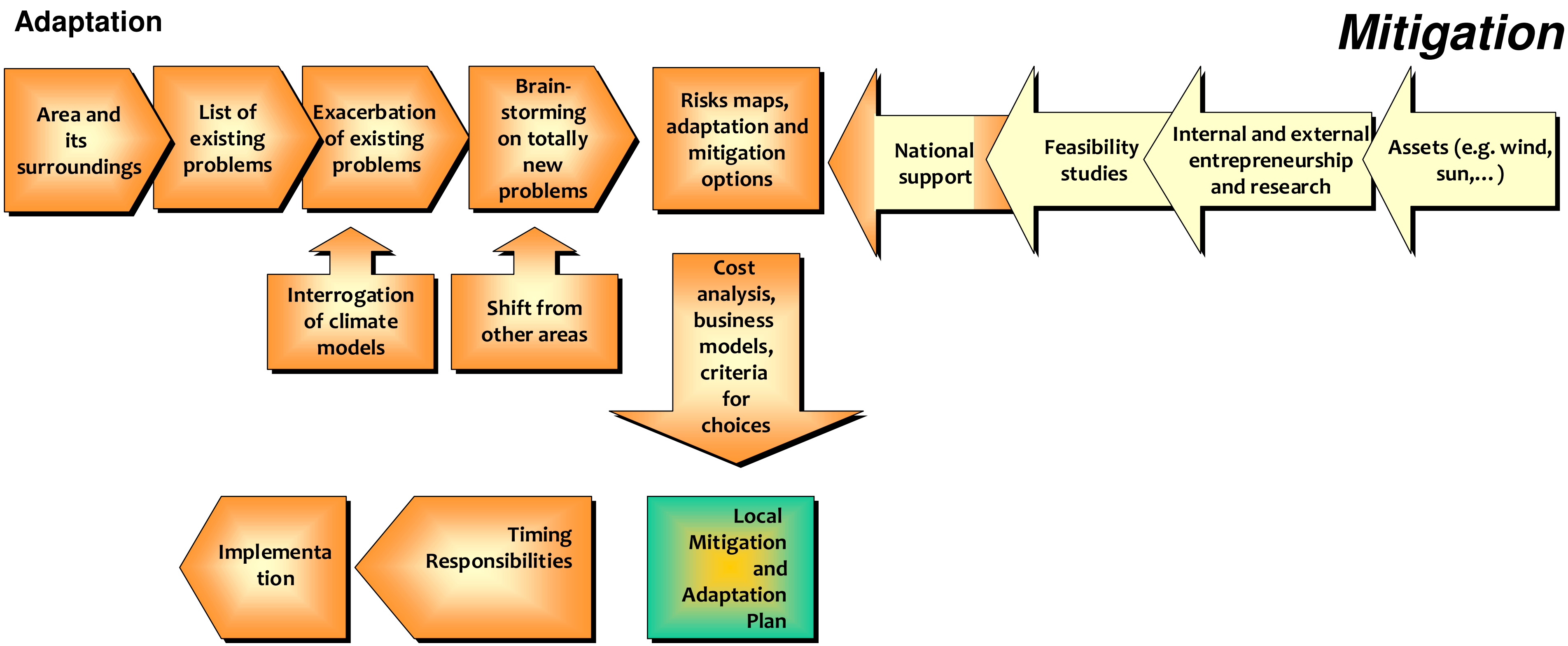
3. Action plans at local level

Local Action plan for mitigation and adaptation should:

- embrace the Declaration and its messages;
- start from local assets (both in terms of fragile assets under environmental stress and of possible mitigation resources);
- mobilize population around changes in lifestyles (or protecting old traditional ones!);
- offer Strategic Niche Management to particularly appropriate innovative technologies.

A scheme that we are implementing in a Local action plan for Monterotondo (Italy) on the level of eco-neighbourhood is, in principle, proposed in the following page (Piana V., 2011c).

The components of a Local Action plan for adaptation and mitigation:



4. The process of writing Action plans

To be successful, Action Plans should:

- be built on strong analysis but explicitly devote more “pages” to proposals;
- once chosen the tool, offer alternatives for parameters and ways of implementation;
- be written relatively quickly (6 to 12 months), to become relevant for current policymaking;
- involve policymakers, academicians, technologists, practitioners;
- mix local and global competences;
- generate advantages for those embracing them.

Conclusions

Timely and ambitious national, sectoral and local Action plans for mitigation and adaptation should be laid down to implement the Thessaloniki Declaration and to contribute to the fight to climate change, the looming disaster of our age, a common challenge for all countries and communities in the world.

International cooperation is important to highlight leaders, foster good practices, spread knowledge, skills and policies that need to make the difference in these difficult times.

In the view of what is happening in Europe and BSEC countries, it’s important to channel urgency into a combined solution to financial, economic, environmental and social crises.

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Simulation of energy reduction in CO_2 absorption using split-stream configurations

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Abstract: CO_2 absorption in an amine solution is a standard technology for large scale CO_2 removal. A way to reduce the high energy consumption for regeneration is to use a split-stream configuration. A partly regenerated amine (semi-lean stream) can be sent to the middle of the absorption column, and a completely regenerated amine (lean amine) to the top. The regenerated amine from the desorber column can be pressure reduced (in a lean amine flash) and the resulting gas can be recompressed and returned to the desorber (vapour recompression). Flowsheets of different configurations for CO_2 removal from atmospheric exhaust from a natural gas based power plant have been calculated with the process simulation program Aspen HYSYS. The energy consumption have been reduced from 4.2 GJ/ton CO_2 removed for a standard process to 2.5 GJ/ton CO_2 for a split-stream configuration. The configuration showing the lowest energy consumption was a process with a semi-lean stream from the bottom of the desorber to the middle of the absorber, a lean stream from a lean amine flash to the absorber top, and vapour recompression back to the desorber column. Capital cost and operating cost for the cases have been evaluated. The operating cost decreases with decreased energy consumption, but the capital cost increases with a split-stream configuration due to higher complexity. A solution with only a lean amine flash and recompression looks attractive because it achieves a large energy reduction with a limited increase in complexity.

Keywords: absorption, simulation, split-stream

1. Introduction

1.1 Principle for CO_2 removal by absorption in amine solutions

There is a large interest in finding an efficient method for removing CO_2 from atmospheric exhaust gas to avoid global warming. The process of absorption into an aqueous amine solution is the most mature technology for large scale CO_2 removal. A draw-back with the process is that it consumes large amounts of energy needed for desorption of the CO_2.

The principle of a standard CO_2 absorption and desorption process is shown in Figure 1. CO_2 is absorbed into the amine solution in the absorber. The most mentioned amine in this process is MEA (monoethanolamine). The amine loaded with CO_2 (rich amine) is pumped through a heat exchanger to a desorber (stripper), and regenerated (lean) amine is cooled and recirculated back to the absorber. This process has a large energy demand, and the most important is the steam consumption in the reboiler.

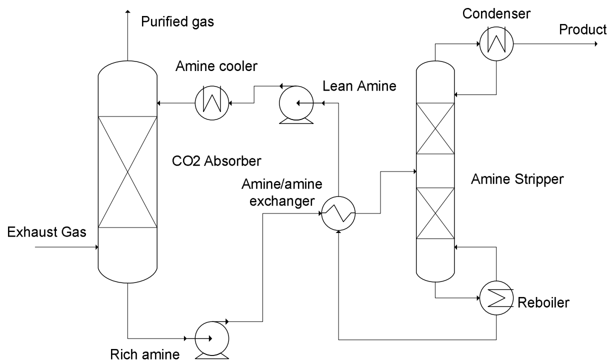

Figure 1 Principle for a standard CO_2 absorption and desorption process

1.2 Literature on alternative flow schemes

There are different ways to reduce the energy consumption in a CO_2 absorption process using alternative flow schemes. The standard reference book (Kohl and Nielsen 1997) shows some alternatives for CO_2 removal at high absorption pressures. A systematic overview of alternative flow schemes for CO_2 removal at high pressures was presented by (Polasek et al. 1982).

Several patents can be found for alternative flow schemes for CO_2 absorption. Especially the company Fluor has many patents on different configurations. One patent from Fluor is for a split-flow process (Won et al. 2003) and one application is for integrated compressor/stripper configuration methods (Reddy et al. 2009).

References to calculations of alternative flow schemes for CO_2 removal from flue gas at atmospheric conditions were presented by (Aroonwilas and Veawab 2006). An evaluation of different stripper configurations was presented by (Oyenekan and Rochelle 2006). A recent survey of process flowsheet modifications for energy efficient CO_2 capture from flue gas using chemical absorption was presented by (Cousins et al. 2011a). Preliminary calculations using rate-based simulation were also presented by (Cousins et al. 2011b). They have further plans to validate the simulations by comparisons in a pilot plant.

There is very little published on calculations or simulations of alternative flow schemes and there has been little published on economical evaluation of alternatives. Simulations with the commercial programs Unisim and ProTreat followed by economical calculations have been performed by (Karimi et al. 2011). Aspen HYSYS has been used to simulate a split-stream configuration (Vozniuk 2010; Øi and Vozniuk 2010). It was calculated that a split-stream configuration could reduce the heat consumption down to about 3.0 GJ/ton in CO_2 removal from exhaust gas. This work is based on the master thesis work of (Shchuchenko 2011) which comprised simulations with Aspen HYSYS and cost estimation of several different alternative flow schemes.

1.3 Principle for split-stream and vapour recompression

A traditional alternative is a split-stream configuration as in Figure 2. This was evaluated in (Øi and Vozniuk 2010). A partly regenerated (semi-lean) amine solution is pumped from the middle of the stripper to the middle of the absorption column, and a completely regenerated (lean) amine is sent to the top.

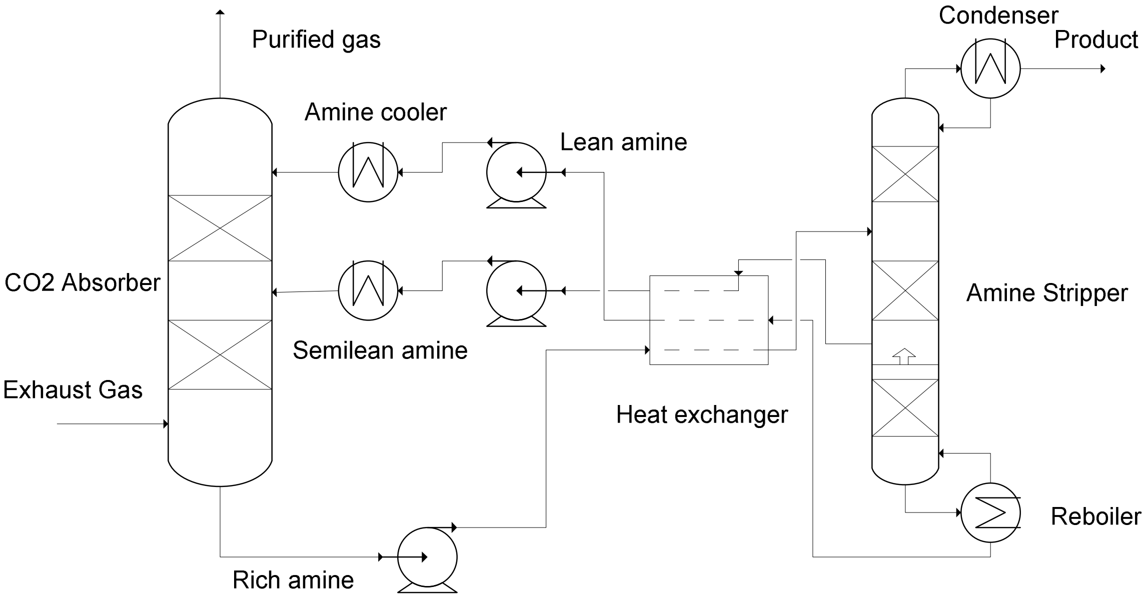

Figure 2 Principle for CO_2 absorption and desorption using split-stream configuration

Figure 3 shows the principle for a desorber with vapour recompression.

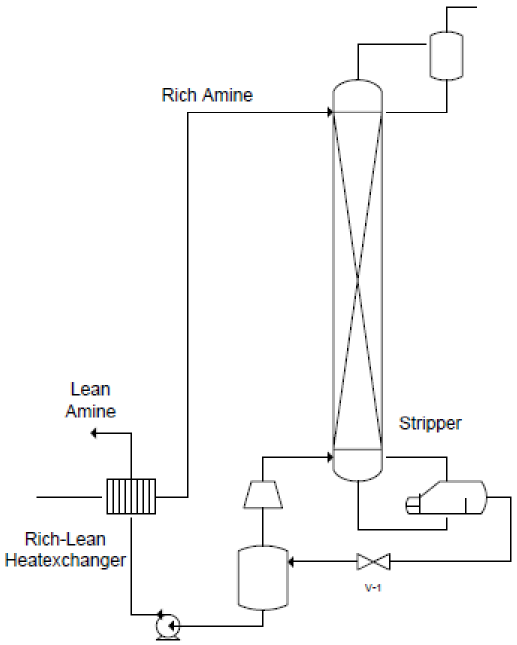

Figure 3 Principle for a CO_2 removal process with vapour recompression

The regenerated amine solution from the desorber bottom is pressure reduced and led to a flash tank (lean amine flash). The liquid from the flash tank is the lean amine stream which is recirculated back to the absorber. The vapour from the flash tank is compressed and returned to the bottom of the desorber. The temperature in the process should not exceed about 120 ºC because the amine will degenerate. To avoid that, the vapour can be cooled between the flash tank and the compressor.

It is possible to combine vapour recompression and a split-stream process. Figure 4 shows such an alternative. The semi-lean amine stream from the middle of the desorber is sent to the middle of the absorption column, and the lean amine stream from the lean amine flash is sent to the top of the absorber.

Another alternative is to take the semi-lean stream from the bottom of the desorber. The regenerated stream from the bottom of the desorber is split into two streams. One part (the semi-lean part) is recirculated to the middle of the absorption column. The other part is pressure reduced in the lean amine flash, and the liquid is sent as lean amine to the top of the absorption column.

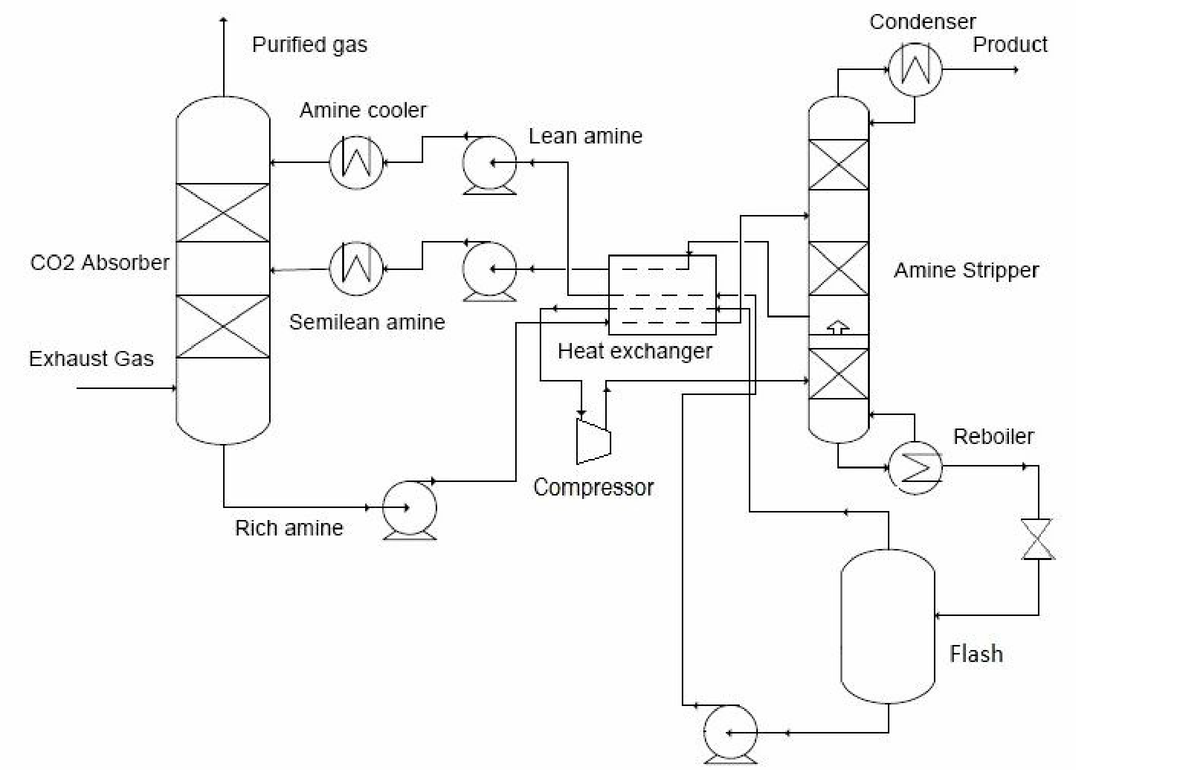

Figure 4 Principle for CO_2 absorption configuration with vapour recompression and split-stream from the middle of the desorber

The main purpose of this paper is to present simulations of alternative flow schemes for removing CO_2 from atmospheric exhaust gas in Aspen HYSYS and compare the energy consumption. Another purpose is to evaluate the operating and investment cost and find out which of the flow schemes that look most promising.

2. Process simulation

2.1 Base case specifications

The flowsheet in Figure 1 has been simulated using Aspen HYSYS version 7.0. The amine package with the Kent-Eisenberg thermodynamic model and non-ideal gas (using the Redlich-Kwong equation of state) was used. The calculation method is based on earlier simulations of CO_2 removal using Aspen HYSYS (Øi 2007). The specifications for the base case simulation given in Table 1 are for typical CO_2 removal from a natural gas based power plant. 85 % CO_2 removal and 5 K minimum temperature difference in the main heat exchanger was specified for all the simulations in this work.

The number of stages in the absorber was 14 with a Murphree efficiency of 0.15. The Murphree efficiency for a plate is the mole fraction (of CO_2 in the gas) change from the plate below divided by the change if equilibrium was achieved on the plate. The number of stages in the desorber was 10 in the base case, but it was specified to 6 in the other calculations with Murphree efficiency 1.0. The simulation is not much influenced by the number of stages in the desorber. The desorber feed was to the middle stage of the column.

The Aspen HYSYS process flow diagram for the process is presented in Figure 5. The main result from the simulation was the heat consumption in the reboiler, which was calculated to 4.23 GJ/ton CO_2. This is a typical value for the heat consumption in a standard CO_2 removal plant removing CO_2 from an exhaust gas from a natural gas based power plant. Lower values have been calculated (Øi 2007) but then the Murphree efficiency was estimated to be higher. The result is compared with other calculations in Table 2.

Table 1 Input specifications for Aspen HYSYS base case simulation with 85 % CO_2 removal

Parameter	**Value**
Inlet gas temperature	40 ºC
Inlet gas pressure	1.01 bar
Inlet gas flow	110 000 kgmol/h
CO_2 in inlet gas	3.7 mole-%
Water in inlet gas	7.8 mole-%
Lean amine temperature	40 ºC
Lean amine pressure	1.01 bar
Lean amine rate	165 000 kgmol/h
MEA content in lean amine	29 mass-%
CO_2 in lean amine	5.5 mass-%
Number of stages in absorber	14
Murphree efficiency in	0.15
Rich amine pump pressure	1.69 bar
Heated rich amine	104.2 ºC
Number of stages in stripper	10+Cooler+Reboiler
Reflux ratio in stripper	0.1
Reboiler temperature	120 ºC
Lean amine pump pressure	4 bar

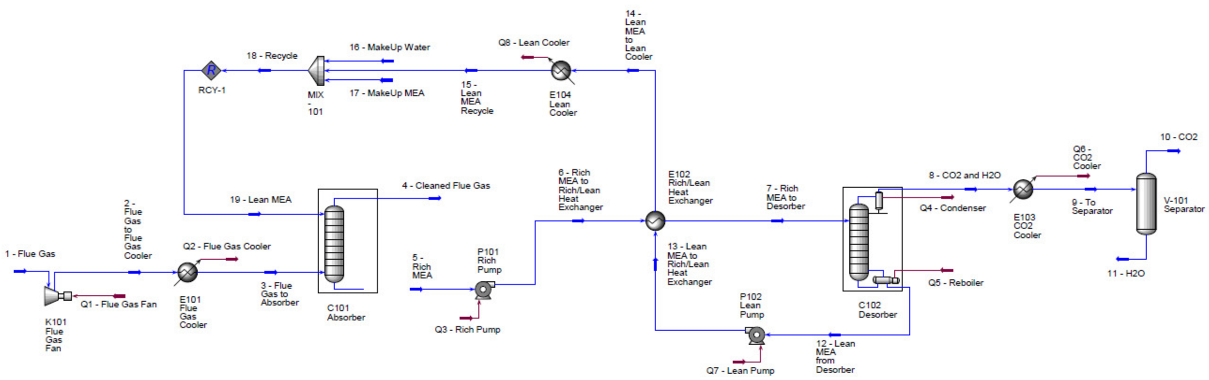

Figure 5 Aspen HYSYS flowsheet for a standard CO_2 absorption and desorption process

2.2 Simulation of a split-stream configuration

The split-stream process in Figure 2 has been simulated in Aspen HYSYS. The calculation method is based on earlier simulations performed by (Vozniuk 2010) with slightly different specifications. The specifications for the simulation were the same as in Table 1 with some changes and additions. The number of stages in the absorber was increased from 14 to 24 with the semi-lean feed to stage 21. The number of stages in the stripper was 6 (in addition to condenser and reboiler) with the feed to stage 3. The semi-lean amine rate was 100000 kmol/h and the lean amine rate was 103500 kmol/h. The semi-lean CO_2-concentration was 9 wt-%.

The heat consumption in the reboiler was calculated to 3.1 GJ/ton CO_2 removed which is considerably lower than for a standard process. 3.1 GJ/ton is close to the value of 3.0 GJ/ton calculated by (Vozniuk 2010) for a similar process.

A multi-stream heat exchanger was used to simulate the heating of the rich amine stream and the cooling of the lean and semi-lean streams. In practice, this heat exchange may be performed by a system of traditional heat exchangers.

It was also tried to simulate a process with two semi-lean streams from two locations in the middle of the desorber which were sent to two locations in the middle of the absorber. This did however not lead to a lower heat consumption than achieved with only one semi-lean stream.

This is expected to be because the energy saved by an extra split-stream is lost in heat exchanger losses. It has been shown (Øi and Vozniuk 2010) that a high minimum temperature difference of 15 K in a simple split-stream configuration results in no heat reduction compared to a standard CO_2 removal process.

2.3 Simulation of a vapour recompression configuration

The vapour recompression principle shown in Figure 3 has been implemented in a CO_2 removal process in Aspen HYSYS. The specifications for the simulation were the same as in Table 1 with some changes and additions. The number of stages in the absorber was increased from 14 to 16. The lean amine rate was 136000 kmol/h and the lean CO_2-concentration was 5.1 wt-%. The vapour from the lean amine flash was cooled in the multi-stream heat exchanger so that the temperature after compression was 120 ºC. The adiabatic efficiency in the compressor was specified to 75 %. The flowsheet from Aspen HYSYS for the process is presented in Figure 6.

The heat consumption in the reboiler was calculated to 2.64 GJ/ton CO_2 which is considerably lower than for a standard process. In a similar calculation with the simulation program Unisim, 2.6 GJ/ton has also been calculated (Karimi et al. 2011). Using a rate-based simulation tool, a vapour recompression process has been calculated with an energy consumption of 3.0 GJ/ton CO_2 removed (Cousins et al. 2011b).

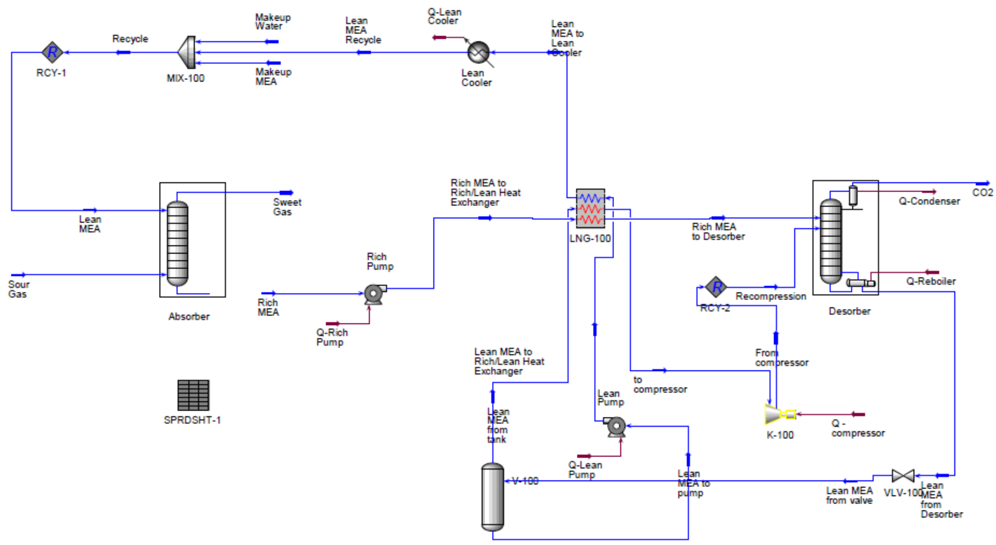

Figure 6 Aspen HYSYS flowsheet for a vapour recompression CO_2 removal process

2.4 Simulation of a configuration with vapour recompression and split-stream from the middle of the desorber

The vapour recompression process has been combined with a split-stream configuration and simulated in Aspen HYSYS. The semi-lean amine stream from the middle of the desorber is sent to the middle of the absorption column, and the lean amine stream from the lean amine flash is sent to the top of the absorber. The specifications for the simulation were the same as in the base case and the vapour recompression case with some additions. The number of stages in the absorber was 24 with the semi-lean feed to stage 21. The semi-lean amine rate was 70000 kmol/h and the lean amine rate was 99500 kmol/h. The semi-lean CO_2-concentration was 9 wt-% and the lean amine stream was 5.1 wt-%. The flowsheet from Aspen HYSYS for the process is presented in Figure 7.

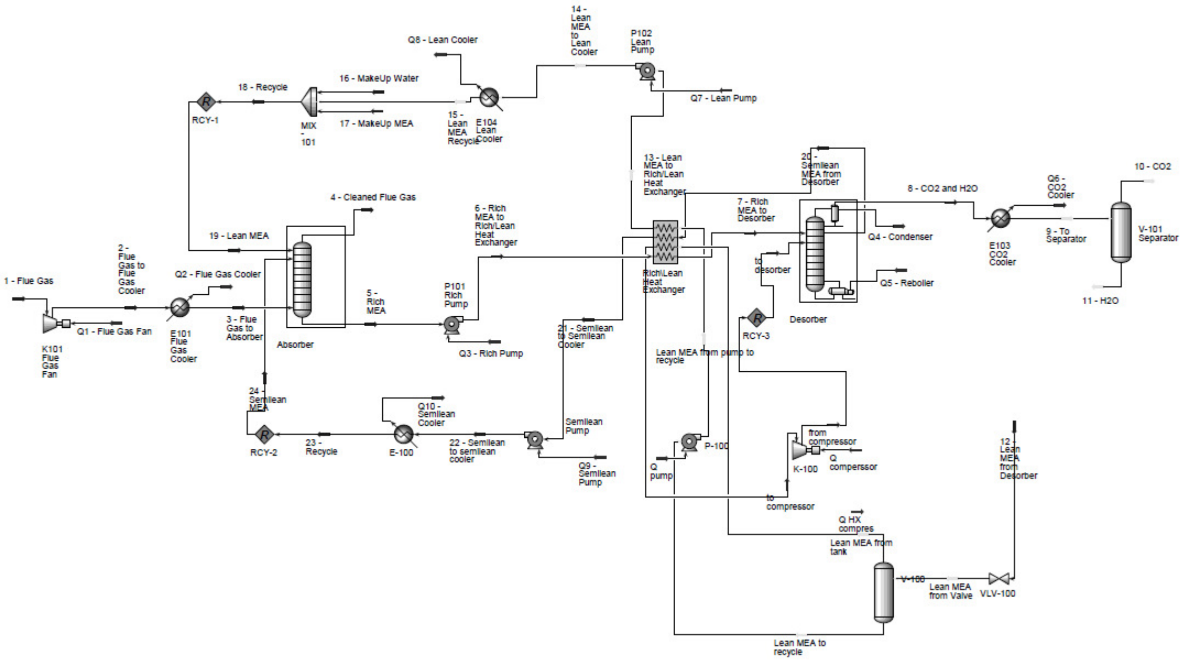

Figure 7 Aspen HYSYS flowsheet for a configuration with vapour recompression and split-stream from the middle of the desorber

The heat consumption in the reboiler was calculated to 2.59 GJ/ton which is only marginally lower than for a simple vapour recompression process with 2.64 GJ/ton CO_2.

2.5 Simulation of a configuration with vapour recompression and split-stream from the bottom of the desorber

The vapour recompression process has been combined with a split-stream configuration based on a semi-lean stream from the bottom of the desorber. The stream from the bottom of the desorber is split into two streams. One part is the semi-lean amine stream and is sent to the middle of the absorption column. The other part is pressure reduced and sent to a lean amine flash, and the lean amine stream from the flash is sent to the top of the absorber. The number of stages in the absorber was 24 with the semi-lean feed to stage 13. The semi-lean amine rate was 48300 kmol/h and the lean amine rate was 55000 kmol/h. The semi-lean CO_2-concentration was 5.6 wt-% and the lean amine stream was 5.0 wt-%. The flowsheet from Aspen HYSYS for the process is presented in Figure 8.

The heat consumption in the reboiler was calculated to 2.45 GJ/ton which is slightly lower than for a configuration with vapour recompression and split-stream from the middle of the column with 2.59 GJ/ton CO_2. The recompression flow is considerably lower for the case of vapour recompression and split-flow from the bottom of the desorber. This results in a reduced effect in the compressor.

