Session 4. Renewable Energy Sources

THE IMPACT OF DIESEL FUELS' COMBUSTION IN CARS
"An overview of wave energy devices. Case study: wave energy in Agios Efstratios, the first greek green island"

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Abstract

Wave energy is a renewable source, which has not yet been exploited to a large extent. So far the main focus of wave energy conversion has been on the large wave energy resources of the great oceans on northern latitudes (Diamantaras et al., 1995; Bernhoff et al., 2003). However, large portions of the world potential wave energy resources are found in sheltered waters and calmer seas, which often exhibit a milder, but still steady wave climate (Soerensen et al., 2009). Examples are the Baltic Sea, the Mediterranean and the North Sea in Europe, and ocean areas closer to the equator (Bernhoff et al., 2003). The wave energy contribution from sheltered waters has been little investigated, but there have been many attempts to successfully convert the irregular wave energy into electricity (Glendenning, 1978; Thorpe, 1992, 1998; Boud 1999).

This paper presents an overview of some of the main developments in wave energy and their implementation to Agios Efstratios, the first greek green island, in Aegean sea. It concentrates on devices for which new data have been produced since 2009. It presents the technical characteristics of each device and their economical valuation, which includes the capital cost, operation and maintenance cost, payback period, cost of electricity and life cycle.

The methodology, which is followed, consists of two parts. In first part, it is examined the technical characteristics of the device and if it's efficient in the place, we have chosen. It's taken into consideration the wave height, depth of water, wind velocity and the annual output. If the device is efficient and productive, then we continue in the second part of methodology, where the economic characteristics are examined. If a device meets the requirements then it's appropriate for implementation in Agios Efstratios.

The review methodology indicates that wave energy could become a useful source of energy. The results show that wave energy is already economically competitive and has good prospects of being commercially competitive with further R&D. But, in Agios Efstratios only a restrictive number of the examined devices could be implemented, due to the shallow water and the small wave power. However, the more promising offshore devices are still at the assessment stage.

Keywords: wave energy, economical valuation, technical characteristics, Agios Efstratios

1. Introduction

Nowadays the need for new energy sources became more urgent. Traditional methods of energy production are contributing to serious environmental problems. Renewable energy sources could provide a solution to the problem, as they are inexhaustible and have less adverse impacts on the environment than fossil fuels.

There are many types of renewable energy that can replace the use of fossil fuels (e.g. oil and coal). Nowadays, the most widespread exploitable renewable energy sources are wind and solar. Wave energy is one of the most promising sources, as demonstrates a relatively high power density. Wave power generation is not currently a widely employed commercial technology although there have been attempts at using it since at least 1890 (Miller, 2004).

The energy from waves alone could supply the world's electricity needs. Wave energy contains roughly 1000 times the kinetic energy of wind (Kumar, 2007). Wave energy varies as the square of wave height whereas wind power varies with the cube of air speed. Water being 850 times as dense as air results in much higher power produced from wave averaged over time. The total power of waves breaking on the world's coastlines is estimated at 2 to 3 million megawatts.

The theoretical global ocean energy resource is estimated to be on the order of (IEA, 2007):
* 2.000 TWh/year for osmotic energy

* 10.000 TWh/year for ocean thermal energy (OTEC)
* 800 TWh/year for tidal current energy
* 8.000 – 80.000 TWh/year for wave energy

This theoretical potential is several times greater than the actual global electricity demand, and equivalent to 4000 – 18000 MToE(million tons of oil equivalent).

In some locations, the wave energy density can average 65 megawatts per mile of coastline (Wave Energy, 2010). In the Mediterranean basin, the annual power level off the coasts of the European countries varies between 4 and 11 kW/m, the highest values occurring in the area of the south-western Aegean Sea (Clement et al., 2002). This area is characterized by a relatively long fetch and high wind energy potential. The entire annual deep-water resource along the European coasts in the Mediterranean is of the order of 30 GW, the total wave energy resource for Europe resulting thus to 320 GW (Clement et al., 2002). The problem is how to harness wave energy efficiently and with minimal environmental, social, and economic impacts.

Even though ocean waves is a substantial energy source, with no fuel costs, a high power density and high utilization over the year, wave energy conversion is often neglected on technological grounds. There are numerous suggestions on how to convert wave energy into electricity in the literature. Some of these are currently being tested in different parts of the world. The broad majority of these approaches use involved interfaces to match the low speed reciprocal wave motion to a conventional electrical generator (Leijon et. al., 2006).

This paper analyzes thirty wave energy devices. It presents the way they function as well as their application and economic valuation in Agios Efstratios, the first greek green island. In section 2 it is presented the state of the art. In section 3 it is described the methodological framework that is applied for the evaluation of the wave energy devices. Section 4 is referred to data collection. Section 5 presents the case study of Agios Efstratios – if the wave energy device is applicable and if it is, the profit of the productivity of each device. Section 6 concludes the paper.

2. State of the art

There are three approaches to capturing wave energy: floats or pitching devices, oscillating water columns (OWC), and wave surge or focusing devices, and energy collection devices can be placed either on the shoreline, near the shoreline, or offshore (Wave Energy, 2010).

Shoreline devices have the advantage of relatively easier maintenance and installation and do not require deep water moorings and long underwater electrical cables (Wave Energy, 2010). The wave energy is less on the shoreline but this can be partly compensated by the concentration of wave energy that occurs naturally at some locations by refraction and/or defraction.

Nearshore devices are situated in 10-25metres of water near the shore. The most common device for this situation is the oscillating water column (OWC). Offshore devices are situated in deep water, with typical depths of more than 40metres. The incidence of wave power at deep ocean sites is three to eight times the wave power at adjacent coastal sites. A range of devices are being trialed for offshore use. Experience of constructing shoreline devices has been poor, with extended schedules and difficulties in providing adequate temporary construction works, (e.g. protection of personnel from waves).

The wave energy converting device placed on the sea bed may be completely submerged, it may extend above the sea surface, or it may be a converter system placed on an offshore platform. The visual impact of a wave energy conversion facility depends on the type of device and its distance from shore. Onshore or nearshore devices could change the visual landscape from one of natural scenery to industrial.

Shoreline and near-shore OWCs were identified in five countries: Scotland, Australia, India, Japan and Portugal (the Azores) (The Carbon Trust, 2005). Of these, presently operational shoreline units are built out of concrete, but steel has been proposed for near-shore devices. All structures have been bespoke designs for particular locations, with the collector geometry a function of the local water depth and wave climate.

3. Methodological Framework

In order to design the methodological framework that is applied in this paper, it is used as base the Methodology for Economic Appraisal that has been developed by Thorpe (1999), with some changes, as it is taken into consideration other aspects such characteristics of location, wave energy machine's lifetime and payback period. The new methodological framework is presented in Figure 1 and described below.

The clearest and simplest measure of the commercial viability of wave energy is probably the predicted cost of electricity produced by a wave energy station in terms of p/kWh (Thorpe, 1999). Although some of these aspects are common to all devices and, as such, can be discussed in general terms under appraisal methodology, other aspects are device-specific.

First Step: Site Selection
Wave energy can be considered as a concentrated form of solar energy. Winds are generated by the differential heating of the earth. As they pass over open bodies of water they transfer some of their energy to form waves (Southgate, 1987). Clearly, the amount of energy transferred, and hence the size of the resulting waves, depends on the wind speed, the length of time for which the wind blows and the distance over which it blows (Thorpe, 1999).

Also, as concern the site selection, it should be taken into consideration and other location characteristics, such as the depth of water, wave height and the distance from the coast.

If the location is appropriate for installing a wave energy device, then it is examined the device selection (second step).

Second Step: Device Selection
If the device isn't applicable to the site, there are two options: either to select another place, or to select another device. If the device is appropriate for the selected place, then they are examined the annual output, the cost of electricity, the cost of capital, the O&M costs, the payback period and finally the profit of the investment. If the profit satisfies the investor, then the wave energy device is appropriate for applying in the selected location, if there is loss or the profit is low, it is examined again the site and device selection

Electrical Output
• *Available Wave Power.* The amount of wave energy available for capture has a strong influence on the amount of energy any device can generate. It is a function of location, water depth and local sea bed topography. This aspect was studied in the project undertaken by the Queen's University of Belfast.

• *Captured Wave Power.* The efficiency with which a particular device captures wave power is a function of the sea state. Most devices have been tested in wave tanks to determine this aspect of their performance. In those cases where no such data are available, theoretical analysis had to be used. The applicability of such data to the performance of full size devices in real seas is one of the most important areas of uncertainty in this review.

• *Maximum Annual Output.* The amount of energy delivered to the grid from a particular device in a given sea state depends on the losses in the power chain (turbines, generators, rectifiers, transformers, transmission lines etc.). Data exist on the relative losses as a function of power level and rating of electrical equipment but often the performance of mechanical plant had to be estimated from theoretical assessments.

• *Actual Annual Output.* The amount of energy predicted by the above calculation assumes that the wave energy scheme functions continuously (i.e. without failure). In practice there will be periods of reduced output due to breakdown and maintenance and an availability model was developed to model these and their effect on electrical output.

Availability: In the context of this assessment, system availability has been defined as the probability of the whole system functioning at any specific time and is therefore taken to include the effects of scheduled maintenance and breakdowns (Thorpe, 1999).

O&M Costs: Good maintenance procedures are essential if any energy technology is to perform successfully. However, in addition to this planned maintenance there will be other, unscheduled outages due to component failure. Therefore, any estimation of annual O&M costs has to encompass both these aspects. This assessment evaluates three main components of O&M costs (cost of spares, repair cost, operational costs).

Annual Costs: There are three main factors which make up the annual running cost of any power station: fuel, repayment of capital costs and payment of recurrent costs such as insurance and O&M. The annual sum involved in repayment of the capital cost of a wave power scheme can be assessed in a number of ways. The approach adopted in this review was that used in previous appraisals, namely amortisation of the capital costs over the complete lifetime of the scheme using various discount rates.

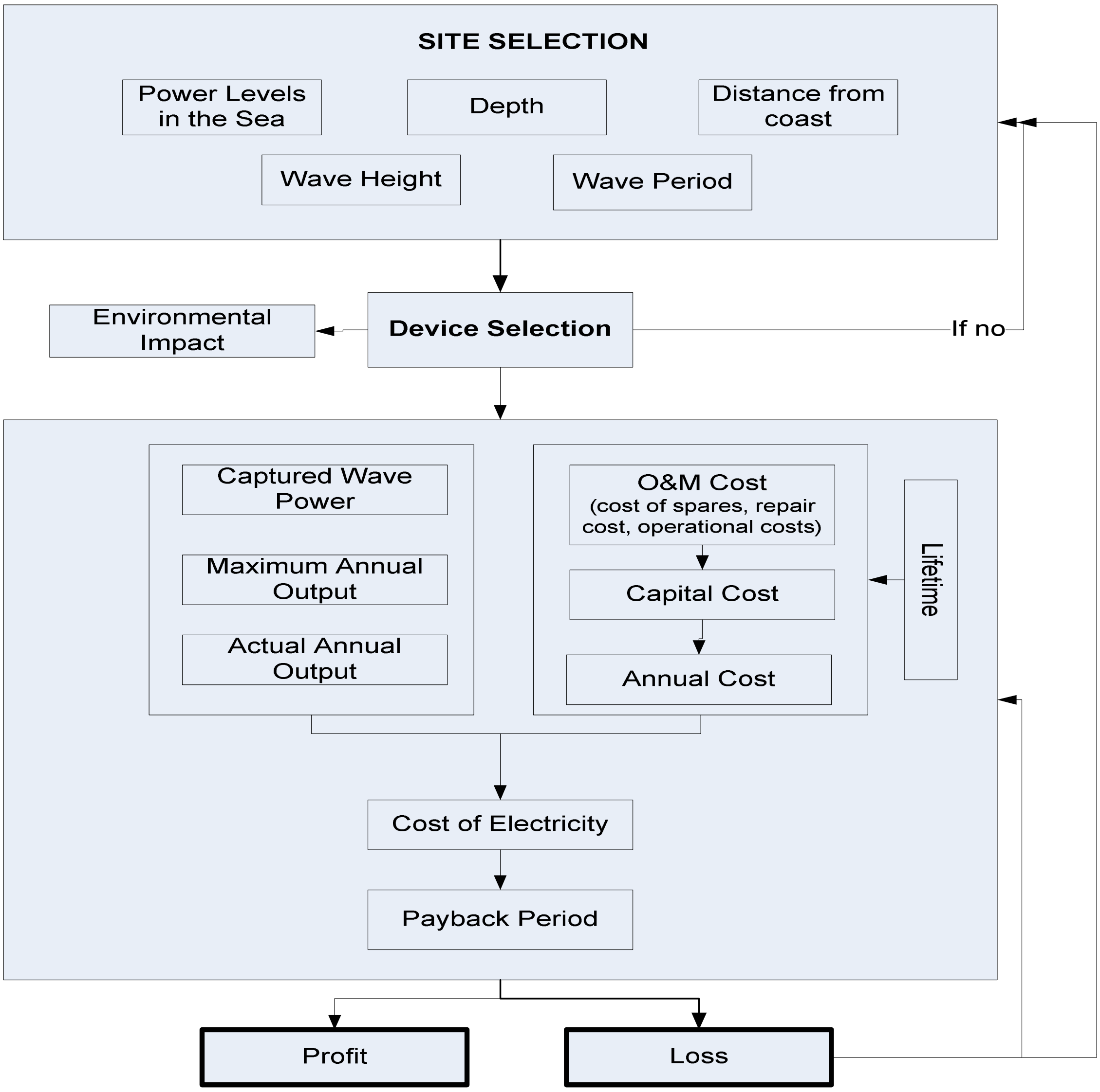


Figure 1: Methodological Framework

4. Data Collection

The aim of this paper is to examine the technical and economic characteristics of a wide range of wave energy devices. It's examined the technology of wave energy devices and their characteristics, and their commercial use˙ examined the costs of construction, the operational and maintenance costs, the payback period, the lifecycle, etc. In order to have all these details of the wave energy devices, the manufacturer companies were called to complete a form referred to the above characteristics. Also, for this purpose were used the web sites of the devices.

5. Analysis

Case Study: Agios Efstratios, the first Greek green island

5.1 Agios Efstratios

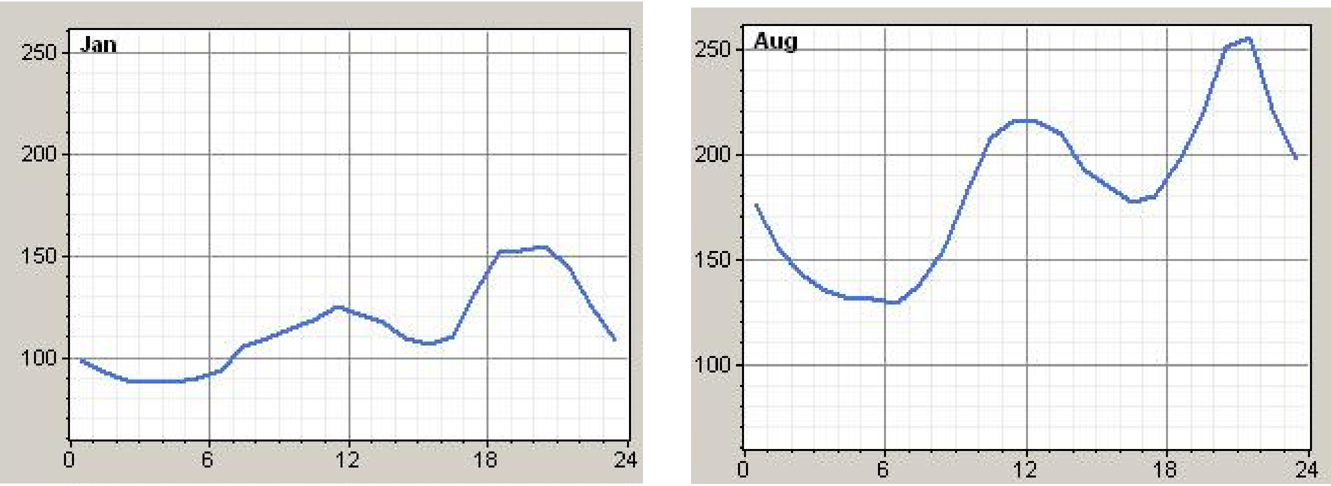
Agios Efstratios is a small island with 250 residents, located between Lesvos and Lemnos, to which it belongs administratively. The geographical coordinates are 39 ° 27'N 24 °58'E. It is the most isolated island in the Aegean sea. The island is shaped like a triangle with unequal the hypotenuse to the West and an area of 49,6 km^2 (Figure 2).The climate is arid, with little rainfall during the winter months and long, hot summers. The landscape is mostly rocky, with scarce and low vegetation.

Athens News Agency(2009) reporteded that, on 4 June 2009, at a two-day international conference in Athens on "Climate Change and Challenges for the Future Generations" under the patronage of UNESCO, Agios Efstratios would soon become the country's first "green" island, entirely powered by renewable energy sources (RES), its residents relying on solar and wind generated energy and moving around the island on bicycles and in electric cars. A €10 million project would be implemented by 2010. Agios Efstratios, could serve as a global model for 100% reliance on

RES. Also, the island is included in the European Union's Natura 2000 network of nature protected areas.