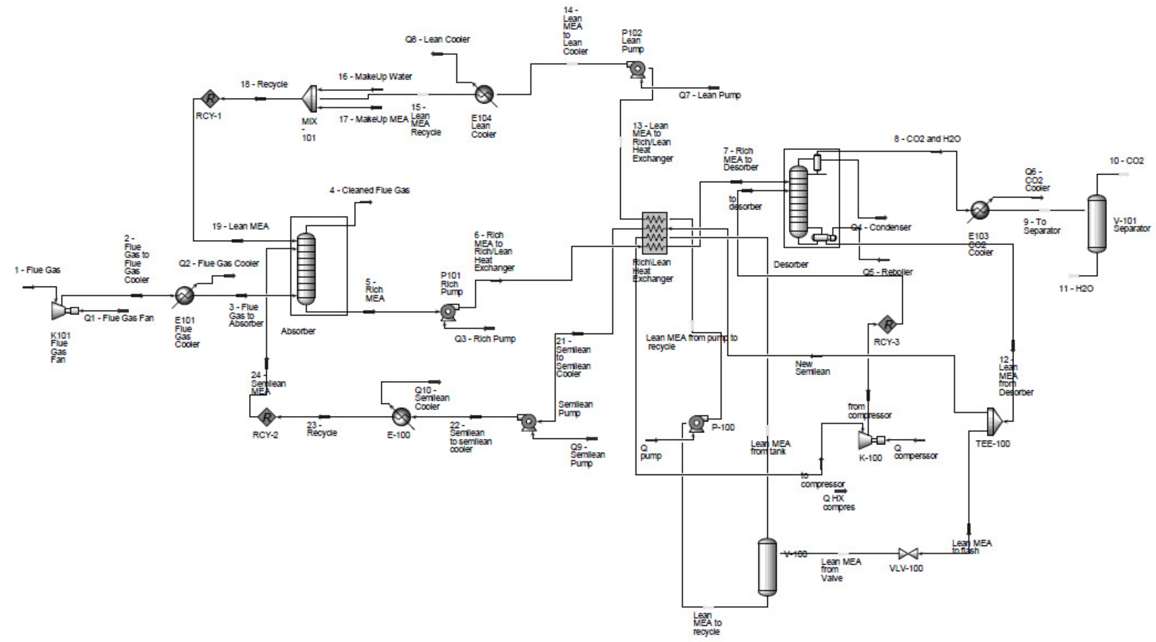

Figure 8 Aspen HYSYS flowsheet for a configuration with vapour recompression and split-stream from the bottom of the desorber

2.6 Simulation strategy and calculation sequence

The simulation strategy and calculation sequence were based on earlier works at Telemark University College (Øi 2007; Øi and Vozniuk 2010). The calculation sequence in Aspen HYSYS was based on guessed (or specified) flow rates and compositions to the absorption column. In the case of vapour recompression and recirculation to the desorber column, the flow rate, temperature and compositions from the compressor to the desorber also had to be guessed (or specified).

In the calculation sequence, the exhaust gas fan and the following cooler were calculated first. Then the absorption column was calculated and then the rich amine pump and the rich side of a multi-stream heat exchanger were calculated before the desorber. After the desorber and lean amine flash, the lean and semi-lean side of the multi-stream heat exchanger, the return pumps, the compressor and the coolers were calculated. Then the concentrations of the lean and semi-lean streams were checked (manually) against the specified concentrations in the feed streams to the columns. The concentrations in the streams to the columns (especially the CO_2-concentration) were then adjusted (manually) to achieve convergence.

In some cases, the recycle iterations were performed automatically using recycle blocks in Aspen HYSYS. The recycle blocks are located prior to the feed to the columns. It was however experienced that such automatic iterations often led to divergence. The convergence of the recycles improves if the total material balance of water and amine is fulfilled. This was performed in the simulations by adding make-up water and make-up amine into the lean stream before the recycle blocks.

The number of stages in the absorber was normally (not for the base case) increased until problems with convergence occurred. In some cases an increase in the number of stages led to an unphysical temperature (and concentration) profile. The columns were calculated with the modified HYSIM in and out solver which in most cases gave the best convergence. The specified CO_2 removal grade of 85 % was achieved by adjusting the lean amine circulation rate. The lean/semi-lean flow ratio was normally adjusted to optimize (minimize) the heat consumption.

There is potential to improve the accuracy, efficiency and robustness in such calculations.
Since it is a challenge to achieve convergence in the columns, it is reasonable to use a simple

equilibrium model like Kent-Eisenberg and a simple equilibrium based (with Murphree efficiency) stage to stage calculation. To achieve convergence in a recycle block, the influence of the adjusted variable on the concentrations must be accurate and stable. It is a challenge to select reasonable variables to vary. The default tolerances in Aspen HYSYS were used in the presented cases in this work.

3. Economical evaluation

3.1 Operating cost

The operating cost was estimated from the energy cost as in (Øi and Vozniuk 2010). The electricity cost was specified to 0.05 EURO/kWh and the steam cost was specified to 0.013 EURO/kWh. The ratio between electricity and steam cost is about 4. This is reasonable in a steam based power plant with a conversion efficiency of low pressure steam into electricity of approximately 25 %. Operating time was set to 8000 hours/year.

Only the electricity consumption for the recompression is included. The differences in pump effects are assumed to be negligible. The exhaust gas fan is not included because the differences in pressure drop through the columns are assumed to be small. It could however be reasonable to assume a pressure drop per stage in the absorber to include the effect of the absorber height on the operating cost. The estimated operating costs are shown as total energy cost in Table 2.

Table 2 Energy duties and energy cost

Flowsheet configuration	Reboiler duty [GJ/ton]	Compressor duty [MW]	Total energy cost [M€/yr]
Base case CO_2 removal	4.23	0	18.54
Split-stream configuration	3.10	0	13.56
Standard vapour recompression	2.64	3.9	13.15
Vapour recompression with split-stream from the middle of desorber	2.59	2.8	12.46
Vapour recompression with split-stream from the bottom of desorber	2.45	1.2	11.15

3.2 Evaluation of investment cost and total cost

In the master thesis works (Vozniuk 2010; Shchuchenko 2011), differences in investment cost and total cost for the alternatives in Table 2 were estimated. Vozniuk calculated that a split-stream process was more economical than a standard process when the calculation time was as long as 20 years.

Shchuchenko calculated the capital cost and compared the total cost for the alternatives in Table 2. The main equipment units were dimensioned by traditional methods. One absorber stage with a Murphree efficiency of 0.15 was assumed to be equivalent to 1 meter of structured packing, and the overall heat transfer number in the rich/lean heat exchanger (or multi-stream heat exchanger) was estimated to 500 W/(m^2·K). Equipment cost was based on cost estimations from Aspen ICARUS (Vozniuk 2010), and installed cost was calculated based on a detailed factor method. In this work only qualitative arguments based on the numbers in Table 2 are used.

A vapour recompression process looks promising compared to a standard process because it achieves a large energy reduction with a limited increase in complexity. This is also a conclusion in (Karimi 2011).

Vapour recompression combined with split-stream can reduce the energy consumption slightly compared to a simple vapour recompression process. It is doubtful whether the added complexity can be justified by the reduction in energy consumption. It is however interesting in the alternative with a semi-lean stream from the bottom of the desorber, that the recompression flow is considerably reduced compared to the standard vapour recompression alternative. Because of that, both the operating cost and investment cost of the compressor is considerably reduced.

The uncertainty in the economical calculations is high. The electricity cost is very case dependent, and the uncertainty in the heat (normally steam) cost is even larger. The uncertainty in the capital cost is especially high for the equipment parts that are different between the processes like a special compressor for these conditions and an extra absorption column section. Due to these high uncertainties, accurate conclusions about the most optimum process are difficult to draw.

4. Conclusions

Different split-stream configurations for CO_2 removal at atmospheric pressure have been simulated in the process simulation tool Aspen HYSYS. It has been shown that it is possible to reduce the energy consumption considerably using a split-stream configuration or using vapour recompression. A process with two semi-lean streams from both the middle and the bottom of the desorber did not achieve any further energy improvement. An energy reduction from 4.2 to 2.5 GJ/ton CO_2 removed has been calculated using a combination of vapour recompression and a split-stream configuration with a semi-lean stream from the bottom of the desorber.

Operating cost for the different cases has been calculated, and a total cost evaluation has been performed for the most promising alternatives. The capital cost increases with a split-stream configuration or vapour recomression due to a more complex process. The split-stream and vapour recompression alternatives become more attractive when the energy cost increases.

The alternative with the lowest energy consumption can reduce the energy consumption only slightly compared to a simple vapour recompression process. It is doubtful whether the added complexity can be justified by the reduction in energy consumption. It is however possible that the lowest energy alternative is the most economical because the reduced recompression flow reduces both the operating cost and the capital cost of the compressor. A solution with only a lean amine flash and recompression looks very attractive because it achieves a large energy reduction with a limited increase in complexity.

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Overview of multi-criteria analysis methods for climate change policy

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Abstract: This paper aims to present the use of multi-criteria evaluation methods in the decision making process regarding climate change policy instruments. A substantial part of this work, which was carried out as part of the Promitheas-4 project, is to provide an overview of the multi-criteria analysis tools available on this field. Therefore an extensive literature review was carried out, the results of which were compiled, processed and presented. Multi-criteria analysis (MCA) and evaluation methods establish preferences between competitive options, by reference to an explicit set of objectives that the decision making body has identified, and for which it has established measurable criteria to assess the extent to which the objectives have been achieved. The core of the MCA and multi criteria evaluation methods is the decision model, which is a formal specification of how different kinds of information data and crucial parameters are combined together to achieve a viable solution. Within the frame of this paper, the following methods will be described and evaluated: Analytical Hierarchy Process (AHP), Elimination and Choice Expressing Reality (ELECTRE), Multi-Attribute Utility Theory (MAUT), Simple Multi-Attribute Rating Technique (SMART) and AMS. Emphasis will be placed on information referring to objectives, assumptions, methodology, advantages, disadvantages, applications, relevant software studies for the multi-criteria evaluation methods that have been used particularly for mitigation/adaptation policy instruments.
Keywords: multi-criteria analysis methods, decision making process, climate change policies

1. Introduction to decision making process

Decision-making for sustainable development and energy planning is often characterised by a mixture of interactions, criteria, uncertainties, conflicting interests and opinions. Such a multidimensional issue needs the suitable assessment tools, efficient enough, to address issues of incommensurability, complexity and adaptivity should be selected.

Multi-criteria tools have the potential to consider the multidimensional, contradicting and uncertain properties of decisions, and at the same time to make available significant insight to a specified problem. Moreover, they can support decision-making process by clarifying conflicting values and conditions, increasing the transparency of the process.

Multi-Criteria Decision Making (MCDM) is a division of the broad family of Operations Research (OR) models which can solve a number of decision problems based on a specific set of decision criteria. This family is further divided into multi-objective decision making (MODM) and multi-attribute decision making (MADM) (Konidari and Mavrakis, 2007;).

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The basic stages of applying a multi-criteria evaluation tool (DCLG, 2009) are summarised in the following:

- Establishment of the decision issue;
- Detection of the alternatives to be evaluated;
- Detection of objectives and criteria;
-"Scoring". Determination of the expected performance of every alternative in relation to the criteria and the

corresponding consequences of each alternative for each criterion;
- "Weighting". Assign weight coefficients to each criterion for revealing its relative importance to the decision;
- Combination of the weight coefficients and scores for each option to derive an overall value;
- Examination of the results;
- Sensitivity analysis.

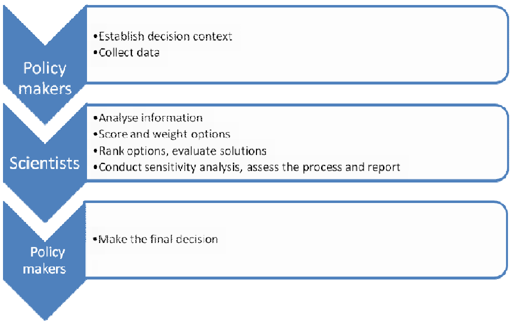

Figure1. Decision making process ingredients

Climate change is a complicated issue with many interacting parameters when it comes to strategy planning. Aldy et al. (2008) noted that the conceptual and empirical challenges are intensified by the lack of well-defined criteria as well as an objective process for defining weight coefficients to the considered criteria. Meanwhile, in order to select an optimum tool, the potential solutions should be first assessed with respect to the set of specific criteria of climate change issues. Otherwise there is a serious risk that a policy portfolio will be ineffective.

2. Multi-criteria evaluation methods for mitigation/adaptation (M/A) policy instruments

There are several categories of multi-criteria methods, depending on the type of input data, the initial assumptions, the adapted method of analysis and the output result. Priority based, outranking, distance based and mixed methods are different kind of analysis applied to various problems. From another point of view, methods can be classified as deterministic, stochastic and fuzzy, while there are combinations of them keeping some of their major characteristic (Greening and Bernow, 2004).
Belton and Stewart (2002) suggest the following widely accepted categorization of MCDM methods:
- value measurement methods or optimization methods;
- outranking methods;
- goal, aspiration or reference level models.
From a different point of view,Zopounidis and Doumpos (2002) suggest the following categories:
- multi-objective/goal programming;
- multi-attribute utility theory methods (AHP, MAUT, MACBETH etc.);
-outranking methods (ELECTRE, PROMETHEE, ORESTE etc.);
- preference disaggregation methods (UTA, UTADIS, MHDIS);
- rough set theory methods.
Indicatively, within the framework of this project, the following five methods are described in detail: Analytical Hierarchy Process (AHP), Elimination and Choice Expressing Reality (ELECTRE), Multi-Attribute Utility Theory (MAUT), Simple Multi-Attribute Rating Technique (SMART) and AMS.

3. Overview of multi-criteria analysis methods and evaluation criteria

Due to the fact that an evaluation of multi-criteria methods differs in terms of validity, suitability for the problem considered and ease of use, value criteria are needed on which to base judgment regarding significant impacts. The structure of the analysis allowed the comparison of the evaluation methods through: Objectives; assumptions; methodology; advantages – disadvantages and applications.
Zanakis (1998) suggests that any MADM method cannot be considered as a tool for discovering an "objective truth". Such models should function within a decision support system's context to aid the user to learn more about the problem and to provide solutions to reach the ultimate decision. Such insight-gaining methods are better termed decision aids rather than decision making. MADM methods should not be considered as single-pass techniques, without an posteriori robustness analysis. A sensitivity (robustness) analysis is essential for any MADM method.
"The multi-criteria evaluation approach forms a useful tool for defining national priorities for greenhouse emission reductions and for developing a realistic time schedule of the former's implementation, as it allows for a simultaneous consideration of criteria other than cost, which have been proven to be of a significant importance in many real-world decision situations. In reality, the least-cost path for emissions reduction is not always followed, due to legal or institutional system imperfections, which can be hardly introduced in bottom-up or top-down energy environmental simulation models" (Georgopoulou et al., 2003). Furthermore, the behaviour of certain decision-makers is not driven always from the same motivation, for instance, sometimes the strongest motivation is cost minimisation, some other times social aspects have more influence on the decision making procedure (Georgopoulou et al., 2003).
Some methods are used to solve single dimension problems. Other methods are used for multi dimension problems, as the evaluation of M/A policy portfolios. It is also observed from the surveyed literature that AHP is the most popular method for prioritizing the alternatives, followed by ELECTRE (Pohekar and Ramachadran, 2004). On the other hand AHP relies on the decision makers' subjectivity and in very complex problems where a lot of alternatives and different

points of views exists is not preferred. In cases characterized by an extensive number of criteria, methodologies like PROMETHEE and ELECTRE are preferable (Theodorou et al., 2010).
The methods of the ELECTRE family according to Rangel et al. (2009) have three main advantages in comparison to the MAUT method. "The first is that they accept the non – compatibility of the alternatives in the decision process. The second has to do with the option of using subcriteria so as to indicate the preference between the alternatives and the third deals with the difficulty occurring to the decision maker to establish in practice the values of each alternative in terms of utility for diverse aspects. MAUT theory relies on the alternatives preference and the transitivity of preference or indifference". Moreover, Zopounidis and Doumpos (2002), regarding MAUT, claimed that the implementation of such interactive procedures in practice can be cumbersome, mainly because it is rather time consuming and depends on the willingness of the decision maker to provide the required information and the ability of the decision analyst to elicit it efficiently. Attributes seem adequate for screening and designing. Utility measurement is preferable and often works well for all steps, except if the distance between alternatives is very close, resulting in decision makers to make direct comparisons one relative to another.
SMART is a quite simplified method and its implementation requires limited resources and effort.
MAUT involves both effort and resources, because decision makers need to conduct judgements about the utility scores for each alternative as well as the criteria combination.
In AHP, where the alternatives should be compared, seem to be more difficult. Many alternatives tend to complicate the process further. Nevertheless, in the final evaluation phase, only two or three alternatives should remain. Given that AHP is characterized by complex mathematics, it reveals problems in the case of closely ranking alternatives.
According to the previous highlighted points, the comparative evaluation of the studied methods is exhibited in Table 1 and 2.
The sophistication, meaning complexity and/or user expertise, of the described methods varies between different steps. The need to use an appropriate level of sophistication rather than a homogenised approach seems to be an important factor when selecting the appropriate one.
Moreover, methods based on utility functions assume only two states in the underlying model of preferences, meaning that the decision maker either prefers a to b or he is indifferent between the two actions (Georgopoulou et al., 1998). As a result, the hesitations in the decision maker's mind which prevent him from clearly adopting one of these two states may be ignored. However, there is the possibility the linear structure of the utility functions to overcome similar obstacles (André and Riesgo, 2007; Gomez- Limón and Martinez, 2006).

Table 1: Comparison of the mutli-criteria decision methods (MCDM).

MCDM	Uncertainty treatment	Ease of use Time and resources needed	Solve complex problems
ELECTRE I	+	--	++
ELECTRE II	+	+	+
ELECTRE III	+	++	++
ELECTRE IV	+	+	+++
ELECTRE TRI	+	+	++
MAUT	++	+	+
AHP	++	+	+
SMART	+	+	++
AMS	+++	+++	+

The positive scale is defined with '+++' (excellent) which is more preferable than '++'(very good) which is more preferable than '+' (good). The negative scale follows the same concept and is defined with '-' (not good) which is more preferable than '--' (bad).
However, this is not a serious problem in the designing phase. AHP's lack of refinability is a greater cause of concern, because it requires the decision maker to keep the set of alternatives fixed during a round of (often numerous) scoring of pairwise comparisons of alternatives with respect to the criteria. Having decided against an alternative, decision makers have a tendency to ensure that it scores poorly afterwards. This reflects a lack of confidence in a procedure that requires them to continue scoring an alternative that they do not want, and possibly a fear that the unwanted alternative might score higher. The risk is that pairwise comparisons between unwanted and possibly wanted alternatives could contaminate the scores of the remaining genuinely competing alternatives (Brugha, 2004).
A thorough comparison based on Wang et al. (2009) points out those criteria weights of discussed methods influence directly the decision-making results of climate projects' alternatives. Equal criteria weights are still the most popular in weighting methods. AHP method in the rank order weighting method is more prevalent because of its simplicity in understanding in theory and the simplicity in its application. The objective and combination weighting methods rise in the decision-making gradually and will be largely applied to sustainable energy decision-making because they evaluate the relative importance objectively without decision-makers (Wang et al., 2009).

Table 2: Comparison of the mutli-criteria decision methods (MCDM).

	Complexity	Data requirements	Software
AHP	+	+	+
ELECTRE	++	++	-
MAUT	+	+	+
SMART	+	+	-
AMS	-	+	++

The MCDA methods can be implemented to several decision making problems related to environmental and energy planning. More specific AHP, MAUT, SMART and ELECTRE are applicated to renewable energy planning and environmental management issues. More specific the Electre III model is a highly developed multi-criteria analysis model, which takes into account the uncertainty and vagueness, which are usually inherent in data produced by predictions and estimations (Papadopoulos and Karagiannidis, 2008). In addition ELECTRE is more preferable when complex decision making problems arise in the field of energy systems planning and waste management. Finally AMS range of applications is focused on environmental planning issues with emphasis to M/A climate change policies.

In M/A climate policy portfolios, as well as in complex decision processes in general, where several alternatives are analysed, multiple criteria exist, and many different stakeholders with conflicting preferences are involved; there is hence a clear necessity to use MCA methods to solve the problems. The MCDA framework also makes the requirements for new information explicit, thus supporting the allocation of resources for the process. It is also believed that the results obtained by the aggregation methods are more rational and more aggregation methods will aid in the sustainable environment decision-making in the future.

4. Conclusions

Multi-criteria analysis and evaluation methods establish preferences between competitive options, by reference to an explicit set of objectives that the decision making body has identified, and for which it has established measurable criteria to assess the extent to which the objectives have been achieved. In simple circumstances, the process of identifying objectives and criteria may by itself provide enough pieces of information for the decision-makers. However, on a higher level of details, multi criteria methods offer a number of ways for aggregating the data on individual criteria to provide indicators of the overall performance of options.

A key feature of multi criteria evaluation methods is their emphasis on the judgment of the decision making team, in establishing objectives and criteria, estimating relative importance weights and, to some extent, in evaluating the contribution of each option to each performance criterion. The subjectivity that pervades this can be a matter of concern. Its foundation, in principle, is the decision makers' own choices of objectives, criteria, weights and assessments of achieving the objectives, although 'objective' data such as observed prices can also be included. MCA, however, can reach a satisfactory degree of structure, analysis and openness to classes of decision for M/A policy portfolios.

Nevertheless, there are no better or worse methods per se; there are different methods and techniques, more suitable to the other or the other problem, depending to a large extent on the decision making procedure. Hence, a single, objectively best solution does not, and cannot, exist, as the planning process is characterized as a search for acceptable compromise and/or consensus solutions.

5. Acknowledgements

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"Selecting AMS as the appropriate multi-criteria evaluation method for climate change policy portfolios"

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-full paper not submitted-

“Kazakhstan path to low carbon economy: Integration of Climate Change Policy into Strategic Planning”

Prof. S. INYUTIN, Turan – Astana University, Kazakhstan

-full paper not submitted-

“Forest ecosystems and biodiversity in order of climate change in Albania, actual situation and challenges for, in the future”

Prof. As.Dr. H. HASKA, Agency of Environment and Forestry, Albania

-full paper not submitted-

PARTITIONING OF HEAVY METALS IN SEDIMENTS OF THE RIVER PRUT

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Abstract

The goal of the present work was to establish the distribution of heavy metals contents among the various components of sediments along the Prut River (Republic of Moldova). Compared with more complex models, we applied a simplified model assuming three main categories of the metal partitioning likely to be affected under various environmental conditions, namely: (a) metals on the sediment-water interface, i.e. in the interstitial water phase where metal ions are bound to the surface by weak forces, (b) metals chemically associated with organic-mineral complexes and amorphous phases present as colloidal coatings on particles, (c) metals contained in the detrital crystalline material in which they are bound internally. The bottom sediments of the river Prut were collected seasonally during 2009, and were analyzed for the heavy metals (Cu, Ni, Cr, Zn, Cd, Pb) content. It was established that the ability of sediments (integral samples) for metals binding decreases in the series Zn>Ni>Cr>Cu>Pb>Cd. The ability of the mineral phase for metal accumulation decreases as follows: Zn>Pb>Ni>Cr>Cu>Cd. The affinity sequence of heavy metals for the organic-mineral complex, amorphous phase and interlayer material of sediments diminishes in the sequence Zn=Ni>Cr>Cu>Pb>Cd. Generally, the obtained ordering of metals partitioning is consistent with the one presented yearly for the more complex model.

Keywords: bottom sediments, heavy metals

1. Introduction

It is well known the essential role of many metals for life, but at the same time it is necessary to mark that all metals are toxic at sufficiently high concentrations. The differences between the required concentration and the toxic one for many metals are very small. Aquatic sediments are reservoir of heavy metals. The incorporation of metals on sediment particles is the result of some phenomena, such as adsorption on hydroxides of Fe and Mn, ionic exchange on clay minerals, surface binding on particles coated with organic matter, adsorption of metal-ligand complex by the colloidal particles [1]. Sometimes, the many metals may degrade or react with other constituents to form soluble and possibly even more toxic [2]. Thus, the sediments may be a source of heavy metals in the water layer and may be the one of factors which determinate the oxygen regime, the red-ox conditions in water body etc.

Bottom sediments are a heterogenic system and have the polymineral and polydisperse structure. As the rule, the mineral phase prevails in the aquatic sediments [1]. The main components of mineral phase frequently are the clay minerals, organic-mineral complex and amorphous phases (hydrous Al, Fe and Mn oxides), present as colloidal coatings on particles distributed as “island” or covered total as “coating”. The different non-clay components (carbonates, sulfates etc.) and crystallized oxides (goethite, hematite etc.)

also inter in the composition of mineral phases, segregated or mechanical shared. The clay components (and the “coating” constituents on the surface) are very important for physical-chemical processes, which take place in overlying water horizons. Clay minerals possess the porous structure therefore particles of sediments have developed surface area.

The adsorption-desorption processes, ionic exchange, complexation, hydrolyses or, more generally, the mobilization (from sediments toward overlying water horizons) or the immobilization (from overlying water horizons toward sediments) of heavy metals take place through the interstitial water (sediment pore water). The concentrations of constituents in interstitial water and in the overlying water horizons may considerably differ, thus the direction of mobilization-immobilization of the contaminants determinates the pollution – self-purification processes of water body, depending on the environmental conditions (red-ox conditions, pH etc).

2. Case study

The goal of the present work was to establish the distribution of heavy metals contents (Cu, Ni, Cr, Zn, Pb, Cd) among the various components of sediments along the river Prut. Compared with more complex model [1], in this work a simplified model was applied assuming three main categories of metal partitioning likely to be affected under various environmental conditions, namely (i) metals on sediment-water interface, i.e. in interstitial water phase where metal ions are bound to the surface by weak forces, (ii) metals chemically associated with organic-mineral complex and with amorphous phases, present as colloidal coatings on particles, (iii) metals present as detrital crystalline material in which the metals are bound internally. Bottom sediments were collected seasonally during 2009, and were analyzed for heavy metals (Cu, Ni, Cr, Zn, Cd, Pb) content. River Prut was divided into three sectors: sector A (lake Costeşti-Stînca, above weir – Ungheni), sector B (Valea Mare – Stoianovca), sector C (Cahul – Giurgiuleşti). The contents of heavy metals in interstitial water, bottom sediments and their components were determined. The procedure recommended by USA Geological Survey was used to determine total acid-recoverable content of metals in sediments [3]. The analyses of the metals were conducted using atomic absorption spectrometer AAS-3.

Sampling sites along river Prut: sector A (lake Costeşti-Stînca, above weir – Ungheni), sector B (Valea Mare – Stoianovca), sector C (Cahul – Giurgiuleşti).

3. RESULTS AND DISCUSSION

Figure 1 and 2 represent partitioning of metals among components of bottom sediments along the river Prut.

Obtained results reveal the predominant accumulation of Cu, Pb and Cd (Fig. 1) along all river sectors in the mineral phases of sediments. Considerable amounts of Cd were registered also in the amorphous phases of sediments.

Spatial dynamics for Ni, Cr and Zn partitioning was quite different as compared to Cu, Pb and Cd (Fig 2). Thus, amounts of Ni, Cr and Zn were decreased in the mineral phases and were increased in organic-mineral complex and amorphous phases. The amounts of metals in the interstitial water of sediments were <0,5% for Ni, Cr, <1% for Zn, Pb, Cu and account for ~2% for Cd, from their total contents in sediments.

The metal distribution in various substrates of bottom sediments is very complex [2]. Hydrous Fe and Mn oxides, aluminosilicates minerals, organic matter and carbonates all may be present in sediments. All are capable to bind the metals from water layer by co-precipitation, adsorption or ionic exchange. The metals contents in sediments depend on specific surface of sedimentable particles. Thus, the fine-grained sediments bound metals more efficient than coarse-grained and sand-sediments. The ability of components to collect heavy metals is as follows: manganese oxides>humic substances>hydrous iron oxides>clay minerals, recording a substantial variability in each category, depending on the metals involved, the available substrates (e.g. type of clay minerals, presence of organic matter) and the geochemical character of the environment (pH, Eh). It is very important the type of clay minerals. Their ability as metals concentrators as follows: montmorillonite>vermiculite>illite>chlorite> kaolinite.

Partitioning of metals among binding components of sediments, depicted by statistical associations, reveals some common particularities [1]. Maximal concentrations for Cu and Zn are predominantly accumulated in amorphous phases, with less probability in organic phases and crystalline oxides. The accumulation in crystalline phases, especially in iron oxides is characteristic for Pb. Although still exist some uncertain concerning allocation of Cd, the high probability for its accumulation in the organic phases is remarked. Presented results in this work (Fig. 1, 2), generally, are consistency with yearly presented for more complex model [1].

The affinity sequence of heavy metals for clay minerals generally decreases in the series Pb>Ni>Cu>Zn [1]. The ability of organic matter as metals concentrators depend mainly on the stability of metal-organic compounds. The affinity sequence of heavy metals for organic matter decreases in the series Cu>Ni>Co>Zn>Cd>Fe>Mn>Mg. The extent of metal extraction from amorphous phase of sediments decreases as follows Mn>Zn>Cu>Cd.

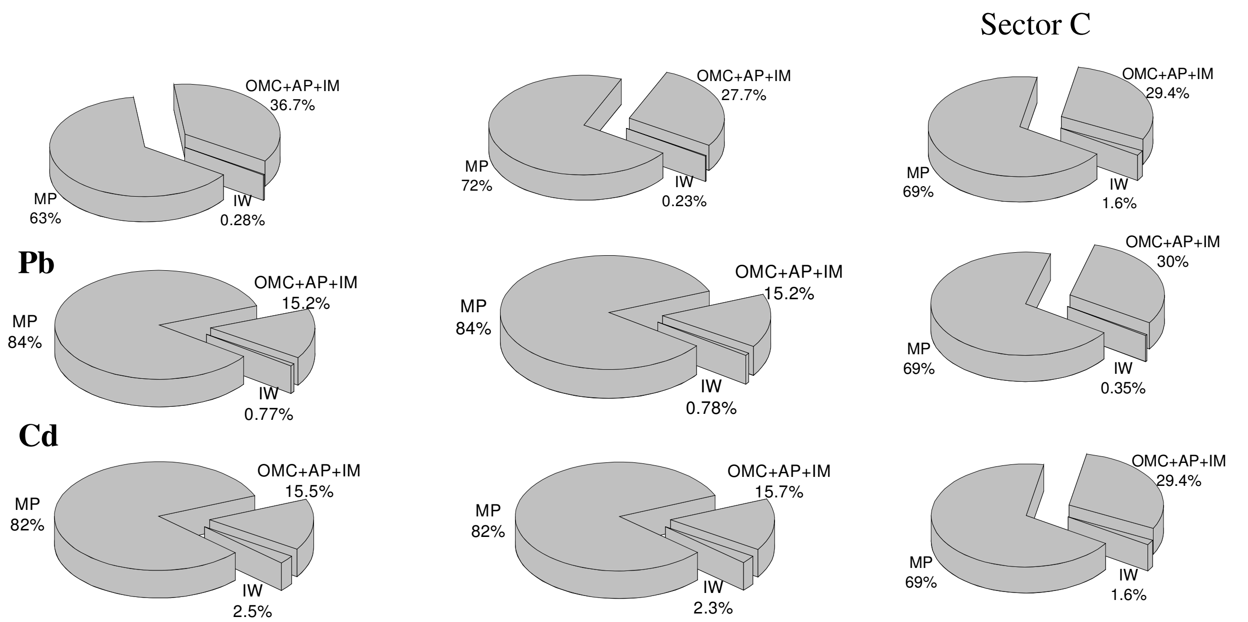

Fig. 1 Partitioning of Cu, Pb, Cd among the components of sediments of river Prut, summer 2009. Sector A – site Sculeni, sector B – Valea Mare, sector C – Giurgiuleşti. IW – interstitial water of sediments, OMC+AP+IM – organic-mineral complex, amorphous phase and interlayer material of sediments, MP – mineral phase of sediments.

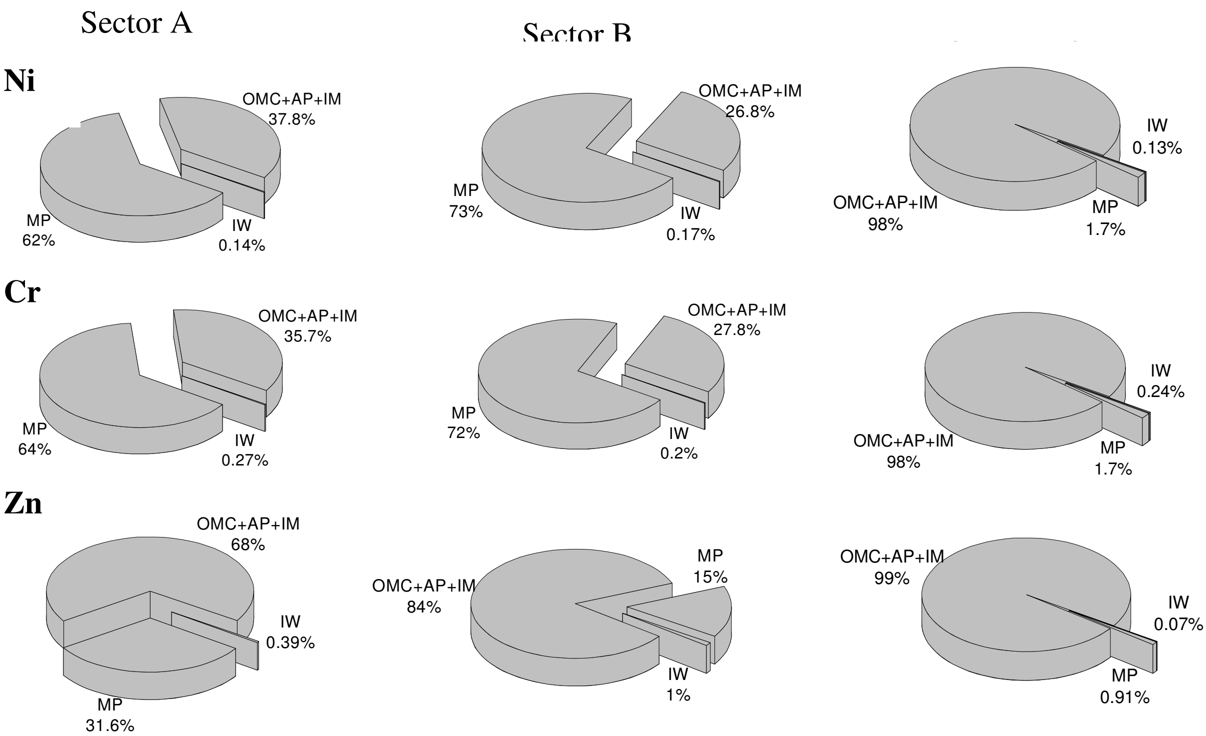

Fig. 2 Partitioning of Ni, Cr, Zn among the components of sediments of river Prut, summer 2009.

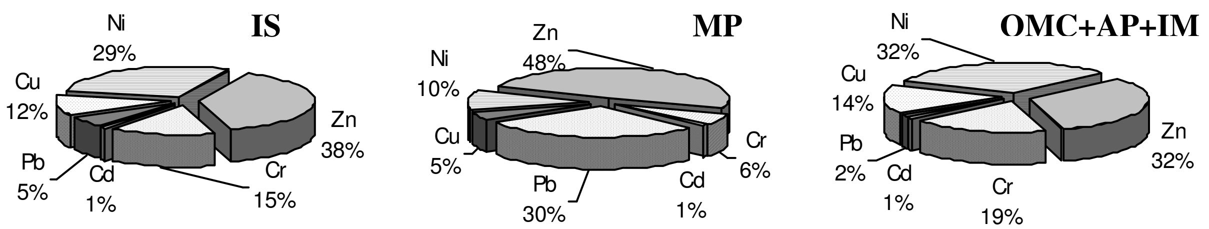

Fig. 3 Distribution of metals among the components of sediments from river Prut (site Sculeni, summer).

Fig. 3 presents distribution of metals among the components of sediments from river Prut. Thus, ability of integral sediments (IS) for metals binding decreases in the series Zn>Ni>Cr>Cu>Pb>Cd. Ability of mineral phase (MP) for metal accumulation decreases as follows Zn>Pb>Ni>Cr>Cu>Cd. The affinity sequence of heavy metals for organic-mineral complex, amorphous phase and interlayer material of sediments (OMC+AP+IM) decreases in the series Zn=Ni>Cr>Cu>Pb>Cd. In general, the obtained ordering of metals partitioning is consistency with yearly presented for more complex model [1].

4. CONCLUSIONS

It was established that the ability of sediments (integral samples) for metals binding decreases in the series Zn>Ni>Cr>Cu>Pb>Cd. The ability of the mineral phase for metal accumulation decreases as follows: Zn>Pb>Ni>Cr>Cu>Cd. The affinity sequence of heavy metals for the organic-mineral complex, amorphous phase and interlayer material of sediments diminishes in the sequence Zn=Ni>Cr>Cu>Pb>Cd. Generally, the obtained ordering of metals partitioning is consistent with the one presented yearly for the more complex model.

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“Removal of metal – complex dye from a liquid solution by adsorption on the waste ashes”

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-full paper not sumbmitted-

Session 3. Renewable Energy Sources

Feasibility study of offshore wind turbine installation in North Aegean – Thracian Sea
Part I

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The feasibility of an offshore wind turbine installation depends on the favourable wind conditions in the area to be installed. Other factors like distance to the shore and sea depth influence the construction, operation and maintenance costs.

Abstract

Wind energy is an alternative clean energy source and its rapid growth rate has already begun to play increasingly important role in providing electricity. The global wind resources estimated to be 72 TW which is seven times the world's electricity demand and in contrary to the global pollution issues and the significant cost of fossil fuels, wind seems to be a clean, affordable and inexhaustible energy.

Wind farms should be located in areas where winds blow continuously at high speeds. Offshore winds are generally stronger and more constant than onshore winds and the need for increasing the efficiency factor in electricity production has shifted the wind turbines locations from onshore to offshore.

The present study is focused on the North Aegean –Thracian Sea area and examines in which locations would be technically and economically viable to install wind farms with concern for the environmental issues. The mentioned area has a significant aeolic potential, relatively not deep waters and close distances to the shore. Wind data and geographical information were collected from the data bases of National Observatory of Athens, Hellenic National Meteorological Service and the Hellenic Centre for Marine Research.

It has to be mentioned that no offshore wind farms have been installed in Greece yet.

Keywords: renewable energy, wind turbine, offshore wind farms, feasibility study

1. Introduction

Wind energy is a clean and inexhaustible solution in meeting the increasing demand for electrical energy and the planned targets of the carbon dioxide emission reductions. The increasing fossil fuel prices and the restriction of pollution levels have transform wind energy to a vital factor for the economic development of any nation. As a consequence wind power generation is in an era of rapid growth rate both globally (end of 2010 totally installed 194.154 MW - Fig. 1) and in Greece (end of 2010 totally installed 1.208 MW - Fig. 2).

Enormous power can be generated by the selection of suitable wind farm sites. At this point offshore wind farms seem to be advantageous due to the enormous energy potential associated with the vast offshore areas. Stronger winds, less turbulence and the availability of large continuous areas promise greater productivity and make this form of energy more competitive. According to a scenario of European Wind Energy Association investments related to the offshore turbines will surpass those of onshore turbines after 2020. (1. Krohn et al. 2009

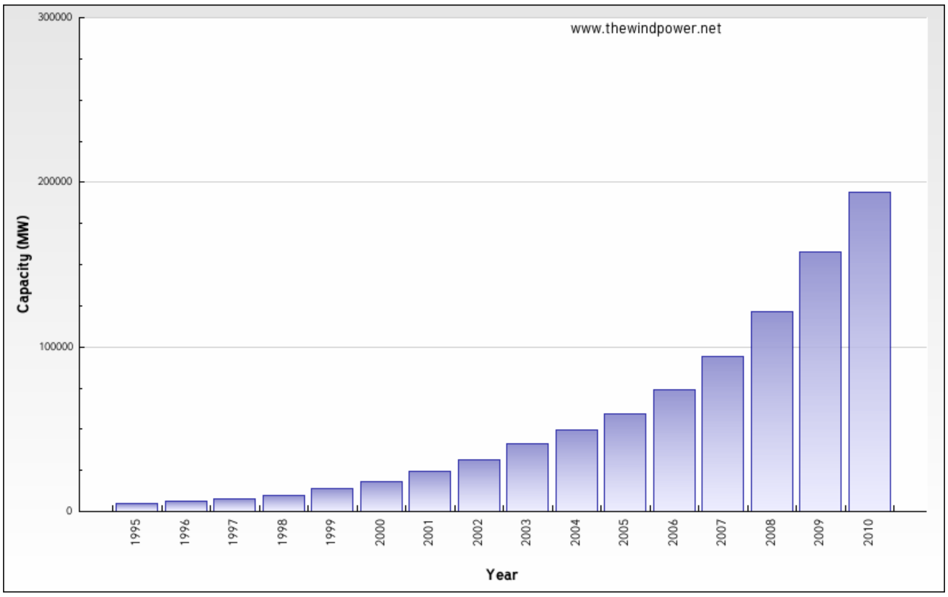


Fig. 1 Global wind power capacity

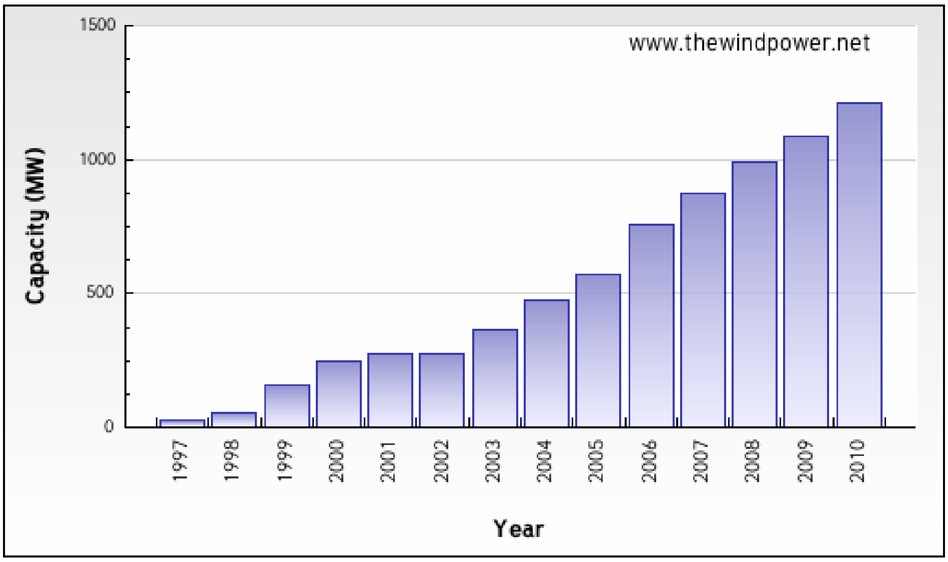


Fig. 2 Wind power capacity installed in Greece

Greece has a significant offshore aeolic potential. The elaborate study of the proposed areas for offshore wind turbine installation that takes under consideration environmental issues and other sectors of the economy such as touristic development, fishery and transportation, indicates the proper way to the sustainable development of the country. The present work describes the current status of offshore wind power technology and analyses the feasibility of introducing this technology in the North Aegean – Thracian Sea (N.A.T.S.).

2. Offshore advantages and disadvantages compared to onshore

The major advantages of offshore wind energy compared to onshore are:

1. Availability of large continuous areas, suitable for major projects.
2. Higher wind speeds, which generally increase with distance from the shore.
3. Offshore areas provide winds less turbulent and more predictable, which allow the turbines to harvest the energy more effectively and reduce the fatigue loads on the turbine (onshore wind is disrupted by hills or buildings making it more turbulent and less predictable).
4. Lower wind-shear (i.e. the boundary layer of slower moving wind close to the surface is thinner) which allows the use of shorter towers.
5. There is no limit on the size of the turbines that can be installed, unlike to

the limits imposed by road restrictions onshore.

6. Reduced visual and noise impact.

On the other hand there are severe disadvantages of offshore compared to onshore:

1. The higher investment costs related to the more expensive marine foundations, to the costly integration in to the electrical network and in some cases to the necessary increase in the capacity of weak coastal grids. Installation procedures are also more expensive and the access is restricted during construction due to weather conditions (Table 1 & 2).
2. The limited access for operation and maintenance during operation which results in an additional penalty of reduced turbine availability and hence reduced output (in Northern Europe 10 to 50 per cent of all offshore work-hours are lost due to bad weather).
3. Higher repair costs mainly due to the need for expensive crane vessels and waiting periods for suitable weather conditions (repairs estimated 5-10 times more expensive offshore than onshore).

Table 1

Increase in offshore investment cost as function to the coast[1]

		Distance to coast (km)							
		0-10	10-20	20-30	30-40	40-50	50-100	100-200	> 200
Cost (EUR/kW)	Turbine	772	772	772	772	772	772	772	772
	Foundation	352	352	352	352	352	352	352	352
	Installation	465	476	488	500	511	607	816	964
	Grid connection	133	159	185	211	236	314	507	702
	Others	79	81	82	84	85	87	88	89
	Total cost (EUR/kW)	1 800	1 839	1 878	1 918	1 956	2 131	2 534	2 878
	Scale factor	1	1.022	1.043	1.065	1.086	1.183	1.408	1.598

Source: EEA, 2008.

Table 2

Scale factors for cost increases as a function of water depth and distance to coast[2]

		Distance to coast (km)							
		0-10	10-20	20-30	30-40	40-50	50-100	100-200	> 200
Depth (m)	10-20	1	1.022	1.043	1.065	1.086	1.183	1.408	1.598
	20-30	1.067	1.090	1.113	1.136	1.159	1.262	1.501	1.705
	30-40	1.237	1.264	1.290	1.317	1.344	1.464	1.741	1.977
	40-50	1.396	1.427	1.457	1.487	1.517	1.653	1.966	2.232

Source: EEA, 2008.

3. Offshore wind turbine foundations and floating wind turbine concepts

There are different types of foundations that are used for offshore wind turbines. For depths up to 30m the most frequently used concepts are the gravity based Fig. 3(a) and monopile Fig. 3(b) foundations. An alternative to these two is the suction caisson Fig. 3(c), in which by removing the water from a caisson onto which the turbine is situated the suction force thus created is used to promote easy installation. For waters deeper than about 30m multiple piles which are driven into the ground Fig. 3(d) or multiple suction piles Fig. 3(e) allow the structure to be stable enough at reasonable costs.

The need for higher quality wind resources unconstrained by water depth has turned the wind industry developers in the direction of floating support options (which are already experienced in the offshore Oil and Gas industry). This is very important for Greece, which, compared to countries like Denmark, Germany and Netherlands, has deepwater coastlines.

[1, 2] European Environment Agency, Europe's onshore and offshore wind energy potential –An assessment of environmental and economic constraints –EEA Technical report No6/2009 ISSN 1725-2237

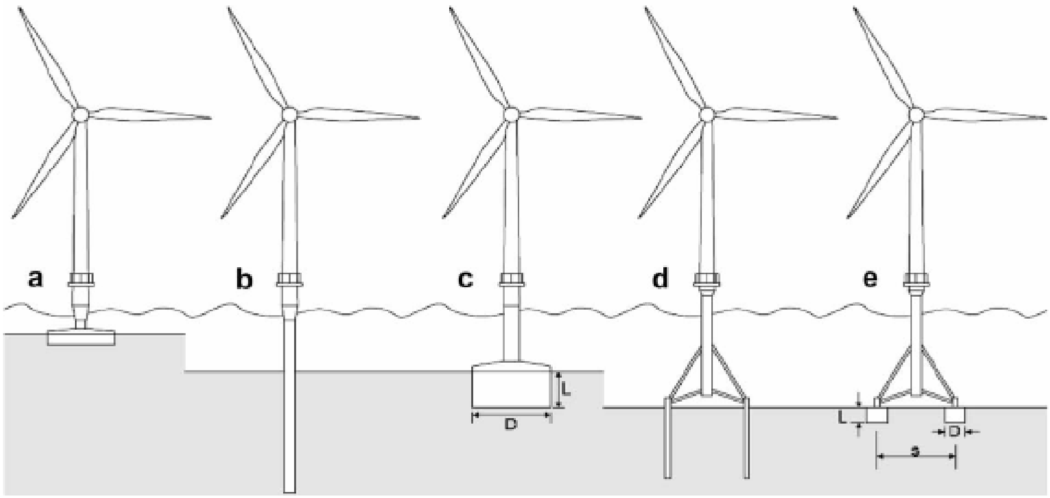


Fig. 3 Options for offshore wind turbine foundations

There are three main types of floating concepts (Fig. 4). In the "Ballast Stabilized" case the ballast is used to get the center of gravity well below the center of buoyancy providing stability and catenary mooring drag – embedded anchors keeping the system in place (for depths 200m-700m). In the "Mooring Line Stabilized Platforms" type the corners of the platform are connected by pretensioned mooring lines anchored to the seabed by suction piles (for water depths 80m-300m). The third type of "Buoyancy Stabilized" concept is to have the wind turbine stand on a platform floating near the surface and held in place by catenary mooring lines. (3. S.-F. Breton, G. Moe. Status 2009)

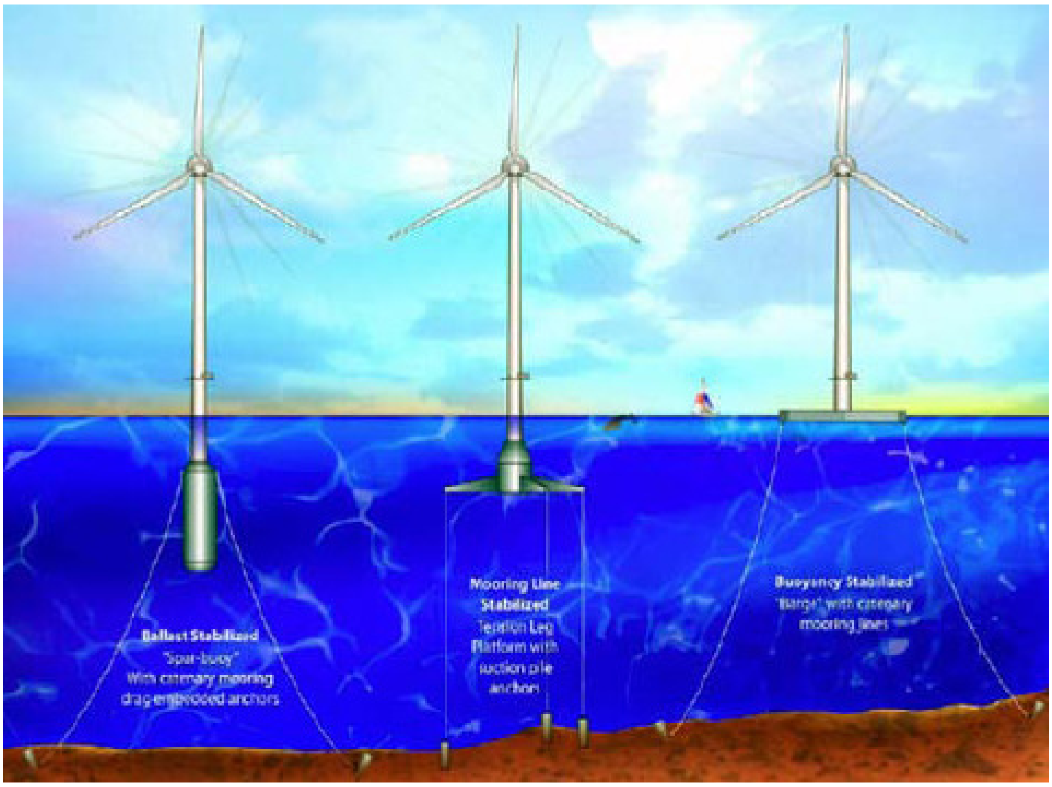


Fig. 4 Main types of floating wind platforms

4. Manufactured offshore wind turbines

There are different types of wind turbines specially designed for offshore conditions in order to be economically feasible for offshore use and some of them are presented below:

VESTAS

The V90 offshore model of the Danish world leader wind turbine manufacturer, with a capacity of 3MW, rotor diameter of 90m and designed to be low weight for easier transportation and installation, is already installed in different offshore wind farms across the world (Thanet – UK, Egmont ann Zee – Netherlands). The models V112-3MW offshore, designed with focus in optimal serviceability and V164-7MW offshore, a new generation of offshore turbine with minimum maintenance requirements, are larger scale models built also for offshore installation. (http://www.vestas.com)

SIEMENS

The SWT-2.3-93 with nominal power 2,3MW and rotor diameter of 93m (Horns Rev II-Denmark, Baltic I -Germany),the SWT-3.6-107 (Gunfleet Sands-UK) which is currently the world's most popular offshore wind turbine and the SWT-3.6-120 (London Array-UK). (http://www.siemens.com)

REPOWER

The type 5M with 5MW rated power and 126m rotor diameter installed in Ormonde-UK, Alpha Ventus – Germany and the type 6M (6,15MW – 126m) have offshore versions specifically designed to withstand extreme environmental conditions. (http://www.repower.de)

GENERAL ELECTRIC

The GE model 3.6-111 with a capacity of 3,6 MW and rotor diameter of 111m was installed in Arklow Bank offshore wind park in Ireland. The model 4.1-113 (4,1 MW – rotor diameter 113m) is designed specifically for offshore environment. (http://www.ge-energy.com)

SINOVEL

The Chinese wind turbine manufacturer produces the model SL3000 with 3MW rated power and rotor diameter range 90-100-105-113m which is also for offshore installation (Donghai Bridge-China). (http://www.sinovel.com)

WINWIND

The Finnish wind turbine manufacturer produces the WWD-3 model with rated power of 3MW and with rotor diameter range 90-100-103-109m suitable also for near-shore installations (Kemi Ajos I + II -Finnland). (http://www.winwind.com)

5. Offshore current status and plans

The first world's offshore wind power plant was installed in Vindeby (Denmark) in 1991 and had a total capacity of 4,95 MW (11 X 0,45 MW - BONUS). Denmark is the leading country in the world in this field owning the world's second biggest offshore wind farm located in Horns Rev (II) in the North Sea composed by 91 X 2,3 MW (SIEMENS) wind turbines. Since 2010 Thanet offshore wind farm (UK) with a capacity of 100 X 3 MW (VESTAS) WT is the largest one in the world. North West Europe is the place with the most concentrating wind farms globally.

Offshore wind energy development is taken very seriously in Europe and in February 2007 it was given high priority when European member states made a firm commitment to increase the total share of renewable energy in primary energy consumption to 20% by 2020. The target is to reach 50 GW of offshore wind energy by 2020. (10. Chair of the European policy workshop on offshore wind power development. Berlin declaration, conclusions of the chair. Berlin, February 2007)

In Europe as of 30 June 2011, there are 1247 offshore wind turbines fully grid connected, with a total capacity of 3.294 MW. (http://www.ewea.org/).

Global offshore wind power is going to reach 75 GW by 2020 with China and U.S.A. to have important contribution to this.

6. The geographic profile and informational data of North Aegean – Thracian Sea

Greece (Hellas Fig. 5) is situated in south-eastern Europe at the southern part of Balkan peninsula and borders the states of Albania, F.Y.R.O.M., Bulgaria to the north ,Turkey to the east and is surrounded by the Aegean sea (East) and Ionian sea (West). The North Aegean – Thracian Sea (N.A.T.S-Fig. 6) territory, that the present study deals with, is the region surrounded by the Mount Athos peninsula, the Ierissian Gulf and the Strymonian Gulf to the east, the coastline of Kavala, Xanthi, Rhodope and Evros prefectures to the north, Saros Gulf (Turkey) and the peninsula of Gallipoli (Turkey) to the west. It includes the islands of Thassos, Samothraki, Lemnos, Imvros and Tenedos. Only the greek part of N.A.T.S. is examined in this study. The territory of Mount Athos and its surrounding coasts are also excluded from this study as Mount Athos belongs to the Worlds Heritage List of UNESCO and has among others a unique landscape and seascape. (http://whc.unesco.org/en/list/454)

Fig. 5 Greece
(http://maps.google.com/)

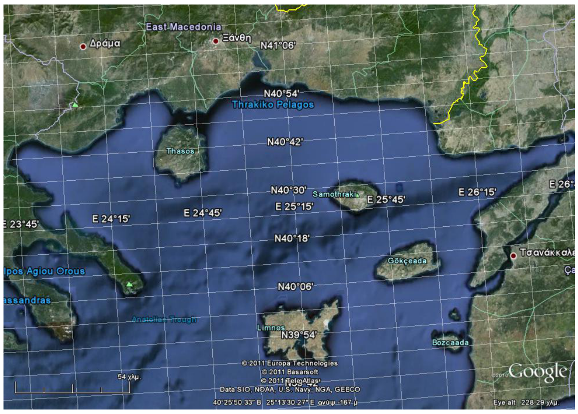


Fig. 6 North Aegean – Thracian Sea
(http://earth.google.com/)

N.A.T.S. has certain regions where the waters are relatively deep. The maximum depth is 1534m north of Lemnos and southeast of Samothraki islands. The depth of the coasts of Ierissian Gulf, Strymonian Gulf and Kavala coastline, already reaches 30 – 50 m within 1 mile distance from the shore. Thrace coastline is shallower with a maximum depth of 25m within a mile from the coast and with extensive areas near rivers ends to have less depth than 10m. The east, north and west waters of Thassos island within a mile from the coast are less than 50m, but the south areas have a depth of 50 – 100m. The maximum depth between Samothraki island and Alexandroupolis is ~80m with many areas to have a depth around 30m. The southwest, west and northwest coasts of Lemnos island have depths more than 100m, but the east coasts have less than 100m depth with local areas to be around 20-50m.

N.A.T.S. has an interesting aquaculture and fishing is an important economical source for the inhabitants, as the waters are rich in fish. A lot of fish farming and maricultures are located across the coastlines. There are living significant populations of marine animals like dolphins and whales and among them the protected species of seals Monachus - Monachus and the sea turtles Caretta - Caretta. A lot of bird species have their permanent residence in the territory of N.A.T.S. (among them eagles, falcons and vultures) and many other species like geese, pink flamingos, cormorants, swans, storks etc stay temporarily or travel across the sea during the bird migration periods.

The touristic development in N.A.T.S. is an important economic activity and during summer period in many coast regions hundreds of thousands tourists from inland and from abroad have their vacations and enjoy the beautiful seascape. Especially in the coasts of Chalkidiki and in Thassos island the tourist industry is the major activity for the most of the people living there. An offshore wind parks installation in these areas would probably provoke negative reactions by the inhabitants and the negative environmental impacts of the offshore wind parks (on marine life, aesthetic of ocean view, birdlife etc.) would be overemphasized.

The main ports that serve the touristic, trade, industrial, mining and fishing activities of the N.A.T.S. territory are the ports of Kavala and Alexandroupoli. Secondary ports that can also support the activities mentioned before are the ports of Stavros (Chalkidiki), N. Peramos (Kavala), Keramoti (Kavala), Porto-Lagos (Xanthi), Limenas (Thassos town), Kamariotissa (Samothraki) and Myrina (Lemnos).

Between the gulf of Kavala and Thassos island there are offshore Oil and Gas Platforms that are connected to the shore with undersea oil and natural gas pipelines. These plants that were installed almost 35 years ago have created a whole infrastructure in the greater area of Kavala: trading companies that supply spare parts and equipment for supporting offshore activities, rescue ships for all weather conditions, technical personnel, engineers and diving specialists capable and familiar with safety procedures regarding offshore installations. There are also technical companies - contractors that supply technical personnel for installation, operation and maintenance of offshore projects.

Important types of winds that blow in N.A.T.S. are the sea breeze and land breeze. The sea has a greater heat capacity than land and therefore is more able to absorb heat than the land, so the surface of the sea warms up slower than the land's surface. During daytime the air over the land heats up and hence expands more rapidly than the air above the sea. Due to the hydrostatic conditions at a given height the pressure is higher over the land than over the water. This pressure gradient produces a slight flow of air from the upper levels above the land to the upper levels above the sea. This leads to an increase in the pressure over the sea, so that air subsidence occurs. Departure from hydrostatic equilibrium leads to the flow from the sea to the land, in the lower level. This is called the sea breeze. During night hours the reverse process occurs and a land breeze takes place. Sea breeze speed usually ranges between 6 and 10 m/s and land breeze between 3-5 m/s and the on/offshore extent of the sea breeze is about 10-20 km. In Greece the sea breeze and land breeze develop mainly in summer. They are of great importance as they can raise the power productivity of wind turbines especially in the summer time when the environmental winds are generally weaker. (13. A. Mostafaeipour, 2010)

7. Restrictions - Wind data of the N.A.T.S

The geographical information for this study was found in nautical charts of the Hydrographic Service provided by the Hellenic Centre for Marine Research. Useful data regarding sea depths, distances and topographic details of these maps were used (Fig. 7) Restrictions relative to offshore installations (oil & gas platforms, undersea pipelines, tanker anchorages etc) and military practice areas have been taken into account and excluded.