Main characteristics of Agios Efstratios' electricity demand (year 2008) (Ministry of Development, 2009):

- Maximum Electricity Demand 2008: 300 kW (mean), 350 kW (maximum)
- Minimum Electricity Demand 2008: 70 kW (mean)
- Annual Electricity Demand 2008: 1020 MWh
- Mean Electricity Demand per day: Graph 1 (winter and summer)
- Expected RES Output : +150% base year 2008 (power and energy)



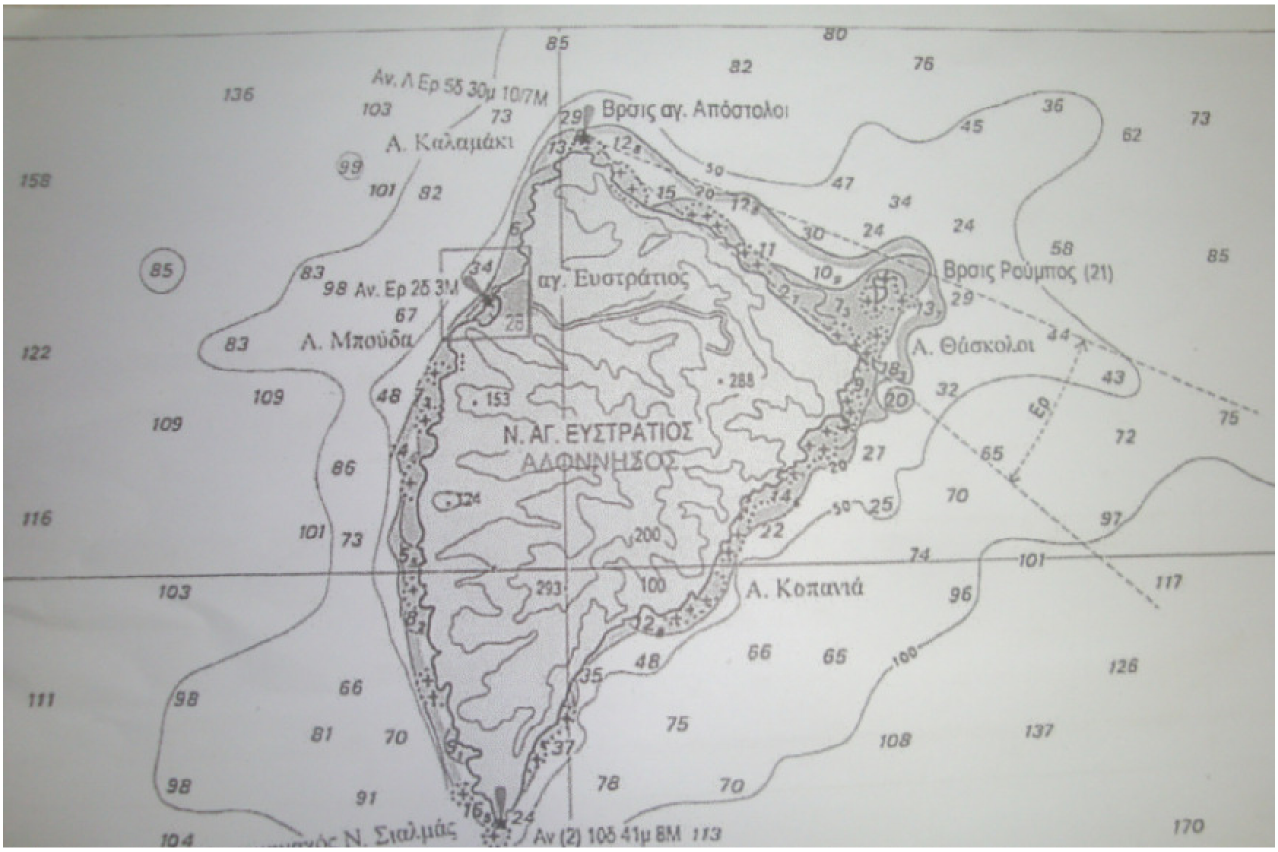
Graph 1: Mean Electricity Demand per day – January and August 2008 (Source: Ministry of Development, 2009)

5.2 Agios Efstratios' Characteristics

Agios Efstratios has an average wave height 0.7m. Specifically, accordingly to each season, the wave height is: 0.7m in autumn is, 1.1m in winter, 0.7m in spring and 0.4m in summer (Picture 1). Sea depth is shown in Picture 2.

The wave height is small enough to implement most of the wave systems that analyzed below. But there are some wave energy devices, which could be applied and be profitable.

Picture 1: Mean Wave Height (left to right: Autumn, Winter, Spring, Summer)



Picture 2: Sea Depth of Agios Efstratios (Source: Police Marine, 2009)

5.3 Analysis

As it is already said, in order to evaluate a wave energy device, it should be taken into consideration both the characteristics of the selected site and of the selected device as well.

Table 1 shows the results from each system's evaluation, when the selected site is Agios Efstratios.

The devices discussed in this section are evaluated on behalf of the criteria that are referred in section 3 (Methodological Framework).

Construction Cost, Cost of Electricity, Output are divided into: High, Medium, Low.

Table 1: Valuation of Wave Energy Devices

Wave Energy Device	**Site Selection: Agios Efstratios** Mean Wave Height: 0,7m (min 0,4m during the summer) Mean Wave Period: 4,4sec. Sea Depth: maximum 170m Wave Power: 20kW	**Economic Valuation** (+)	 (-)
SHORE BASED			
1. LIMPET	Construction cost: €1.34m. Capital cost too high.		×
2. WECA	Immature technology. Not applicable.		×
3. Mighty Whale	Sea Depth: 40m.		×

	Construction cost:€13,5 εκατ.		
4. SARA MWEC	Output: medium Construction Cost: low O&M Cost: low	√	
5. MAWEC	Output: low (Wave Height: 0,6cm, Wave Period: 0,9sec – collects 75%wave energy -> output 16%) Construction cost: low		×
6. Oceanlinx	Ideal for oceans, not for the Aegean sea. Wave Height: 2m, Wave Period: 0,7sec.		×
7. Sperboy™	Construction Cost: low Cost of Electricity: €67-187/MWh Sea Depth: 50m Location: SE of the Island	√	
8. WaveMaster	Construction Cost: high O&M Costs: high Wave Height: 5m		×
2. ABOVE WATERLINE WITH OVERTOPPING			
1.SSG	Construction Cost: high Output: low Wave Height: 4m		×
2.Wave Dragon	Immature technology Sea Depth: 6m (0,4kW/m) Not appropriate for the site -> low mean wave height		×
3. ABOVE WATER			
1. LabBuoy	Ideal for the selected location. Cost of Electricity: low (€0,07-0,09/kW)	√	
2. SDE	The most ideal for the selected site. Construction Cost: €600.000 Cost of Electricity: low (€0,02/kW) Payback Period: 3 years	√	
3. WET EnGen™	Applicable to the selected site Construction Cost: low Output: 10-15kW/m	√	
4. Trotman Unit	Sea Depth: 12m on coast		×
5. Wave Star©	Distance from coast: 10-20km Cost of Electricity: €0,33-0,8/kW O&M Costs: low (every 10years) Lifetime: 50years	√	
6. AquaBuoy	Ideal for open seas, not for the Aegean sea.		×
7. Manchester Bobber	Sea Depth: 30-60m		×
8. CETO™	Sea Depth: 15m Cost of Electricity: €0,084/kW Output: 23,6kW per 1m wave height It can be used to produce fresh water through reverse osmosis.	√	
9. SyncWave™	Construction Cost: Medium Cost of Electricity: €0,03-0,05/kW O&M Costs: Low	√	
10. Power Buoy®	Ideal for open seas.		×
11. OWEC®	Ideal for open seas and oceans.		×
12. FWEPS	Its construction depends on the characteristics of the selected site. Construction Cost: low O&M Costs: low	√	
13. Brandl Generator	Construction Cost: low (€1300/kW) O&M Costs: low Electricity Cost: €0,033/kW Profit: 8% of capital cost per year. Payback Period: 10years	√	
14. WaveBlanket	Wave power: 30-70kW.		×
4. ABOVE WATERLINE WITH HYDRAULIC PTO			
1. Pelamis P-750 WEC	Wave Power: 55kW/m. Cost of Construction: €190m.		×

	O&M Costs: €8,9m/year		
2. DEXA	Distance from coast: 16km Cost of Capital: €13.130.000 O&M costs: €9.248.000 for 50years Cost of Electricity: €0,068/kW.		×
3. Crestwing	Immature technology.		×
4. McCabe Wave Pump	Wave Height: 7m		×
5. Floating Wave Generator	Its construction depends on the characteristics of the selected site. Construction Cost: low (€3.400-6.800). Cost of Electricity: €0,034/kW Payback Period: 20-40 days	√	
5. BOTTOM MOUNTED			
1. Oyster™	Sea Depth: 10m Wave Power: 15kW/m Construction Cost: €1.200.000 O&M Costs: low (easy to reach)	√	
2. WaveRoller	Wave Period: High It is applied in Crete (0,9-1,1m), where the annual output was		×
3. bioWAVE™	Not enough information in order to evaluate.		×

6.Conclusions

Last decades, the technology of wave energy devices has improved significantly, but still is lacking behind compared to other RES devices.

The construction of a wave energy device is usually too expensive and the cost of capital in order to apply them in a site is too high. Moreover the payback period is too long, as in most cases is more than 17 years. Also, the O&M costs are too high.

On the other hand, the environmental impact is low as in the most of them are used only environmental friendly materials. Also, they provide minimal obstruction for marine life.

In conclusion:

- In order to maximize the profit of such an investment, it should taken into consideration not only the selected site, but the proper device, with the maximum output as well.

- The cost of electricity is usually bigger than this of other RES. The mean cost of electricity in EU is €0,030-0,080/kWh, whereas the mean cost of electricity for wave energy is €0,06-0,10/kWh

- The wave power in greek seas is low and the majority of the wave energy devices, that analyzed above, are inappropriate, with low output.

- Wind and solar energy devices are more productive and more profitable than wave energy in Greece.

- Although, wave energy can provide big amounts of electricity, the technology is still immature. Further R&D is needed in order wave energy to become commercially competitive.

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Experience of Renewable Energy Sources use in Uzbekistan.

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Abstract

Renewable Energy Sources (RES) are widely discussed but their penetration in Central Asian countries is still low. The article presents a brief overview of RES policy and experience of RES usage in Uzbekistan, lessons learned, existing barriers for RES implementation, and possible solutions.

A way to overcome existing barriers is presented on the example of an on-going RES project financed under a EuropeAid programme. The project involves an integrated approach through the use of various RES technologies for sustainable development, creation of jobs and improvement of living conditions.

Description of RES technologies for the supply of electricity, heat and hot water to small enterprises and selected domestic consumers in Kamar village of Shahrisyabz region in Uzbekistan is followed by an analysis of the environmental impact of suggested installations.

Key Words
Renewable Energy Sources, CO_2 emissions, sustainable development

1. Introduction

Renewable Energy Sources (RES) applications are currently widely discussed in the Central Asian countries, while academic research in this field was on-going long before RES had been accepted by the world community as one of the ways of reduction of greenhouse gasses emission as well as pollution. Nevertheless, RES penetration in the Central Asian countries is still low. There is a number of reasons for that, the main one being the low tariffs of electricity generated by the conventional power plants. Another reason is the comparatively low prices for fuel, due to reach gas and oil deposits in several Central Asian countries and the dominating social policy paradigms in all Central Asian countries.

In this article a brief overview of the RES policy and experience of RES usage in Uzbekistan, lessons learned, existing barriers for RES implementation, and possible solutions are briefly analysed and discussed. Additionally, a way to overcome existing barriers demonstrated on the example of an on-going RES project financed under a EuropeAid programme is presented. The project involves an integrated approach through the use of various RES technologies for sustainable development, creation of jobs and improvement of living conditions. Description of RES technologies for the supply of electricity, heat and hot water to small enterprises and selected domestic consumers in Kamar village of Shahrisyabz region in Uzbekistan is followed by an analysis of the environmental impact of suggested installations. The projected financial and economic results of the Cooperative, which was created in Kamar village in the framework of the project are also included. Finally, the conclusions are made on the basis of an analysis of the experience collected so far.

2. Brief overview of the RES policy and projects in Uzbekistan

Since eighties there are a number of important scientific and research institutes in Uzbekistan involved in development of various applications on the basis of renewable energy sources (UNDP, 2006). The Institute Phisika-Solntse (Phisics-Sun) of the Academy of Science of the Republic of Uzbekistan, which operates the Unique Solar Furnace for melting metals, with a capacity of 1 MW and the Physical Technical Institute, are the two leading institutes with research activities in the field of RES. Uzbekistan has the best preserved system of meteorological stations developed in the framework of operation of the Central Asian Scientific Research Hydrometeorological Institute (CASRHI) stations and establishes new stations in the territories potentially reach in RES (Abdullaev, Isaev, 2005). There are also some industrial enterprises that started production of RES equipment. Among those there are: Kurilishgelioservcice LLC, founded by the Physical Technical Institute, Zenit, Foton and Algorythm (UNDP, 2006).

Since 2000 some demonstration projects were implemented with participation of international donors. Thus in 2000-2001 in the framework of the EU Tacis programme a solar heating system with 46 m^2 of solar cells integrated into the local boiler-room was installed in one of the multy-store houses in Tashkent (UNDP, 2007). This project reported annual saving of 2260 m^3 of natural gas. A complex of Hybrid Solar Wind equipment was constructed and put into experimental operation in 2000 in the framework of the EU INCO-Copernicus Program (D.A.Abdullaev, R.I.Isaev, 2005). In 2003-2004 the Danish Government and the Scandinavian Trust Fund in cooperation with UNDP and Tashkent City Khokimiat had provided technical assistance to the Foton Enterprise for production of solar cells from the imported spare parts. A demo-site of this project included installation of a solar heating boiler with solar cells of Greek, Danish and Uzbek production. In 2005 the Physical Technical Institute in association with the Institute of Nuclear Physics implemented UNESCO funded project, had produced and put into operation a self-contained photovoltaic power supply and water treatment system (assembled from the spare parts available on the local market) in an isolated community of Ayozkala-Tur (Karakalpakstan). Another project in Karakalpakstan was implemented by the Technology Transfer Agency under UNDP Clean Energy for Rural Communities; twenty five solar electric systems were put into operation for covering of some communal needs and pumping up underground water (UNDP, 2006). In 2006-2008 two biogas reactors of 60 m^3 each with total capacity of daily biogas production of 300 m^3 were installed by the Technology Transfer Agency under UNDP at Milkagro factory in Zangiatinskyi rayon of Tashkent Viloyaty.

Lessons learned as a result of RES implementation projects are as follows:

- Although the majority of the territory of Uzbekistan is considered as territory with the wind speed lower than 3-5 m/sec, hollows and valleys of the mountain rivers, possess quite high wind energy potential. Especially in Tashkent region this potential can be easily utilized due to well-developed transport network (D.A.Abdullaev, R.I.Isaev, 2005);

- Solar energy is not a feasible source of energy in Uzbekistan, even for water heating in industrial applications. Nevertheless, there are some policy measures that could change the situation and make solar energy more attractive – development of legal basis and initiatives for participation in Clean Development Mechanism, cooperation with donor organizations for development of RES technologies affordable by local consumers, increase of awareness among entrepreneurs about emerging opportunities (UNDP-1, 2007);
- Legal measures for development of RES applications could include increase of penalties for emissions, introduction of ecological standards, and introduction of obligation to purchase energy from renewable energy sources (UNDP-2, 2007);
- Uzbekistan possesses quite big resources of gas, however, it is important that measures directed at gradual introduction of solar systems in district and water heating as well as energy supply from RES installation at the remote locations can free additional amounts of gas for export (UNDP-1, 2007).

Barriers for RES Implementation in Uzbekistan

Some barriers to the implementation of RES projects in Uzbekistan identified from the literature on the subject (UNDP, 2006, UNDP-1, 2007, UNDP-2, 2007 D.A.Abdullaev, R.I.Isaev, 2005), include:

- Low prices of conventional energy sources and existing power and fuel balance in the country;
- Lack of legislative support;
- Low purchasing power of population;
- Lack of financing and absence of investors interested in investing in these technologies
- Absence of a united coordinating state body responsible for RES development in the country and lack of information and public awareness

3. Description of the on-going RES project

From 2009 in the framework of the EU Institutional Building and Partnership Programme a Greek Non-Government organisation ANCE is implementing the project “Creation of new jobs and improvement of living conditions through the establishment of a rural cooperative and the supply of renewable energy” in cooperation with the Association of Farmers of Uzbekistan, at the remote village of Kamar in the Shakhrizabs region of the Kashkadarya province. The project supports job creation/income generating activities at local level (creation of small enterprises managed by the community) through access to renewable energy services.

The Kamar Project is different from the other projects mentioned above, as it is aimed not only at demonstrating of the possible technical solution for operation of RES based equipment in a remote village, but it attempts to introduce an integrated solution for improvement of life conditions in the whole village. The partial provision of electricity from RES to the village of Kamar will enable the development of economic activity and increase in employment that will lead to the improvement of living standards, and will ensure sustainable economic growth and the reduction of poverty. The use of renewable energy will also have beneficial effects on the levels of health, and potentially education and literacy of the local population and will also contribute to the protection of the environment.

The Cooperative (Shirkat) Kamar had been registered on the 11th of March 2010 and functions under the auspices of the Administration of the Kamar Citizens General Meeting (AKCGM). Kamar Cooperative had received the RES equipment from the project and concluded individual contracts with the members (small enterprises or cooperatives) on the targeted use of this equipment. The following services are provided by the project in cooperation with AKCGM to each member:

- accounting and legal support
- office and/or production space renting
- RES equipment
- electricity supply
- marketing and promotion
- training

Depending on the level of support provided by the Cooperative, two types of membership are foreseen: 1. Full members enjoy all services, while Associated Members receive RES equipment, electricity supply, marketing and promotion, training. The total planned number of the Cooperative’s staff is 29 persons.

The investment needed for the Kamar Cooperative start-up amounts to Euro 85,300.

The breakdown of this amount and the sources of funding are presented in the Table 1. This amount is covered by the project (Euro 80,600) and jointly by AKCGM and Kamar inhabitants-members of the Cooperative (Euro 4,700).

Table 1. Total investment needs for the Cooperative start up

Investment	Amount Euro	Sources of funding
Total start up investment	**85,300**	
Full members	2,000.00	
Dried fruits production	1,000.00	costs of equipment covered by the cooperative members
Photographic shop	300.00	
Hairdressers	100.00	
Sewing workshop	500.00	
Phone payment point	100.00	
Legal/professional fees	40	paid by the project for one month involvement of a local legal expert
Equipment	60,000.00	provided by the project
Equipment Installation	20,000.00	
Associated Members	2,700.00	
Bathhouse	1,000.00	pre-establishment costs of repairs/construction and others are covered by the members/owners; legal/professional fees are included in the costs for full members
Canteen	500.00	
Vegetable oil production	300.00	
Flour mill	400.00	
Fertilisers	500.00	
Additional cash for covering first six months deficit	560	Was secured prior the start of operations of the Cooperative

The main products of the Kamar Cooperative include dress making, dried fruits and food. The Cooperative also provides the following services: photography, organisation of events and celebrations (room, catering services, etc); on-line telephone bill payments, public baths, hairdresser, electricity supply for oil extraction, flour production, and biological fertilizers.

4. RES installations for the supply of electricity and hot water to small enterprises operating in Kamar village

4.1 Micro hydro power plant

In general, the process of selecting the site for hydro generation and estimating its potential is rather complex and time consuming. Under the current project, in which both funds and time are limited, a site for construction of the micro hydro plant was selected in a location near an existing water mill. The topographical conditions in this location and the use of the existing open canal (supplying water to the flour mill which is operating only for few days every year) required a minimum of construction works.

The technical characteristics of the micro hydro plant that includes water turbine (propeller type), asynchronous generator and an automatic regulation unit are shown in Table 2.

Table 2. Technical characteristics of the suggested micro hydro plant.

Output power, kW	Head, m	Discharge Rate, m^3/s	Output Voltage, V	Frequency, Hz
Max 10	Less than 5	Less than 0.15	230 3 phase	50

4.2Solar photovoltaic systems

Because of the interrupted electricity supply in the Kamar village 23 stand-alone PV modules were provided. Nineteen PV modules were provided to 19 selected poor families, 1 PV module to the Building of Kamar Village General Meeting, 1 PV module to the canteen and 1 PV module to the public baths building of the village. Those PV systems can cover basic loads of approximately **200 W** each for about **8 hours** on average. Each PV system consists of the following equipment:

- **PV Module with 160 W rated maximum power** – to convert sunlight into DC electric power
- **Inverter with 500 W maximum power** – to convert DC power into standard AC power whenever the electricity supply from the grid is interrupted
- **12 Volts deep-cycle Battery** with capacity **150 Ah** – to store energy produced by the PV Module
- **Charge Controller** – to prevent battery overcharging and prolong the battery life of the PV system

In Figure 1 a simplified block diagram of the PV system used is shown.

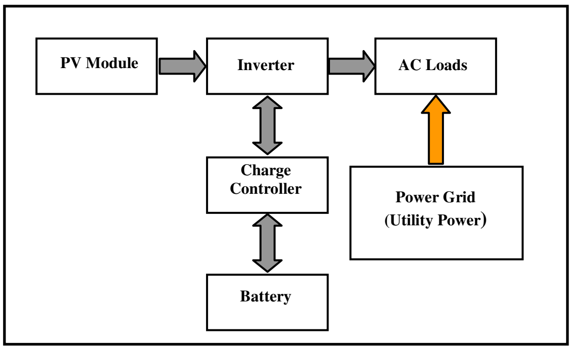

Figure 1. Simplified block diagram of the PV system used

4.3 Wind-driven generators

Due to the absence of meteorological data (in particular local wind speeds and wind directions) for the region of Kamar village it has been decided to proceed with a limited degree of accurate estimation-assessment of the local wind potential. As a result, two wind turbines each with max rated power **of 1 kW**, of light construction, designed to begin producing power at wind speeds **3 - 4 m/s** and mounted to towers with **8 m** height were installed. The optimum location to install the wind turbines has been selected in a flat land on the top of a small hill with no structures around and well protected from lighting, since at a distance less than 200 m there is an open air power distribution station with lighting protection.

In Figure 2 a simplified block diagram of the wind turbine system used is illustrated. The system is battery backed with utility grid connection to the basic AC loads.

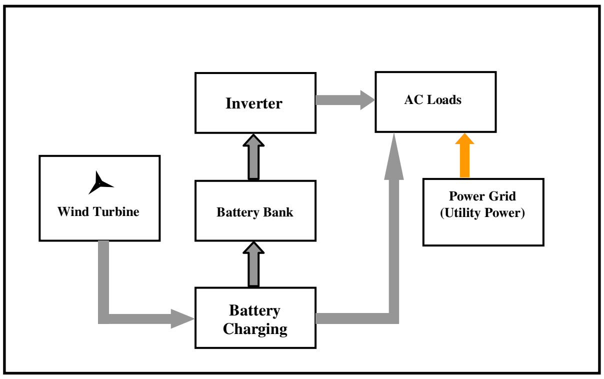

Figure 2. Simplified block diagram of the wind turbine system used

In this system when the wind is blowing the electricity stored in a bank of batteries consisting of four batteries of **200 Ah/12 V** each. The stored electricity can be used when there is no wind or during interruptions in the electricity supply from the power grid. The bank of batteries provides autonomy of approximately **9 kWh daily**.

Thus, the small scale 'wind farm' consists of the following equipment:

- **Two Wind Turbines with rated maximum power of 1 kW each –**single phase, connected in parallel
- **Towers with height 8 m –** to mount the Wind Turbines
- **Bank of Batteries of four 200 Ah** – to store energy produced by the wind turbine
- **Battery Charge Controller –** to connect and disconnect wind turbine in response to the battery voltage
- **Inverter with 2 kW maximum power –** to convert DC power stored in batteries into standard AC power

Large and deep foundations for the towers were constructed to withstand high speed winds since there are no available wind speed data for the region.

4.4 Solar water heaters

The climatic conditions in Uzbekistan in general are suitable for the use of Solar Water Heaters to generate hot water from the sun. The closed-loop solar water heaters, for supplying hot water the public bath facilities and the hair-dresser shop operating within the premises of the of Kamar Village General Meeting building, are used. More specifically three units have been purchased, two with storage tank capacity of **500** and **200 liters** for the public baths and another of **100 liters** for the hair-dresser shop. All storage tanks are equipped with **3, 1** and **1 kWh** backup electric heating elements respectively. The solar heaters are installed on the flat roofs of the buildings and function satisfactory with the local water flows and pressure without circulating pumps or additional electricity for pumping. Attention was paid to proper insulation of every exposed pipe of the system.

Small biogas plants (SPBs)

The cylindrical type was selected as the more favorable design for small size biogas plants. In addition to the production of biogas, the effluent bio-slurry produced can be used as fertilizer.

The installation of small biogas plants for cooking has started for about ten households in the Kamar village. Data on the available average quantity of dung per household were not available. Therefore the capacity of the biogas plant on the basis of the following considerations was proposed. On average each person requires **0.4 m^3** of biogas for cooking each day and five- member family would require for cooking approximately **2 m^3** of biogas daily. Therefore a small biogas plant of cylindrical type with a production **2** to **3 m^3** of biogas per day should cover the average family needs for cooking. Table 3 bellow gives the relevant technical information for the biogas plants selected.

Table 3. Technical information for small biogas plants.

Biogas production per day, m^3	Required dung per day, kg	Volume of the digester, m^3	Volume of the gas cap, m^3	Fertilizer production per day, kg
3	60	5.0	2.1	6-12

The recommendation with regard to cthe onstruction of the biogas plants included the following:

- away from the drinking water supply,
- in the sun,
- close to the source of the manure, and
- as close as possible to the point where the biogas will be used.

4.5 Solar fruit dryers

In general small size solar fruit dryers are difficult to be found in the market. Therefore, the possibility of construction locally of a simple small size solar fruit dryer as the one described below was secured. The capacity of this dryer is **15 to 20 kg** of fruits within **3 to 4 days**. It is assumed that during hot season **three** such units can process **15 to 20 kg** of fruits on a daily basis.

Figure 3 illustrates the simple solar fruit dryer construction used. The units are situated outside with the solar panel facing south. The solar rays travel through the glass and are absorbed by the black sheet of the solar panel. Fresh air entering through the opening is heated by the black painted metallic sheet of the solar panel and then rises to the dryer. The drying fruits are placed on trays made from metallic frame to support a stretched woven mesh which allow the hot air to pass. The roof of the dryer is raised so that the air can leave. The framework structure is constructed from metal and covered by transparent panels of rigid plastic and the opening is covered by a mosquito net which allows the air to pass but not insects.

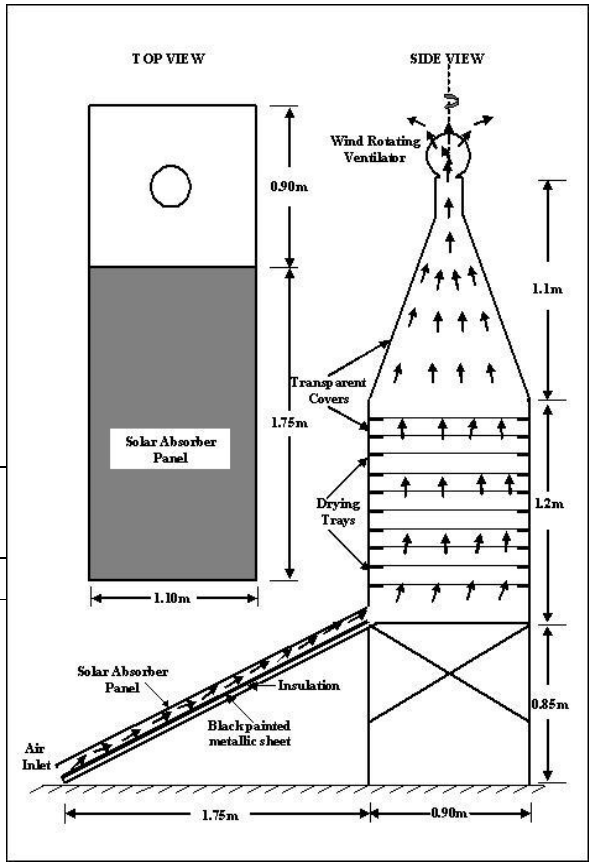

Figure 3. A simple solar fruit dryer construction.

5. Energy production from RES suggested installations and their impact on Climate Change

The total electricity capacity installed from the micro hydro, the solar photovoltaic panels and the wind generators is approximately 11 kW as analytically shown in Table 4.

Table 4. Energy Production from RES suggested installations

RES technologies	Capacity	No of units	Average annual electricity production
Micro hydro power plant	10 kW	1	**51,840 kWh**
Solar photovoltaic systems	0.16 kW	23	**6,182 kWh**
Wind-driven generators	1 kW	2	**7,200 kWh**
Solar water heaters	500 liters 200 100 liters	1 1 1	**2,400 kWh**

Small biogas plants (SPBs)	3 m^3/day	10	**64,800 kWh**

This small installed electricity capacity from RES will produce approximately 65,222 kWh annually. Some 2,400 kWh must be added to the total electricity saved annually from the use of solar water heaters through the avoided use of their boosting electric heating elements for at least 120 days annually due to the high potential of solar energy utilization during the summer months. Thus, when all the technically feasible RES technologies are fully operating in Kamar village, annual electricity saving of approximately 67,622 kWh from the main greed will be achieved. Using the conversion factor of 0.68 kg of carbon dioxide emissions per kWh of electricity produced by power plants in Uzbekistan (UNDP-1, 2007) the estimated annually avoided CO_2 emissions is 45,984 kg or approximately 46 tons.

Electricity Production from RES	
Annual Avoided Electricity Consumption from Grid	**Annual Avoided CO_2 Emissions**
67,622 kWh	**46 metric tons of CO_2**

With SBPs a renewable source of energy (biogas-methane) is captured, which has an important climatic twin effect:

1. The use of renewable energy reduces the CO_2 emissions through a reduction of the demand for fossil fuels as well as branches of trees, bushes, leaves and dried dung.

2. At the same time, by capturing uncontrolled methane emissions from dung the second most important greenhouse gas (methane) emissions are reduced.

Additionally, after the operation of the SBPs in the ten households the annual production of 28.8 tons of bio-fertilizer will result to a considerable reduction of CO_2 emissions from the avoided production of chemical fertilizer.

When 10,800 m^3 of biogas is burnt emissions of (10,800 m^3 ×1,6 kg CO_2/m^3) 17,3 tons of CO_2 would be produced. Estimation of the CO_2 emissions from the fuel mix used currently in the Kamar village is not possible due to limited available information with regard to the mixture of wood and dung used. However, it is considerably small compared with 44 tons of CO_2 that produced for example from the equivalent use of 64,800 kWh of electricity for cooking.

Heat Production from SBPs	
Annual CO_2 Emissions from 10,800 m^3 of Biogas use	**Avoided CO_2 Emissions from equivalent use of Electricity**
17,3 metric tons of CO_2	**44,04 metric tons of CO_2**

6. Projected financial and economic results

Break-even point is the moment when the Cooperative will achieve the level of revenue beyond which it will generate a surplus. As follows from the monthly cash flow projection calculations presented in the Figure 4, the break-even point of the Kamar Cooperative is reached during the seventh month if 100% of monthly sales planned for the first year of operation are achieved.

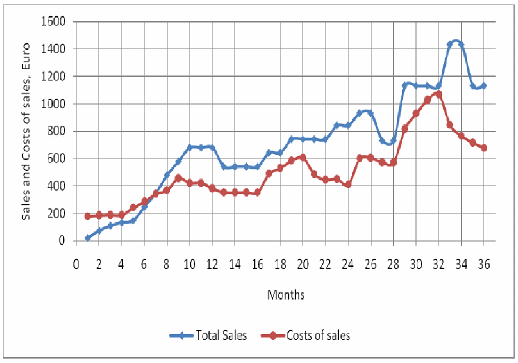

Figure 4 Monthly Sales and Costs of Sales of Kamar Cooperative for the first three years

The cash flow projections (after taxes) for the Kamar cooperative for the first three years of operation are as follows:

Years	**1**	**2**	**3**
Cash flow projections (after taxes), Euro	523,88	2.677,88	4.383,17

The Cash flow projection is calculated as the Company's operating cash flow minus its capital expenditures. This essentially refers to the cash the cooperative is able to use after taking into account its capital expenditure needs for its expansion plans. This cash can then be utilized to generate growth for the business.

In the forecast income statements for three years, the depreciation was deducted from the cash flow projections. As a result, the

Cooperative demonstrates loss during the first year of operation.

Years	1	2	3
Net surplus (loss) after taxes, Euro	-1,076.12	1,077.88	2,759.98

However, the depreciation is a non-cash expense that reduces the value of a fixed asset over the fixed asset's useful life. Both depreciation and amortization are accounting concepts and should be added back into a cooperative's profits because they require no immediate cash spending.

Working capital reveals more about the financial condition of a business than almost any other calculation. It tells what would be left if a company sold all of its short term resources, and used them to pay off its short term liabilities. The more working capital, the less financial strain a company experiences. By studying a company's position, it can be clearly seen if it has the resources necessary to expand internally or if it will have to take a loan. From this point of view, the Kamar Cooperative projections seem to be reasonably good.

Years	1	2	3
Working Capital, Euro	1,340.55	2,917.88	6,533.57

The working capital and net surplus (loss) after taxes for the first three years are presented in Figure 5.

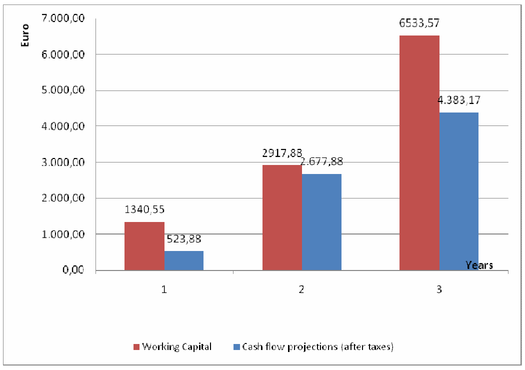

Figure 5 Kamar Cooperative working capital and cash flow projections after taxes for the first three years

The Cooperative will accumulate <u>Euro 7.584,93 as total retained earnings after tax by the end of the third year (2,761.74 after depreciation was deducted)</u>. This amount seems to be rather small in comparison with the total investment of Euro 85,300, which was made. However, the new working places will be created boosting the business development in Kamar. Furthermore, the quality of life of inhabitants of Kamar will be improved drastically.

Conclusions

The project is on-going, as it has been mentioned above. Some results achieved so far are as follows. The Kamar Cooperative had been officially registered and the business plan for the three years of the Cooperative operation had been prepared. The purchase of the RES equipment and the installation of equipment is practically finished.

Some **specific technical, economic and environment protection related conclusions** that can be made at this stage include the following

<u>Technical</u>

1. Due to budget limitations the selected equipment does not cover completely the existing energy demand in Kamar village. Nevertheless, the variety and the number of the RES installations selected, as well as the fact that they are used in parallel with the existing problematic electricity supply grid (with prolonged daily interruptions in electricity supply) make the project a good demo site where the advantages of RES utilisation in the rural areas could be demonstrated fully.

2. The design and construction of the necessary infrastructure for installation and operation of RES installations is at the final stage and proper conclusions will only be possible after the equipment monitored for a year or so. For that reason the cooperation with Tashkent State Polytechnic University had been secured and the relevant work plan agreed. The results of the monitoring are important, because this is the first example of sustainable use of practically all RES technologies in a rural area of Uzbekistan.

<u>Economic and social</u>

3. With the additional electric power from RES the quality of life of inhabitants of Kamar is improved and new working places are created boosting the business development.

4. With start of operation of biogas installations the sanitary conditions should be improved drastically. The use of biogas, which is a clean fuel, as replacement of fuel wood and dung will reduce the levels of indoor air pollution which is a major cause of ill-health

(respiratory and eye infections) for those living under these conditions.

Environment protection and climate change

5. With RES technologies in full operation in Kamar village, annual electricity saving of approximately 67,622 kWh from the main greed will be achieved along with the estimated annually avoided CO_2 emissions of **46** tons.

6. With SBPs a renewable source of energy (biogas-methane) is captured, which has an important climatic twin effect:

- The use of renewable energy reduces the CO_2 emissions through a reduction of the demand for fossil fuels as well as branches of trees, bushes, leaves and dried dung.
- At the same time, by capturing uncontrolled methane emissions from dung the second most important greenhouse gas (methane) emissions are reduced.

7. Additionally, with the SBPs in the ten households the annual production of 28.8 tons of bio-fertilizer result to a considerable reduction of CO_2 emissions from the avoided production of chemical fertilizer.

On the basis of the results of the project, as well as information presented above, **the overall conclusion** is the following.