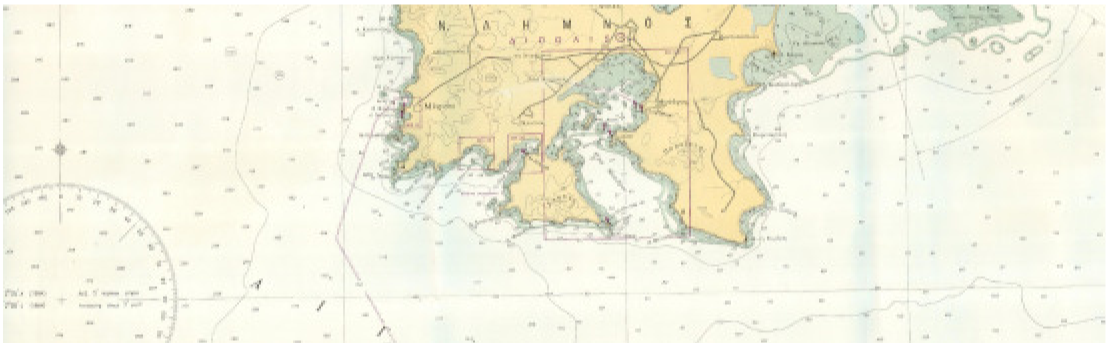


Fig. 7 Naval chart

Other areas that were rejected are the ones protected by Natura 2000 network. These are the special protection areas for birds and the special areas of conservation for species other than birds. (http://natura2000.eea.europa.eu/#) Although the installation of wind farms in Natura 2000 protected areas is not forbidden by the European directives, it is better to be avoided showing respect to the environment and wild life.

Greece has not yet claimed an exclusive economic zone so the geographic extension of this study is limited to 6 nautical miles from the shore.

With the above restrictions a map was created were the excluded areas and the 6 miles zone are shown (Fig.8). The red color marks the Natura 2000 areas, the dark green are military practice areas, the yellow are tanker anchorages, the light brown line with the red stars are the underwater pipelines and the offshore platforms and the light green zone is the 6 mile zone.

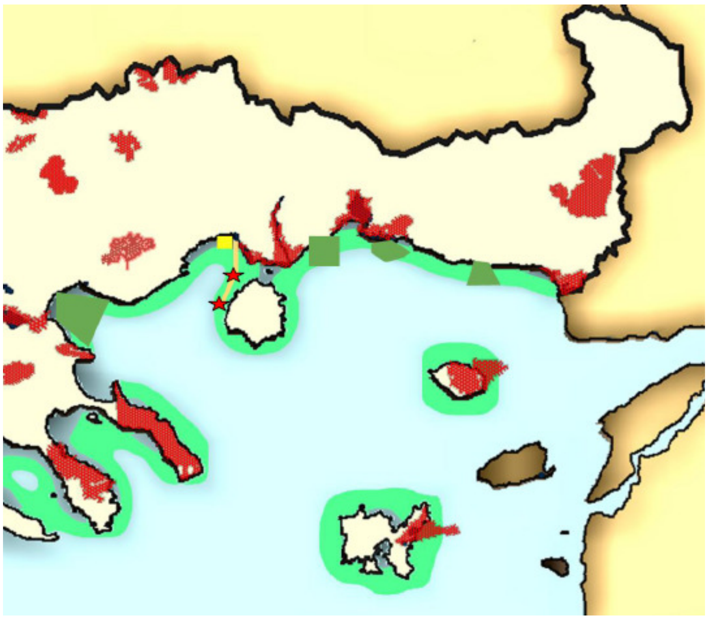


Fig. 8 Restrictions map

The wind data that were used to estimate the aeolic potential in the greater N.A.T.S. area, were taken by the data archives of meteorological stations of the National Observatory of Athens and Hellenic National Meteorological Service. (Table 3). The available data came from meteorological stations installed in Stratoni (Chalkidiki), Hrisoupoli (Kavala), Xanthi, Maronia (Rodopi), Alexandroupoli, Samothraki and Lemnos and cover a period of time up to five years.

Table 3

Meteorological data (http://penteli.meteo.gr/meteosearch/stationInfo.asp)

MONTHLY CLIMATOLOGICAL SUMMARY for AUG. 2008

NAME: samothraki CITY: STATE:
ELEV: 90 m LAT: 40° 28' 00" N LONG: 25° 29' 44" E

TEMPERATURE (°C), RAIN (mm), WIND SPEED (km/hr)

DAY	MEAN TEMP	HIGH	TIME	LOW	TIME	HEAT DEG DAYS	COOL DEG DAYS	RAIN	AVG WIND SPEED	HIGH	TIME	DOM DIR
1	26.8	30.8	4:50p	23.5	7:40a	0.0	8.4	0.0	25.6	74.0	10:40p	NE
2	26.2	30.7	4:50p	22.4	7:00a	0.0	7.9	0.0	25.6	69.2	1:10p	NE
3	26.8	30.7	5:30p	22.7	7:20a	0.0	8.4	0.0	27.8	67.6	2:00a	NE
4	27.4	32.5	3:10p	23.6	11:50p	0.0	9.1	0.0	17.4	59.5	12:50a	NE
5	26.1	29.3	10:10p	21.9	6:30a	0.0	7.8	0.0	7.2	25.7	9:50a	ENE
6	27.9	33.3	10:50a	23.6	3:10a	0.0	9.6	0.0	6.8	32.2	9:50a	SW
7	28.6	32.3	4:00p	24.9	7:00a	0.0	10.2	0.0	12.2	56.3	2:50p	NNE
8	26.1	29.8	4:00p	23.4	11:40p	0.0	7.8	0.0	9.2	45.1	12:50p	SW
9	25.2	28.1	3:20p	22.6	4:40a	0.0	6.9	0.0	7.2	37.0	5:50a	SW
10	25.9	31.6	3:20p	19.8	9:50p	0.0	7.6	15.6	11.7	57.9	6:00p	NNE
11	24.5	28.7	6:10p	20.7	1:40a	0.0	6.2	0.2	15.9	54.7	6:00a	NE
12	26.2	29.3	5:20p	23.3	5:20a	0.0	7.9	0.0	10.3	33.8	1:40a	NNE
13	26.9	30.3	7:00p	23.1	4:50a	0.0	8.6	0.0	7.4	30.6	1:10p	ENE

8. Proposed Areas

Considering the general wind potential of the territories near the meteorological stations and using the map with the available areas and the restrictions, offshore areas for wind parks were initially proposed (Fig. 9).

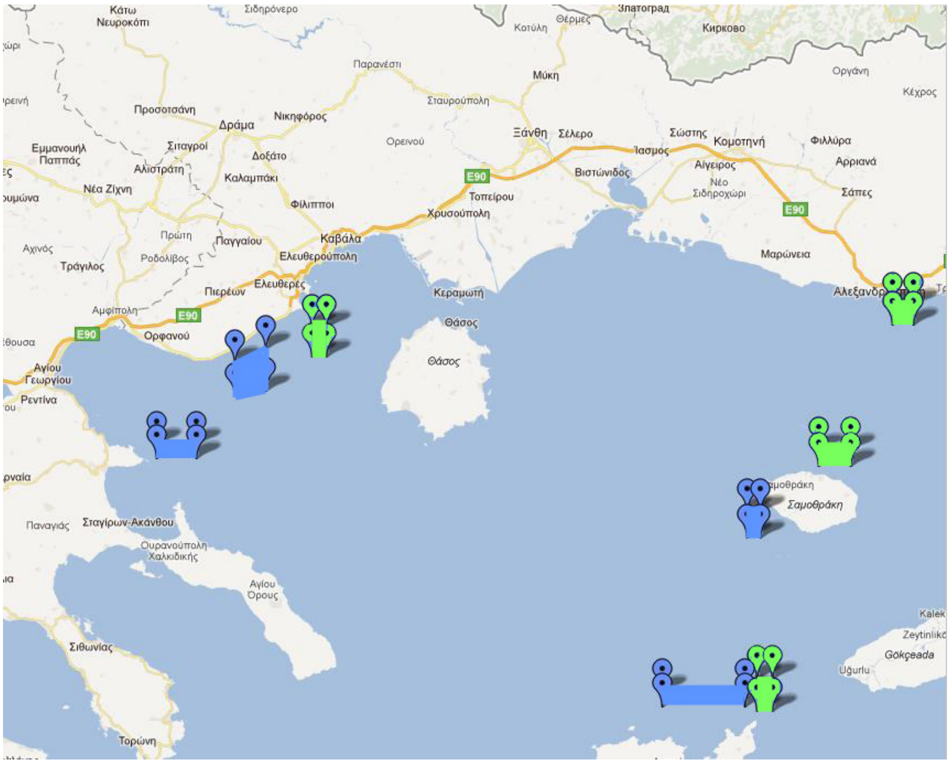


Fig. 9 The initially proposed areas

These areas were divided in two subcategories: the green points mark the areas with depths up to 50m and the blue points mark the areas with depths between 50-100m.

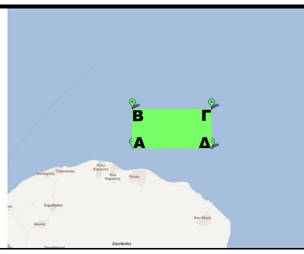
The second step was to estimate the wind potential in the proposed areas. The coordinates of the centers of each area were sent to National Observatory of Athens (N.O.A.) which uses the meteorological model BOLAM for weather forecasts. (16. K. Lagouvardos et. al. 2003) The Bologna Limited Area Model (BOLAM) is a meteorological forecasting model that can calculate wind speeds at 10 m above the surface and for grids ~ 6,5 km X 6,5 km. The wind forecasts of the proposed areas that were given by the N.O.A. cover the time period 2007-2010.

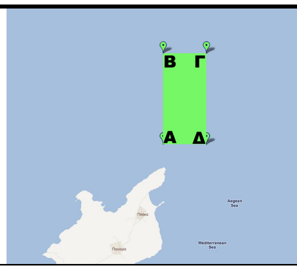
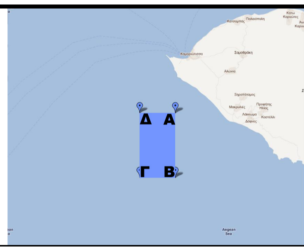
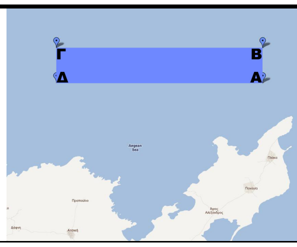
The market potential for offshore wind is, like land-based wind, estimated by comparing the generation cost forecasts for offshore wind to projected electricity tariffs and average production costs of electricity in 2010 and 2030. The lower limit of wind speed at hub height has been set to 5,0m/s. At wind speeds of 5,0m/s or below, the number of full load hours decrease to below 1000 which are not considered economically viable. (2. European Environment Agency, Europe's onshore and offshore wind energy potential –An assessment of environmental and economic constraints –EEA Technical report No6/2009 ISSN 1725-2237)

Roughly 7,0 m/s and faster are economically worth exploiting today even in higher-cost offshore locations. In many areas especially on land the 6,0m/s are already economically viable. (13. A. Mostafaeipour, 2010)

The wind forecasting data have shown that four out of the eight proposed areas are appropriate for offshore wind turbines installation. These are the following: (Table 5), (Fig. 10)

Table 5
Appropriate areas for offshore wind turbines installation

North of Samothraki island	A	B	Γ	Δ	
	40°31'06"N	40°32'51"N	40°32'51"N	40°31'06"N	
	25°36'07"E	25°36'07"E	25°40'48"E	25°40'48"E	
Surface area					~22 km^2
Min. Distance to	1,5 km				

the shore					
Average wind speed					6,20 m/s
Depth					<50 m
Distance of the areas center to the closer port					Kamariotissa port ~9 nautical miles
Northeast of Lemnos island	A	B	Γ	Δ	
	40°03'08"N	40°06'51"N	40°06'51"N	40°03'08"N	
	25°26'44"E	25°26'44"E	25°29'04"E	25°29'04"E	
Surface area					~22 km^2
Min. Distance to the shore	1,8 km				
Average wind speed					6,76 m/s
Depth					<50m
Distance of the areas center to the closer port					Myrina port ~30 nautical miles
Southwest of Samothraki island	A	B	Γ	Δ	
	40°25'50"N	40°22'55"N	40°22'55"N	40°25'50"N	
	25°27'23"E	25°27'23"E	25°25'16"E	25°25'16"E	
Surface area					~16 km^2
Min. Distance to the shore	2,7 km				
Average wind speed					6,42 m/s
Depth					-100 m
Distance of the areas center to the closer port					Kamariotissa port ~6 nautical miles
North of Lemnos island	A	B	Γ	Δ	
	40°03'43"N	40°05'20"N	40°05'20"N	40°03'43"N	
	25°25'03"E	25°25'03"E	25°12'36"E	25°12'36"E	
Surface area					~54 km^2
Min. Distance to the shore	3,7 km				
Average wind speed					6,51 m/s
Depth					-100m

Distance of the areas center to the closer port					Myrina port ~23 nautical miles

Fig. 10 Finally proposed areas

It has to be mentioned that the BOLAM forecasting model calculates the wind speed at 10m above the surface. The hub heights are usually more than 60m, so the wind at these heights is stronger than the one calculated by the BOLAM. Further research on real wind data (by installing local meteorological stations in the proposed areas) is suggested.

The current research team is conducting a feasibility study on the economic factors concerning the installation of a number of wind turbines of appropriate size in the areas mentioned above.

9. Conclusions

Offshore wind power generation is a very promising important source of clean energy in the future. By the end of this decade wind parks with a total capacity of thousands of megawatts will be installed in European seas. Although the 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 competitive compared to onshore. Even though Greece has not the strong wind offshore potential the North Sea territory has, there are areas where the offshore installation could be economically viable. There are certain areas in North Aegean – Thracian Sea where it is worth installing offshore wind parks addressing the environmental and other issues (touristic development, marine life etc) respectfully. A more extensive research in the field of wind data for the offshore areas of Greece is needed, in order to increase the reliability of the viability studies in moderate wind territories.

10. Acknowledgments

The National Observatory of Athens, the Hellenic National Meteorological Service 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.

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Potential of renewable energy sources in Republic of Srpska

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In the last ten years, renewable energy sources are the fastest growing segment of the production of energy in the world. With discussions on climate change and the obligation to reduce CO2 and other greenhouse gases, *renewable energy sources* receive their true dimension of energy. Republic of Srpska, because of its natural characteristics, counts in a region with significant potential of water power. Total useful technical potential of the Republic of Srpska, including the border river is 13.505 GWh / yr. In addition to this , it has other renewable energy sources, included: wind, solar, geothermal energy and use of biomass for energy purposes. The fact is that today, renewable energy sources in the Republic of Srpska, with the exception of the use of hydro-potential and fuel wood, are very few or almost not in use for energy purposes. Scientific contribution of this paper is to assess and promote the potential of renewable energy sources, which is resulting in a goal that renewable sources are no longer alternative or supplemental but serious sources. Those sources will significantly change the current structure of energy production. The need for planning actions and measures in energy consumption has led to the development of so-called sector "end-use" model. These are mathematically simple models, with detailed structural analysis on all sectors of consumption and their sub-sectors. Presentation of these resources is essential and showing opportunities for investment and construction of energy facilities, which makes a significant contribution to reducing greenhouse gases emissions and general environmental protection.

Key words: renewable energy sources, potential of water power, wind energy, solar energy, biomass, geothermal energy

1. Introduction. Importance of renewable energy sources in Republic of Srpska

In the modern world, energy is one of the key factors for all activities, whether in terms of housing, industry, transport or information technology. Production, distribution and consumption are activities that directly or indirectly affect all areas of human activity, but also social and economic progress of any country. Energy sources in its origin can be shared in renewable and non-renewable. The non-renewable sources include coal, petroleum, natural gas and nuclear energy and renewable sources include solar energy, hydropower, wind energy, geothermal energy, bioenergy, biofuels, and ocean energy (wave energy and tidal energy). Coal and nuclear energy are now considered the most controversial sources of energy in the world.

Republic of Srpska has determined general objectives of energy development. The essential issues for renewable energy are:

- ensuring the development of energy sector in terms of CO2 emission limits, combined with increased energy efficiency and increased use of renewable energy and
- developing an effective system of encouraging energy efficiency and using renewable energy sources in accordance to local opportunities and obligations that Bosnia and Herzegovina will gain by membership of Bosnia and Herzegovina in the European Union

Renewable energy sources are important for the development of the energy sector because they:

- contribute to the diversification of energy sources,
- increase the security of energy supply and
- encourage economic activity

The purpose of projects using renewable energy sources is wider than just energy-economic benefits because they realize positive effects such as:

- reducing emissions of pollutants,
- waste management (municipal and wood waste, agricultural byproducts and industrial production),
- creating of new and existing jobs, and
- opportunity to develop and increase the competitiveness of domestic industry

The widest application of renewable energy sources is expected in electricity generation (wind and small hydropower), but also in other sectors (e.g. domestic hot water and space heating using solar collectors, the use of geothermal energy for heating purpose, the use of modern systems for biomass heating etc).

2. Potential and use of water power in Republic of Srpska

Republic of Srpska is one of the areas with great hydropower potential. Total technically exploitable hydropower potential of the Republic of Srpska is about 3200 MW installed capacity and 9500 GWh/year of annual production of electricity. Exploited amount is about 2420 GWh/year. Energy potential power below 0.5 MW (micro and mini hydro power plants) is not explored in detail in the Republic of Srpska.

Because of its natural characteristics (developed relief, the relative high level of rainfall, developed hydrographic network), the Republic of Srpska ranks in areas with great hydropower potential. The most important part of the hydropower potential is located in the basins of the rivers Drina, Vrbas and Trebisnjica, a small part of the river basins of Una, Sana, Bosna and Neretva. All of these watersheds have been investigated for the purpose of exploitation of water resources for electricity generation.
Total technically exploitable potential of streams in the Republic of Srpska including the boundary river is 13,505.0 GWh/year. Technically exploitable potential, which belongs to the Republic of Srpska is 10027.5 GWh/year. Used hydro potential of Republic of Srpska is 2985.8 GWh / year.
The remaining unused hydro potential of Republic of Srpska is 7041.7 GWh / year.

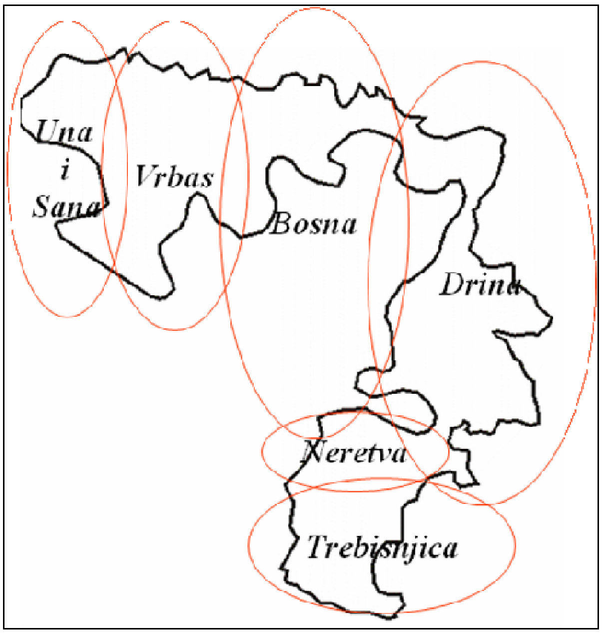


Figure 1. Catchment areas in Republic of Srpska: Drina, Vrbas, Trebisnjica, Bosna, Neretva, Una i Sana

In order to provide a larger number of participants in the electricity market and to attract investments in the energy sector, The Republic of Srpska Government issued a public call for the construction of small hydropower plants in 2005. The expected results were not achieved in the implementation of concession contracts and the construction of small hydropower plants because the various concessionaires faced barriers that can be classified into technical, administrative, social and financial barriers. On the basis of public invitation in 2005, and later under unsolicited offer in accordance with the Law on Concessions, The Government of the RS awarded the concession for the construction of 107 hydro power plants (total of 47 concessionaires), with a total installed capacity of 281.67 MW and estimated total annual production GWh.

If considered that the total hydropower potential in Republic of Srpska forces in the area of 0.5 to 10 MW is estimated at about 1500 GWh/year, it can be assumed that large part of the technically and economically exploitable potential for small hydro power in Republic of Srpska will be used by 2030 by the realization of projects that have received concessions.

Table 1. Review of hydropower potential in Republic of Srpska

Catchment area	Watercourse	Possible installed power	Average annual production
		MW	**GWh**
Drina	Sutjeska	37,74	169,96
	Bistrica	40,90	158,54
	Praca	20,90	124,60
	Lim	43,8	165,10
	Cehotina	43,77	182,20
	Other smaller streams	51,13	231,76
	Drina- main stream	1710,10	3709,21
Total Drina		**1948,34**	**4741,37**
Vrbas	Janj	36,52	142,90
	Vrbanja	59,90	203,60
	Other smaller streams	11,03	49,86
	Vrbas- main stream	287,68	1182,92
Total Vrbas		**395,13**	**1579,28**
Trebisnjica	The upper horizons	256	488,20
	Trebisnjica –main stream*	482,08	1949,88
Total Trebisnjica		**738,08**	**2438,08**
Una i Sana	Una	10	55,20
	Sana	45,96	214,04
Total Una i Sana		**55,96**	**269,24**
Neretva	Neretva	48,33	145,29
Total Neretva		**48,33**	**145,29**
Bosna	Biostica	28,20	112
	Other smaller streams	24,45	108,20
	Bosna – main stream	113,20	569,20
Total Bosna		**165,85**	**789,40**
Total republic of Srpska		**3351,69**	**9962,66**

Source: Study on energy sector in Bosnia and Herzegovina

3. Potential and use of wind power in Republic of Srpska

Until now, the wind power in Republic of Srpska is not used for energy purposes, since there was not built any commercial wind plant.

Due to the technology development and the general trend in terms of exploitation of wind energy in the world, it is likely that the construction of wind plants and their significant integration in the energy system will come into force until 2030 in Republic of Srpska. It will be necessary to introduce a system to encourage and establish the necessary energy entities, consolidating the institutions and the establishment of reality in life and entrepreneurial organizations in the energy sector.

The most promising area for further construction of the wind plants is southern part of Republic of Srpska, in the region from Kalinovik to Trebinje, in municipalities Gacko, Trebinje, Nevesinje and Berkovići. Theoretically usable potential for using wind power is estimated at 640 MW and 1200 GWh/year. Technically exploitable potential depends on the conditions of each micro-location (location access and availability of infrastructure).

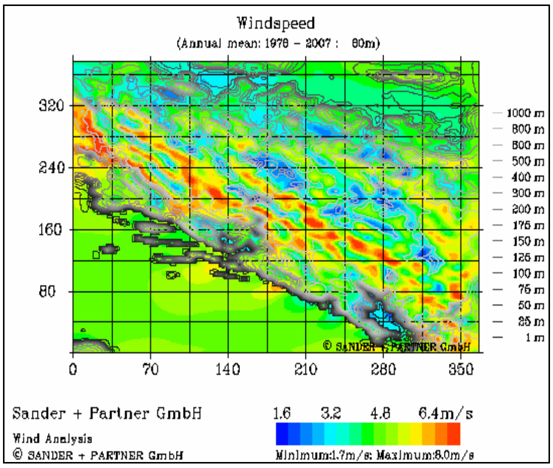
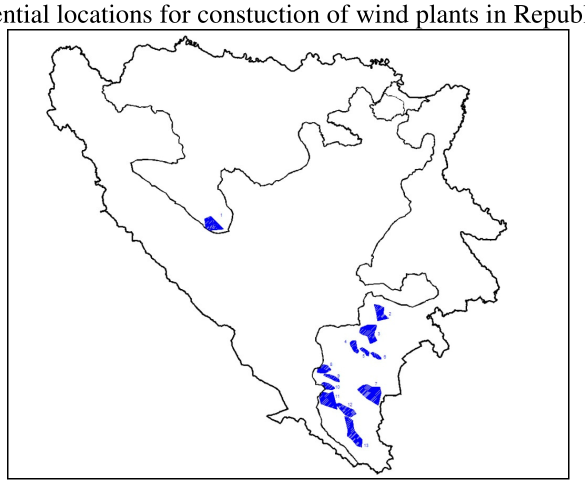


Figure 2. Regional Wind Atlas REGIONAL RE-ANALYSIS - The average annual wind speed at height 80 m above the ground in the period since 1978 to 2007

Regional Wind Atlas REGIONAL RE-ANALYSIS uses global meteorological data and the results obtained using this model were not verified with the ground measurements. Assimilating measurements on the characteristic points on the ground in the model, would give more accurate results. However this wind atlas can be considered sufficiently representative for the selection of macro location areas for construction of wind plants. For Republic of Srpska there was made a model wind atlas that is necessary to verify with the wind measurement.

Detailed measurements of wind parameters on location and at certain height above the ground are required for detailed calculations. Orography in the entire area of interest is very complex, indicating very different wind climate conditions even in locations that are close (< 3 km). The highest yield of wind power in Republic of Srpska can be expectedin in southern part of state, in Eastern Herzegovina.

Figure3. Potential locations for constuction of wind plants in Republic of Srpska



Source: Energy Development Strategy for Republic of Srpska to 2030

The analysis of available surface maps, maps of wind and spatial plans showed that possibilities of this area are very large. Locations listed in the table below are the detailed analysis of orographic characteristics of the terrain, wind and the available space included in the analysis of potential sites for construction of wind power in the RS.

According to the Energy Development Strategy, technically exploitable wind potential in Republic of Srpska is about 640 MW deployed at 13 locations. It is planned to build wind plants with the total installed capacity of 200 MW by year 2020, and with the total installed capacity of 350 MW by year 2030. Taking into account all locations and combining calculated data on production, total annual production at the observed locations is estimated to 1.22 TWh. This estimate should be viewed strictly as indicative, since a quality assessment with less uncertainty should conduct a detailed analysis of the measured wind data, and make a study of wind for particular locations.

Table 2. Expected production of wind plants in Republic of Srpska on potential locations

No.	Location	Power, MW	Average wind speed, m/s	Annual production, MWh/year:	Equivalent hours of nominalplant	Factor of utulization
1	Vitorog	28	6,11	51991,8	1857	21,2%
2	Treskavica	74	5,63	115687,5	1563	17,8%
3	Lelija	42	7,33	109300,9	2602	29,7%
4	Morine	36	6,23	69508,2	1931	22,0%
5	Brnjac	22	5,61	34088,6	1549	17,7%
6	Vucevo	18	6,43	36961,7	2053	23,4%
7	Podbaba	124	6,24	240184,8	1937	22,1%
8	Nevesinje	34	6,38	68644,7	2019	23,0%
9	Krupac	28	6,47	58152,1	2077	23,7%
10	Hrgud	32	6,62	69359,6	2167	24,7%
11	Trestanica	60	6,28	117431,9	1957	22,3%
12	Kmen	72	5,91	124570,9	1730	19,8%
13	Trebinje	70	5,86	119234,2	1703	19,4%

Source: Energy institute Hrvoje Pozar, Zagreb

4. Biomass potential and use in Republic of Srpska

Biomass, a renewable energy source, is biological material from living, or recently living organisms, such as wood, waste, gas, and alcohol fuels. Biomass is commonly plant matter grown to generate electricity or produce heat.

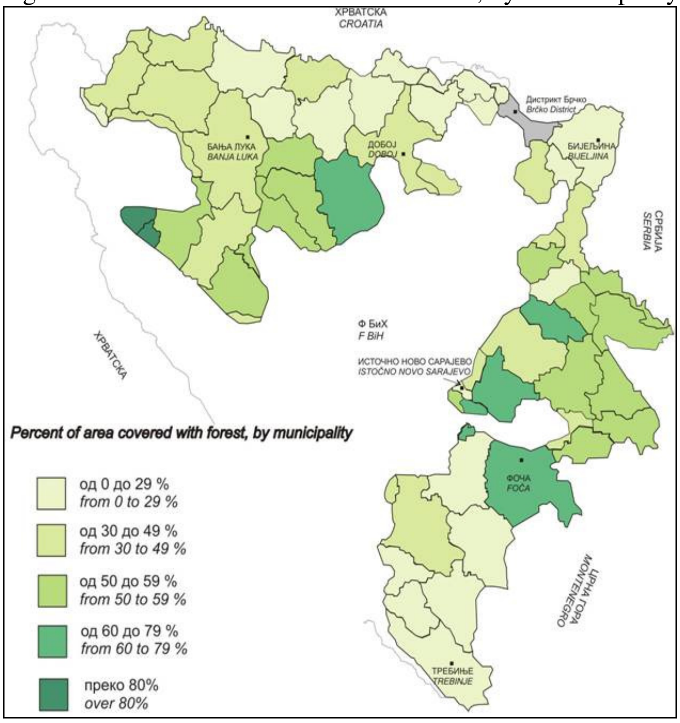
When assessing the potential of biomass it is necessary to observe three main sectors where biomass comes from such as **forestry, agriculture and waste management.**

Total theoretical potential of biomass in Republic of Srpska is estimated at 31.08 to 46.24 PJ. The largest part (59%) belongs to biomass suitable for combustion (waste from the timber, firewood, wood scrap, rests of pruning of perennial crops). 39% of biomass is suitable for producing biogas from municipal waste, energy crops and livestock.

4.1. Wood biomass potential

Forests cover about 40% or 2,371,062 ha of the total area of Bosnia and Herzegovina. 53% or 1,250,391 ha are located in Republic of Srpska, which means forests are one of the most important natural resources of Republic of Srpska. Only about 60% of the annual allowed cut is realized, or from 7,44 million m^3, 4,43 million m^3 is cut.
Public Corporation "Forests of Republic of Srpska" manages about one million hectares or about 80% of forest reserves, while the remaining forests and forest land are in private ownership. Overall stocks of timber during the editing is 181 567 000 m^3 of which 62% is deciduous and 38% is conifers. The annual increment is 5 222 700 m^3, and the annual allowed cut 3 447 140 m^3.

Figure 4. Percent of area covered with forest, by mmunicipality



Source: Forestry Statistics, StatisticBulletin #8, Republic Office of statistics of Republic of Srpska, Banja Luka

Theoretical potential of forest biomass can be calculated in two ways and both of them depend on Public Corporation's "Forests of Republic of Srpska" decision of the share of biomass that can be used for energy purposes. To calculate the potential of forest biomass there was used the average calorific value of wood 9 MJ/dm³.

Table3. Theoretical potential of forest biomass in Republic of Srpska

Category		Total	Theoretical potential of categories
		M^3/year	PJ/year
Prescribed allowed cut		3 447 140	31,0
Realized allowed cut	Total, of it	2 754 114	24,8
	Industrial and technical wood	1 314 268	11,8
	Firewood	824 424	7,4
	Waste	615 422	5,5
Unused allowed cut		693 026	6,2

Source: Forestry Statistics, StatisticBulletin #8, Republic Office of statistics of Republic of Srpska, Banja Luka

4.2. Agricultural biomass potential

Agricultural use of biomass for energy purpose is divided into wood waste (perennial crops), animal excrement (livestock) and harvest residue and energy crops (farming).

Estimation of the potential of biomass from farming focuses on involvement of raw agricultural land for the purpose of energy. Potential from farming ranges from 7.4 to 15.1 PJ/year, assuming separating energy policy from agricultural policy. There was considered yield of biogas and 1st generation of biofuels from planting corn, rapeseed and grass. The potential of biogas from livestock is calculated based on three-year average of livestock from the statistics. The yield of biogas from cattle, pigs, sheep, horses, goats and poultry was analyzed according to Republic Office of statistics of Republic of Srpska, Banja Luka.

Reference values for the yield of biogas per cubic meter of fresh substrate and the share of methane in the biogas were obtained from the „*Bayerische Landesanstalt für Landwirtschaft*“(*Bavarian State Institute for Agriculture*) since Germany has the most developed sector of biogas. Used methodologies have shown similar potential from livestock, which ranges from 4.4 to 5 PJ / year.

4.3. Waste biomass potential

The potential of waste can also be estimated by the number of inhabitants and the total waste produced in the RS (0.7 to 0.9 kg/per capita of waste per day). This annual production of municipal waste in the RS is 367-473 thousand tons. Assuming that the organic fraction of waste is the same as the one in Croatia (74.5%), then it can be assumed that 0.98 to 1.26 PJ per year could be obtained of landfill gas (200 m3 per ton of organic waste for 20 years, 50% methane in biogas).

According to the next table, the theoretical annual total biomass energy potential of the Republic of Serbian ranges from 31.08 to 46.24 PJ. Excluding agriculture, theoretical potential is reduced from 23.7 to 31.11 PJ. The greatest potential is in the forestry sector and related industries (52-77% of potential, depending on the treatment of husbandry), followed by agriculture (20-39%) and waste (3-5%).

5. Possibilities of use and development of solar energy in Republic of Srpska

Solar energy is one of the most accessible and safest energy on Earth. The Earth receives 174 petawatts (PW) of incoming solar radiation (insolation) at the upper atmosphere. Approximately 30% is reflected back to space while the rest is absorbed by clouds, oceans and land masses. Use of solar energy reduces the need for fossil fuels and reduces environmental pollution caused by their combustion.

Important climatic data for the use of solar systems are solar energy and air temperature. Total available energy is defined by irradiation of the surface with the solar radiation, while temperature defines the conversion efficiency of solar energy into other forms in solar systems.

There is definitely a significant potential of biomass resources that can be used to produce electricity and heat (separately and combined). Utilization of biomass cannot be done without an adequate legal framework to stimulate this sector. New legislation must be supported by financial mechanisms to lower a cost of investiment of building new plants for renewable energy and improvement of existing power plants on fossil fuel / heating plant in order to facilitate co-combustion and cogeneration.

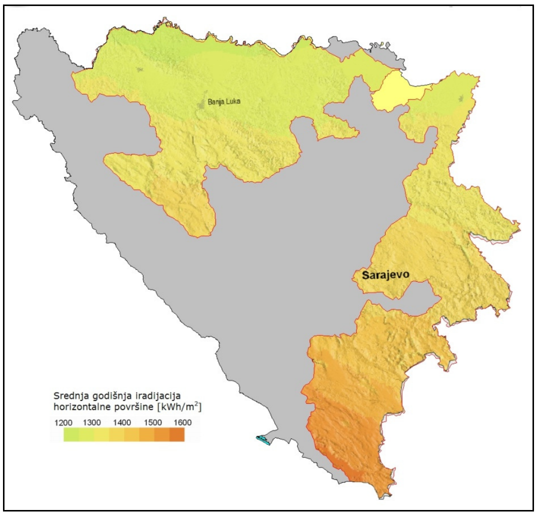
Table 4. Annual theoretical potential of biomass in republic of Srpska

Source of biomass	**Theoratical potential (PJ)**	
	from	**to**
Wooden biomass		
Waste from wood industry	4,88	6,96
Firewood	7,42	9,58
Waste	5,54	7,54
Total forest biomass	**17,84**	**24,08**
Agricultural biomass		
Perennial crops	0,37	0,71
Animal husbandry	4,38	4,96
Crop husbandry	7,41	15,13
Total agriculture	**12,17**	**20,80**
Waste		
Waste cooking oil	0,10	0,10
Landfill gas	0,98	1,26
Total waste	**1,08**	**1,36**
Total biomass PJ	**31,08**	**46,24**

Source: Energy Development Plan for Republic of Srpska to 2030

Figure 5 shows the map of spatial distribution of average annual radiation on horizontal surfaces with total solar radiation in Republic of Srpska. In accordance with the latitude, the total annual amount of solar radiation, in general, decreases from northwest to southeast. The area around the Posavina can expect radiation from 1.25 to 1.3 MWh/m² of solar energy. The amount of radiation is increased by lowering to the south so that areas of southern Herzegovina generate radiation between 1.5 and 1.55 MWh/m².

Figure 5. Map of mean annual radiation horizontal surface solar radiation



Source: PV GIS, process: EIHP

A significant modifier of radiation is proximity of Adriatic Sea, which entered the continent in the northwest-southeast, so that isolines of radiation throughout southeastern part deviate significantly from providing in the east-west direction. Month with the greatest amount of radiation received is July when the value of radiation ranging from 6.1 to 7.5 kWh/m2 kWh/m2. At least daily radiation can be expected in December and from 0.98 to 1.46 kWh/m2 kWh/m2. Total solar radiation on tilted surface consists of direct, scattered and reflected radiation from the ground. The quotient D/G is the share of the total scatter solar radiation. Number of hours of sunshine - insolation in northern part of Republic of Srpska is about 2000 hours per year while in the southern part is about 2500 hours per year.

5.1. Potentials of use of solar panels in Republic of Srpska

The greatest potential for use of solar panels is in family homes, hotels, healthcare institutions and sport facilities. When setting priorities, the installation of solar collectors should be most represented in the buildings that seek to reduce consumption of fuel oil, electricity and gas.

5.2. Photovoltaic application of solar energy in Republic of Srpska

Photovoltaic (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. Depending on the technology, efficiency of conversion of solar energy into electricity is between 4 and 16%.
Common applications of photovoltaic system connected to the network are residential, commercial and industrial buildings where photovoltaic modules are installed on the roof. In this way, the energy produced in photovoltaic system is spent on the production site, which minimizes losses in transmission / distribution and reduces the network load.

Also, in combination with other sources such as wind turbines, small diesel generators and energy storage, photovoltaic modules are often used for electrification of remote villages of the entire electricity network. According to the Republic Bureau for Statistics ("Survey of Living Standards in Bosnia and Herzegovina") 1.40% of rural households in Republic of Srpska has no connection to the electricity grid. Electrification of these objects can be implemented using just photovoltaic system. Productivity of photovoltaic system is expected production of electricity from power stations photovoltaic system in the period a year for a particular area. Productivity of photovoltaic system for Republic of Srpska ranges from 1100 kWh/kWp for the northern regions to 1380 kWh/kWp for the southern part (near Trebinje).

Table 5. Productivity of photovoltaic system [kWh/kW$_p$] for Republic of Srpska

Banja Luka		Bijeljina		Brcko[6]		Doboj	
monthly	**daily**	**monthly**	**Daily**	**monthly**	**daily**	**monthly**	**daily**
51	1,6	49	1,6	48	1,5	50	1,6
63	2,2	61	2,2	59	2,1	61	2,2
94	3	94	3	92	3	94	3
108	3,6	107	3,6	107	3,6	109	3,6
123	4	125	4	123	4	124	4
122	4,1	123	4,1	122	4,1	121	4
141	4,5	138	4,4	137	4,4	139	4,5
130	4,2	131	4,2	130	4,2	130	4,2
113	3,8	114	3,8	112	3,7	113	3,8
85	2,7	90	2,9	88	2,8	87	2,8
53	1,8	54	1,8	52	1,7	53	1,8
42	1,3	43	1,4	41	1,3	42	1,4
94	3,1	94	3,1	93	3	94	3,1
1125		**1129**		**1111**		**1123**	

lFoca		Prijedor		Sarajevo		Trebinje	
monthly	**daily**	**monthly**	**Daily**	**monthly**	**daily**	**monthly**	**daily**
66	2,1	51	1,6	62	2	72	2,3
75	2,7	64	2,3	72	2,6	82	2,9
104	3,4	93	3	101	3,3	114	3,7
117	3,9	106	3,5	115	3,8	128	4,3
131	4,2	123	4	129	4,2	142	4,6
129	4,3	122	4,1	127	4,2	140	4,7
149	4,8	140	4,5	146	4,7	157	5,1
142	4,6	129	4,2	140	4,5	151	4,9
124	4,1	111	3,7	122	4,1	135	4,5
101	3,3	82	2,7	99	3,2	110	3,6
67	2,2	51	1,7	64	2,1	77	2,6
56	1,8	40	1,3	53	1,7	63	2
105	3,5	93	3,1	103	3,4	114	3,8
1261		**1112**		**1230**		**1371**	

Source: Energy institute Hrvoje Pozar, Zagreb

[6] Brcko District is special administartive part of Bosnia and Herzegovina

Made analysis show that Republic of Srpska has the significant potential for use of solar energy. Solar systems are not in greater use because of the lack of incentives for their use. Due to the high initial cost of investment, we can not expect greater use of photovoltaic system without introducing incentive prices and guaranteed period purchase of electricity. Without this stimulation use of photovoltaic system in public institutions (schools, children homes, etc...) can only be expected as demonstrative technology and education of professional staff. Photovoltaic systems, combined with other sources of energy are certainly interesting for electricity supply of settlements and facilities that are not connected to the electric network until adoption of legislative framework for purchase of electric power to electrical grid at fixed price.

6. Potential and use of geothermal energy in Republic of Srpska

The northern part of the Republic of Srpska has significant geothermal potential while southern and south-east parts have much less resources. In geothermal reservoirs it is expected water of average temperature 100ºC (80-150ºC). Thermal water is now used primarily in balneological purposes, while use of geothermal energy for space heating is still at the beginning of development.

The main geothermal sources are located in Triassic and Cretaceous limestone where geothermal water with temperatures ranging from 30 to 150° C is accumulated. The energy potential of the carbonate complex is estimated to 1260 PJ (equivalent to 30 million tons of oil).

Previous research has mostly concentrated on the cities in which the district heating systems have been eligible, such as Bijeljina and Banja Luka, as well as research for use in complex areas of Dvorovi Spa, Bijeljina and Banja Luka. The continental part of Europe has an average density of heat flow 60 mW/m2. The values of heat flow density in Republic of Srpska are very diverse. In the area of eastern Herzegovina density is 20 to 30 percent lower than the European average. The highest density of heat flow values is on the southern edge of the Pannonian basin, and in Posavina, where the values are 30% more than the average of continental Europe.

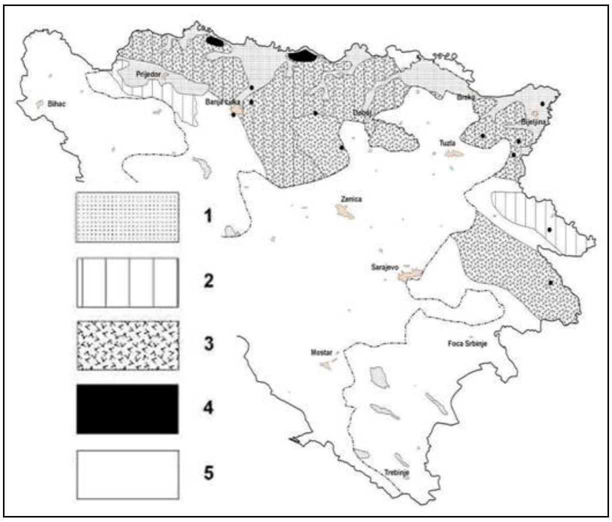


Figure6. Map of geothermal resources of the Republic of Srpska
1. hydro geothermal site in alluvial sediments where geothermal energy can be used by heat pumps
2. hydro or petrographic geothermal site in a depth of 300 m where geothermal energy can be used with vertical heat exchangers and heat pumps
3. hydro site in the Triassic and Cretaceous limestone and dolomite where geothermal energy can be directly used
4. petrographic geothermal site in granite rocks where geothermal energy can be used to transmit electricity
5. an area without significant geothermal sites

Natural sources of geothermal water are mostly found in the western part of the state. On the basis of available data is estimated that the volume of the reservoir made of limestone and dolomite in Semberija, Posavina, Banja Luka and Lijevče field, can form a geothermal heat power 50-100 MWt. The greatest potential use of geothermal energy in Republic of Srpska is in agriculture, aquaculture, and public utilities such as heating and heating of the village.
Republic of Srpska has recognized the importance of its geothermal resources. It is considered to be necessary additional investigative work on all wells that show potential for energy production. Since the specific investment in geothermal plants is high and the state is rich in other forms of energy (primarily coal and energy watercourses), production of electricity from geothermal sources is still not planned in the future twenty years. However, in case of adoption of a legislative framework to encourage the production of electricity from this source it will be possible to improve the economic viability of such projects, and thus probably the construction of such facilities.

	Location	Municipality/ City	Type of occurrence	I –source (I) – more sources	B- drill (B) – more drills	Estimated yield (l/s)	Type of source	Average temp. (°C)
1	Gornji Seher	Banja Luka	Thermo-mineral Swater	(I)	(B)	108	outflow	32
2	Slatina	Laktasi	Thermo-mineral water	(I)	(B)	100	pumping	43
3	Laktasi	Laktasi	Thermal water	(I)	(B)	100	outflow	30
4	Kulasi	Prnjavor	Thermal water	(I)	(B)	20	pumping	30
5	Dvorovi	Bijeljina	Thermal water	n/a	B	20	outflow	20
6	Teslic	Teslic	Thermo-mineral water	(I)	(B)	50	pumping	30-38
7	Voljanic	Petrovo	Thermo-mineral water	I	B	2	outflow	24
8	Sockovac	Petrovo	Thermo-mineral water	(I)	(B)	200	pumping	39
9	Visegrad resort	Visegrad	Thermal water	(I)	(B)	90	outflow	34
10	Domaljevac	Samac	Thermo-mineral water	n/a	B	20	outflow	92
11	Ljesljani	Novi Grad	Thermo-mineral water	(I)	B	9	outflow	20-32
12	Prijecani	Banja Luka	Thermo-mineral water	I	n/a	0,1	outflow	16
13	Perin Grad	Sekovici	Thermal water	I	n/a	2	outflow	28

Table 6. Data on existing geothermal sites according to „Geozavod“(Geo Office) Zvornik, Republic of Srpska

7. Conclusion

Nowadays energy is a source of wealth and a precondition for people's lives. Possession of energy resources is a source of cooperation and integration. Disposing of energy must be in accordance with the policy of sustainable development through rational planning of spending. In Europe in 2009 more than 60% of newly installed power plants were constructed in conection with renewable sources. Further investment in renewable energy provides economic growth as the employment of a large number of workers. The assessment is that the European market by providing investment of 300 billion euros employed about 3.5 million people.

In terms of developing non-traditional forms of energy production Republic of Srpska has not gone away, but at the present time there is a will to establish a legislative framework that would allow rational management of energy and affirmation of renewable energy sources. This year The Republic of Srpska Government has adopted the Regulation on production and consumption of energy from renewable sources and cogeneration. This act defines the incentives for energy production from renewable sources.

„Environment protection Fund of Republic of Srpska“ as an institution that was established to ensure protection of natural values of the environment, supports the rational management of energy production and consumption and affirmation of renewable sources. The Fund will support future projects in its implementation taking into account the fact that until 2020 Republic of Srpska has to provide 20% energy savings especially in transport, building and manufacturing processes. Rational use of energy and increase of energy efficiency in buildings and transport reduces the amount of CO_2. That make Republic of Srpska one of the countries that consistently comply with signed conventions and take into account all necessary steps that contribute preservation of enviroment.

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“Cost effective solutions for energy demand in buildings”

Prof. Y. TRIPANAGNOSTOPOULOS, University of Patras, Greece

-full paper not submitted-

“INRES: Cooperation of European Insular Regions for maximizing benefits from RES”

Mr. A. SAITAKIS, Foundation for Research & Technology Hellas, Greece

-full paper not submitted-

“Cooperative education – A successful strategy to overcome obstacles for the use of Renewable Energy Technologies in industry”

Mr. Johannes HAAS, FH JOANNEUM University of Applied Sciences, Austria

-full paper not submitted-

Development and assessment of policy-mix scenarios for RES-E penetration in Bulgaria, Greece and Romania

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Abstract

According to the National Renewable Energy Action Plans, published and notified to the European Commission in June 2010, Greece, Bulgaria and Romania target to 16%, 18% and 24% energy from Renewable Energy Sources (RES), respectively, in gross final consumption of energy up to year 2020. To achieve these targets the corresponding percentages in electricity production in 2020 must be 25%, 36% and 47%, respectively. This paper focuses on the identification of the most suitable policy mix separately for each country in achieving or approaching their aforementioned commitments as EU Member States. The selection of these specific countries is based on the following facts: (i) their electricity sector depends mainly on fossil fuels; and (ii) all of them attempt to attract foreign investments for the exploitation of considerable RES potentials so as to accomplish their 2020 targets. Additionally, these 3 countries are BSEC and EU Member States and parties of the Energy Community Treaty and the Kyoto Protocol.

Two research tools are used for developing 2 policy-mix scenarios and assessing them, the Green-X model and the AMS multi-criteria evaluation method, respectively. The Business As Usual (BAU) scenario reflects the current framework for penetration of electricity from RES (RES-E) and the available funding tools; the improved BAU (ImBAU) scenario adopts additional incentives for boosting the most promising RES types taking into consideration national financial parameters. The assessment results show that no country will achieve its target for RES-E penetration unless there are changes in their policy framework. The last session of the paper discusses possible proposals for improving the examined policy mixes.

1. Introduction

The Directive 2009/28/EC, regarding the promotion of energy from Renewable Energy Sources (RES) sets mandatory EU Member State targets for their overall share in gross final consumption of energy and transport by year 2020. These targets are consistent with the 20% and the 10% share of energy from RES in EU's gross final consumption of energy and the transport sector, respectively, by 2020. Furthermore, the Directive establishes a common framework for promoting energy from RES regarding statistical transfers between Member States and third countries, guarantee of origin, administrative procedures, information, training and access to the electricity grid from RES (Kambezidis et al., 2011).

Greece, Bulgaria and Romania aim at using 16%, 18% and 24% energy from RES, respectively, in gross final consumption of energy (transport sector included) up to year 2020. The corresponding percentages for RES-E production in 2020 must be 25%, 36% and 47% of electricity production (RES2020, 2011). The specific countries were selected under the following criteria:

- all three countries are Black Sea Economic Cooperation (BSEC) and EU Member States and parties of the Energy Community Treaty and the Kyoto Protocol;
- their electricity sector depends mainly on fossil fuels (KEPA, 2009);
- all attempt to attract foreign investments for the exploitation of considerable RES potentials in order to accomplish their 2020 targets;
- all can benefit from the Solidarity mechanism that concerns the increased amount of emission permits to auction generating substantial revenues that could be used for promoting RES (Council of the European Union, 2009);
- Bulgaria and Romania are among the most recent EU Member States with important RES potential; simultaneously they have gained access to the internal energy market while being subject to EU policies and regulations (Srebotnjak and Hardi, 2011);
- in 2005 Bulgaria, Greece and Romania had 9.4%, 6.9% and 17.8% RES share in energy (transport included); in 2020 the corresponding targets are 16%, 18% and 24%, meaning that Bulgaria and Romania have lower gaps to cover compared to Greece (DG Energy, 2011).

This paper focuses on the identification of the most suitable policy mix for each one of the selected countries that will constitute the approach basis for the achievement of the aforementioned targets. For the determination of this policy mix two research tools are used, the Green-X simulation model and the multi-criteria evaluation method AMS. Brief presentation of the two tools and the whole approach are given in Section 3, after presenting the policy framework for the countries in Section 2. The scenarios and their evaluation are discussed in Section 4. Section 5 includes the discussion of the outcomes.

2. Policy framework

2.1. Legislative framework

Bulgaria

A new feed-in tariff (FIT) system was introduced in June 2007 according to the "*Renewable and Alternative Energy Sources and Biofuels Act*" promulgated in State Gazette No. 49/19.06.2007 (Center for the study of Democracy, 2011; Patlitzianas and Karagounis, 2011; EREC 2009; Coenraads et al., 2008). This law also addressed the use and production of alternative fuels (e.g., biofuels) in transportation, as required by EU directives but not yet introduced in Bulgaria (Center for the study of Democracy, 2011).

The new "*Energy from Renewable Sources Act*" (State Gazette No. 35/3.05.2011-Decree 92 of May 2, 2011 of the President of the Republic of Bulgaria) integrates Directive 2009/28/EC into the national legislation and sets the legislative framework in accordance with the National Renewable Energy Action Plan (NREAP), the main developed instrument for ensuring achievement of Bulgarian RES targets (Bulgarian NREAP, 2010). The law resolved issues pertained to improved regulation for access to the grid and shifting out excessive demand for RES development; increased the financial burden on RES investors/producers by introducing pre-connection fees (Center for the study of Democracy, 2011).

Bulgaria overshot its 2010 target of reaching 11% of total final electricity consumption provided by RES by 4% according to preliminary data from the Ministry of Economy, Energy and Tourism (Center for the study of Democracy, 2011). The 2010 target was set on 5.75% share of biofuels (Coenraads et al., 2008).

Greece

The new Law 3851/2010 on "*Accelerating the development of Renewable Energy Sources to deal with Climate Change and other regulations in topics under the authority of Ministry of*

Environment, Energy and Climate Change" (Governmental Gazette A 85/4.6.2010) integrates Directive 2009/28/EC into the national legislation and sets the aforementioned national targets until 2020. It also includes issues regarding the simplification of licensing procedures for RES-E units and the establishment of a RES agency under the Ministry of Environment, Energy & Climate Change (MEECC) for advising RES-E investors. In addition, the Ministerial Decision on "*Physical planning and allocation of RES"* was issued (Governmental Gazette B 2464/3-12-08).

Romania

The legal act 199/2000 launched the support for promotion of RES. It established also the "National Regulatory Authority for Energy" for supporting the liberalized electricity market (Patlitzianas and Karagounis, 2011). A quota system with tradable green certificates (TGC) for new RES electricity was introduced with Decision 1892/2004 of the Romanian Government (Dusonchet and Telaretti, 2010). TGCs are issued for electricity production from wind, solar, biomass or hydro plans, with less than 10-MW capacity (Law no. 220/2008 and Law no. 139/2010 (Table 1)) (Invest East, 2010; Dusonchet and Telaretti, 2010; Patlitzianas and Karagounis, 2011). In addition, the European legislation of Biofuels was transposed into the national legislation in 2005, while the government designed to upgrade its hydropower plants – HPP (Patlitzianas and Karagounis, 2011). The development of RES is also based on the Electricity Law, which established the framework for promoting RES-E in 2007 (Dusonchet and Telaretti, 2010).

Table 1: Annual obligation share for RES technologies (Source: Romanian NREAP, 2011; Dusonchet and Telaretti, 2010)

RES technology	Purchase obligation per year (%)		Annual obligation share according to Law 220/2008	Annual obligation share according to Law 139/2010 amending and supplementing Law 220/2008
All	2008		5.26	
	2009		6.28	
	2010	8.7	8.30	8.3
	2011	10.4	8.30	10.0
	2012	10.9	8.30	12.0
	2013	11.4	9.00	14.0
	2014	11.9	10.00	15.0
	2015	12.4	10.80	16.0
	2016	11.9	12.00	17.0
	2017	12.4	13.20	18.0
	2018	11.9	14.40	19.0
	2019	12.4	15.60	19.5
	2020		16.80	20.0

2.2. Prices and subsidies

Bulgaria

FIT rates are set by the State Energy and Water Regulatory Commission (SEWRC) on 31 March every year; the contract duration is set to 25 years for photovoltaic (PV) and geothermal units and to 15 years for the rest RES types (Bulgarian NREAP, 2010).

Due to the European Cohesion policy Bulgaria has been allocated 6853 million € in total according to the National Strategic Reference Frameworks for the period 2007-2013 (EU, 2008). More specifically the Operational Programmes for the *Development of the Competitiveness of the Bulgarian Economy* and *Regional development* will absorb around 66.5 million € (representing 2.1% of the total *European Regional Development Fund* budget) for RES projects deployment (Bulgarian NSRF, 2008). Additionally the *Energy Efficiency Fund* of the *European Investment Bank* finances investments in energy efficiency and RES technologies under conditions (Bulgarian NREAP, 2010). The investment subsidy is between 15% and 20% on average for RES projects, while for small HPPs this percentage may climb up to 70% (Bulgarian NREAP, 2010).

Greece

The energy produced by RES is purchased by the Hellenic Transmission System Operator (HTSO) at favorable prices. The RES producer has a contract for selling its total RES-E at those tariff prices to HTSO for 20 years with an exception of the CSP plants for 25 years.

According to Law 3908/2011 subsidy percentages differ depending on the size of the enterprise and the geographical zone (Governmental Gazette A 8/1.2.2011). The 30% investment subsidy constitutes the average. The Greek economy has restricted capabilities due to the economic recession and, therefore, the National Strategic Reference Framework 2007-2013 constitutes the main funding mechanism for RES investments in Greece too (Greek NSFR, 2007). The goal of the Greek government is to increase the absorption rates (Pagoulatos, 2010). Greece has been allocated 20420 M€ in total while the energy sector will absorb 3.9% of the *European Regional Development Fund* budget (EU, 2008).

Romania

The following RES types participate in the Quota Scheme: hydro with installed capacity less or equal to 10MW, wind, solar, geothermal, biomass, biogas, bioliquids, solid and liquid waste. The Romanian Energy Regulatory Authority (ANRE) defined in Order 44/2007 a regulated price of approximately 32€/MWh for which RES-E can be sold to suppliers. Additionally, the allocation of green certificates (GC) depends on the type of RES technology and the age of installations. For example, until 2017 wind-energy producers will receive 2 GCs per MWh delivered into the network. Starting in 2018 this number will be reduced to one. Biomass-energy producers will receive 3 GCs and solar-energy ones 6 GCs per MWh etc (Romanian NREAP, 2010). The quota support is available for 15 years to all new facilities to benefit (i.e. commissioned between 1 January 2004 and 31 December 2014) (Mihailescu, 2009).

Romania's main funding mechanism for RES-E promotion from structural funds is carried out under the Sectoral Operational Programme *Increase of Economic Competitiveness* – Axis 4 *Increasing Energy Efficiency and Security of Supply, in the context of Combating Climate Change* (Romanian NSRF, 2006). *Increase of Economic Competitiveness* will absorb 13.3% of the total allocated amount of 19668 M€ for Romania (EU, 2008). Finally subsidies of investments are foreseen at rates of 70%, 60% and 50% for small/micro, medium and large enterprises, respectively.

2.3. Electricity production

The distribution of the various shares in gross electricity production of the 3 countries is shown in Figures 1, 2 and 3. All 3 countries have a strong dependence on coal for their electricity generation. For all of them the oil share in electricity generation is declining for the specific time period. For Greece this is due to the increased use of natural gas.

The nuclear share in electricity generation is considerable for Bulgaria and Romania since it amounts to 35.06% and 18.60%, respectively. It is worth mentioning that for Romania this share is increasing considerably through the time period 2006-2009.

The small variations in RES-E production are due to the fact that RES-E mainly depend on hydroelectricity for all 3 countries (Table 2). The biggest share of RES-E in Bulgaria and Romania comes from hydroelectric power plants. Due to the full exploitation of hydro power in both countries, the pertinent authorities are considering the reduction of large HPP systems. Biomass is exhibiting an increase in Bulgaria, while in Romania it just started recording percentages during 2009.

Bulgaria's installed capacity in 2010 was 488 MW for wind power, almost 25 MW for photovoltaics and 3,108 MW for HPPs (SEWRC, 2010). Greece's total installed capacity in 2010 was 1,298 MW for wind power, 3,118.5 MW for hydropower, 191.1 MW for PV and 41.05 MW for biogas-biomass (HTSO, 2011). Romania's total installed capacity in 2009 was 6,715 MW for hydro power, 13.1 MW for wind - with 10.6 MW of these referring to "second-hand" turbines - 8 MW for biomass and 0.009 MW for PV (ANRE, 2009; EBRD, 2009; ENREG ENERGIA REGENERABILA, 2009). Bulgaria's PV share in 2009 was 0.001% corresponding to a production of 20 MWh.

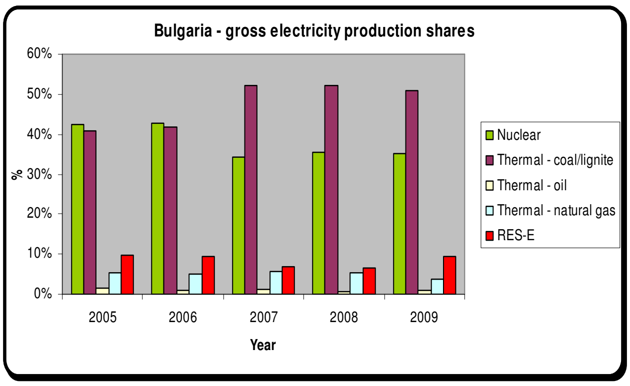

Figure 1: Bulgaria – gross electricity production shares 2005-2009.