The integrated approach to RES installations implementation for rural development in Uzbekistan leads to finding solutions for solving urgent social, economic and environment protection issues. Thus, improvement of life conditions in the areas can be achieved along with the development of economic activity and increase in employment that in turn will lead to the further improvement of living standards, and will ensure sustainable economic growth and the reduction of poverty. The use of renewable energy will also have beneficial effects on the levels of health, and potentially education and literacy of the local population and will also contribute to the protection and conservation of the environment. The RES installations are still not feasible from the conventional economic point of view; however, the social needs, sustainable development and environment protection issues are enough strong arguments that can help find the solutions to the economic problem.

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Are membrane gas separation processes able to meet the product specifications of post combustion CO_2 capture?

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Abstract: Membrane-based CO_2 capture from coal fired power plants is an emerging technology. In comparison to amine absorption, membranes potentially offer greater energy efficiency and operation without additional chemicals. The majority of the relevant publications focused so far on CO_2 enrichment and performance indicators such as energy consumption and CO_2 recovery, but neglected the impact of co-captured species like O_2 or SO_2. Hence, this paper evaluates performance characteristics of single- and multi-stage membrane processes while taking into account co-captured species. Single-stage membrane processes are unable to achieve the required CO_2 enrichment in conjunction with reasonable recoveries. In contrast, two-stage processes may achieve the required CO_2 enrichment at reasonable recoveries but, fail to meet strict concentration limits on co-captured species.

Keywords: CO_2 capture, membrane process, CO_2 purity

1. Introduction and objective

Amine absorption is presently considered the best available technology for post combustion CO_2 capture from coal fired power plants. However, recent publications indicate that the energy requirement for solvent recovery might result in overall power plant efficiency losses up to 16%-points [1]. Furthermore, chemical solvent degradation leads to continuous solvent replacement and thus additional material and disposal costs. Membrane systems, in contrast, operate without any additional chemical. Moreover, they may offer higher energy efficiencies, greater operational flexibility and simplicity of operation and maintenance [2-3]. The increasing number of research projects and publications in this field illustrates the increasing interest in membrane technology for CO_2 capture. The majority of the relevant publications focused so far on CO_2 enrichment and performance indicators such as energy consumption and CO_2 recovery, but neglected the impact of co-captured species like O_2 or SO_2. Consequently, this paper investigates performance characteristics of membrane processes while taking into account co-captured species. Subsequent to the definition of the boundary conditions up- and downstream to the membrane process, potential membrane materials for post combustion CO_2 capture will be identified. Since the flue gas is present only at ambient pressure, driving force generation for the CO_2 transfer across the membrane is critical. Hence, the authors review briefly the different types of driving force generation prior to the performance evaluation of single- and multi- stage membrane processes for post combustion CO_2 capture.

2. Boundary conditions

Upstream boundary conditions: The membrane gas separation process is ideally located between the flue gas desulphurization unit (FGD) and the stack. Thus, the flue gas sets in-flow boundary condition of the CO_2 capture process. To determine the flue gas condition at the outlet of the FGD unit, a model of a state-of-the-art hard coal fired power plant was implemented in Aspen Plus. The power plant features a net thermal efficiency of 45% (based on the lower heating value of the feedstock) and a thermal duty of 1210 MW. Table 1 summarizes the calculated flue gas composition, which is in good agreement with other publications [4].

N_2	CO_2	O_2	H_2O	SO_x	NO_x
71.2%	13.6%	3.2%	12%	200*	200*

Table 1: Flue gas composition at the FGD outlet; * in mg/m³

The flue gas leaves the FGD unit at 50°C and 1.013 bar. The total flue gas flow accounts to 560 kg/s. For simplicity only SO_2 and NO are further considered in this work.

Downstream boundary conditions: CO_2 transport and CO_2 storage set constraints on the composition, temperature and pressure of the CO_2 rich stream. Due to the ongoing uncertainty regarding the composition of the captured CO_2, this work considers different purity scenarios for the performance evaluation of membrane processes. Scenario A reflects rather relaxed requirements, as they may apply for aquifer storage. Scenario B, in contrast, accounts for much stricter limitations regarding co-captured species. At the delivery point to the pipeline, the CO_2 exhibits 130 bar and 30°C.

	N_2+O_2	O_2	H_2O	SO_2 + NO
A	**< 4%**	**< 4%**	**n. a.**	**< 0.5%**
B	**< 4%**	**< 0.01%**	**n. a.**	**< 0.01%**

Table 2: Allowed impurities in captured CO_2

3. Membrane selection

General classification: Melin and Rautenbach [5] provide a general classification of membrane materials. For technical applications only synthetic, solid membranes are relevant. Solid membranes can be further categorized with respect to the material they are made off. State-of-the-art organic gas separation membranes consist of a thin, dense polymer film and an organic, porous support. The class of inorganic materials includes dense metals but also porous materials such as carbon, zeolite or silica membranes [5]. Besides purely organic and inorganic membranes, combinations of both materials as in mixed-matrix or hybrid membranes exist. The selectivity and permeability of membranes is predominantly related to the prevalent gas transport mechanisms and hence the material itself. Literature provides extensive descriptions and reviews on respective mass transfer mechanisms [5-6].

Membrane requirements: A variety of CO_2 selective membrane materials are described in literature [7-8]. To restrict the calculations in section 5 to the most promising membrane materials, a pre-selection among potential materials is performed. According to Powell and Qiao [7], membranes applicable for CO_2 capture from coal fired power plants have to meet the following criteria:

- high CO_2 selectivity and CO_2 permeance,
- thermal, chemical and mechanical resistance towards flue gas conditions as well as
- cost effective membrane and module production.

Polymeric membranes: Currently only 8-10 polymer materials have at least a 90% market share for gas separation applications. Despite considerable separation characteristics evaluated on laboratory scale, other polymers failed in industrial practice so far [9]. In view of CO_2 separation from power plant flue gases, most commercial membrane materials show either a low CO_2 selectivity or low CO_2 permeability. Furthermore, most of them suffer from CO_2 induced plasticization or react sensitively to water. Currently, the polymer PPO seems to show the least trade-offs among the required / desired properties. In particular, its high permeance combined with its high chemical resistance makes it attractive for CO_2 capture from coal fired power plants. Among rubbery polymers, PEO based block polymers received considerable attention in the recent past. The high polarity of PEO results in a high CO_2/N_2 gas separation factor as well has a high CO_2 permeance. Due to the rubbery nature of PEO based block copolymers, water vapour and plasticization is expected to have only a light impact. Chemical and mechanical resistance to flue gas conditions are currently evaluated in the NanoGLOWA project. Facilitated transport membranes and in particular fixed site carrier membranes are very interesting with respect to CO_2/N_2 separation characteristics, too. However, saturation effects, wetting requirements at the low pressure side as well as a high uncertainty with respect to carrier degradation are significant shortcomings. Thus, carrier membranes appear presently less attractive for CO_2 capture from coal fired power plants than other rather simple polymer materials. However, they may be an interesting option for CO_2 capture from gas fired power plants, which are not considered in this work.

Inorganic membranes: There are two major categories of inorganic membranes, dense and porous membranes [5]. Dense inorganic membranes are generally prepared from Pd or perovskite and allow only certain gases (generally either H_2 or O_2) to pass via mechanisms such as solution-diffusion or solid state ionic conduction. These membranes are not applicable for CO_2 capture from flue gases [5]. Most porous inorganic membranes have an asymmetric structure consisting of a thin top layer and a support structure that provides mechanical strength [10]. Various types of materials including aluminum, silica, carbon or zeolite are suitable for membrane manufacturing. In comparison to polymers, most inorganic membranes exhibit a better separation performance in terms of permeability and/or selectivity. Moreover, their higher chemical, thermal and mechanical durability makes them in principle very attractive for CO_2 capture from flue gases. However, inorganic membranes are much more difficult to handle and to process reproducibly at a larger scale, which explains their high unit price [11]. Furthermore, their inherent brittleness associated with making modules that are crack-free and have large surface areas in conjunction with low volume-to-surface ratios are still serious issues that limit their applicability [8]. To fully exploit the advantage of high temperature stability, suitable sealings for membrane modules have to be developed. According to Nunes and Peinemann [12], the market for inorganic gas separation membranes is small. One of the very few applications are small-scale Pd-based membrane systems for the production of ultra pure H_2. Despite the appealing properties of inorganic membranes, it remains doubtful that their market share in gas separation will significantly increase [8], [12].

Mixed membranes: The development of mixed organic inorganic membranes aims to combine the processibility of polymer membranes with the gas separation performance of inorganic materials [5]. Two different types of mixed organic inorganic membranes exist:

- Mixed-matrix membranes (MMMs) are characterized by a heterogeneous gas separation layer comprising a dispersed phase of discrete inorganic particles in a continuous polymeric phase [5].
- In hybrid membranes the organic and inorganic phase becomes intermingled at the molecular level (covalent bonds) via chemical reactions between monomers of both phases [13].

Due to a weak interfacial adhesion among the hosting organic and the discrete inorganic phase, the gas separation performance of MMMs suffers significantly [12], [14]. Reasonable permeabilities have been achieved, but the required thickness of MMMs results in moderate fluxes only. The brittleness, the costs and the difficulties in production are presently the major barriers for their large-scale application [5]. In contrast to MMMs, the organic and inorganic monomer form covalent bonds in hybrid membranes. Literature reports a variety of hybrid combinations, but it seems that only moderate improvements in comparison to the original polymer have been achieved. Thermal, chemical and mechanical properties of hybrid membranes are hardly investigated yet. Hybrid membranes are not used on an industrial scale for gas separation applications [8].

Summary of membrane selection: The prior discussion revealed that polymeric membranes appear to be currently the best choice for membrane based post combustion CO_2 capture. Table 3 summarizes the performance of the considered polymeric membranes. While PPO exhibits a high CO_2 permeance and a relatively low CO_2/N_2 selectivity, PEO shows an inverse behavior.

	CO_2 Perm.	CO_2/N_2 Selectivity	CO_2/O_2	CO_2/SO_2	CO_2/NO
PPO	4.1*	20	4,5	5	1
PEO	1.25*	45	15	0.2	5

Table 3: Allowed impurities in captured CO_2; * permeance in $m^3/(m^2\ h\ bar)$

4. Membrane modelling

Permeation model: Mass transfer in dense polymeric membranes is mostly described by the widely accepted solution-diffusion mechanism, which comprises three consecutive steps: sorption of the gas molecules from the feed phase, molecular diffusion through the membrane and desorption of the gas molecules at the low pressure side [5-6]. Hence, separation is not just diffusion-dependent but also relies on the physical-chemical interaction between the gas species and the polymer. The relationship between permeability, diffusivity and solubility can be described according to equation 1

$$P_i = D_i S_i \qquad (1)$$

where P_i is the permeability, D_i the diffusivity and S_i the solubility of the respective component in the polymer. The gas transport through dense polymer membranes is governed by equation 2

$$J_i = \frac{D_i S_i}{\delta}(p_{i_F} - p_{i_P}) = Q_i(p_{i_F} - p_{i_P}) \qquad (2)$$

where J_i represents the flux density of component i across the membrane, p_{iF} and p_{iP} the partial pressures of component i on either side of the membrane, δ the membrane thickness and Q_i the permeance of component i. Thus, the driving force for mass transfer relies on a partial pressure difference across the membrane, which can be generated by a difference in pressure and/or by differing concentrations of species i.

Membrane model: To analyze membrane processes the permeation model given in equation 2 was implemented in FORTRAN and interfaced with the process design software Aspen Plus. The mathematical model further relies on the following assumptions:

- Solution according to Henry's law, diffusion according to Fick's law;
- Permeance is independent of pressure;
- Non-coupled gas species' flux over the membrane;
- Gas diffusion coefficients are independent of concentration;
- No concentration polarization;
- Negligible pressure losses at the feed and the permeate side;
- Plug flow at the feed side, free flow at the permeate side.

A detailed summary of all model equations is available elsewhere [5]. Besides, the model and its implementation has been validated with experimental data [15]. Most engineering studies regarding membrane based post combustion CO_2 capture are based on similar model assumptions [16-20].

5. Membrane processes

Driving force generation: Since the flue gas leaves the FGD unit only at ambient pressure, driving force generation for CO_2 transfer across the membrane is a crucial factor. Four options for its generation exist:

- Compression of the flue gas stream;
- Pressure reduction at the permeate side by operating vacuum pumps;
- Dilution at the permeate side by sweeping with an inert gas;
- Any combination of the options before.

Follmann at al. [21] reviewed the different options of driving force generation and came to the following conclusions:

- Axial and centrifugal compressors appear to be most suitable to pressurize large volume flows.
- Suction at the permeate side seems to be limited to approx. 200 mbar.
- A combination of flue gas compression and suction at the permeate side seems to be the best solution. While flue gas compression lowers the required membrane area, suction at the permeate side reduces the specific energy consumption.
- Sweeping at the permeate side appears unattractive, particularly due to large scale technical implementation.

Thus, a combination of feed compression and suction at the permeate side (compare figure 1) is used for driving force generation.

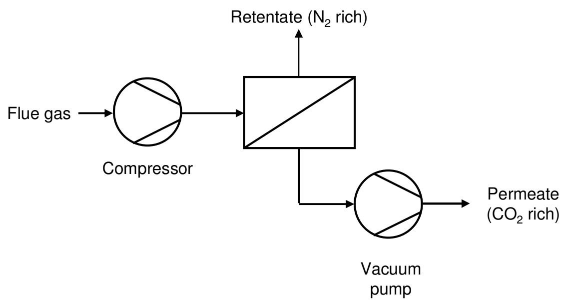

Figure 1: Schematic flow sheet of a single-stage membrane process with feed compression and suction at the permeate side

Single-stage membrane process: To evaluate the performance of membrane based CO_2 capture, the authors have chosen the following key performance indicators (KPI): the specific energy consumption SEC (equation 3), the CO_2 recovered from the flue gas, the composition of the CO_2 rich permeate stream and the required membrane area.

$$SEC = \frac{energy\ \ for\ CO_2\ \ capture}{mass\ \ flow\ CO_2\ \ captured} \quad \left[\frac{kJ_{electric}}{kg_{CO_2}} \right] \qquad (3)$$

An isentropic efficiency of 0.9 was assumed for the compression machines and of 0.75 for vacuum generation equipment. Figures 2 and 3 show the specific energy consumption of a single-stage membrane process as a function of the flue gas pressure. The permeate pressure was fixed to 0.2 bar, the lowest possible suction pressure. Figures 2 and 3 lead to the following conclusions:

- Single-stage processes are not able to reach the CO_2 purity specifications given in table 2.
- While the lowest specific energy consumption may be observed for PPO at a CO_2 permeate concentration of 40% to 55% (figure 2), PEO has its optimum between 50% and 65% (figure 3). To the left of the flat minimum, the specific energy consumption of the flue gas compressor increases (lower recovery), while the energy demand of the vacuum unit drops (higher enrichment). However, the increase of specific energy demand for compression outweighs the decrease for vacuum generation. To the right of the energetic minimum, the opposing effect becomes noticeable.
- Higher membrane selectivities reduce the specific energy demand and yield a higher enrichment at a given recovery and a given feed pressure. However, due to the lower permeance of the more selective membrane (table 3) the membrane area increases (not shown in figures).

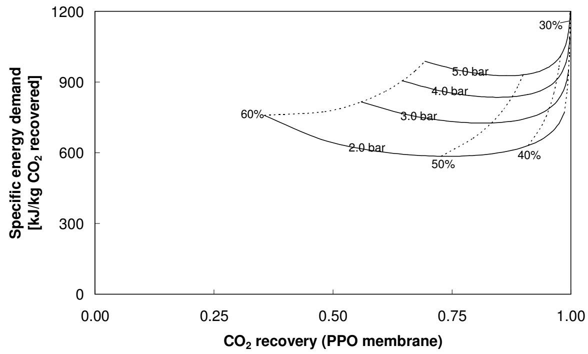

Figure 2: Specific energy consumption of a single membrane stage as a function of flue gas pressure (solid line), CO_2 recovery and CO_2 enrichment (dotted line); 0.2 bar permeate pressure; PPO membrane

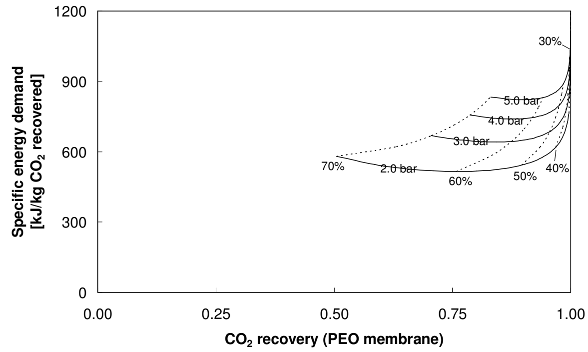

Figure 3: Specific energy consumption of a single membrane stage as a function of flue gas pressure (solid line), CO_2 recovery and CO_2 enrichment (dotted line); 0.2 bar permeate pressure; PEO membrane

Two-stage membrane process: The previous section revealed that single-stage membrane processes are not able to achieve the required CO_2 purity for pipelining and storage in conjunction with reasonable recoveries. Thus, it is necessary to introduce a second membrane stage to further enrich the CO_2. The permeate stream of the second stage yields the CO_2 stream for storage. Due to its elevated CO_2 concentration, the retentate stream of the second stage is recycled back into the flue gas. In analogy to the single stage process, the driving force is generated in both stages by feed compression in conjunction with suction at the permeate side. The feed pressures in both stages were varied while the permeate pressures were fixed to 200 mbar. To keep the membrane area as small as possible (investment costs), the high flux PPO membrane was used in the first stage and the more selective PEO membrane in the second stage. Table 4 presents the specific energy consumption and membrane area of such a two stage membrane process at 90% CO_2 recovery from the flue gas and 95.5% CO_2 in the permeate steam. Table 4 reveals that it is possible to match the CO_2 requirements given in scenario A (table 2). Due to a lack of selectivity among CO_2, O_2, NO and SO_2, membrane systems fail to meet the purity limits of scenario B. An absorption column upstream to the capture process or in between the two stages would certainly accomplish the targeted SO_2 concentration. However, the reduction of the O_2 content is a more difficult task. Since the operation of the power plant less excess O_2 appears unlikely, cryogenic O_2 separation from the captured CO_2 remains the most likely option.