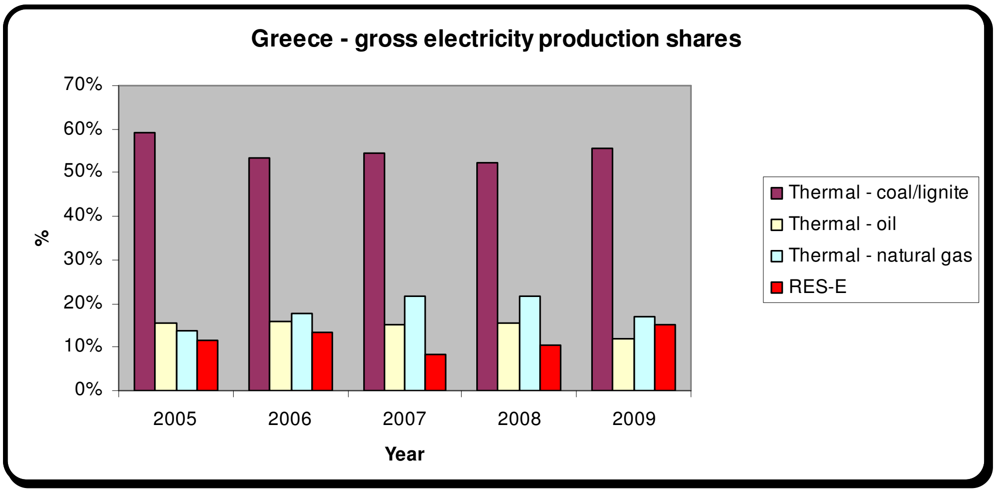

Figure 2: Greece - gross electricity production shares 2005-2009.

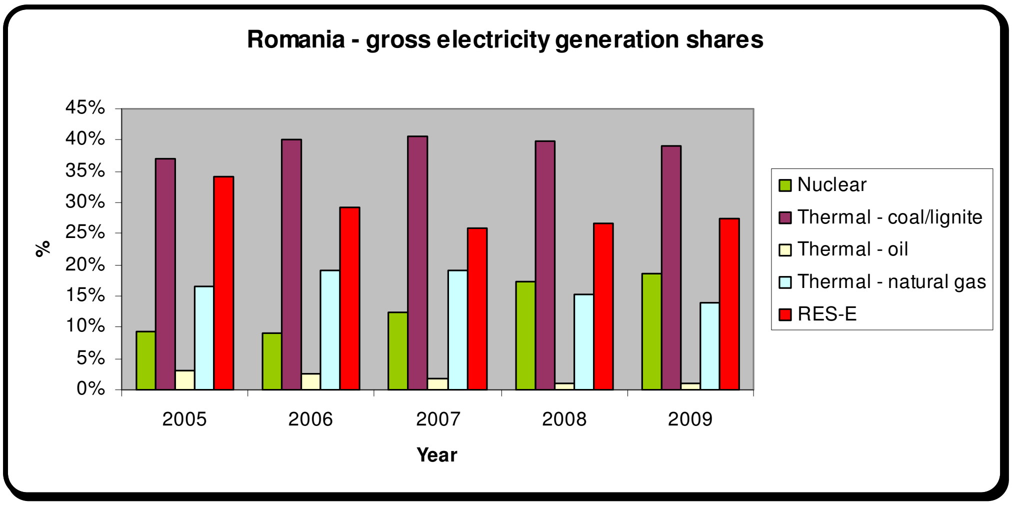

Figure 3: Romania - gross electricityproduction shares 2005-2009.

Country	Distribution per year					
	RES type	**2005**	**2006**	**2007**	**2008**	**2009**
BULGARIA	*Hydro*	99.90%	99.53%	98.39%	95.78%	90.57%
	Wind	0.10%	0.47%	1.61%	4.22%	8.93%
	PV	-	-	-	0.00%	-
	Biomass-biogas	-	-	-	-	0.50%
GREECE	*Hydro*	80.16%	77.90%	63.05%	62.99%	66.91%
	Wind	18.09%	21.03%	33.94%	34.04%	30.37%
	PV	0.01%	0.02%	0.03%	0.08%	0.55%
	Biomass-biogas	1.74%	1.05%	2.99%	2.90%	2.17%
ROMANIA	*Hydro*	99.97%	99.97%	99.76%	99.83%	99.68%
	Wind	-	0.01%	0.02%	0.03%	0.13%
	PV	-	-	-	-	-
	Biomass-biogas	0.03%	0.02%	0.22%	0.14%	0.19%

Table 2: Distribution of RES technologies in electricity production (EEA, 2009b; Eurostat 2011c; 2011d, 2010).

3. Approach

3.1. The Green-X simulation model

The *Green-X Simulation Model - Deriving optimal promotion strategies for increasing the share of RES-E in a dynamic European* *electricity market* - was the core objective of the project *Futures-e* (EEG, 2006). The Green-X model allows for the economic assessment of different policy instruments, oriented to an increase of the RES-E penetration, based on the minimisation of generation costs and reduction in producer profits so as to avoid the transfer of costs to the consumers and by taking into account the relative EU legislation (Huber et al., 2004a). The results can either be country-specific or technology-specific at an annual basis or as time series for the whole simulation period. Finally Green-X includes the following RES technologies: biogas, landfill gas, sewage gas, biomass (agricultural products/residues, forestry products/residues, biogenic fraction of waste), geothermal, hydro (<=10 MW, >10 MW), wind (onshore, offshore), solar (PV, solar thermal) and tidal; and Combined Heat and Power (CHP technologies: biogas, biomass (5 cases), landfill gas and sewage. Common or single strategies can be adopted for the divided technologies.

3.2. The AMS multi-criteria evaluation method

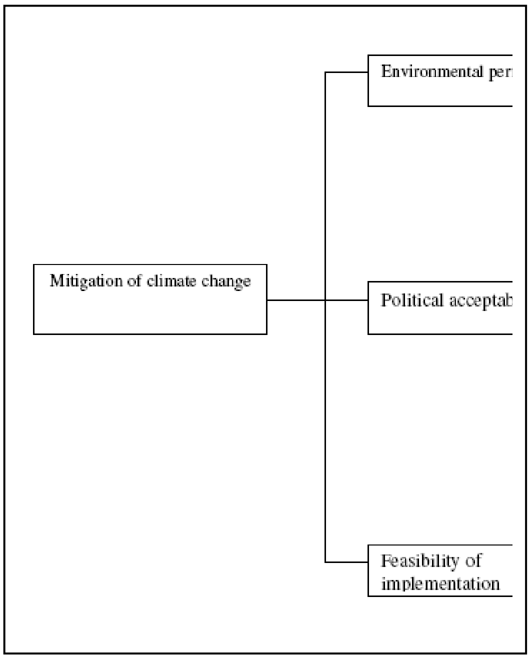

Figure 4: The AMS criteria-tree (Konidari and Mavrakis 2007; Konidari and Mavrakis, 2006).

AMS (an acronym for the combination of three standard multi-criteria methods: Analytical Hierarchy Process (AHP), Multi-Attribute Utility Theory (MAUT) and Simple Multi-Attribute Ranking Technique (SMART)) is an evaluation method developed especially for climate-change policy needs. The evaluation is performed against three main criteria, environmental performance, political acceptability and feasibility of implementation (Figure 4). MAUT procedure is used for assigning grades when the performance of the scenario is expressed in numerical data form and SMART when there are no numerical data, but assessments. Assessments are converted to grades of the MAUT scale (Kambezidis et al., 2011; Konidari and Mavrakis 2007; Konidari and Mavrakis, 2006).

4. The scenarios and their evaluation

4.1.1. Common settings

The simulation covers the period 2006-2020. Two basic choices constitute the first steps, when working with Green-X. The first is named *Country-specific scenario option* and concerns 3 different possible options regarding the price development for fossil fuels (low/moderate/high price choices). A high price was selected for all scenarios following the price projections of the World Energy, Technology and Climate Policy Outlook (WETO) (Huber, 2004b). This selection includes a constraint of 20€/t-CO_2 for the tradable emission allowance (Faber, 2007). The second is *Technology-specific scenario option* and concerns the removal capability of the non-economic barriers. Removing non-economic (social) barriers was selected for this option, despite the controversial attitude of society towards the deployment of various RES projects in Bulgaria and Greece and taking into consideration that removal of social barriers constitutes an obligation for all EU Member States, as declared in their NREAPs (Kaldelis, 2009; Todorov, 2011). Large-scale HPPs were excluded, since they are not included in the policy schemes of the countries.

4.1.2. 1st scenario: Business as usual (BAU)

BAU scenario reflects the implementation of the current legislative framework and the available funding mechanisms. It takes also into consideration – regarding technologies in the *Supply side* option of Green-X – the RES and CHP technologies that are included in each of the 3 NREAPs. More specifically tidal technology for all countries, geothermal, solar thermal and wind offshore technologies for Bulgaria and Romania are excluded. All 4 CHP technologies - available in Green-X - are included for Greece and Romania, but only biogas and biomass CHP for Bulgaria, since no tariffs are available for the others. FITs and annual obligatory shares of GCs that were valid for the period 2006-2010 are applied for Bulgaria, Greece and Romania.

<u>Bulgaria</u>

The scenario settings reflect the situation as defined in *Renewable and Alternative Energy Sources and Biofuels Acts*. Several sources were used for obtaining time series for the period 2008-2012 able to expose tendencies in various FITs (RES2020, 2011; SEWRC, 2011; Center for the Study of Democracy, 2011; Bulgarian NREAP, 2010). The most recently FITs, obtained from the SEWCR website and in force since 20/06/2011, were used as the 2012 FITs (SEWRC, 2011). For the cases at which the average value of the annual FIT changes had the same sign with the year-to-year changes, this average was applied for the 2013-2020 period (Table 3). It is noticeable that the RES type *Agricultural products* of Green-X contains both the energy-crops category and the category for biomass from vegetable and animal substances. The 4.77% in *Forestry residues* RES type is also not representative given that the increase by 21.2% in 2011 is followed by a decrease of 3.14% in 2012 (based on the most recent FITs by SEWCR). The 18.85% average does not fall into the previous case, but the corresponding time series include an outlier. More specifically, the FIT price for the *Agricultural products* RES type increased in 2011 by 59.94% compared to 2010. The effort to promote the various biomass RES types is clear. Biomass has a zero share in RES-E in 2010, while the target for 2020 is set to 11.4% share of total RES-E.

The 2008-2012 time series for *Agricultural products* and *Forestry residues* was correlated applying the SPSS linear regression method with time being the independent variable. Finally the FIT prices for all RES & CHP types are formulated as shown in Figure 5. Biomass FITs concern the average of the 4 types. For the CHP-biomass case the average annual change of the biomass RES types is applied.

The contract duration is 15 years for all RES types except of that for PV, which is set to 25 years. The investment subsidy was selected at 20% for all RES and CHP technologies, except of small HPPs (installed capacity <= 10 MW), for which the subsidy is set to 70%).

RES types	Average of annual FIT changes
Biogas (CHP incl.)	-1.59%
Biomass-Forest products	0.32%
Biomass-Forestry residues	4.77%
Biomass-Agricultural products	18.85%
Biomass-Agricultural residues	4.95%
Small scale hydro <10MW	3.79%
Landfill gas	-1.59%
Sewage gas	0.36%
Photovoltaic	-6.02%
Wind onshore (<=2250 hours)	0.68%
Wind onshore (>2250 hours)	0.77%

Table 3: Average of Bulgarian annual FIT changes for RES types - as classified in Green-X - for the period 2008-2012.

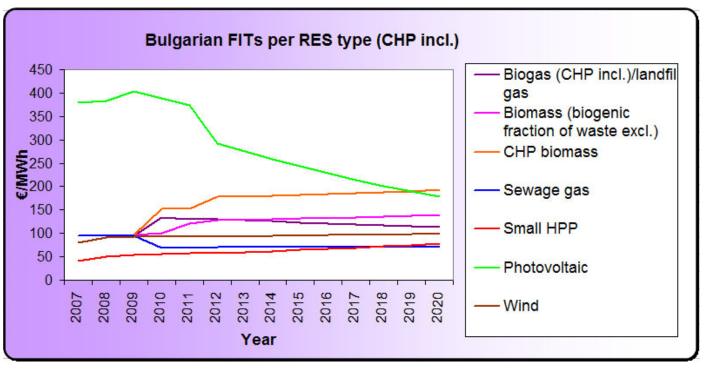

Figure 5: Bulgarian FITs for various RES/CHP technologies during 2007-2020.

Greece

Beginning from 2010, the BAU scenario reflects the situation due to the implementation of Law 3851/2010. Provisions of this latest law promote mostly the biomass/biogases technologies (Figure 6). Starting from year 2011 FITs follow an annual increase of 1.53%, which is a typical increase, assumed in similar developed scenarios (Capros et al., 1999). Furthermore according to Eurostat estimations on GDP growth rate for 2011-2012 (Eurostat, GDP growth rate, 2011a) and the estimations until 2030 as included in the NREAP, the GDP growth rate for the next 2 decades has an average rate of 1.53% (recession is assumed for both 2011 and 2012).

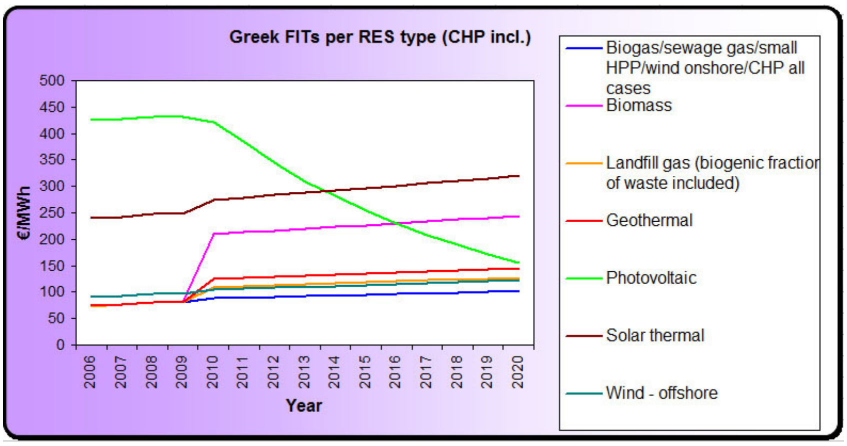

Figure 6: Greek FITs for various RES/CHP technologies during the period 2006-2020.

The FIT prices for the PV technology are used for the time interval 2009-2014 as they are mentioned in Law 3734/2009 (Governmental Gazette A 8/28-01-2009), which still remains in force. PVs are the only RES type for which FITs decline, starting from year 2010. More specifically for the time period 2015-2020, these tariffs are decreasing annually by 9.5%. The contract duration is 20 years for all RES and CHP types except of solar thermal that is set at 25 years.

The investment subsidy was selected at 30% for all RES and CHP technologies - except of solar energy (PV and CSP) given that it is excluded from the latest Development Law - as the average value of the 3 types of subsidies that are applied per geographical and GDP growth rate according to the latest Development Law (Governmental Gazette A 8/1.2.2011). The 4 CHP tariffs are the same with those of biogas.

Romania

All already mentioned RES and CHP technologies are included in the quota scheme. The percentages of annual obligatory shares of TGCs that are applied are those presented in Table 1. Regarding the penalty price per non-purchased certificate, two prices are known: 70€ for year 2008 and 110€ for 2011. These two prices define the following linear equation: $y = 13.33x – 26{,}703.43$ (y is the penalty price, x is the year). This equation was applied for estimating intermediate missing prices and prices until 2020.

The current floor price per certificate is 27€ and, according to NREAP, it is adjusted annually based on the average EU27 inflation rate (Romanian NREAP, 2010). In order to estimate the average inflation rate Eurostat time series from 1998 to 2010 for GDP growth rate and average inflation rate were correlated applying the SPSS curve estimation method. The inverse linear equation was used for defining the relationship between GDP and inflation for the examined time interval: $y = 0.05246/x + 1.92256$ (y is the average inflation rate; x is the GDP growth rate). This equation is applied for the estimation of the inflation rate until 2020

and finally the floor price of 27€ has been updated with the corresponding percentages.
The international trade is set to be possible from 2011 and the certificate validation is set to 15 years.
The investment subsidy is set to 60% for photovoltaics and wind farms. In 2010 photovoltaics installed capacity ascends at 1.94 MW (on- and off-grid) and wind installed capacity at 462 MW, while the country targets to 260 and 4000 MW in 2020, respectively, to accomplish its obligations (Wikipedia, 2011; PV-NMS-NET, 2010). For small HPPs 70% subsidy is applied since the specific technology is well known in Romania and the investment cost is relatively low compared with the other technologies (de Jager David et al., 2011). Finally for biomass and biogases (CHP included) the 50% subsidy is chosen in order to keep a balance between two facts: Romania has a large, but still unexploited potential of biomass and potential investors face high operation and maintenance costs due to the need for collection/conversion, transformation and storage of the "fuel" (ENERO, 2009; de Jager David et al., 2011).

4.1.3. 2nd scenario: Improved business as usual (ImBAU)

The Improved BAU scenario adopts available additional incentives compared to the current legislative framework for boosting the most promising for each country RES types. Regarding technologies in the *Supply side* option of Green-X, the offshore wind farms and the CHP technologies of landfill/sewage gases are added for Bulgaria compared to the BAU scenario.

Two main - additional to the policy scheme – instruments of Green-X are applied where appropriate. These are the *Tax incentive capacity based* and the *Tax incentive generation based*. The first instrument is similar to investment subsidy and affects only new installations. It is given as a price per installed kW. The second consists of a long-term incentive and can increase the possibility that the plants remain in operation over total expected lifetime. It is given as a price per produced MWh. For the application of the *Tax intensive capacity based* instrument the average investment costs per technology that are included in the final report of ECOFYS 2011 - entitled *Financing Renewable Energy in the European Energy Market* – were taken into consideration (de Jager David et al., 2011).

All changes are applied from 2011.

Bulgaria

The applied FIT price for the offshore wind farms is the same with the corresponding Greek FITs. This was selected due to the fact that the FITs for onshore wind farms of both countries are very close and also that these FITs are consistent with the lower FITs for offshore wind farms in European countries (KPMG, 2010). The investment subsidy of all wind farms is set to 30%. The investment subsidy of PV was also increased to 40% and the *Tax incentive capacity based* instrument is applied meaning that 30% of the investment cost per kW is tax absolved from 2011 to 2020.

In any case biomass (production of biogas included) remains a significant RES in Bulgaria considered unused at 76% (Ivanov and Rumen, 2009; Dimitrova and Cheriyska, 2009; Dimitrova et al., 2008). The investment subsidy for the 4 types of biomass and biogas is set to 50%, instead of 20% in BAU scenario. Finally FITs of the 2 added technologies of CHP-landfill gas and CHP-sewage gas start with the same FIT of landfill and sewage gas in 2011 and follow the same change (decrease for 1st case and increase for the 2nd one, see Table 3).

Greece

PVs are included in the investment subsidy regime with 40%. PVs could cover 25-30% of the national needs since Greece has one of the highest values of solar radiation in EU (Tsoutsos et al., 2003; Thomopoulos, 2006). The corresponding estimation for PV – needed to meet the target in NREAP – is set at 2.2 GW, which lies far from the already installed capacity of 280.13 MW in the mainland (HTSO, 2011). Finally the *Tax incentive generation based* instrument is applied for PVs, more specifically tax absolving the 1/3 of the annual FIT price until 2020.

The *Tax intensive capacity based* instrument is applied for the following RES and CHP plants at the referred percentage (per kW) from 2011 to 2020: landfill/sewage gases (CHP included) and geothermal at 50%, PV at 30%. The lower percentage for PVs is selected due to the fact that the investment cost of PV steadily decreases, so the year-by-year the percentage will become bigger. The biogases case should be promoted not only because of the targeted 210 MW for 2020 but also due to the fact that Greece faces high penalties for non-compliance with the EU Directive 1999/31/EC regarding waste management (European Commission, 2008; IEA, 2010).

Greece has also a high unexploited biomass potential. The average annual quantity of agricultural and forestry residues are estimated to equal to 3-4 millions oil tones (CRES, 2006). This quantity corresponds to 30-40% of annual oil consumption in the country. The investment subsidy of CHP with biomass is increased to 50%.

Wind power of 1,039 MW was installed in the mainland at the end of 2010 (1,298[7] MW with non-interconnected islands included), while NREAP refers to 7.5 GW of wind capacity for the whole country in 2020 in order to accomplish the target. According to the latest update of HTSO 2,900 MW in the mainland have already connection offers (HTSO, 2009). The wind potential of the country is estimated at 11-14 GW (PPC, 2008; National Bank of Greece, 2008). The *Tax incentive generation based* instrument is applied for wind farms; more specifically tax absolving the 1/2 of the annual FIT price until 2020; in order to guarantee the future operation of the existing wind farms and also keep the investors interest high.

Romania

The percentages of annual obligatory shares of TGCs were set as follows: 16% for 2014, 18% for 2015, 19% for 2016 etc. increasing by 1% every year (23% in 2020). The previous selection is based on the fact that quota systems provide no incentive to investments beyond the target set (SEI, 2004).

As aforementioned, Romania targets to 260 MW of PVs and 4000 MW of wind capacity in 2020. The investment subsidy is already set high (60%) so the mechanism of *Tax incentive capacity based* is added in order to offer the needed boost to these technologies. From 2011 to 2020 50% for wind farms and 30% for PVs of the investment cost per kW is tax absolved. According to the technical report of European Environmental Agency on *Europe's Onshore and Offshore Wind Energy Potential* Romania's estimated wind potential – classified in the categories most likely competitive and competitive – ascends at 57 TWh until 2020 and 470 TWh until 2030 (EEA, 2009a). Romania's solar electricity is estimated to 1.2 TWh (EBRD, 2009).

The *Tax incentive generation based* mechanism is applied for all types of biomass and also for CHP from forestry products and residues. The tax absolving ascends at 50% of the regulated price, which according to the NREAP is set to approximately 32€ per produced MWh. The investment subsidy of all biomass types is decreased (compared to BAU scenario) by 10% and set in 40% while the investment subsidy for CHP from forestry products and residues is increased to 70%. The following facts influenced the aforementioned choices. Romania is covered at 27% by forests and 37% by arable land. According to NREAP biomass is expected to contribute by 9% in total RES-E in 2020. This percentage corresponds to 600 MW of CHP production with biomass.

[7] 1375 MW according to Hellenic Wind Power Association website, www.eletaen.gr

3.2.4. Green-X scenarios results

Bulgaria has the biggest increase of 2.65% in RES-E penetration corresponding to a 17.7% increase for the costs of society due to the extra funding instruments while the corresponding 0.37% increase in RES-E penetration in Greece corresponds to a 151.9% increase in costs for society.

The *Tax incentive capacity based* mechanism burdens the country with unequal long-term retributive benefits. On the other hand the *Tax incentive generation based* mechanism applied for wind farms (and PVs) in Greece and for biomass (some CHP cases included) in Romania does not have long-term effects. In the ImBAU scenario the wind share in total RES-E for Greece in 2020 decreases and the corresponding biomass share increase for Romania is very restricted (see Table5).

Table 4: Green-X's results.

	Bulgaria		Greece		Romania	
Parameter	**BAU**	**ImBAU**	**BAU**	**ImBAU**	**BAU**	**ImBAU**
Share of RES in total electricity generation (%)	20.19	22.84	26.14	26.51	39.42	39.45
Total generation costs due to RES (in M€/year)	448.65	480.67	869.62	904.28	1,001.33	997.14
Total costs for society due to all policy instruments (in M€/year)	275.3	324.11	331.28	834.47	2,752.14	2,838.92

Table 5: RES-E distribution per type per country in 2020.

	Bulgaria		Greece		Romania	
RES type	**BAU**	**ImBAU**	**BAU**	**ImBAU**	**BAU**	**ImBAU**
Biogas, landfill/sewage gas	5.00%	4.75%	4.99%	4.89%	16.35%	16.31%
Biomass	41.87%	43.45%	8.99%	9.46%	70.17%	70.25%
Geothermal	-	-	0.78%	0.76%	-	-
Small HPP	21.19%	20.15%	3.66%	3.59%	11.13%	11.10%
Photovoltaic	0.33%	0.88%	0.43%	1.67%	0.62%	0.62%
Solar thermal	-	-	4.30%	4.22%	-	-
Wind onshore	31.61%	30.07%	73.64%	72.26%	1.73%	1.72%
Wind offshore	-	0.70%	3.21%	3.15%	-	-

Changes worth to be noticed between BAU and ImBAU scenarios are observed in PV shares for Bulgaria (almost 3 times more) and Greece (almost 4 times more) and in biomass shares. Changes in Romania are very small, only biomass share moves slightly upwards (Table 5). Remarkable notice is that for the PV share increase in Greece almost all available funding instruments needed to be used (subsidies, tax incentives).

In Romania the quota system with TGCs restricts the influence of possible extra interventions perceiving almost the same shares of the various RES technologies. Regarding the FIT scheme applied in Bulgaria and Greece the extra funding instruments do not increase significantly the RES-E share but reallocate the distribution among the various RES types.

4.2. Application of AMS

4.2.1. *1st criterion: Environmental performance*

The 2 scenarios for each of the 3 countries are evaluated against the 2 sub-criteria. Their score in "*Direct contribution to reduction of GHG emission emissions*" is calculated with the MAUT procedure. A linear function y=ax+b is determined using the respective results of Green-X. The scenario with the highest share is assigned with grade 100 and the scenario with the lowest share with 0. Table 6 shows these grades after multiplying them with the respective weight coefficient for this sub-criterion.

Indirect environmental effects are expected, but they are not determined in quantities nor is there a respective Green-X model outcome. The increase of RES-E penetration is expected to eliminate pollution associated with electricity services (Resch et al., 2005). Therefore, the same grades with the previous sub-criterion are assigned considering these effects proportional to their direct contribution in reducing GHG emissions.

4.2.2. *2nd criterion: Political acceptability*

Every scenario is evaluated against each of the 5 sub-criteria.

For *cost effectiveness*, the MAUT procedure is used again for the estimations of the Green-X model regarding the total generation costs due to RES. The scenario with the lowest costs is the most cost effective one and receives grade 100. Final grades for the sub-criterion are presented in Table 6.

For *dynamic cost efficiency*, there are no available data from the Green-X model so the SMART procedure is used. Each scenario is assigned a grade from 0 to 10 and these grades are converted to the grades of the MAUT scale (Kambezidis et al., 2011; Konidari and Mavrakis, 2006). The justification for the assigned grades for each country and scenario are quoted.

Bulgaria

Under the BAU scenario research projects and pioneer technologies are not supported enough, although - according to the NREAP – there is an aggregate technical potential for generation of energy from RES of approximately 4500 ktoe/year. Its distribution among the various RES types is uneven, with the largest share held by biomass (~34%) and hydro-power (29%) (Bulgarian Government, 2011). Technical and economic potential of large-scale hydro power is already fully exploited (Ganev, 2009; EWEA, 2009).

Biomass is considered a main potential RES type with opportunities since 60% of land consists of agricultural land and about 30%-35% is forest cover (Bulgarian Government, 2011; Ganev, 2009; EWEA, 2009). On the other hand, it is fully utilised primarily for heating, mainly as firewood, in households and public buildings representing 4% of the 2005 Total Primary Energy Sources (TPES), but also for biogas and liquid fuels (Bulgarian Government, 2011; Ganev, 2009). Applications in electricity generation are insignificantly limited only to several CHP installations that utilise the waste by-products in the pulp and paper industry (Ganev, 2009). Despite the existence of a theoretically significant potential for wood utilization because of the aforementioned 35% there is a limitation by the possibility of concurrent uses of timber and nature conservation objectives (Ganev, 2009). 11% of the total consumption of bioenergy is generated from industrial waste (Srebotnjak and Hardi, 2011). Contribution from combustible renewables and waste to primary supply from renewables is 72.6% (Srebotnjak and Hardi, 2011). Under the ImBAU scenario this type of RES is supported.

The contribution of wind energy to the electricity fuel mix in Bulgaria is very limited (Ganev, 2009).

From zero PV capacity in 2005 Bulgaria reached 1 MW in 2008 and 6 MW in 2009 (Ragwitz et al., 2010). Solar potential exists in East and South Bulgaria, and 200 MW could be generated from geothermal sources (EWEA, 2009). Research pilot programmes of small-scale applications were implemented in household sector (Demonstration PV project 10 kW in Sofia) (Patlitzianas and Karagounis, 2011).

The assigned grades are 4 for both scenarios (BAU and ImBAU).

Greece

Wind and PV technologies were considered as "mature" for the Hellenic national framework, while developments in these technologies follow with a relative delay those occurring aboard. Technological barriers such as capability of the network in absorbing RES-E and covering peak demands restrict the performance of all scenarios under this criterion (Oikonomou et al., 2009).

The assigned grades are 3 and 3 for both scenarios.

Romania

Research on new RES technologies is really limited, although wind, biomass and hydro are most promising types of RES (Patlitzianas and Karagounis, 2011; Mihailescu, 2009). Particularly for wind, Romania is considered to have the highest wind energy potential in the South Eastern region of Europe, with a predicted total installed capacity of 14,000 MWh, equivalent to total annual production of 23TWh (Nitoiu, 2011; Invest East 2010; Mihailescu, 2009).

A pilot research programme was applied supporting the use of PV systems to agricultural communities. Solar project development was meaningful during the communism period, but due to poor quality equipment and inadequate installations, a deep dissatisfaction for solar projects resulted affecting this sub-criterion (Nitoiu, 2011). The use of solar energy and biomass in Romania is still mostly in the inception phase with a few experimental projects, which were set up across the country (Nitoiu 2011).

The grades are 3 for both scenarios.

For *competitiveness* there are no available results from Green-X, therefore the SMART procedure is followed and grades are assigned based on the following justifications.

Bulgaria

The investors' interest is not significant since energy from RES is still considerably more expensive compared to energy produced from conventional sources and by traditional technologies – coal, natural gas, nuclear fuel (Bulgarian Government, 2011).

With the 2006 Energy Act, the FITs for some RES stimulated private investors. Interest in large power storage HPPs is limited since they are used for balancing the national electricity network and are operated only in emergency cases (Gaven, 2009). The state controls fully the largest HPPs, including 14 power generators holding around 86% of the total hydropower generation in the country (Ganev, 2009). On the contrary, due to unbundling and privatisation procedures in the electricity sector, private companies own all small hydropower facilities (Ganev, 2009).

Another limitation for competitiveness is the grid connection. SEWRC estimated that connecting renewable energy in the next 4-5 years, will require 100-120 million € (Lefkowitz 2009).The grid connection costs should be equitably shared between distributors operating in renewable energy rich and renewable energy poor regions on the basis of final customers served (Lefkowitz, 2009).

Under the ImBAU scenario competitiveness is supported more compared to the BAU scenario. The assigned grades are 3 and 4.

<u>Greece</u>

The Hellenic market is not large yet. The framework under the BAU scenario was considered as favourable for RES investments, but mainly for wind and PV technologies, placing Greece as the 10th most attractive country in 2007 for such investments (with score 57 out of 100; National Bank of Greece, 2008; Ernst and Young, 2008). By the end of 2008 there was an estimation that approximately 172 projects for RES-E of 665 MW power in total worth of 735 M€ were implemented with financial resources from the 3rd EU Framework Support of EU (MD, 2009). The BAU scenario created a new situation by favoring RES technologies with low investment interest and terminating the financial support towards photovoltaics and solar thermal. The ImBAU scenario favours conservatively wind and PV for which as already mentioned there is a considerable investment interest and high potentials of both sources in the country.

The assigned grades are 3 and 4.

<u>Romania</u>

2008 was considered to be the year of boosting wind energy for Romania because of the acquisition by the Czech energy company, CEZ, of a wind project located in Dobrogea with total capacity of 600 MW. The investment was estimated at 1.1 billion €. The list of investors in the Romanian wind sector includes Enel (Italy), Energias de Portugal, CEZ (Czech Republic), Iberdrola (Spain), and RWE (Germany) (Nitoiu, 2011).

Depending on the evolution of the RES legal framework for confronting the aforementioned problems, the Romanian Wind Energy Association predicts that 3,000-3,500 MW of wind power will be installed by 2013, and 6,000 MW by 2020 based on a pipeline of approved projects, while 4,632 MW at the end of 2010 (Global Wind Energy Report, 2010). The anticipated implementation of at least 3,000 MW in wind power for the period 2011-2015 would lead to an increase in total investments in new capacities of over 5 billion € (+28%) (Invest East, 2010). This promising development will allow Romania to become one of the main wind power markets in Central and Eastern Europe (Global Wind Energy Report, 2010).

Additionally, energy price is relatively high, especially for industrial application (National Union of County Councils of Romania, 2009). This is despite the facts that internal production energy capacity represents, depending on the year and the used for production sources, a range of 70%-100% of internal demand; and in several years (with high precipitations) Romania may become even an energy exporter in the Balkan region. No evaluation about the profits of RES installation is available on the Romanian market (National Union of County Councils of Romania, 2009).

The grades are 3 and 4.

For *flexibility* the grades are assigned with the SMART procedure.

<u>Bulgaria</u>

There are 2 mechanisms supporting RES-E: (i) support through preferential prices, and (ii) loan support (Dimitrova et al., 2008). In the case of energy generation by RES for heating and cooling purposes the support mechanisms are not sufficiently developed (Bulgarian Government, 2011). A bill is foreseen for 2011 on the market mechanisms for encouraging production of electricity and renewable heating power (Patlitzianas and Karagounis, 2011). The relatively low level of incentives makes the RES penetration particularly difficult, since the current commodity prices for electricity are still relatively low. A green certificate system to support RES-E developments has been proposed, for implementation in 2012, to replace the mandatory purchase price (EWEA, 2008). On the other hand, major governmental incentives encourage Foreign Direct Investment with the introduction of a 10% corporate tax rate (2007), the lowest in the EU, and a 10% flat income tax (2008) (Patlitzianas and Karagounis, 2011). There is a tax exemption for RES producers.

Bulgaria is implementing the Bulgarian Energy Efficiency and Renewable Energy Credit Line (BEERECL). Under the second, RES projects are eligible for a 20% grant (Patlitzianas and Karagounis, 2011; PV-NMS-NET, 2010).

There are investment disincentives due to subsidies of other energy sources (primary fossil fuels) (Srebotnjak and Hardi, 2011).

The scenarios received grades 4 and 5.

Greece

The scenarios received grades 4 and 5, respectively. The ImBAU offers a higher investment subsidy compared to the BAU scenario.

Romania

The RES support mechanism has 2 main pillars: 1) compulsory quotas, and 2) TGCs. All power plants aiming to RES-E qualify for this support mechanism, except for HPPs with an installed power exceeding 10 MWh. Biogas is also included (Mihailescu, 2009). The support mechanism doesn't apply for export of RES-E, or to electricity generated from imported industrial and/or urban waste, irrespective of the installed capacity of the energy facility (Mihailescu, 2009).

The GC scheme for RES-E covers a period of 15 years, with loan guarantees and tax exemptions for RES investments. The value up to 2014 of a GC ranges from 27 to 55 €/MWh (wholesale price of 35-40 €/MWh) (Global Wind Energy Report, 2010). The minimum and maximum value of the green certificates are defined annually by Romanian Energy Regulatory Authority in the Romanian national currency (RON) at the exchange rate established by the National Bank of Romania for the last month of the previous year. The minimum and maximum price levels are reviewed each year, and indexed with the Consumer Prices Index. Starting from 2015, the minimum value of the GCs cannot be lower than the minimum value applicable in 2014 (Mihailescu, 2009). The producer of RES-E is benefiting from this support mechanism and is assuring income from: (i) selling the electricity to the electricity market; (ii) the sale of GCs on the existing market for GCs (Trinergi Grup, 2011).

Current legislation offers the following incentives to RES generators:

- accelerated depreciation for investments in RES facilities;
- tax exemptions for any reinvested profit from a RES project for three years from the project's commission date;
- the cost of authorisations and licenses is reduced by 50%;
- there are financial contributions from the state budget for new jobs;
- up to 50% of medium or long term loans are guaranteed.

The RES-specific scheme will support initial investments of up to 50 million € in electricity and heat production from RES technologies (solar, wind, biomass, biogas, geothermal, wave, micro-hydro (systems with an installed capacity of less than 10 MW) and waste fermentation gas). The aid can cover up to 50% of eligible costs for large companies, 60% for medium-sized companies and 70% for small companies, with the remainder provided by the recipient. The general investment schemes will contribute around 28 million € for initial investments and up to a maximum of 50% of all eligible costs where they reach 50 million € or more. The recipient must contribute the remainder (Mihailescu, 2009). The scenarios received grades 5 and 6 respectively.

For *equity* the evaluation is based on the third result of Green-X model (Table 4). Here through the MAUT procedure the scenario with the highest total costs for society due to all the policy instruments is assigned with grade 0, while that with the lowest with grade 100.

For *stringency for non-compliance* and non-participation the SMART procedure is followed again.

Bulgaria

Energy suppliers in Bulgaria must collect all of the energy fed into the grid by RES producers. Failure to comply with this obligation is subject to fines up to 75,000€ (PV-NMS-NET, 2010). Delays by utilities in providing a connection point to the grid for investors who got approval by the National Electricity Company (or Natsionalna Elektricheska Kompania (NEK)), are subject to a 25,000€ fine (PV-NMS-NET, 2010). The assigned grades are for both scenarios 5.

Greece

The 2 scenarios have no such provisions. The high penalty is one more influencing mechanism for persuading target groups to comply (Mavrakis and Konidari, 2003). The assigned grades are 5 for both scenarios.

Romania

There are obligations on electricity suppliers with targets specified from 2005 (0.7% RES-E) to 2010 (8.3% RES-E). Non-compliant suppliers pay maximum price (i.e. 63 €/MWh for 2005-2007; 84 €/MWh for 2008-2012, penalties)

(EWEA, 2008). The assigned grades for both scenarios are 7.

4.2.3 3rd criterion: Feasibility of implementation

The scenarios are evaluated against three sub-criteria. For the first sub-criterion *Implementation network capacity* grades are assigned to the scenarios.

Bulgaria

The performance of the Bulgarian Implementation network is poor compared to other EU member States. The Ministry of Economy and Energy (MEE) is the main institution responsible for the national energy policy. It was created in 2005 after the merge of the Ministry of Economy and the Ministry of Energy and Energy Resources (MEER) (KEPA, 2009; Ganev, 2009). The Ministry of Environment and Waters (MOEW) has 2 important functions related to distributed generation: (i) its regional branches decide on the screening whether projects require Environmental Impact Assessment (EIA) and accept the assessment or not; (ii) it has functions to issue permits for water usage. The Ministry of Regional Development has functions related to issuing of land-use permits. The State Energy and Water Regulatory Commission (SEWRC) is an independent regulator of energy and water markets. It was established in 1999 as energy regulator but from the beginning of 2005 water regulation was included in its functions (Ganev, 2009).

Information and data regarding RES and RES-E that these entities provide in English through their web-sites are limited. Technological infrastructure and particularly the national grid require upgrading as already aforementioned (Srebotnjak and Hardi, 2011). Bulgaria is still far from achieving specific grid quality and management capacity for promoting RES (Centre for the Study of Democracy, 2011).

The assigned grades were for both scenarios 5.

Greece

The main state authorities involved in the energy sector are the following: The Ministry of Environment, Energy and Climate Change is the main entity for implementing the Hellenic energy and environmental policy. The Regulatory Authority for Energy (RAE) is the independent authority for regulation and monitoring of the liberalised energy markets in Greece, with main responsibilities in the electricity and natural gas sectors. The HTSO is responsible for the planning and operation of the electricity transmission system, and the operation of the electricity wholesale market.

Under the BAU scenario, the structure of the implementation network responded sufficiently and problems mentioned during previous years were handled progressively (Mavrakis et al., 2003). The implementation network had adjusted to this policy framework and weaknesses were identified and handled (Oikonomou et al., 2009; Boukis et al., 2009). The ImBAU scenario will need improved technological infrastructure and additional number of trained personnel. Most researchers have mentioned the lack of information concerning biomass and hydropower (Malesios et al., 2010; Zografakis et al., 2010; Boukis et al., 2009; Oikonomou et al., 2009).
The assigned grades were for both scenarios 6.

Romania

The Ministry of Economy is responsible, inter alia, for the drawing up and implementation of the national energy policy. The Ministry of Environment is responsible for the implementation of the Romanian environmental policy. The Romanian Energy Regulatory Authority (ANRE) is an independent public legal entity of national interest under the Vice Prime Minister's coordination (KEPA, 2009). Its mission is to create and implement the appropriate regulatory system for the proper operation of the electricity, heat and gas markets. Transelectrica manages and operates the electricity transmission system and provides electricity exchanges among Central and South - Eastern countries, as a member of Union for Coordination of Transmission of Electricity (UCTE) and of Association of European Transmission and System Operators (ETSO) (KEPA, 2009).

The information and data regarding RES and RES-E that these entities provide in English through their web-sites are limited. Technological infrastructure and particularly the national grid require upgrading as already aforementioned (Srebotnjak and Hardi, 2011). The grid in certain regions was designed 30-40 years ago and urgently needs to be upgraded in order to accommodate the growing wind power capacity and transport the electricity to the rest of the country (Global Wind Energy Report, 2010).
The assigned grades were for both scenarios 5.

For the first sub-criterion *Administrative feasibility,* grades are assigned to the scenarios.

Bulgaria

RES development requires higher administrative capacity from the part of the national regulators and policy making entities than is currently available (Centre for the Study of Democracy, 2011). SEWRC has most of the main responsibilities for the implementation of RES projects (Ganev, 2009). This creates an administrative burden. Additionally, the insufficient support of RES development is attributed to the administrative incapability to formulate and implement policies (Centre for the Study of Democracy, 2011). The legal framework and the governmental support to overcome high initial financial and capital requirements are characterized as insufficient (Srebotnjak and Hardi, 2011).

The assigned grades are 3 for the BAU scenario and 2 for the ImBAU.

Greece

The administrative framework under the BAU scenario was acceptable. This assessment is based on the increase growth that RES-E production has demonstrated during its implementation (HTSO, 2011). The recent NREAP is not explicit concerning the necessary RES distribution for achieving the target of 40% (HTSO, 2011; PPC, 2011). Researchers also mention administrative barriers for the penetration of RES that are not faced under the BAU and ImBAU scenarios (Oikonomou et al., 2009; Michalena et al., 2009). More work from the part of the competent authorities is required in the ImBAU scenario due to the lack of experience for its implementation and to the remaining short period until year 2020. The possibility of international trading due to TGCs imposes additional administrative work.
The assigned grades are 3 for the BAU scenario and 2 for the ImBAU.

Romania

There are several unclear aspects and administrative issues about the legal framework for the establishment of the GC system that hinder the economical effectiveness of the system, especially for the projects privately developed (National Union of County Councils of Romania, 2009). As in Bulgaria, the legal framework and the governmental support to overcome high initial financial and capital requirements are characterised insufficient (Srebotnjak and Hardi, 2011). Administrative burden is significant since there are an excessive number of authorities involved in licensing procedures (Pirlogea, 2011).

The assigned grades are 3 for the BAU scenario and 2 for the ImBAU.

For the sub-criterion *financial feasibility* grades are assigned to the scenarios.

Bulgaria

The competent authorities will need less overall costs in implementing the first scenario. Additionally there are revenues from the penalties imposed during the stages of the whole procedure as already aforementioned. For the ImBAU no additional revenues are foreseen, but the proposed funding mechanisms limit the financial feasibility in this case. The assigned grades are 6 and 4.

Greece

The competent authorities will need less overall costs in implementing the first scenario. FITs are considered easy to install with minimal administrative costs (Brick et al., 2009). The costs will be higher in the ImBAU scenario, but restricted since the investment subsidy concerns only 2 types of RES technologies. The revenues due to the high penalty are expected to limit the costs for the government. The assigned grades are 5 and 4.

Romania

The implementation of a quota system is much more expensive for the competent authorities. Additionally the funding mechanisms that are used for supporting RES in Romania limit more compared to the other 2 countries the performance of policy mix under this sub-criterion. On the other hand, the foreseen penalty is collected and transferred to the Romanian Environment Fund to finance the production of energy from RES by individuals who want to invest in energy capacity installed power up to 100 kW (Trinergi Grup, 2011). The assigned grades are 3 for both scenarios.

4.2.4 Results of AMS

The results for each scenario and for each country are presented in Table 6. For Bulgaria and Greece the BAU scenario has a higher performance compared to the ImBAU one. For Romania the ImBAU is more effective compared to the BAU scenario. It is noticeable that although the ImBAU scenario for Bulgaria and Greece has a higher performance under the criterion of environmental performance exhibiting the higher share of RES in total electricity generation, its higher total generation costs and the generation costs for society placed it second. For the Romanian case the ImBAU had a higher environmental performance and its respective costs were more preferable.

Despite the great difference in Bulgarian and Hellenic total generation costs and costs for society (Table 4) both ImBAU scenarios received the same grade under the sub-criterion of cost effectiveness. This happened because even if the difference between the respective categories of costs for BAU and ImBAU scenarios for each country is significant, the scenario with the lowest cost is graded higher for both countries.

In Table 7 the results of applying the AMS method at a regional level are shown. In this case the results are consistent with the ones at national level (Table8). The BAU scenario received again a higher score compared to the ImBAU scenario for Bulgaria and Greece. The Romanian ImBAU had a higher score compared to the respective BAU scenario. This application allows the authors to draw conclusions for the implementation of the same policy framework for a group of countries by taking into consideration their specific and particular national circumstances. All 3 countries have to implement Directive 2009/28/EC and achieve defined targets adjusting according to their capabilities and priorities.

The Bulgarian scenarios scored higher mainly due to the lower total generation costs and the total costs for society compared to those for the other 2 countries. On the other hand, these scenarios have the lowest penetration of RES-E compared to the other 2 countries. Bulgaria has also one of the lowest gaps to cover between the 2005 situation and the anticipated 2020 for supporting RES, while Greece has one of the highest. Consequently, the implementation of Directive 2009/28/EC has better chance to be effective in the case of Bulgaria. The higher performance of both policy mixes under political acceptability in the Bulgarian case will serve as a transitory situation for the development of RES in this country. Bulgaria became an EU member State in 2007 and since then had to transpose Directives and harmonize its energy and climate policy to that of the EU. Both scenarios will allow the adjustment of the country and a careful design of any future policy instrument will allow a higher RES-E penetration.

Table 6: AMS results for each scenario. Evaluation is performed at national level.

	Scenarios					
	Bulgaria		Greece		Romania	
Criteria	**BAU**	**ImBAU**	**BAU**	**ImBAU**	**BAU**	**ImBAU**
Direct contribution to GHG emission reductions (0.833)	0	83,3	0	83,3	0	83,3
Indirect environmental effects (0.167)	0	16,7	0	16,7	0	16,7
Environmental performance (0.168) - A	**0**	**16,8**	**0**	**16,8**	**0**	**16,8**
Cost efficiency (0.474)	47,4	0	47,4	0	0	47,4
Dynamic cost efficiency (0.183)	9,15	9,15	9,15	9,15	9,15	9,15
Competitiveness (0.085)	3,32	5,18	3,32	5,18	3,32	5,18
Equity (0.175)	17,5	0	17,5	0	17,5	0
Flexibility (0.051)	1,96	3,14	1,96	3,14	1,97	3,13
Stringency for non-compliance (0.032)	1,6	1,6	1,6	1,6	1,6	1,6
Political acceptability (0.738) - B	**59,73**	**14,07**	**59,73**	**14,07**	**24,76**	**49,04**
Implementation network capacity (0.309)	15,45	15,45	15,45	15,45	15,45	15,45
Administrative feasibility (0.581)	35,73	22,37	35,73	22,37	29,05	29,05
Financial feasibility (0.110)	7,88	3,12	6,76	4,24	4,26	6,74
Feasibility of implementation (0.094) - C	**5,55**	**3,85**	**5,45**	**3,95**	**4,58**	**4,82**
Total (A+B+C)	**65,28**	**34,72**	**65,18**	**43,82**	**29,34**	**70,66**

Table 7: AMS results for each scenario. Evaluation is performed at regional level.

	Scenarios					
	Bulgaria		Greece		Romania	
Criteria	**BAU**	**ImBAU**	**BAU**	**ImBAU**	**BAU**	**ImBAU**
Direct contribution to GHG emission reductions (0.833)	0	2,72	25.73	27.33	83.17	83,30
Indirect environmental effects (0.167)	0	0,55	5.16	5.48	16.67	16,70
Environmental performance (0.168) - A	**0**	**0,55**	**5,19**	**5,51**	**16,67**	**16,70**
Cost efficiency (0.474)	47,4	44,65	11,27	8,32	0,00	0,36
Dynamic cost efficiency (0.183)	4,01	4,01	2,57	2,57	2,57	2,57
Competitiveness (0.085)	1,11	1,73	1,11	1,73	1,11	1,73
Equity (0.175)	17,50	17,16	17,12	13,68	0,59	0,00
Flexibility (0.051)	0,55	0,87	0,55	0,87	0,87	1,38
Stringency for non-compliance (0.032)	0,35	0,35	0,35	0,35	0,89	0,89
Political acceptability (0.738) - B	**52,34**	**50,76**	**24,33**	**20,32**	**4,45**	**5,12**
Implementation network capacity (0.309)	4,31	4,31	6,83	6,83	4,31	4,31
Administrative feasibility (0.581)	12,90	8,07	12,90	8,07	8,07	8,07
Financial feasibility (0.110)	3,76	1,48	2,37	1,48	0,95	0,95
Feasibility of implementation (0.094) - C	**1,97**	**1,30**	**2,08**	**1,54**	**1,25**	**1,25**
Total (A+B+C)	**54,31**	**52,61**	**31,60**	**27,37**	**22,48**	**23,17**

Table 8: Comparison of AMS results

	Evaluation results			
Scenario name	**Regional level**	**Order**	**National level**	**Order**
Bulgaria - BAU	54.30	1	65.28	1
Bulgaria - ImBAU	52.61	2	34.71	2
Greece - BAU	31.59	3	65.17	1
Greece - ImBAU	27.37	4	34.82	2
Romania - BAU	22.48	6	29.33	2
Romania - ImBAU	23.17	5	70.66	1

5. Conclusions

The evaluation of the developed scenarios showed that the BAU scenario is more effective overall as compared to the other one for Bulgaria and Greece. The BAU reflects a situation that occurs and is acceptable. These scenarios scored higher compared to the other ones in political acceptability and more specifically in cost efficiency and equity.

The common characteristic of all scenarios is that no country reaches its target by 2020. Further analysis is needed in order to test the mid-term effectiveness of the different instruments of the basic policies – FITs and Quota.

The combination of FITs with investment subsidies is more effective compared to the Quota obligation scheme with TGCs. On the other hand, quota obligations scheme encourages competition among RES-E generators given that the market is sufficient large (Brick et al., 2009).

Another conclusion is that tax exemptions burden the country without respective long-term retributive benefits.

Finally, the AMS application allows comparison at regional and national level. Outcomes are consistent between them. It is the first time that AMS is used for the evaluation of a common framework as that of the Directive 2009/28/ECat regional and national level simultaneously.

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“Zero emission’s port using floating windturnies”

Prof. N. NIKITAKOS, University of Aegean, Greece

-full paper not submitted-

“Impact of implementation of the Renewable Energy Sources on the power system technical and economical characteristics”.

Dr. V. SARGSYAN, Energy Strategy Centre – Scientific Research Institute of Energy, Armenia

-full paper not submitted-

Legislative impact on significance of RES in the Latvian Energy market

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Abstract

Latvia is a new European Union country, with 20-year experience in the efforts to develop the energy policy that would favour reliable supply of the state with energy and promote its effective and rational utilization. The energy law should take into consideration the technological progress and increasing energy consumption as well as the poorly regulated sphere of production and utilization. At present, new regulations are needed, as the existent ones have become outdated and unable to ensure stable development of the energy sector. However, the lack of experience and sometimes external influence could lead to a situation when the new law would not be conducive to the industrial development but vice-versa – would slow it down.

Since Latvia has been confronted by counterproductive laws, it is highly important to estimate beforehand the future impact of legislation on the state economy. On issues of the day for our country is now to guarantee – by force of law – the optimal share of renewable energy in the national energy mix. The objective set within the framework of European Union policy is to achieve a 40% share of renewable energy by 2020; therefore, it is necessary to work out a separate law concerning the renewable energy sources (RES). The new RES law is to regulate support and to promote increase in the share of renewables. However, there are many influencing factors – not clearly specified outlooks for the energy sector and national economy development, the interests of energy importers, lobbying, etc.; these factors can make the RES law not only ineffective but even negatively affecting the RES share stability in the state energy balance. It is therefore essential, before the law has been adopted, to thoroughly analyze it so that the optimal variant is accepted.

Keywords: Energy policy; renewable energy.

Introduction

In the last ten years a 10% increase in the energy consumption in Latvia has been observed. This means increasing import of electricity and energy resources, since the volumes of electricity produced in Latvia are insufficient for covering energy demand. The ever increasing demand, along with the limited fossil fuel reserves as well as environmental pollution and global climate change, has aroused an active interest in renewable energy resources. In the EU, support for the RES use has become an integral part of its energy policy. For Latvia (as for other European countries) this issue is especially topical. In the world, a tendency is developing fast – that of step-by-step replacement of the traditionally employed energy carriers by those of higher quality, with inclusion of renewable energy resources - biomass, solar and wind energy. This would undeniably lead to the cost reduction for the RES - technologies, which, in turn, would mean their increased competitiveness and wider utilization.

For small countries, constant boosting of their external sovereignty, both political and economic, is particularly important. Therefore, promotion of self-sufficiency of the energy sector is one of the key tools for reaching this goal. Currently, in terms of the energy supply structure, Latvia is one of the most vulnerable EU member states. The level of self-sufficiency is low, and the dependence on one resource and one supplier is high. Moreover, the position of such a supplier’s capital on the local energy market and in the economy as a whole is significant, as is that of the associated business culture; also, the chance of political and economic manipulation is ever-present, whilst opportunities for supply diversification and greater RES share in the energy balance are limited both in the short and medium terms. At the same time, the use of local renewables and energy efficiency improvement should undoubtedly become the priority objectives in diversification efforts and promotion of self-sufficiency. This way, the end consumption will be reduced. At the same time, gradual integration of the Baltic ‘energy peninsula’ into the ‘continent’ of the EU energy infrastructure, and its legal and technological framework, creates conditions for energy security (particularly in crisis situations) as well as supports the upgrading of the energy sector and development of the country’s economy in general. [7]

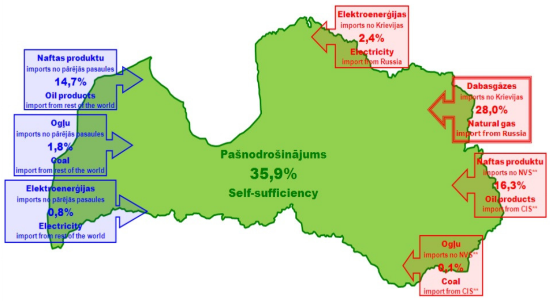

Fig.1 Latvian energy self-sufficiency and import in 2009

It is of vital importance to increase the Latvian energy independence. Therefore, it is obligatory that the Government energy strategy for 2030 includes the RES development.

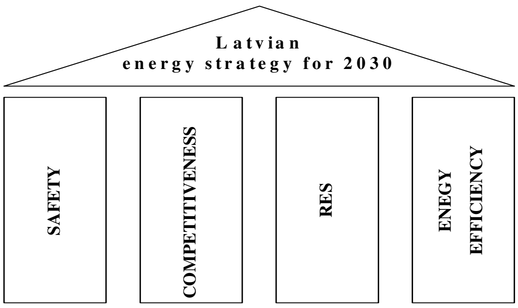

Fig.2. Latvian energy strategy for 2030

<u>RES advantages in the Latvian energy balance.</u>

In 2010, the RES share in the Latvian final energy consumption reached 34.6%. The local RES share in heating was 45-50%, in district heating – 18%, and in electricity production – > 40%.

<u>RES deficiencies</u>

- Ineffective use of heat produced by cogeneration;
- insufficient support for renewable energy in electricity generation;
- gaps in modern and innovative renewable energy technologies.

<u>Objectives of the strategy for RES promotion</u>

- Increase of the RES share in the energy mix (mainly in the heating and transport sectors).
- Introduction of sustainable support mechanisms for RES.
- Priority for economically attractive technical solutions.
- Promotion of RES and related technologies by raising investments.
- Development of a sustainable and cost-based support mechanism for the RES use.
- Achievement of the 40% RES share in the final energy consumption by 2020.

It is important that expanded use of renewable resources does not impair the economic situation of businesses thus reducing the competitiveness of Latvian products.

Policy and Strategy for the RES use

The Government's policies should be oriented towards greater RES capacities; besides, it would be useful to think of the new regulations concerning the use of alternative power (e.g. nuclear or gas turbines). Currently, without the TES (Thermal Electro station) and HPP (Hydro Power Plant) regulatory capacities fast RES development is impossible.

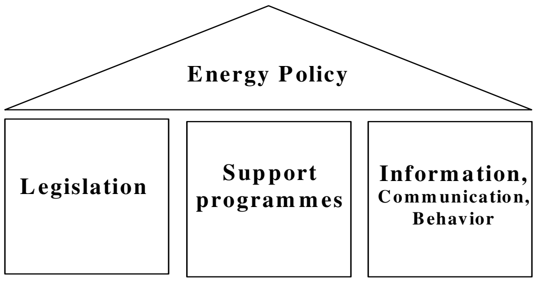

Fig.3. Policy instruments

To reach this goal, not a single measure but a coherent mix of measures is required.

Energy policy framework documents:

Guidelines for Energy Sector Development for 2007-2016

The main goal of the Energy Policy is to develop the guidelines for ensuring security of supply in the country. The next in importance are the goals: to increase self-sufficiency and to achieve greater diversification of energy resources. Latvia has to seek for its own fossil fuels, to increase effective use of RES and promote cogeneration (CHP);

Legal Framework

The legal framework includes the EU Directives and National laws & regulations.

One of the issues associated with utilization of energy resources (in particular, RES) is heat consumption in buildings. In accordance with the Latvian "Law on the Energy Performance of Buildings", the environmental and economic considerations as well as binding regulations of local governments and other regulatory enactments should be taken into account in designing buildings, in order to evaluate the possibility to implement RES as an alternative solution in the relevant heating systems.

Main support instruments

The main support instruments are the investments in the energy sector.

The Latvian government and parliament have produced a number of energy-related planning documents, legislations and regulations. The framework strategic planning document is Latvian National Development Plan 2007-2013. An updated and more comprehensive Sustainable Development Strategy 2030 is being drafted that will broaden the Principles for Sustainable Development passed in 2002. The mentioned strategic documents consider the issues of energy among others, while the key strategic document intended for the energy sector is The Principles of Energy Sector Development 2007-2016 (adopted in 2006). The Principles of Renewable Energy Resource Use 2006- 2013 have also been passed. Now, there are a number of energy sector related medium-term programmes and action plans, e.g. The Climate Change Mitigation Programme 2005-2010, Latvia's Rural Development Programme 2007-2011, the programme of/Programme for Biofuel Production and Use in Latvia 2003- 2010, the Programme for Development of Biogas Production and Use 2007-2011, as well as the EU action plans: the Action Plan for Energy Efficiency 2008- 2010 (passed in 2008), and the Action Plan for Renewable Energy.

The most important energy-related legislative document is the Energy Law of 2005, which regulates the use of and support for all renewable resources. The government also adopted a series of regulations; the most notable among them being Regulation No 198 (24 February, 2009) and Regulation No 486 (26 May, 2009), which define the most significant and, in practice, the only consistent tool for promotion of RES: the mandatory procurement scheme, which entails a guaranteed procurement price for electricity produced from renewables. In addition to this scheme, Chapter VII of the Electricity Market Law dealing with the electricity production and pricing was amended in April 2008. Now, Section 29.164 of this Chapter stipulates that the energy production businesses with generating capacity above 1 MW which use biogas or biomass can apply for the guaranteed imbursement for the installed generating capacity of biomass and biogas power plants. As of March, 2009, the rules of issuing the rights to obtain the guaranteed imbursement and the requirements the applicants have to meet are laid out in Cabinet Regulation No 198 and New Regulation No 262. In addition to the aforementioned regular support mechanisms, Section 29 of the Electricity Market Law stipulates that the Cabinet of Ministers shall specify the measures which, in particular, would promote electricity production from biomass and the feed-in tariffs for electricity produced using renewable resources. [7]

Currently the State support in the energy sector is only given to the projects linked to adjustment of heat supply system. The priorities for the use of EU Structural Funds are listed in the Development Plan; these priorities are sub-divided into measures, which, in turn are sub-divided into activities. It is planned to allocate approximately 140 million EUR in the energy sector from the Cohesion Fund in the next Structural Funds utilization period of 2007-2013. This money will be allocated to the measures for increasing the efficiency of district heating systems, for development of biomass-fuelled cogeneration plants and wind farms in Latvia.