Feed press. 1st/2nd stage	Energy [kJ/kg]	Area [10^5 m^2]	O_2 [%]	SO_2 [ppm]
3 bar / 4 bar	1910	7	1.8	510
4 bar / 4 bar	1940	5	1.8	510

Table 4: Key performance indicators of a two-stage membrane process with retentate recycling (PPO first stage, PEO second stage) at 90% CO_2 recovery and 95.5% CO_2 concentration

6. Summary and conclusions

Due to the moderate flue gas temperatures, polymeric membranes are the best choice for CO_2 capture applications. Two membranes with different separation characteristics were investigated in this study. A combination of feed compression and suction at the permeate side provides the driving force for CO_2 permeation. The investigation reveals that single-stage membrane processes are unable to reach the CO_2 purity requirements for pipelining and storage in conjunction with reasonable recoveries. Thus, it is necessary to introduce a second membrane stage to increase CO_2 enrichment. Two-stage processes achieve the CO_2 enrichment target at reasonable recoveries.

However, the residual content of co-captured species does not meet the strict purity specifications for scenario B. The major reason is the rather low CO_2/O_2, CO_2/NO and CO_2/SO_2 selectivity of the considered membranes.

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Estimation of Maximum PV Penetration in the Domestic Sector in Greece

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Abstract: In the current work the maximum technical potential for the installation of <10kWp PV systems, which is the limit set by the "Solar Roof" project of the Greek Ministry of Environment, Energy and Climate Change, is estimated taking into account physical limitations, such as the available area and the total number of buildings for all the regions of Greece. Having estimated the maximum potential, the electricity that can be generated is estimated taking into account the different meteorological conditions throughout the country.

Keywords: Solar Energy, Energy Policy, Environment

1. Introduction

The residential sector in the EU and also in Greece, requires large quantities of energy (close to 25% of the energy supply is absorbed in the residential sector) [Ministry of Development, 2006] causing negative environmental effects. Renewable Energy Sources (RES) have the potential to negate those effects, particular solar energy which possesses an important place among them, as they reduce the costs (economic and environmental) associated with burning imported fossil fuels or using electricity.
Solar energy possesses an important place among RES as more than 4.07 m² million of solar thermal collectors are already installed [ESTIF, 2010] in Greece, covering domestic hot water production in more than 25% of Greece's households.
Domestic Solar Hot Water Systems that are currently installed in Greece are mostly closed loop systems that substitute mainly fossil fuel-based electricity and to a lesser extend oil and natural gas [Tsilingiridis, Martinopoulos, 2010].
In order to reach the goal set by the Greek Ministry of Environment, Energy and Climate Change (MEECC) for 40% contribution from RES in electricity consumption by the year 2020, solar energy should be utilized for electricity production mainly with the use of PV.
Main goal of this paper is the estimation of maximum PV penetration in the domestic sector in Greece, taking into account the incentives that were recently introduced by the Greek government. Furthermore, having estimated the maximum installed capacity in the domestic sector, the annual electricity production is also estimated.

2. RES Electricity utilization in Greece. Current State and Prospects

The Interconnected Electric System is the electric system of the Greek mainland, consisting of the production, transmission, distribution and final consumption systems. It incorporates the mainland and islands that are close and are connected through underwater cables, such as Evia, Thassos, the Ionian Islands among others [Kalampalikas, Pilavachi, 2010].
Currently (2005), Greece's electricity mix is dominated by lignite thermal power plants with an installed capacity of more than 5,000 MW and other fossil fuel plants (oil and natural gas) with an installed capacity of more than 3,200 MW. RES capacity comprises of 3,400MW with more than 85% coming from large Hydro plants [Rampidisa I.M. et al, 2010]. As of 2009 RES capacity was increased, due to private funding, and an additional 1,086 MW were installed excluding cogeneration (Table 1) [HTSO, 2009].
RES contribution to the national energy balance in 2008 was approximately 7.8% of gross final energy consumption and around 16.3%, of primary energy production. Primary energy produced from RES in 2008 was 1.64 Mtoe with more than 50% coming from the use of biomass in dwellings and industries [MEECC, 2010].
In an attempt to further promote electricity production from RES, the greek goverment set specific targets for RES electricity share (40%), RES heating and cooling share (20%), and RES transport share (10%) in order to

achieve the national target of 20% contribution of the energy produced from RES to the gross final energy consumption.

Table 1: RES installed Capacity as of 6/2009				
	Installed Capacity [MW] (Operational)	% of Total	Installed Capacity [MW] (Awaiting)	% of Total
Hydro	177	14%	218	7%
PV	178	14%	110	3%
Biomass	41	3%	43	1%
Wind	842	68%	2900	89%

According to the National Renewable Energy Action Plan in the Scope of Directive 2009/28/EC, the electricity contribution from different technologies will escalate as presented in Figure 1 for the 2010-2020 period. In Figure 2 the estimated installed capacity of different RES electricity production is presented.

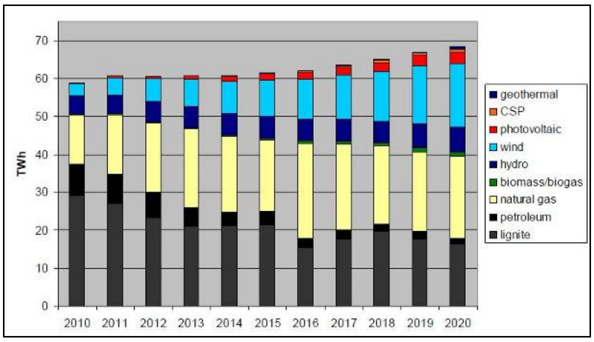

Figure 1: Electricity contribution from different technologies

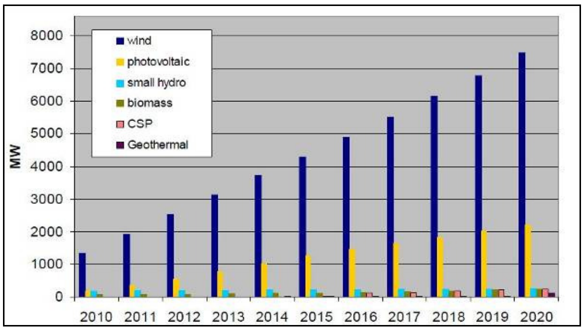

Figure 2: Installed Capacity of RES technologies

As is evident from these Figures, the electricity mix will change considerable with strong emphasis on natural gas, wind and PV installations.

The 20% share of RES in the gross final energy consumption in 2020 will be achieved through the combination of measures for energy efficiency as well as for the enhanced penetration of RES technologies in electricity production, heat supply and transport.

A major role in this respect will be played by the streamlining of the existing framework of licensing regulations and the rationalization of the terms and conditions of land management.

3. PV policies and Legislation in Greece

The evolution in the Greek RES policy framework, regarding deployment of solar electricity can be divided in three distinct periods. The first period covers the early years until 1999, where all RES installations were controlled by the Greek government through the Public Power Corporation and/or local authorities. In this period installations were limited mostly in isolated areas that were not usually connected in the main interconnected electricity grid of Greece. In 1999, in an aim to liberalize the electricity market, a new law was implemented (2273). The impact of this law in the total installed capacity of PV was small, as it didn't surpassed 1.4 MW, although it did boost the installed capacity of wind energy.

The second period started in 2006, when law 3468 was passed aiming at stimulating the PV market. The new law established a new feed in tariff system with a guaranteed period of 10 years for PV generated electricity, with the possibility of another 10 year extension. Furthermore, some simplifications for the administrative procedures necessary to obtain a permit for the installation of RES systems were introduced. There were also incentives for domestic producers (households), where a fifth of the total PV installation cost could be tax deductable up to a maximum of 700€.

Law 3468 had a positive effect on PV installations as more than 7.500 applications were submitted to the Regulatory Authority of Energy with a total installed capacity of more than 3.750 MWp [Papadopoulos, Karteris, 2009]. According to the MEECC at the end of 2009 total installed PV capacity in Greece's interconnected grid reached 37 MWp.

Finally in 2009, Law 3734 and in 2010, Law 3851 were introduced. These two laws in conjunction provide a step in the right direction for PV installations.

The new laws simplify even more the permits necessary for the installation of PV systems, furthermore the concept of solar roofs is introduced for households.

This initiative concerns households that want to install PV up to a maximum of 10kWp in the roof of their buildings. This initiative is restricted to areas of the interconnected electricity grid of Greece (continental Greece and islands connected with it).

For multi stories buildings only one system can be installed regardless of the number of households dwelling there. The produced electricity is sold to the Public Power Corporation at a rate of 0.55€/kWh.

In order to qualify for this program, the following conditions have to be fulfilled:

- an electricity connection in the owner's name
- part of the building's water thermal load must be covered from RES (DSHWS, GHP, etc).

The concept of solar roofs can be applied also in commercial buildings up to the limit of 10kWp.

4. Methodology – Results

In order to estimate the maximum technical potential for the installation of <10kWp PV systems, a number of physical limitations, such as the available area and the total number, area and type of buildings for all the regions of Greece must be considered. Furthermore, the regulations that are in effect from the “solar roof” programme are also factored in. Having estimated the maximum potential, the electricity that can be generated is estimated taking into account the different meteorological conditions throughout the country.

In order to achieve an accurate estimate, the total installed capacity and the electricity that can be produced, is calculated by considering the installation location. Due to different climatic conditions, the calculations are performed for each of the country’s regions. For the calculations, meteorological data of each region’s capital, considered representative for the entire prefecture since the capital usually includes the highest percentage of population and buildings are used. Furthermore, due to the restrictions set by the “Solar Roof” programme, only areas in the interconnected power grid are taken into account.

According to the legislation, the installed PV arrays must have a minimum distance of 1 m from the building outline for safety reasons, in case of a building with a terrace. Furthermore PV’s are not allowed to be installed on top of elevator shafts or staircases.

In case of buildings with sloped roofs the PV arrays must be set in a distance of 0,5 m at a minimum from the roof’s edge. Data from the Greek national census for the year 2001 and from surveys by the National Statistical Service for the building sector provided the necessary data for the distribution of PV systems in all regions of Greece [National Statistic Agency, 2001].

The area necessary for the installation of a PV system ranges (depending on the type of arrays used and the type of the building’s roof) from 12-15 m² in a terrace to 7-10 m² in a sloped roof per installed kW. That means an area of 70 m² to 150 m² per system and per building (in all cases an area available in almost all dwellings in Greece). In Attica 72% of all buildings have a terrace, while for the rest of the country the percentage drops to 35%. Total installed capacity of PV systems that can be installed in the main regions of Greece is calculated and presented in Table 2.

Excluding regions that are not grid connected (Aegean Islands and Crete), maximum installed capacity reaches 25,975 MW.

In order to calculate the annual electricity production the RetScreen 4 software is employed [RetScreen 2009].

The RetScreen Photovoltaic Project Model can be used to evaluate the energy production and financial performance of photovoltaic projects, from small-scale to large grid-connected systems, anywhere in the world.

Table 2: Number of buildings (housing), total built area and technical potential

Region	Total number Of Buildings	Number of Buildings used for housing	Number of buildings with a Terrace	Maximum Installed Capacity [MW]
Thrace	159,191	131,588	46,056	1,316
Macedonia	830,938	589,004	206,151	5,890
Thessaly	349,655	250,485	87,670	2,505
Epirus	171,112	127,929	44,775	1,279
Ionian Islands	128,876	95,290	33,352	953
Attica	754,728	663,207	470,877	6,632
Central Greece	410,476	308,249	107,887	3,082
Peloponnesus	555,272	431,704	151,096	4,317
Aegean Islands	343,454	253,691	88,792	2,537
Crete	287,268	214,803	75,181	2,148
Total	**3,990,970**	**3,065,950**	**1,311,837**	**30,660**

There are three basic applications that can be evaluated with the PV model:

- On-grid applications,
- Off-grid applications, which include both stand-alone and hybrid systems, and
- Water pumping applications, which include PV-pump systems.

In this case the on-grid model was used. The PV array model is based on work by Evans [Evans, D.L., 1981], and is characterised by its average efficiency, n_p, which is a function of average module temperature, T_c:

$$n_p = n_r[1-\beta_p(T_c - T_r)] ,$$

n_p corresponds to module efficiency at reference temperature (T_c=25°C) and β_p to the temperature coefficient for module efficiency. Reference temperature is related to the mean monthly ambient temperature T_α through equation:

$$T_c - T_a = (219 + 832\bar{K}_t)\frac{NOCT - 20}{800} ,$$

$\bar{K}_t$ being the average monthly clearness index and NOCT Nominal Operating Cell Temperature. If the array is tilted at an angle that differs from the optimum one, a correction factor is used.

The energy produced (E_p) by the PV array is calculated using:

$$E_p = Sn_p\bar{H}_t ,$$

S being the array area and $\bar{H}_t$ the average solar radiation on the array (Figure 3).

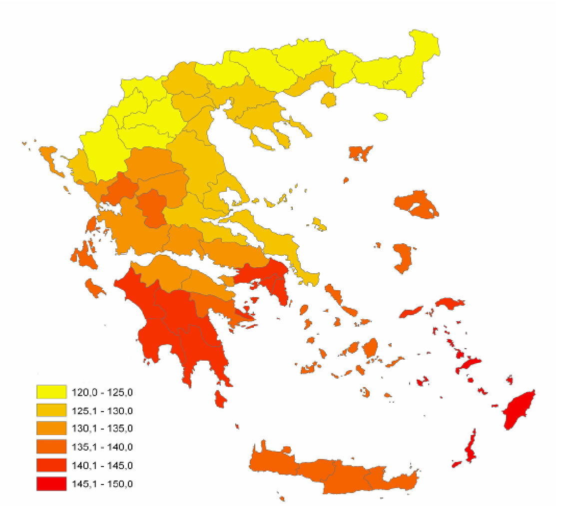

Figure 3: Average annual solar radiation on a 45° inclined surface [kWh/m²]

Energy produced by the array is then multiplied with loss factors regarding power conditioning and array losses in order to calculate the available energy E_A.
For the on grid model, no load is specified and the array size is defined by the user. The available energy is what is produced by the array minus inverter losses.
For convenience in the current work, all produced energy from the system is considered to be absorbed by the grid. A typical 10kWp system is assumed in all regions of Greece and the produced energy (that is fed to the grid) is then calculated. The annual electricity production for a typical 10kWp system in each region is presented in Table 3.
Total energy production is calculated by multiplying the number of buildings that are used as dwellings with the energy produced by a single 10 kWp system for every region in Greece.

Table 3: Monthly Electricity exported to the grid by a typical 10kwp PV system [MWh]

Month	Macedonia	Thrace	Ionian Islands	Epirus	Peloponnesus	Thessaly	Attica	Central Greece
1	0.891	0.969	1.025	0.934	0.960	0.900	0.714	0.866
2	0.938	0.985	1.090	0.992	0.948	0.928	0.859	0.881
3	1.167	1.192	1.444	1.301	1.233	1.166	1.177	1.130
4	1.184	1.155	1.480	1.311	1.256	1.247	1.301	1.250
5	1.293	1.232	1.587	1.454	1.376	1.321	1.448	1.331
6	1.385	1.287	1.606	1.531	1.472	1.422	1.386	1.438
7	1.440	1.365	1.690	1.581	1.515	1.465	1.456	1.474
8	1.436	1.357	1.676	1.547	1.486	1.465	1.455	1.469
9	1.291	1.239	1.521	1.358	1.334	1.321	1.314	1.323
10	1.004	1.081	1.293	1.186	1.151	1.020	1.138	1.071
11	0.798	0.866	0.986	0.849	0.837	0.788	0.933	0.796
12	0.722	0.796	0.850	0.751	0.763	0.722	0.738	0.694
Annual	**13.550**	**13.524**	**16.247**	**14.795**	**14.330**	**13.767**	**13.920**	**13.724**

Total electricity fed to the grid could reach 36.3 TWh, indicatively total electricity consumption in Greece in 2008 was 67 TWh [MEECC, 2010].

5. Conclusions

It is evident that PV penetration in the domestic sector can reach very high levels. In case of the maximum potential, taking into account the limitations set by the "Solar Roof" programme, the theoretic installable capacity will be able to cover at least half of today's electricity needs.
The simplification of the administrative process for the installation of PV systems for domestic users and the implementation of an attractive feed in tariff scheme have, and will continue to have, a positive impact on new installations. In order though, to reach even a small percentage of the theoretical PV potential another obstacle has to be removed, that of the power transmission grid saturation. With a current capacity of about 12,000 MW the inter-connected grid will require substantial investments, both financial and time consuming, to meet the 30,660 MW capacity of PV's.
It has to be noted that the above estimation doesn't take into account regions that are not in the interconnected power grid, and also that there is a limit to 1 system per building, making thus the true maximum potential even higher.

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Past, present and future capability of RES penetration into the non-interconnected energy system of the Greek islands

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ABSTRACT

The energy production in the so-called non-interconnected islands is based on thermal power plants approximately at 90%. Worldwide crude oil prices have undergone variations in the last ten years. On top of that Greece faces its own fiscal crisis. To cope with this extreme situation, the Greek government is turning to “green energy” not only to achieve the EU 2020 target, but also to encourage investments into the RES -Electricity production sector and try to depend less and less on oil.

The present study has created a database with the monthly energy productions on the non-interconnected islands from 2000 to 2009. The aim of the study is to comment on the past national policy of integrating RES into the energy system and propose a gradual increase of RES penetration into the island energy system over the next decade. Simultaneously the paper attempts to support the aforementioned proposal by cross-checking the costs of the investments in RES versus the benefit from decreasing the conventional energy production. The proposal takes into consideration environmental and social factors, such as CO_2 emissions reduction and creation of new jobs.

The results show that the RES penetration was almost non-existent in the islands up to now. From the analysis it is seen that RES penetration into the island energy system can reach – or even exceed - the new national target of 40% RES-E production (for the whole country) up to 2020 if the available public expenditure for “green” development (4.2% of GDP for 2010) would be distributed to proper investments in islands interconnections and RES-E penetration.