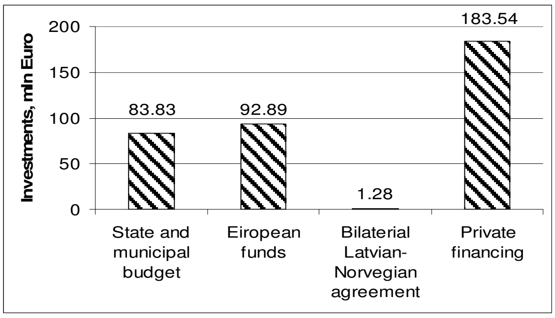

Fig.4 Potential financial sources in RES development (2006-2013)

EU Structural Funds

Financing of RES Projects.

A special budgetary arrangement (28.01.2011 – 24.03.2011) in the framework of the budget programme "Climate change mitigation financial instrument" is financing for the projects concerning the RES use in households (total 16.220 million EUR/Euros). Financial support for each project should not exceed more than 9 960 Euros (with support not exceeding 50% of the total eligible costs).

The mandatory procurement for electricity produced from RES based on the fixed purchase price formulas is reflected in:

- Regulations No. 262 on Production of Electricity from RES (in force since March 2010).
- These regulations define the criteria of produced electricity as compulsory purchase

trades. If the electricity is produced from biomass or biogas at a power plant with the installed capacity over 1 MW, it is possible to receive a guaranteed compensation for the installed capacity.

– Regulations No. 221 on Production of Electricity in Cogeneration Mode (in force since March 2009).

A feed-in tariff

A feed-in tariff (FiT) involves the obligation on the part of a utility to purchase electricity generated by renewable energy producers in its service area at a tariff determined by public authorities and guaranteed for a specific period of time (generally 20 years). A FiT's value represents the full price per kWh received by an independent producer of renewable energy, i.e. including a premium above or additional to the market price, but excluding tax rebates or other production subsidies paid by the government.

Different tariffs can be defined for different technologies (wind, solar, biomass, etc.) or different countries depending on resource conditions (e.g. solar irradiation). The rate of a FiT is furthermore reduced each year for new installations in order to stimulate decrease in production costs. Feed-in laws have been the primary mechanism used to support RES development in Europe and the US. They have a track record of some two decades and are well established throughout the European Union. At present, they are being applied in 21 EU member countries. While many countries in Europe have introduced a FiT on different levels, only some of them (e.g. Germany) have adopted appropriate rates specifically for PV or photovoltaic generation Others used inadequate FiT parameters (for instance Austria – too low a ceiling on total installed PV capacity) and thus failed to stimulate significant investor interest.

In Latvia, the feed-in tariff has been chosen in the mandatory procurement of the energy produced from renewables as a method of support – a straightforward and effective way to reach the relevant targets. This approach is widely used in other member states. However, it also bears a number of risks, namely: the procurement price and support timeline is tied to the moment when the energy production equipment becomes operational; and the pricing formula relies on electricity prices and fossil fuel prices. A thorough and unbiased analysis of conditions needs to be carried out as well as a calculation of reasonable return on assets. The pace and direction of technological progress needs to be estimated, which is a hard task. Misjudgements in setting the procurement price and the length of support could go both ways. Truly effective, market-based mechanisms are yet to be found. In Latvia, a quick analysis of the procurement price for the energy produced from biogas or in established hydro-electric power plants reveals overestimates. The quota system favours a closed circle of businesses, whose ties to the political parties are apparent. No wonder the Ruling Coalition Council had to agree on the pricing principles and quota volumes before the decision was made by the Cabinet of Ministers. Unreasonable procurement pricing undermines the principles of renewable energy use for sustainable development. [7]

Other support mechanisms

Quota schemes (also called Renewable Portfolio Standard - RPS) oblige the producers of electricity and retail providers to attain a specified minimum level of RES shares in its mix. The RPS is commonly combined with the Tradable Green Certificates (TGC) system, which relies on the market competition and therefore is unstable in the matter of price. These certificates, being the subject of trade, contain additional profit for the user of renewable energy. The TGS system does not favour the most future-oriented and ecological technologies of producing green electricity such as photovoltaic and off-shore wind turbine.

Green Investment Scheme for Financing of RES Projects. Funding for Green Investment Scheme (GIS) operation in Latvia is obtained from the state-owned greenhouse-gas (GHG) emissions quota unit (Assigned Amount Unit or AAU) sales. The principles for using the revenues from the sale of AAUs include a clear provision stating that all income from this sale should be reserved for "greening" projects

The Latvian government guarantees that financing from GIS will be used for the "greening" purposes, which means:

- increase in the renewable energy use;
- improvement of energy efficiency;
- application of innovative low-carbon technologies;
- design and implementation of capacities for climate change mitigation .

New Energy Policy

The first proposals have been submitted to the Ministry of Economy of Latvia. Some recommendations for the new legislation on the effective and rational use of RES are as follows.

– To create a well-established national support scheme for production of electricity from RES – a mandatory procurement applicable to the electricity production by wind-, hydro-, biomass- and biogas power plants (PPs).

- To reach a balance between the electricity demand and supply from local PPs using RES by 2011
- To further develop and implement support schemes for highly efficient cogeneration with the use of RES.
- To promote activities for facilitation of bio-fuel production and consumption.
- To implement the energy efficiency measures.
- To actively participate in the EU and other international R&D projects;
- To develop the challenge we regard the upcoming renewable energy policy up to the EU level (with the ambitious individual target for Latvia being the 42% RES share by 2020).
- To develop and implement the relevant pilot projects.

New RES-related Latvian Policy

On the whole, the national renewable energy policy is to promote the RES use, with due regard for environment protection and CO2 emission reduction. The main objectives of the new RES-related energy policy are to be as follows.

- Electricity production from RES – 49.3% of the total electricity produced in 2010.
- The RES share – at least 37% in the total energy mix.

The share of biofuels in the total marketed transport fuel should be 5.75% in 2012.

The aim of the Government policy is to achieve a balance between the electricity demand and the supply from PPs by years 2011-2012. The purpose is to promote the maximum energy efficiency measures for and supply from the PPs that use local fuels and renewable sources of energy in the high-efficiency co-generation cycle. The rest could be fossil fuels other than natural gas so that there will be no it’s over dominance. It is expected that in the development of cogeneration plants the energy from renewables will increase the capacities of transmission and distribution systems. For this purpose the following support tools have been selected:

- compulsory purchase at a specified price for all Latvian electricity consumers proportionally to their consumption;
- earmarking the cogeneration PPs for investment in their power structure from EU structural funds.

For improvement of the RES utilization and promotion of biomass cogeneration, it is expected to attract the means of EU Structural Funds and also to receive support of Cohesion Fund. By the year 2016 it is expected to attract 8.1 million LVL from the State Budget and 27 million LVL from EU Structural Funds. The RES exploitation strategy is closely connected with the introduction of measures for energy efficiency. The RES policy adopts/is to adopt an integrated approach to the energy efficiency issues.

The RES Law (draft project)

The targets of the Law are as follows.

- To promote production, utilization and export of local RES;
- To determine stable long-term investment environment for production, utilization and export of local RES;
- To contribute to the technologies reducing the GHG emissions.

Challenges to achieve the goals:

- by 2020 to increase the RES use in the gross final consumption up to 40% and continue to gradually increase it;
- to promote openness/transparency and accessibility of information on the energy issues;
- to establish administrative procedures in the RES production and use;
- to determine the support measures for local RES production and use.

National goals of the RES use

The Law stipulates a specific period until the year 2020 to achieve the following RES percentage in the gross final consumption:

- by 2012 – not less than 34.08%;
- by 2014 – not less than 34.82%;
- by 2016 – not less than 35.93%;
- by 2018 – not less than 37.04%;
- by 2020 – not less than 40%.

Republic of Latvia National Renewable Energy Action Plan

The NREAP of the Latvian Republic is intended for implementing Directive 2009/28/EC of the European Parliament and the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC by 2020.

Tab.1. Latvia National Renewable Energy Action Plan

(TWh)	Expected bruto demand for heating and cooling from RES	Expected bruto demand for electricity from RES	Expected energy demand for transport from RES	Expected demand from RES

2005	12.9	3	0.1	16
2010	11.8	3	0.5	15.3
2011	12.4	3.2	0.5	16.1
2012	12.8	3.3	0.5	16.6
2013	13.2	3.4	0.6	17.1
2014	13.3	3.7	0.6	17.5
2015	13.7	3.9	0.6	18.1
2016	14.1	4	0.7	18.8
2017	14.5	4.2	0.8	19.5
2018	14.9	4.5	0.9	20.3
2019	15.4	4.8	1	21
2020	16.2	5.2	1	22.2

The Latvia's national renewable energy action plan stipulates indicative targets for the share of RES in each type of the final energy consumption in order to foster the fulfilment of the common objective pursuant to Directive 2009/28/EC, taking into account the potential RES available and usable in Latvia. Having regard to the potential of economically usable RES available in Latvia, the main types of usable RES will continue to be solid biomass (mainly wood), biogas, wind power, and hydro power. [6]

Conclusions

The action plan provides for guidance towards the more extensive use of local RES in Latvia, defining the measures to be taken to attain the target prescribed in Directive 2009/28/EC, implementing sustainable development, conserving environmental quality and contributing to the reduction of greenhouse gas emissions, increasing Latvia's energy self-sufficiency, ensuring the sustainable utilization of Latvia's natural resources and the socio-economic benefits of their utilization. Support mechanisms for generating energy from RES that operate more successfully than previous ones must be established, not only for electricity but also for heating and as transport needs [6]

The EU has stepped up efforts to harmonize policies on the promotion of the use of energy from renewables in all member states by defining legally binding policy principles for the renewable energy promotion measures and setting individual renewable energy targets for each of the countries. Despite that, Latvia's renewable energy support policy, particularly the mandatory procurement scheme for the energy produced in power plants using renewables, is an area with an unstable legal framework, susceptible to frequent fluctuations in political opinions and interests, which often are not based on the country's economic and welfare considerations. The New RES Law is prepared to approval. The Law is intended improve the current situation with RES in total and prevent misunderstanding in this issue.

In the recent years, Latvia's energy policy practice has been marked by inconsistencies and the lack of socio-economic reasoning, which allows, in some cases, suspecting influence of lobbyists on the development of legal framework. Examples of that trend are the aforementioned frequent changes in the mandatory procurement regulation and the feed-in pricing formula, which is politically motivated rather than based in thorough economic reasoning. In the energy sector, the lack of flexibility is observed/exists in regard to the mandatory procurement scheme, which, as said before, is meant to promote the use of renewable energy resources. Such inflexibility may lead to situations when the support schemes follow the letter of the EU directives but not the spirit. The quota system supports the renewable energy target (49.3%) on paper, but the structure of the system does not prevent the situation when the businesses with the procurement rights do not set up the planned renewable energy plants whilst the businesses that would be willing to do so have no access to the quotas.

Within the frame of the State Research Programme's Project ''Research and development of the renewable energy resources production and consumption technologies for mitigation of climate changes generated by the energy sector'' recommendations have been worked up for rational RES use.

As an example of useful experience the activities of the Institute of Physical Energetics (IPE) should be mentioned. The IPE is a leader in the solar energy research and development in Latvia. In particular, our institute employs solar energy for its hot water supply. The IPE solar energy polygon can be used not only as an auxiliary heat supplier but also for education purpose and training of young specialists – students, bachelors, PhD competitors, etc.

The future development of national energy conception should be assessed from a balanced economic, technical and environmental point of view.

The energy vision in this scope should:

- be professionally designed;
- be in compliance with the country's interests;
- be accepted by the government;
- highlight the entire energy sector development frameworks;
- be balanced, with allowance for the use of local resources and expanded opportunities in the transport, electricity and heating areas;
- contribute to the national benefits in the scope of RES use.

To meet this challenge it is necessary to develop a unified national energy document which would include a comprehensive energy analysis of demand, risk and technologies in all energy sectors, taking into account the current situation in the sector and the RES share increase in assessing the cost-efficient green renewable energy applications. Much attention should be paid to the consumption, which is one of the most significant indicators in the energy policy (RES use included).

The short-term targets are: to support the industrial sector in transition of heat production from fossil fuels to renewable energy. The medium-to-long term targets are: to gradually replace natural gas and petroleum products by synthetic natural gas or liquid fuel produced from wood.

In particular, the unified national energy policy should promote energy-saving building as a means of the RES use, the fuel diversification (with the focus on local energy resources), considering the electricity sector from the viewpoint of regional electricity market development and security aspects, as well as providing accurate assessment of past and current support mechanisms and of the impact exerted by changes in the sphere of electricity generation and prices. Based on these considerations an impaired vision of the future energy development could be formed.

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THE INFLUENCE OF ALCOHOLS ON THE MAIN PHYSICOCHEMICAL CARACTERISTICS OF BIOFUEL MIXTURES

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Abstract. The influence of added alcohols, ethanol and butanol, on the main biofuel properties, such as the specific gravity, Reid saturated vapour pressure and distillation curves have been investigated. These properties are intimately related to the fuel composition and their prediction relies on the knowledge of its components characteristics. This research proves the possibility of obtaining fuels with different levels of resistance to detonation, using gasoline with different chemical components and various fractions of alcohols.

INTRODUCTION

The performance of internal combustion engines significantly depends on the physicochemical characteristics of the fuel, which in turn are determined by their chemical composition. For fuels of petroleum origin the mentioned dependencies have been studied more comprehensive than for biofuels prepared from the gasoline and monatomic alcohols. The purpose of our research has been to study the physicochemical properties and exploiting characteristics of abovementioned biofuels.

EXPERIMENTAL PART

The physicochemical properties (the density, saturated vapor pressure, distillation curves, octane number etc.) as well as the exploitation characteristics of such fuels as: (a) Normal-80 gasoline brand, (b) monoatomic alcohols: ethanol C_2H_5OH (produced from sweet sorghum, must of grapes, grain, separated from ether-aldehyde fractions) and n-butanol C_4H_9OH , (c) two-component mixtures of alcohol and gasoline (ethanol-gasoline, butanol-gasoline) in proportions of: 10:90, 20:80, 30:70, 40:60 and 50:50 (% vol), (d) three-component mixtures of alcohols and gasoline (butanol-ethanol-gasoline), have been investigated. The measurements of physicochemical properties and exploitation characteristics have been performed according to the recent technical-normative documents in the Republic of Moldova.

RESULTS AND DISSCUTION

The obtained results show that the physicochemical properties and exploitation characteristics of the mixtures from alcohols (ethanol, butanol) and gasoline depend on the individual properties of alcohols, as well as on the concentration of each component in the mixture.

The crucial process that occurs in the internal combustion engine

More complete burning of the fuel combustion in engine can occur if the fuel is in a gaseous state being at the same time quite dispersed in its mixture with air. Failing to comply with this requirement makes impossible to function the engine in a good state, consequently it is very important to ensure a more complete evaporation of the fuel. The fuel capacity to move from the liquid state in the gaseous one (at certain values of pressure and temperature) represents its **volatility**, which is typically characterized by the distillation point and saturated vapor pressure.

Distillation

Under current officially authorized regulations, the beginning and end of the gasoline distillation of the "Normal-80" type is within the temperature range of 35 ÷ 215° C. The values obtained for the Normal-80 gasoline sample, taken as the base for subsequent mixtures, are within the range of 42 ÷ 194° C (Table 1).

Table 1. The main characteristics of studied fuels

Fuel characteristics	Values of fuel characteristics								
	Gasoline N-80 (really obtained/ norm of SM 226)	Butanol (N-butan) B 100	E 20				EAF Ethanol E 100	E18B10	E16B16
			B 10	B20	Rect. ethanol	EAF Ethanol			
Distillation: - initial temperature of distillation, °C -temperature of distillation, °C: 10% vol. 50% vol. 90% vol. -Final point of distillation, °C -Residue, % vol. -Residue + lost, % vol.	42/>35* 55/<75* 85/<120* 154/<190 * 194/<215 * 1,3 / <2* 2,5 / <4*	110 113 116 116 116 1,0 2,0	43 55 87 154 194 1,2 2,5	40 52 89 147 192 1,2 2,0	40 47 67 143 193 1,1 2,0	40 48 67 145 192 1,2 2,0	76 77 78 83 95 0,1 0,5	38 46 70 131 191 1,3 2,0	43 53 84 120 193 1,4 2,0
Motor octane number MON	75,5	86,5	77,3	78,8	84,8	84,9	91*	84,7	84,6
Density, (20˚C), kg/m^3	728/<775 *	797	733	739	745	745	806/ 790*	742	750
Cinematic viscosity (20˚C), mm^2/s	0,57	3,64	0,65	0,73	0,76	0,69	1,52	0,81	0,91
Saturated vapor pressure, kPa	54,3/<80*	4	50,9	47,5	61,2	58,7	23*	54,8	50,9

* According to the normative or informative data; Rect. ethanol - Rectified ethanol, Ethanol EAF - ether-aldehyde fraction of ethanol

By the chromatographic analysis it has established that ethanol, made from the sweet sorghum and used to prepare combustible mixtures, contains 96 - 98% vol. of ethanol, up to 0.1% vol. of methanol and up to 1.4% of the ether-aldehyde fraction, the remaining part (2-3%) being water. In addition it also contains up to 3 g/L of the fusel oil and 0.3 g/L volatile acids.

The initial point of distillation of the gasoline must be not lower than +35 °C in order to minimize the loss of light hydrocarbons during the transportation and storage. The values of the initial point of distillation for ethanol-gasoline mixtures increase by 2-6 ° C (ethanol = 5-40% vol) in comparison with the usual changes within the range of 38 - 42 °C. The increase of the initial point of distillation for biofuels (ethanol-gasoline mixtures) is determined by the presence of ethanol, whose distillation temperature is 76 ºC. In function of the volume fraction of added ethanol, the temperature increases by 2-6 °C, being at the level of 38-42 °C. From the obtained data one can conclude that the addition of ethanol up to 40-50% vol. conducts to an increase of the initial point of distillation t_{init} for biofuels, so the t_{init} value is established within the range of 38-44 °C. The influence of butanol on the values of the initial point of distillation is similar as for ethanol, but still lower, because the polarity of butanol is closer to that of gasoline and, although the distillation temperature of butanol (110 °C) is much higher, the addition of butanol does not practically change the respective temperature for the binary mixture (t_{init} varies between 40 and 43 ºC) as well as for the ternary mixture of biofuels (t_{init} varies between 38 and 43 ºC).

The distillation temperature of 10% vol. is important for the starting capacity of the engine: the temperature is lower, the better are the starting conditions. Although the distillation temperature of 10% vol. of ethanol (t_{10} =77ºC) is higher than that of gasoline A-80 (t_{10} = 55 ºC), the presence of ethanol in biofuels with the volume fraction up to 20% decreases the t_{10} value by 1-8 °C. The common feature for all ethanol-gasoline blends is the fact that the distillation temperature increases as the ethanol concentration grows. For the ethanol concentrations above 20% vol., the t_{10} value for biofuel exceeds the respective temperature of gasoline by 1-8 °C. Regardless of the composition and properties of studied biofuels, an addition up to 20% vol. of ethanol stabilizes the t_{10} value of biofuels within the range of 47-52 °C, while with the ethanol concentration increasing up to 50% vol. - within the range of t_{10} = 52 °C -59 °C. The distillation temperature t_{10} of butanol (113 °C) is much higher than that of gasoline (55 ºC). At the same time, the t_{10} value for the butanol-gasoline mixture (55 °C for Cbutanol=10% vol., 52ºC for Cbutanol=20% vol.) is by 1-3 °C lower than that of gasoline. This may be explained by molecular interactions, but with a less effect than that for ethanol-gasoline mixtures. The addition of butanol to the ternary mixture E18B10 in proportion of 10% vol. maintains the t_{10} value at 46 °C, while for the ratio of 20% vol. the t_{10} value increases up to 53 °C.

The distillation temperature of 50% vol. characterizes the fuel capacity to ensure a proper functioning of the engine at different loads and especially in the case of their variation. The excellent function of the spark ignition engine (SIE) is guaranteed when the t_{50} value of gasoline is below 120 ºC. In the case of A-80 gasoline, the distillation temperature of 50% vol. is 85 °C, while for ethanol is 78 °C and for butanol is 116 °C.

The addition of butanol (10-20% vol.) increases by 2-4 °C the t_{50} value when mixed with gasoline and by 3-17 ºC in the ternary mixture. In the latter case the largest increase (17 °C) occurs at the butanol concentration of 20% vol. in the E16B16 mixture. For the t_{50} value, the synergic influence of butanol is minimal and with increasing the concentration of butanol, especially in the biofuel mixtures, the temperature t_{50} increases substantially, near to that of the gasoline A-80.

The distillation temperature of 90% vol. and the distillation end point describes the complete combustion capacity and the fuel efficiency. For the A-80 gasoline the t_{90} value is equal to 154 °C, for ethanol is of 83 °C, and for butanol is 116 °C. The increase of the ethanol volume fraction up to 30% results in maintaining or lowering the t_{90} value by maximum 11 ºC compared to gasoline. The increase of the ethanol volume fraction by more than 30% leads to a more pronounced decrease in the t_{90} value. Thus, for the biofuel E50 the t_{90} value is of 87 °C, the decrease being of 72 ºC. In the butanol mixtures the decrease of temperature takes also place: in the gasoline blends of up to 7 ºC, while in the ternary mixtures up to 34 ºC (see Table 1).

The distillation endpoint of studied gasoline varies within the range 177-194 °C. The addition of alcohol decreases by up to 12 ºC the final point of distillation of the ethanol blends and up to 3 °C for mixtures with butanol. In both cases this decrease becomes more pronounced with increasing the volume fraction of alcohols in the mixture.

According to [13], the temperature range $\Delta t = t_{final} - t_{90}$ decreasing reflects the diminish of the probability of condensation for heavy fractions of the fuel. This range is, respectively: for gasoline A-76, Δt = 18 °C; for A-80, Δt = 39-40 °C, for ethanol, Δt = 12 °C and for butanol, Δt = 0 ºC. The addition of ethanol and butanol in the ratio of up to 30-40% vol. changes the temperature difference Δt for the respective gasoline within relative small range: ± 8 °C. With increasing the alcohol fraction over 40% vol., the difference Δt increases to 79 °C, mostly due the t_{90} value decreasing.

The residue is a non-distilled fraction of fuel, formed from its heavy fractions. The residues remained after the distillation of ethanol (0.1% vol.) and butanol (1.0% vol.) are smaller than those for the respective gasoline (1.3% vol.). In the binary mixtures of ethanol-gasoline and butanol-gasoline there is registered a slight decrease of the residue compared with gasoline of the 0.6 - 1.2% vol. levels.

Distillation losses were 1.2% vol. for gasoline, respectively 0.4% and 1.0% vol. for ethanol and butanol.

The fractional composition (distillation) is reflected by the distillation curves (Fig. 1). In the temperature range of t_{init} - t_{10} the distillation of biofuels (except E50) is practically identical to that of gasoline. The use of ethanol produced from various species of raw material (as sorghum mellitus, ether-aldehyde fraction of grapes or grain) does not essentially influence the distillation temperatures of biofuels. The form of distillation curves shows that the addition of ethanol and butanol to gasoline influences insignificantly on the initial and final distillation point values of mixed fuels, but there is a certain decrease in the intermediate distillation temperatures (t_{10}, t_{50}, t_{90}) for the mixtures of monatomic alcohol and gasoline.

The vapor pressure also influences on the proper engine function. The Reid vapor pressure of the gasoline A-80 is equal to 54.3 kPa, while that for gasoline with the ethanol fraction of 10% vol. and 20% vol. is situated within the 57.0 - 61.2 kPa range. The tendency of increasing pressure with growing the ethanol volume fraction has been registered. Since the vapor pressure of butanol is low (4 kPa), its addition to gasoline with the volume fraction of 10% and 20% reduces the pressure of the A-80 gasoline respectively by 3.4 kPa and 6.8 kPa, while for the biofuel E16B16 respectively by 6.4 and 10.3 kPa.

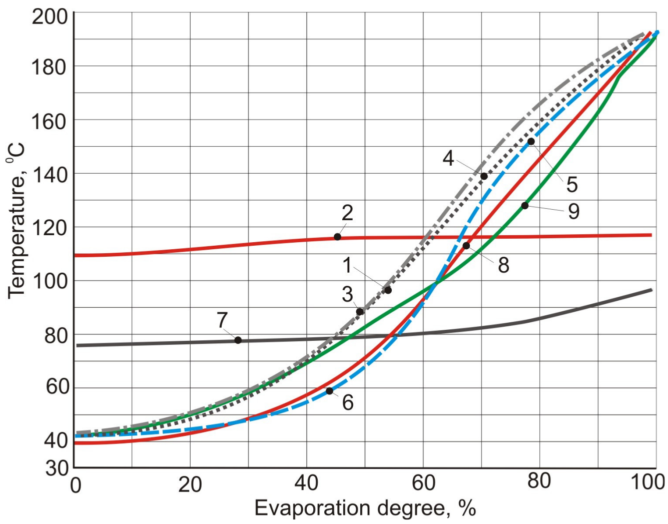

Fig. 1. Modification of the fuel distillation curves: 1 - gasoline A-80, 2 - butanol, 3 - ethanol, 4 - B20 mixture, 5 - biofuel E20 (rectificated) 6 - biofuel E-20 (EAF), 7 - ethanol, 8 - E18B10 mixture, 9-E16B16 mixture.

The octane number characterizes the detonation stability and is determined by the Research Method (RON) or Motor Method

(MON). It has been established that adding alcohol to gasoline usually increases the octane number (Fig. 2). The addition of ethanol causes a higher increase of the octane number (ΔCOM = 0.47 unit /% vol) than in the case of butanol (ΔCOM = 0.17 unit /% vol.).

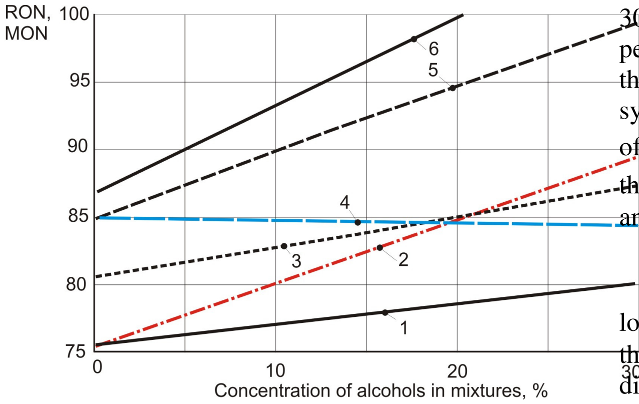

Fig. 2. The dependence of the octane number of biofuel mixtures on the alcohol concentrations: 1, 2, 3, 4 - COM = f (C), 5, 6 - COR = f (C), 1 - butanol + gasoline A-80, 2 - ethanol + gasoline A-76, 3 - ethanol + gasoline A-80, 4 - E16B16 mixture, 5 - ethanol + gasoline A-80, 6 - ethanol + gasoline A-90.

CONCLUSIONS

1. It has been established that adding ethanol to 40 - 50% vol. has a positive effect on the initial distillation temperature values for biofuels, which are stabilized in a range t_{init} 38 - 44 ˚C. The influence of butanol on the initial distillation temperature values is identical to that of ethanol. Even the distillation temperature of butanol (t_{init}= 110 ˚C) is much higher than that for gasoline (t_{init}= 42 ˚C), adding butanol does not practically change the respective temperature of the binary mixture with gasoline (t_{init}= 40 - 43 ˚C) as well as for ternary mixture of biofuel (t_{init}= 38 - 43 ˚C).

2. The addition of alcohols with up to 20% volume fraction in gasoline creates a synergistic effect, reducing that the temperature by 1 - 8 ˚C. At addition of butanol this effect is lower than for ethanol. The increase of the ethanol content more than 20% vol. results in growing the t_{10} value of biofuel by 1 - 8 ˚C. The best fuels to start the engine are the mixtures that contain alcohols up to 20 - 30% vol.

3. The ethanol-gasoline blends E5-E50 (with the ethanol fraction of 5 - 50% vol.) have the t_{50} value within 67 - 79 ˚C, for gasoline - t_{50} = 85 - 95 ˚ C and for ethanol t_{50}=78 ˚C.. Reducing the temperature t_{50} for biofuel, especially with the ethanol concentration up to 30% vol., has to improve the engine performance at different tasks and is caused by the interaction of component molecules with a synergistic effect. The addition up to 20% vol. of butanol (t_{50} = 116 ˚C) increases by 2 - 4 ˚C the temperature t_{50} in the mixture with gasoline and by 3 - 17 ˚C in the mixture with the biofuel.

4. The alcohols have the temperature t_{90} lower than gasoline (t_{90}= 152 - 159 ˚C), so for the alcohol-gasoline fuel blends, the 90% distillation temperature has low values. The distillation endpoint drops to 12 ˚C in the ethanol-gasoline blends and with up to 3 ˚C in the butanol-gasoline mixtures. The reduction of t_{90} and t_{final} leads to the more complete burning of fuel.

5. The distillation curves show that the addition of monoatomic alcohols in gasoline affects slightly the initial and final points of distillation of mixed fuels, but there is a certain decrease in the intermediate distillation temperature (t_{10}, t_{50}, t_{90}) of the mixtures of alcohols with gasoline.

6. The Reid saturated vapor pressure RVP of studied fuels does not exceed the current normative requirements and technical documents (RVP < 80 kPa). The vapor pressure of the A-80 gasoline is within 49 - 54.3 kPa while that of biofuels with the volumetric fraction of 10% ethanol and 20% vol. is respectively within 57 - 61.2 kPa. The addition of butanol (RVP 4kPa) with the volume fraction 10% and 20% decreases RPV in gasoline by 3.4 and 6.8 kPa respectively, while for the biofuel E20 by 6.4 and 10.3 kPa correspondingly.

7. The addition of ethanol to gasoline (MON 75.5) provides a higher octane number growth (ΔMON = 0.47 unit\% vol.) than in the case of the addition of butanol (ΔMON unit = 0.17 unit\% vol). Under the same conditions, the addition of alcohols leads to an increase in the Research Octane Number higher than for the MON. The addition of up to 20% vol. of butanol does not practically influence the resistance to the detonation of the biofuel E20 (MON 84.8 - 84.6).

8. The carried out research proves the possibility of obtaining fuels with different levels of resistance to detonation, using gasoline with different chemical components and various fractions of alcohol.

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