Keywords: Greek non-interconnected islands, RES penetration

1. Introduction

An economical crisis developed across the western world, mostly USA and Europe, after 2007. Greece faces its own type of economical crisis mainly after 2009, due to high public debts. The survey of the oil products trade (MEECC, 2010a) constitutes a starting point to observe the recession in many sectors of the economical life of Greece, the electricity consumption included. Decreases are observed almost in all fuel types from 2008 to 2009.

To cope with this extreme economical situation, the Greek government enforces - among other measures – increases in immediate taxes and is turning to "green energy" not only to achieve the EU target for 2020, but also to encourage investments into this sector and try to depend less and less on oil.

The increases of taxes - as part of the measures, which are required in the frame of the Stability Pact between the three-party body (European Commission, European Central Bank and International Monetary Fund) and the Greek government - must de added to the upturn that crude oil's prices follow after the historical low ($34.57 per barrel) in January 2009 (US EIA, 2010). More specifically the Value-Added Tax (VAT) and the special consumption taxes – of energy products included - have been increased twice the 5 first months of 2010 (Law 3845, 2010). This fact also influences Public Power Corporation (PPC)'s rates. PPC already announced an increase of 0.5% and 0.25% (PPC, 2010a) for domestic/public and enterprise users, respectively, which results from the implementation of the special consumption tax on electricity, included in the Law 3833/2010 on *Protection of National Economy, Urgent Measures to Confront Fiscal Crisis*. Additionally, the application of fuel clause for the second trimester of 2010 causes increases of €0.22, €0.23 and €0.24 per 1,000 kWh for high/medium and low voltage consumers, respectively.

The European Commission estimates the recession (EC, 2010a) to be 3% for 2010 and sets the possible start of Greek economy's recovery in the second half of 2011.

Besides these facts Greece has to be consistent with its obligations, regarding Renewable Energy Sources (RES) penetration into the energy production grid, with subsequent CO_2 emissions reduction and energy saving up to 2020.

The Greek electricity system is divided into the interconnected mainland system and the non-interconnected islands one. The big wind and solar potential of the Aegean Sea, which remains almost unexploited, as well as the fact that the islands depend on oil energy production, brought the last years again the matter of the interconnection of the islands with the mainland in the surface. The total expenditure of PPC for buying liquid fuels decreased by 47.5% in 2009 compared to 2008 (PPC, 2010). From a total installed capacity of 2,732 MW from oil thermal power plants 1,806 of them are on the islands. The last decade the RES-E penetration on the islands moved in the range from 6.9% to 13%.

On the other hand, there have been more than 2 decades that the scientific community started to work in estimating the wind potential in Greece with the Aegean Sea to concentrate the biggest part (Lalas, 1985; Katsoulis, 1992). During the last decade the research is concerned mainly about: RES penetration probabilities given the technical restrictions (Kaldelis, 2006; Katsaprakakis et al., 2007), ways to overcome the technical restrictions of the existing networks in order to increase RES-E penetration (Kaldellis et al., 2001; Katsaprakakis, 2009), schemes for combined exploitation of all RES forms (Koroneos et al., 2003) and new but still immature technologies like the offshore wind farms (CRES, 2010).

Taking into consideration all these facts and also that the Greek government has and will have in the near future restricted possibilities for investment subsidies, it's important to argue on supporting the so-called "green development", given the advantage of the existence of the feedstock for them.

2. The past and the present

A. Legislative framework & funding sources

RES entry into Greece was achieved through Law 1559/1985 on *Regulation of issues of alternative forms of energy and specific issues of power production from conventional fuels and other provisions*, under which PPC installed 24.3 MW and local authority organisations 3 MW until 1995 (MD, 2007). The installed capacity of PPC concerned wind farms, with 19.2 MW on non-interconnected islands.

The Law 2244/1994 "*Regulations of issues on electricity production from RES and conventional fuels and other provisions*" introduces special regulations for the exploitation of RES. Simultaneously OPE (Operational Programme for Energy) supported private investments. It lasted from 1994 until 1999. The market demand for investments in Renewable Energy Technologies (RETs) was such that at the end of the programme 147 projects had been contracted with a total budget of 273 M€, surpassing the initial planning by 82% (Agoris et al., 2004). An additional funding tool was the "*Development Law 2601/1998*". With these funding sources the investments in RETs – 70% wind, 19% small hydro, 11% Combined Heat and Power (CHP biomass/biogas) - reached a budget of 477 M€. In 1999, 71% of the wind farms were on non-interconnected islands.

The Law 2773/1999 on *Liberalisation of the electricity market - Regulation of energy policy issues* brings the private sector in the scene. The EU Directive 2001/77 "*On the promotion of electricity produced from RES in the internal electricity market*" followed and set the global target of 12% in domestic gross energy consumption for all countries. For Greece this meant a 20.1% share of RES-E production in 2010 and 29% by 2020.

Many national laws followed in the direction of clarifying issues about RES and accelerating the liberalisation of the electricity market. The most directly related with RES are the following:

- Law 2941/2001 on *Simplification of the procedures for the establishment of companies, licensing of plants using RES, regulation of* *matters pertinent to Hellenic Shipbuilding S.A. and other provisions*,

- Law 3175/2003 on *Exploitation of geothermal potential, district heating and other provisions*,
- Law 3426/2005 on *Acceleration of procedure towards liberalization of electricity market*,
- The *Development Law 3299/2004* would offer chances for RES investments with subsidies from 30 to 50% depending on the region. The date for the submission of requests submissions expired on 29 January 2010.
- The Law 3468/2006 on *Electricity production from RES and Co-generation of Heat and Power (CHP) high-efficiency plants and other provisions* completed the integration of the Directive 2001/77 into the Greek legislation and aimed at the simplification of licensing procedures.

Despite the aforementioned efforts the licensing issue ended up to the so-called "Licensing Marathon of RES" as long as 27 public agencies and services needed to give advice for a RES project.

The OPC (Operational Programme for Competitiveness, 2000-2006) superseded OPE and lasted from 2000 until 2006. Measure 6.5 "*Promotion of penetration of systems of RES, co-generation and energy saving into the country's energy system*" and action 2.1.3 "*Financial motives for the reinforcement of single private energy investments*" resulted to a total budget of 839.9 M€ in 365 projects (MD, 2010) with

Type of investments	**Mainland**	**Islands**
Energy saving/fuel's substitution	171	12
Biomass/hydro/CHP/geothermal	20/17/14/2	-
Active & passive solar systems	18	17
Wind farms	13	10
PV installations	44	27
Totals	**299**	**66**

Table 1: OPC 2000-2006, distribution of projects

an average subsidy of 30.4% to 43.7%.

First problems regarding the capability of the isolated small energy systems of the islands to absorb wind energy begin to arise. Measure 6.3 "*Special energy infrastructures for the islands and for promotion of RES*" offered the opportunity to PPC and HTSO (Hellenic Transmission System Operator) to affiliate in the subsidy's regime the interconnection of Cyclades (CBTDSA, 2007). Due to intensive reactions of habitants and local authorities these projects haven't been developed according to the previous planning (HTSO, 2008).

The National Strategic Reference Framework (NSRF) 2007-2013 superseded OPC. The 14th general objective entitled "*Supply the country with energy in a safe way, based on sustainability*" set targets regarding the interconnection of the islands with mainland and the reduction of oil dependency of Greece in an environmentally-friendly manner (NSRF, 2007). The interconnection of Cyclades, the construction of an LNG (Liquefied Natural Gas) station in Crete, RES-E projects and the attraction of foreign capitals in this sector consist basic fields to be reinforced. Goal of the Greek government is the increase of the absorption rates. A combination with the Ministerial decision 2464/2008 on *Physical planning and allocation of RES*, is expected to offer the needed boost to the RES-E penetration issue.

The EU Directive 2009/28 *On the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC* sets mandatory national targets for the overall share of RES in gross final consumption of energy by 2020 and for the share of RES in transport, 20% and 10% respectively. According to the directive each Member State should notify its National Renewable Energy Action Plan by the end of June 2010, which should set mandatory national targets for the share of energy from RES consumed in electricity, transport, and heating/cooling sectors up to 2020.

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* integrates the Directive 2009/28/EC into the Greek legislation and sets the following national targets up to 2020: 40% RES penetration in gross electricity consumption, 20% share of RES in gross energy consumption for heating/cooling and 10% share of RES in the transport sector. To the core of this law belong - among other issues – the simplification of the licensing procedures for RES-E units, the creation of motives in order to engage the potential investors into the field of enforcing the networks, so these would be able to absorb more "green energy". As regards the non-interconnected islands the most important intervention of the law is the obligation of the administrator - PPC – to prepare in a period of 6 months the Strategic Plan for the Interconnection of the islands.

B. RES-E penetration issues

An increasing RES-E penetration had and has to confront political, economical, technological and social barriers (Zoulias et al., 2009). First problems regarding the absorption capacity of wind power appeared in the beginning of the decade and concerned Southern Evia (mainland), a region with average yearly wind speed greater than 8-9 m/sec (Kabouris et al., 2006), which also constitute the interconnection point of the interconnected islands of Andros and Tinos. Regarding the non-interconnected islands, the Regulatory Authority for Energy in 2003 releases (RAE, 2003) a methodology to calculate the upper limit of wind power absorption capability separately for each island. In 2007 RAE releases a *Methodology for the verification of RES development margins on saturated networks* (RAE, 2007a). In average this methodology ended up to percentages of 35% of the instant (average hourly) power demand or 30% of the existent thermal power plants capacity. Regarding the PV installations capability the limits for the maximum allowed PV installations power were set at 15% and 35% of the calculated average hourly power demand on islands with significant installed wind capacity and on islands with no wind capacity, respectively. RAE modified these percentages to 28.5% and 45%, respectively (RAE, 2008a), given the fact that studies from the National Technical University of Athens approved the possibility and also the fact that Law 3468/2006 set the target of 200 MW of small PV installations on the non-interconnected islands until 2020. Aiming at greater RES-E penetration capabilities on the islands in order to exploit their significant wind potential, the interconnection issue firstly of the Cyclades islands - that has been studied since 1993 (PPC, 2009) - came strongly in discussion last years (Papadopoulos et al., 2005, 2008).

C. Production

Despite the legislative/regulatory interventions the last decade the RES-E penetration on the islands started from 6.9% in 2000 and reached 13% in 2009. The total RES-E production on the Greek islands of 641.9 GWh for 2009 comes 99.89% from wind farms and the rest from PVs and the 2 very small hydroelectric plants (0.6 MW) of Agia and Almyros in Crete.

This penetration level on the non-interconnected islands can't reduce the oil dependency of the country in the energy production sector, as long as 66.1% of the oil thermal power plants installed capacity in Greece represents the 35 Autonomous Power Stations (APS) in 33 non-interconnected islands. In the aforementioned percentage the following are included: (a) the production of the emergency power generators of interconnected Andros and (b) the production of such units – usually rented - in many others of the non-interconnected islands, covering seasonal peak demands mainly due to tourism.

These APS cover the electricity needs of 57 non-interconnected to the mainland islands, 55 in the Aegean Sea and the 2 very small islands of Erikoussa and Othoni (with their own APS), which geographically belong to the so-called Diapontic group of islands and administratively to the prefecture of Corfu in the Ionian Sea. Except of Antikythira and Skyros, which belong to Attica and Evia prefectures, respectively, the rest 53 constitute the following prefectures: Dodecanese, Crete, Cyclades, Lesvos, Samos, Ikaria and Chios. The electrification of the 54 Aegean islands – Crete with its 3 APS excluded – from the 30 APS is covered by underwater medium voltage connections between the complexes of the islands (PPC, 2009).

Following the pattern of 2000's decade annual average consumption change (interconnected Andros and Samothrace included) of +4.6 % (HSA, 2010a) there was an average change of the APS production of +4.46% for the first 8 years – 2000 to 2007 – and an average change of +3.55% for the whole decade, due to the small increase of 1.57% in 2008 and the decrease of 1.77% for 2009. The decrease in the interconnected system for 2009 exceeded 5% and the downward tendency keeps on these first months of 2010 moving in rates greater than 2% in comparison with the same months of 2009 (HTSO, 2010a), reaching for example 3.3% in March. From this fact and also the estimated 10% tourism reduction for 2010 (Hellenic Chamber of Hotels, 2010) it can be estimated that the downward tendency in energy consumption/production will keep on for the islands too.

3. Data collection and analysis

A. The data sources

Data sources for the creation of the database of the monthly energy productions – conventional and RES-E - of the non-interconnected islands from 2000 to 2009 were: PPC and PPC Renewables. The monthly RES-E productions are in the form of 3 records: Crete, Rhodes and the Rest of The Islands (ROTI). The very small amounts of RES-E productions in medium and small size islands are in annual base for 2003 to 2009 and don't consist part of the database. The annual data of RES-E production per type and per unit has been obtained for the period 2000-2006 from the Centre for Renewables and Saving (CRES).

The sunshine hours per island – obtained from the Hellenic National Meteorological Service - have been used in order to distribute the annual amounts of PV installations productions into monthly ones (in the 3 basic RES-E production records).

B. APS production

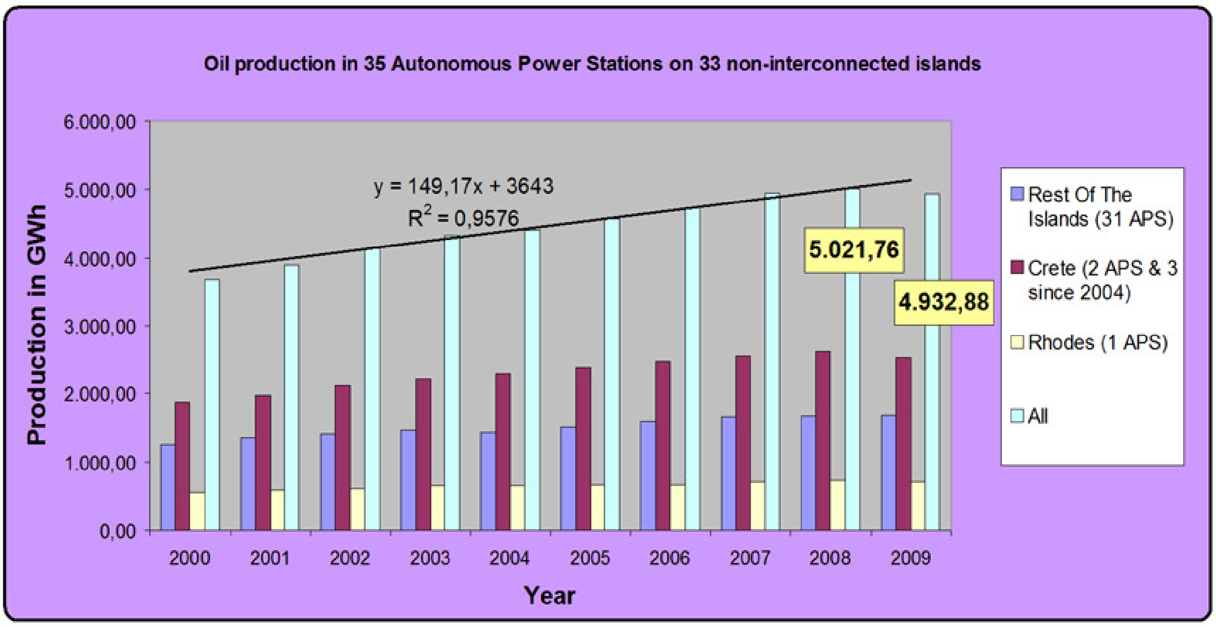


Figure 1: Production from the 35 APS on the Greek islands from 2000 to 2009

As it can be seen in Figure 1 there is a steady linear increase of oil power production for the whole decade with the exception of the 1.77% decrease in 2009, which more specifically is due to production reduction on the islands, shown in Table 2.

Island	2009's APS production change (%)	Share in total APS production (%)
Chios	-1.59	3.9
Crete	-3.48	51.19
Kos	-1.33	5.3
Mykonos	-0.09	2.19
Othoni	-3.41	0.01
Paros	-0.13	3.99
Rhodes	-1.56	14.5
Samos	-1.93	2.66
Syros	-0.12	2.05

Table 2: Islands with APS production decrease

The total capacity of 1,806 MW of the APS on the non-interconnected islands regards units, in which mainly heavy fuel oil is used in steam turbines and diesel is used in internal combustion engines. Many of these units are very old and their big technical minima, the certain limit of power under which these units should not operate in order to avoid increased wear and maintenance requirements, constitute one of the major constraints for greater RES-E penetration (Kaldellis, 2006).

The total fuels supply cost exceeded the amount of 636 M€ in 2008. In PPC's financial results of 2009 (PPC, 2010) is mentioned a reduction in the national oil energy production of 1,904 GWh, which concerns mainland by 95.3% and is due to consumption decrease and an increase in natural gas penetration; the already mentioned decrease in the non-interconnected islands oil energy production of 1.77% corresponds to a production decrease of 89.48 GWh. Furthermore the unit price decreases of crude oil and diesel in 2009 at 27.8% and 31.9%, respectively, caused the already mentioned decrease of 47.5% in PPC's total expenditure for buying liquid fuels.

C. RES-E production

The positive linear correlation between time and APS production, which is seen in Figure 1, is present in Figure 2 too, caused mainly by the RES-E penetration development in Crete. While Crete represents the 51.19% share of conventional production (2009), its share in RES-E production ascends at 72.39%. Crete can not be directly compared to the other islands; itself represents 15% of the national electricity demand (Tsioliaridou et al., 2006) and consequently attracts investors interest (Giatrakos et al., 2009). Regarding the total RES-E installed capacity of 256.9 MW in 2009 – out of which 254.46 MW are from wind farms - Crete owns 65.54% of it. According to the aforementioned approved methodology by RAE (RAE, 2007) the wind capacity on the non-interconnected islands can not exceed 300 MW if no changes are made in the existent energy systems.

The diagrams in Figure 2 are also representative of the wind power production distribution given that the already mentioned share of 99.89% of total RES-E production comes from wind. Of the total installed wind capacity of 254.46 MW the 166.55 MW and 26.35 MW are in Crete and Rhodes, respectively. The rest is distributed as shown in Figure 3.

Adding the capacities in Figure 3 to those of Crete and Rhodes the sum is 256.47 MW, which is 2.01 MW greater than the aforementioned 254.46 MW. In order to locate the wind capacity per island 2 sources are available: PPC's monthly RES reports (PPC, 2010b) and Hellenic Wind Energy Association files (HWEA, 2010). According to Dr Tsipouridis I., former president of HWEA and current managing director of PPC Renewables, this difference exists because of changes in the installed capacity of some wind farms due to disarmament of single wind turbines, mainly because of age.

Taking into consideration the technical restrictions and the hypothesis that nothing changes in the local energy systems it can be concluded that the capability for further wind power penetration in Crete is restricted (conventional installed capacity of 823 MW). On the contrary, Rhodes consists an attractive case for wind farms investments (conventional installed capacity of 234.1 MW and average yearly wind speed greater than 6 m/sec), which is the case for other smaller islands as it can be seen in Figure 3. Zero thermal capacity means that there is no APS on the specific island.

The intensive upturn of the 2.137 MW (December 2009 – Figure 4) PV installations production will continue. In the first 5 months of 2010, the capacity ascended to 2.14 MW, 2.46 MW, 2.78 MW, 4.22 MW and 5.88 MW, respectively (PPC, 2010b). This fact is due to the implementation of the already licensed/excluded from licensing procedure by RAE small (<=20 kW) PV installations. RAE (RAE, 2008b) distributed a total capacity of 190.89 MW for small PV's in all non-interconnected islands.

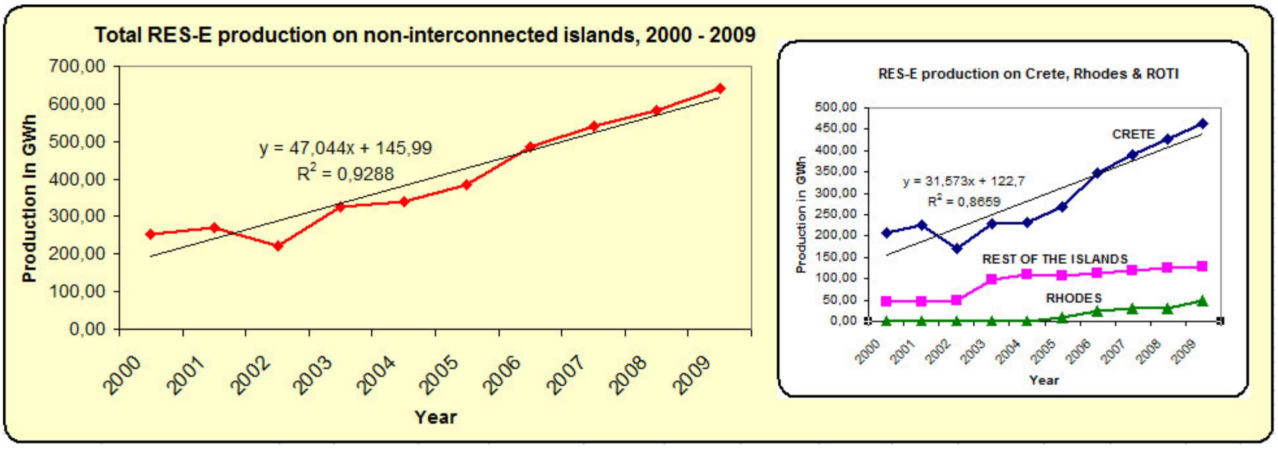


Figure 2: Total RES-E production on the non-interconnected islands, 2000-2009

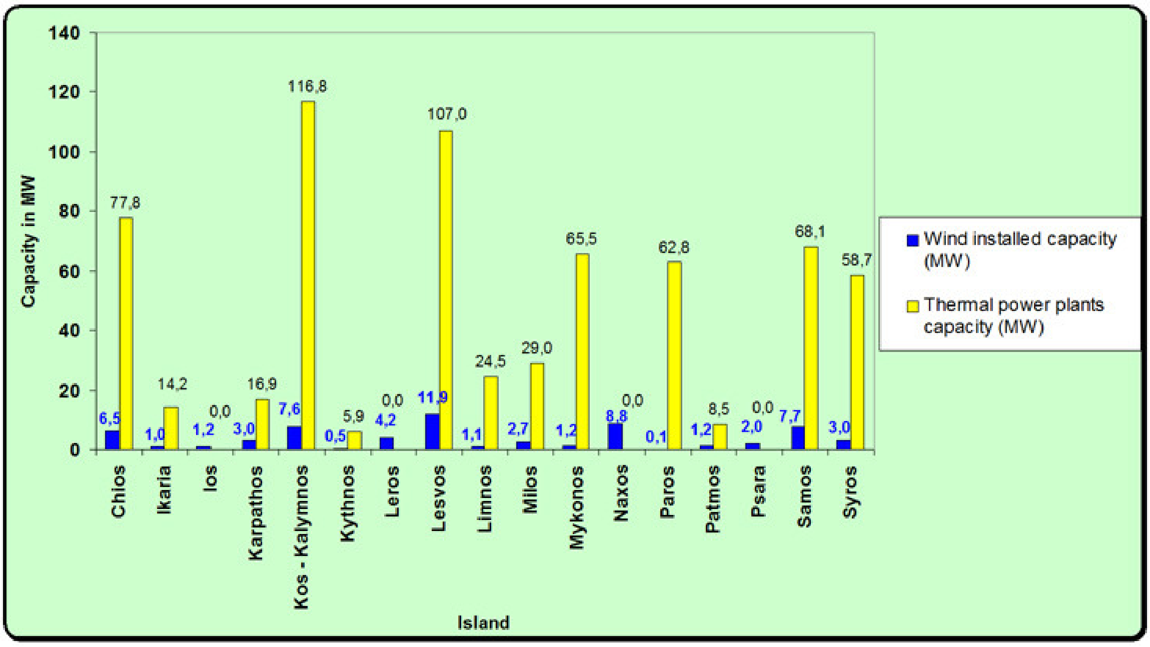
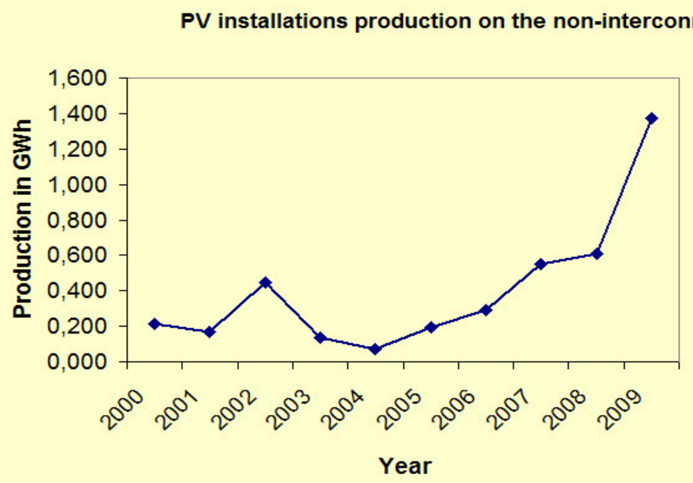


Figure 3: Wind installed capacity - thermal installed capacity (MW)



2000	Antikythira, Arki, Crete, Kythnos, Lesvos, Paros, Sifnos
2001	Antikythira, Arki, Crete, Kythnos, Lesvos, Paros, Sifnos
2002	Antikythira, Arki, Crete, Kythnos, Lesvos, Paros, Sifnos
2003	Crete, Lesvos
2004	Crete, Lesvos
2005	Crete, Lesvos
2006	Crete, Lesvos
2007	Crete, Lesvos, Sifnos
2008	Crete, Lesvos, Naxos, Sifnos, Syros
2009	Chios, Crete, Kythnos, Lesvos, Milos, Mykonos, Naxos, Rhodes, Sifnos, Symi, Sxoinousa,Syros

Figure 4: PV installations production on the non-interconnected islands, 2000-2009

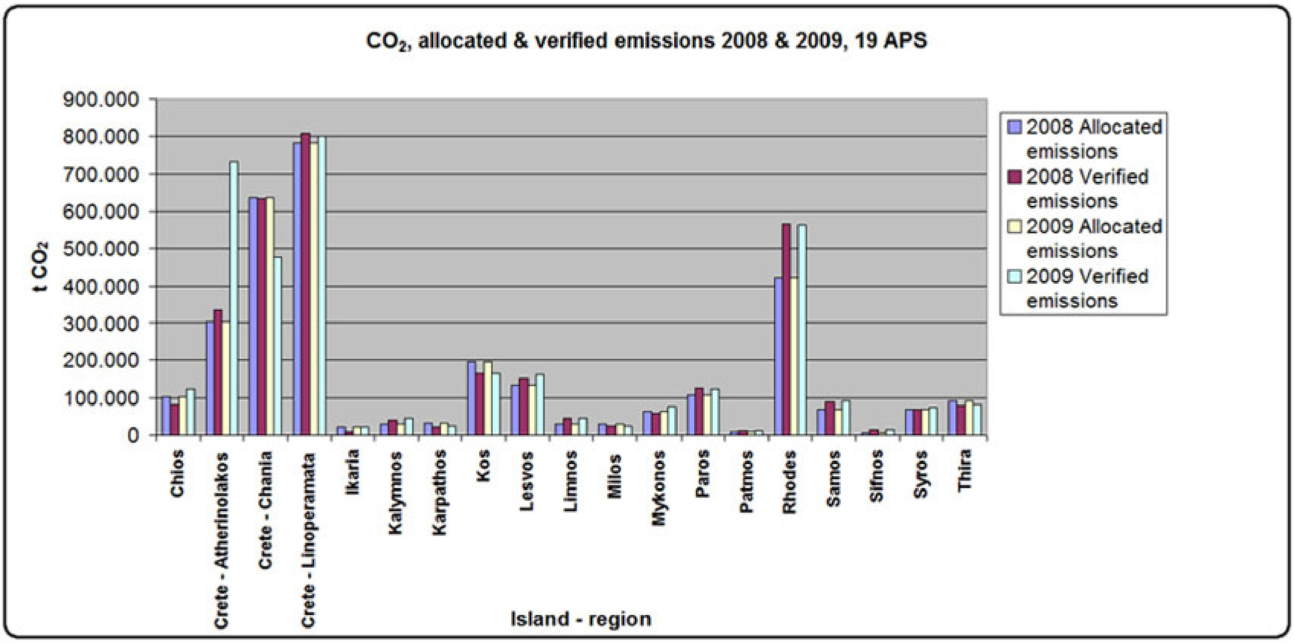


Figure 5: CO_2, allocated and verified emissions of 2008 & 2009 for 19 APS on 17 non-interconnected islands

D. Emissions

According to the National Inventory Report (NIR, 2010) the GHG emissions from the use of liquid fuels in the Public Electricity and Heat Production sector moved in the range from 5.37 in 1990 to 6.95 (Mt CO_2 eq) in 2008, which constitutes 13% of the total GHG emissions of this sector for that year. PPC is obliged to buy emissions rights for 19 APS. In APS-facility level the allocated and the verified emissions for 2008 and 2009 are shown in Figure 5.

Despite the fact that for 2008 in 9 of the 19 power stations the verified emissions are lower than the allocated the total of the verified emissions exceeded the allocated at 6.3% (or 196,562 t CO_2) . The situation is worse for 2009. The verified emissions exceeded the allocated at 16.9% (or 528,153 t CO_2).

4. Results

The following estimations/assumptions have been adopted:

- Regarding the demand development the estimation of the business as usual (BAU) scenario of the National Energy Planning Council (SEES, 2009) has been adopted, which is also adopted by HTSO in the revised version of Transmission System Expansion Study 2010-2014 (HTSO, 2010b) as the most probable scenario to happen.
- The inter-comparison of the production from the 19 APS - that are included in the EU Emission Trading System - with the verified emissions (EU ETS, 2010) for the period 2005-2009, indicated an average emission of 0.694 t CO_2/MWh, which has been applied here.
- The estimation of the allocated emissions for the 3rd period 2013-2020 of the ETS was based on the Commission Decision 4658 (final 09/07/2010) for the overall cap in 2013 and the application of the percentages first for the country and secondly for the islands APS. Calculations resulted to yearly allocated allowances of 63.99567 Mt CO_2, which is consistent with the 64 Mt, referred to also by the *National Committee for Meeting 20-20-20 Targets and other Requirements* (20-20-20 Committee) (MEECC, 2010b) and furthermore to 2.994997 Mt CO_2 for the islands APS.
- The price of €20 per ton has been used to estimate the extra allowances cost. The same price has been adopted by the 20-20-20 Committee during preparation of the National Renewable Energy Action Plan (MEECC, 2010b).
- The estimated crude oil's prices for the period 2010-2030 by the International Energy Association in the World Energy Outlook 2009 have been adopted in order to estimate the mean annual variable cost per thermal MWh on the non-interconnected islands.
- A CF=28.7% (Capacity Factor), which is currently used, has also been applied for the cases examined and a CF=15% for the PV installations, which equals to a mean annual production of 1,300 MWh/MW installed (RAE, 2007b). PV capacity does not exceed in any case the already distributed of 190.89 MW.
- The already distributed capacity of 3.337 MW for small wind turbines has not been taken into consideration.
- The new jobs in the wind power sector must be added to the already existing in 2009. The rate of 15.1 jobs annually per MW has been applied (EWEA, 2009). The number of direct jobs in Greece is estimated at 1,800 for 2008 (EWEA, 2009).

Table 3 contains the results of the 3 cases examined.

A. The No Change Case

The No Change Case basic assumption is that in the coming decade the RES-E penetration on the non-interconnected islands continues at the rate of the last decade. That means that the linear development of wind power does not change to exponential.

Furthermore it is assumed that not even the scheduled changes, regarding the interconnection of Cyclades and the penetration of natural gas in Crete, take place. The RES-E production percentage is restricted at 17.56% and the 352.69 MW wind installed capacity in 2020 constitutes just the 4.7% of the targeted 7,500 MW included in the National Renewable Energy Action Plan (NREAP, 2010). The results in Table 3 show why this case should stay out of the question.

It is worthy to mention that the total expenditure for fuels supply in the conventional APS for the decade ascends at 7,622 M€ and the cost for the allocated allowances exceeds the amount of 492 M€. This last amount does not include any penalties for the excessive releases of CO_2 in the atmosphere.

B. The Scheduled Changes Case

According to PPC plan (PPC, 2007) the use of natural gas in Crete would start in 2012 with 250 MW and would be expanded to 500 MW in 2014 - in Combined Cycle units, starting with the new unit of Corakia (near the Linoperamata station) and secondly with natural gas in the Chania station. Mainly because of the disagreement between PPC and the owners of the land in Corakia the construction of the new unit has not started yet. Because of these delays in the Scheduled Changes Case the production with natural gas has been introduced in 2013 - 250 MW and 2015 – 500 MW, which still remains a very optimistic case. This introduction causes a decrease of 15% in the mean variable cost per thermal produced by natural gas MWh (Giatrakos et al., 2009). The average of 53.5% in power generation performance has been applied (PGC, 2010) and the reference price of 0.42 t CO_2/MWh (EC, 2010b) regarding the emissions. According to PPC the introduction of natural gas in Crete together with the necessary old units substitution constitutes an expenditure of 588 M€ until 2014 (PPC, 2009a).

The interconnection of Cyclades with the mainland is included in the Transmission System Expansion Study 2010-2014 of HTSO (PPC, 2010c). The interconnection plan regards Syros, Paros, Naxos, Mykonos and Kythnos only if the 1st technical solution is selected. HTSO estimates an absorption capability of 150-200 MW wind power and sets in its draft timetable the completion of the project in the beginning of 2014 (HTSO, 2010b). In the examined case the capacity of 200 MW has been adopted and gradually applied from 2015 to 2020.

The numbers of the Scheduled Changes Case simply prove that the scheduled changes are not enough to meet the targets. Despite the fact that the introduction of natural gas contributes significantly to the emissions reduction, the supply cost remains high (7,026 M€ for the whole decade) and consequently there is not much difference regarding the dependency of the country on imported fuels. Additionally the return benefits of a costly investment such as the interconnection of Cyclades are not considered the best since according to the first reactions of various bodies it offers insufficient transmission capacity for further development of RES-E units.

Finally the RES-E production percentage ascends at 25.33% still far from the national targets.

C. Towards NREAP Case

In order to increase the wind power penetration level the hybrid technology of Wind – Hydro Pumped Storage (WHPS) has been intensively examined the last decade – as a whole, for single islands but also in combination with desalination options or hydrogen production (Kaldellis et al., 2001, Theodoropoulos et al., 2003, Katsaprakakis, 2009, Tsikalakis et al., 2009).

In a recent study (Caralis et al., 2010) on the economics of the application of the WHPS technology almost in all Greek non-interconnected islands the cumulative investment cost (of the moderate option) is estimated to 2,297 M€ for 50% hydro-turbine's peak demand supply and overall energy contribution at 43%. The study concerns 24 islands – Paros, Syros and Mykonos included, but the small islands of Othoni, Antikythera, Anafi, Agios Efstratios, Erikoussa, Donoussa and Agathonisi excluded.

In the Towards NREAP Case no natural gas penetration in Crete is considered, the interconnection of Cyclades and the 200 MW wind capacity remains. Applying the WHPS option in 21 islands – leaving outside Paros, Syros and Mykonos (and assuming Kythnos is staying out also) because of their interconnection with mainland – the investment cost ascends at 2,105 M€. The aforementioned study estimates about 1,089 MW of wind capacity needed in these 21 islands, which total installed capacity until 2009 ascends at 236.1 MW (92.8% of 254.46 MW). Giving almost a 4-year period for constructions it is assumed that in year 2014 the system may start to function. Following the linear route (adopted in the No Change Case), in 2013 the total wind installed capacity ascends at 286.46 MW (proportionally 265 MW of the 21 islands). Following converse process – in comparison to the 2 previous cases, namely first setting the targeted capacity of 2020 – and subtracting the already installed (in 2013) 265 MW from the targeted 1,089 MW each year (2014-2020) a capacity of 115 MW is added. In this case the RES-E production reaches at 56.64% in 2020.

PPC represents at this time the unique Administrator of the electricity network on the islands, therefore PPC undertakes the burden for infrastructure projects. 1,145 of the 2,105 M€ total investment cost (for 21 islands) concerns Crete (Caralis et al., 2010). For the specific island PPC's (& PPC's Renewables) 588 M€ expenditure for the natural gas penetration and 27.3 M€ budget for RES investments until 2014 (PPC, 2009a) could be redirected to this option. On the other hand the huge investor's interest for Crete (for example just one enterprise group requested last December for 39 licenses regarding 39 wind farms in Crete of a total of 1,003 MW (RAE, 2009)) but also for all islands (AEA, 2008), guarantees the long-term viability of PPC's infrastructure investments. Taking also into consideration the long-term benefit of the gained allowances, the 34% reduction of fuel supply cost (2020 compared to 2010), and the possibility of increasing the capacity factor of the wind farms, it can be assumed that the viability of private investments (RES-E units) increases.

The National Strategic Reference Framework 2007-2013 constitutes the main funding tool for the aforementioned proposal. According to the newest governmental planning the investments on the Environment and the Energy Sector will reach 44.44 B€ until 2015 and the whole development programme of PPC is enrolled in this funding framework.

5. Conclusions

In the National Renewable Energy Action Plan that has recently been submitted to the European Commission for Energy (NREAP, 2010) the estimated wind potential for the country – needed to meet the 2020 targets – ascends at 7,500 MW (7,200 onshore, 300 MW offshore). On May 2010 the total installed wind capacity in Greece is 1,195 MW (254.46 plus 940.61 MW in mainland). As long as Aegean Sea has a big part of the estimated 14,000 MW (PPC Renewables, 2008) wind potential of the country it is expected that a significant percent of the targeted capacity should come from the islands.

The estimated 1,358 MW of wind farms in the 3rd case mitigates the oil dependency of the non-interconnected islands, contributes significantly to the emissions reduction and simultaneously creates more than16 thousands jobs, in a period that according to the last press release of the Hellenic Statistical Authority (HSA, 2010b) the unemployment of the country reaches 11.9% with the Southern Aegean Sea region at the percentage of 22.7%.

The present paper confined itself almost only in the wind power exploitation capabilities. Further analysis is needed to include the excellent solar potential of this region, the biomass potential of islands like Crete and Lesvos with big agricultural production and the geothermal power of Milos, Nisyros etc.

	No Change Case			Scheduled Changes Case			Towards NREAP Case		
YEAR	**2010**	**2015**	**2020**	**2010**	**2015**	**2020**	**2010**	**2015**	**2020**
Demand estimation (Gwh)	**5,406.00**	**5,932.00**	**6,458.00**	**5,406.00**	**5,932.00**	**6,458.00**	**5,406.00**	**5,932.00**	**6,458.00**
Oil thermal production (GWh)	4,742.52	5,033.30	5,324.08	4,742.52	2,606.30	2,478.59	4,742.52	4,372.02	2,800.34
Share of thermal production	87.73%	84.85%	**82.44%**	87.73%	83.44%	**74.67%**	87.73%	73.70%	**43.36%**
Emissions (t CO_2)	3,291,312	3,493,113	**3,694,915**	3,291,312	2,792,961	**2,704,325**	3,291,312	3,034,181	**1,943,434**
Allowances cost in million € (20 €/t)	2.247	59.899	**59.899**	2.247	55.859	**54.087**	2.247	59.899	**38.869**
Excess of the allocated emissions (t CO2)	112,374.57	498,116.22	699,917.88	112,374.57	-202,035.55	-290,671.77	112,374.57	39,184.29	-1,051,562.81
Fuels supply cost (million €)	615.058	691.928	**773.270**	615.058	632.102	**649.280**	615.058	601.021	**406.721**
WHPS in: Crete, Rhodes,Kalymnos, Kos, Lesvos, Chios, Samos, Santorini, Limnos, Milos, Karpathos, Ikaria, Sifnos, Patmos, Skyros, Kythnos, Serifos, Amorgos, Simi, Astypalaia, Megisti, (2020 targeted extra wind capacity = 805 MW)							**Starting 2014**	230.00	805.00
Natural gas thermal production (GWh)				**2013 > 250 MW, 2015 > 500 MW**	2,343.30	2,343.30			
RES-E production (GWh)	663.48	898.70	1,133.92	663.48	982.40	1,636.11	663.48	1,559.98	3,657.66
Share of RES-E production	12.27%	15.15%	**17.56%**	12.27%	16.56%	**25.33%**	12.27%	26.30%	**56.64%**
PV installed capacity, CF=15% (MW)	11.82	101.39	**190.93**	11.82	101.39	**190.93**	11.82	101.39	**190.93**
PV production (GWh)	15.36	131.81	248.21	15.36	131.81	248.21	15.36	131.81	248.21
PV share in total RES-E (%)	2.32%	14.67%	21.89%	2.32%	13.42%	15.17%	2.32%	8.45%	6.79%
Total wind installed capacity, CF=28.7% (MW)	258.09	305.38	**352.69**	258.09	338.71	**552.67**	258.09	568.71	**1.357.67**
Wind production (GWh)	648.11	766.88	885.70	648.11	850.58	1,387.90	648.11	1,428.17	3,409.45
Wind share in total RES-E (%)	97.68%	85.33%	78.11%	97.68%	86.58%	84.83%	97,68%	91.55%	93.21%
New jobs per wind MW installed	54.7	768.9	**1,483.3**	54.7	1,775.5	**4,503.0**	54.7	4,745.2	**16,658.5**

Table 3: Results of the 3 Cases examined

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Cost effective Renewable Energy Sources innovations to Agriculture with emphasis on Solar Energy

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Abstract: In many countries, the use of Renewable Energy Sources (RES) technologies in the agricultural sector has shown to be efficient and environmental friendly. RES systems are ideally suited for remote and rural areas, where there is no grid-connected electricity. Among RES, Solar Energy (SE) can supply many farm energy requirements. Applications of SE in agriculture include solar crop drying, solar cooking, solar desalination for drinking and irrigation water, solar water pumping for domestic use and livestock supply, solar heating and solar cooling for farm buildings and greenhouses, solar electric systems for lighting etc. There is a need for a systematic review of cost-effective RES technologies to agriculture and this is one of the present paper scopes, with emphasis on SE systems. Some recent developments on SE technologies like hybrid Photovoltaics/Thermal (PV/T) systems, that can provide simultaneously electricity and heat and can be applied to agriculture, are highlighted. In addition, some economy and energy policy aspects provide a wider view of the studied issues. The innovative agricultural engineering systems proposed seem to be attractive commercial solutions and can have a positive contribution towards the sustainable development of rural communities.

Keywords: Renewable Energy Sources, Solar Energy, Agriculture

1. Introduction

Greenhouse effect and the rising of energy demand have led to interest in Renewable Energy Sources (RES) technologies, which should be promoted in order to combat the challenges posed by climate change. Among RES, Solar Energy (SE) presents a potential source of growth. Since energy plays a crucial role in many agricultural sectors, remote, insular and rural areas are among the strongest candidates for RES technologies adoption. In most of these locations grid-connected electricity and supplies of other non-renewable energy sources are unavailable or too expensive and SE as well as other RES can provide social, environmental and economic benefits. RES technologies, including SE, have already been applied in several agricultural sectors and there is potential for further development (Bassam and Maegaard, 2004). Among agricultural applications of SE, solar crop drying has been used extensively in many countries hence extensively research has been conducted in the field of solar dryers (Belessiotis and Delyannis, 2010). In this paper we present some solar energy technologies that can also be applied in remote/rural areas as well as respective economic aspects. In addition, policy issues mainly related to solar energy applications for remote territories are analyzed. Finally, main conclusions of the present work are outlined.

2. Renewable Energy Sources technologies in remote/rural areas with emphasis on solar energy

2.1 Individual applications

Solar drying

Worldwide, many countries produce agricultural products for local consumption and export. Most of these products have large amounts of moisture content and are therefore susceptible to spoilage during storage. Drying of agricultural products is an important post-harvest operation aiming to reduce the moisture content of the products in order to minimize quality deterioration during storage. Traditional sun drying has been practiced since ancient times and has utilized widely by rural farmers. However, this process has many disadvantages such as fungal and insect attacks, spoilt due to rain and dust etc. Thus, drying by using a solar dryer seems to be an attractive suggestion offering high products quality. Solar drying is environmental friendly, can save energy and is ideally suited for remote/rural areas where there is no grid-connected electricity. In the literature, extensively research has been carried out in the field of solar dryers aiming to the investigation of easy-to-use, low cost devices (Imre, 1997; Belessiotis and Delyannis, 2010). Small-scale companies dealing directly with farmers can not afford the price of drying technologies like spray and drum drying. Instead, cheaper, convective drying systems become appealing to these companies or even to the farmers themselves.

Solar dryers can be classified into two broad categories, passive and active. Passive dryers use only natural convection of the heated air. In their simplest form they consist of a transparent box (glass or plastic) with air-holes to allow air to enter and exit the box. This type of solar dryer is known as direct because the product to be dried is directly exposed to sun rays and are best for drying small batches of fruits and vegetables. Passive solar dryers can be constructed easily from locally available materials and provide a low-cost solution for small farms. Active dryers use forced convection and are designed incorporating fans for moving the solar energy in the form of heated air from the collector to the drying chamber. In general, active dryers are more efficient than passive ones and can be used for drying large quantities of high moisture content products (Ekechukwu and Norton, 1999; Sharma et al., 2009).

For the specific case of drying of large quantities of products requiring high drying temperatures, high efficiency dryers may be used. Following is given an example of a recent development in Solar-Assisted Mechanical Drying. Lamnatou et al. (2010) developed a solar dryer which uses an air collector with evacuated tubes as heat source. These collectors have higher efficiencies compared with flat plate ones and can be utilized in the frame of several agricultural applications (Papanicolaou et al., 2007) and in a yearly basis (e.g. during summer for crop drying and the rest of the year for space heating). In Fig. 1, the above mentioned convective dryer is illustrated. Experiments were conducted for drying of agricultural products. The results show that the dryer, due to the solar collector high efficiency, can be used for drying of large quantities of products. In the frame of this study a numerical model was also developed in the pursuit of the energetic optimization of the above mentioned dryer. The methodology developed is certainly of interest to researchers involved in the design of solar dryers (Lamnatou, 2010).

Hybrid PV/T systems can also be used towards the developing an innovative solar dryer. A PV module, properly combined with a heat extraction/thermal unit, constitutes a PV/T and provides electrical as well as thermal energy. Due to the fact that electricity generation is the main priority, the modules should be operated at low temperatures in order to keep the electrical efficiency at a sufficient level. This means that the extracted heat has low temperature and it can be used mainly for low temperature applications e.g. for agricultural products drying. Extensively research in hybrid PV/T systems has been carried out in the University of Patras aiming at simple and cheap heat extraction improvement modifications. Among these modifications is the use of a thin (flat) metallic sheet in the middle of the channel (TMS) and rectangular fins at the back wall of the channel (FIN) (Fig. 2) (Tripanagnostopoulos et al., 2002; Tonui and Tripanagnostopoulos, 2007).

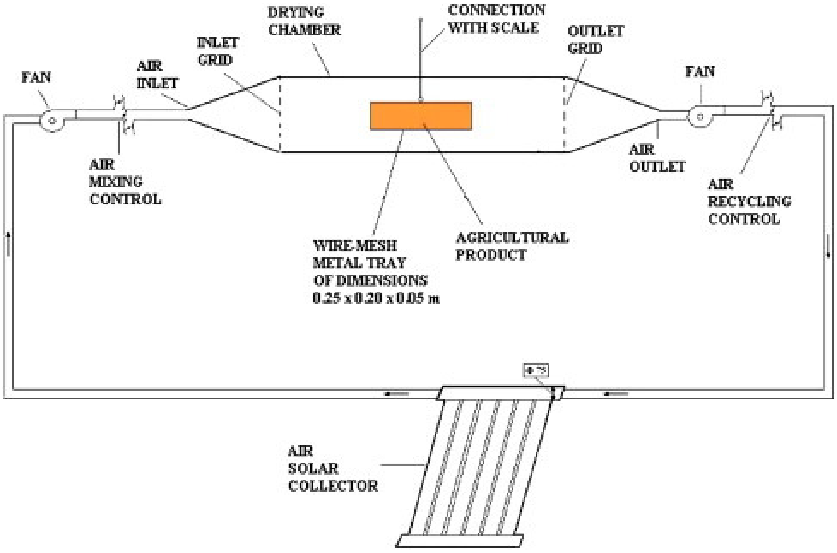

Figure 1: The experimental, active, indirect Solar Dryer developed at the "Solar and other Energy Systems" laboratory of NCSR "Demokritos" (Source: Lamnatou et al., 2010).

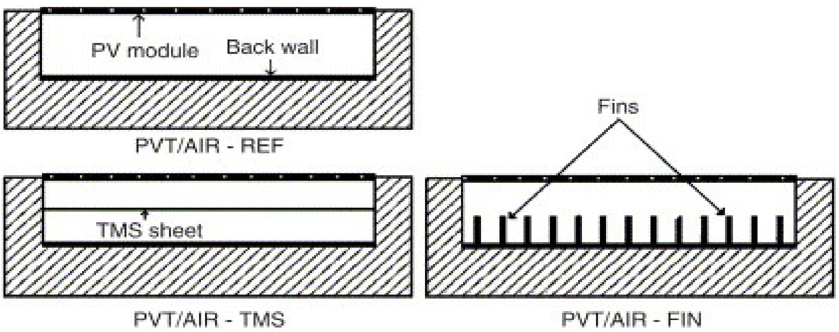

Figure 2: Cross-sectional view of PVT/AIR collector models (flow direction is perpendicular to the page) (Source: Tonui and Tripanagnostopoulos, 2007).

Solar Desalination

Continuous population increase and low quality of available potable water are some reasons for fresh water shortage problems in many areas such as islands, desserts, remote and rural areas. However, the RES potential in these areas is usually high. Thus, desalination by using RES technologies seems to be an appealing solution. *Solar Stills* are an example of simple, solar systems than can easily be constructed. A passive solar still consists of a black, absorbing basin that contains the brackish water and a cover (usually glass). Basin water heats up by means of solar irradiation, evaporates due to the temperature difference basin/cover, condensates at the inner surface of the cover and distilled water is collected in tubes (Fig. 3). The main drawback of passive solar stills is low efficiency especially during winter months (min production in January ≈ 1 kg/m^{2}day, max production in June ≈ 7 kg/m^{2}day) which leads to high fresh water cost. For Athens meteorological data and based on certain assumptions the cost ranges from 10.41 to 12.46 €/m^3 (Lamnatou et al., 2005).

Significant increase of the efficiency of a desalination system can be achieved by using more advanced technologies. Kumar and Tiwari (2008) conducted an experimental study of a hybrid PV/T active, solar still. The PV/T is used to generate electricity to run the pump and thermal energy to heat the basin water, thus system efficiency increases. On the other hand, a seawater reverse osmosis desalination unit powered by hybrid PV-wind that produces potable/fresh water was studied by Mohamed and Papadakis (2004). The cost of the produced water was calculated to be 5.21 €/m^3 for the hybrid operation and is very promising. The system fresh water production is 12 m^3/day in August and 6 m^3/day in January and therefore the needs of a village of 60 inhabitants can be covered.

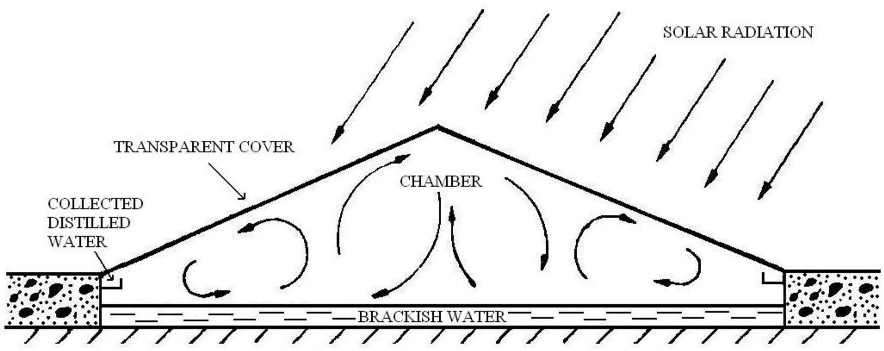

Figure 3: A passive solar desalination system (Solar Still).

Solar Photocatalytic Detoxification

In Greece as well as worldwide large quantities of fertilizers are used in agriculture. Fertilizers consist of complicated organic compounds that do not exist in nature and can cause serious environmental problems. Thus, there is a need to solve the problem of the toxic liquid wastes that are produced during the washing of fertilizers vessels and spray machines. Solar Photocatalytic Detoxification (SPD) is a novel method that can inactivate the liquid wastes before their disposal to a natural receiver. According to SPD method the sunlight is used to activate catalysts, which means that SPD is suitable for the climatic conditions of Greece. For the best utilization of sunlight devices that concentrate SE are preferred and stationary, compound parabolic concentrating (CPC) systems are most commonly used. In addition, the combination of transparent tubes with reflectors can improve system performance more than 50%, mainly from spring to autumn (Poulios and Tripanagnostopoulos, 2007).

Solar Water Pumping

In remote, rural areas there is a demand for domestic and livestock drinking water as well as for irrigation. Omer (2001) studied the potentialities of SE technologies with particular reference to application of solar PV water pumping in remote, rural areas of Sudan. This country has high level of solar radiation and thus SE technologies are appropriate. If water is available in wells that are not near electricity supply, PV water pumping may be considered. In order to study the economic feasibility of a PV pump, factors such as taxes on diesel fuel vs. taxes on PVs, capital and recurrent costs should be taken into consideration. The field experience from PV installation in Sudan showed that operation/maintenance cost is negligible and PV water pumping can be cost competitive with a diesel pump in the near future, as PV pumps costs fall and efficiencies rise. PV pumping works anywhere the sun shines and is a natural match for summer grazing applications since it produces the greatest volumes of water in sunny days when animals need water the most. Thus, PV water pumping seems to be an attractive solution for remote, rural areas having multiple environmental benefits and positive contribution towards living conditions improvement.

Solar Cooking - Heating/Pasteurizing water

Solar cooking is the simplest and safest way to cook food. Nandwani (2007) designed and studied a simple, economic hybrid food processor for cooking, heating/pasteurizing water, distillation of small quantity of water and drying. This device uses solar and electric energy if required (for electrified regions) and consists of an inclined stainless steel box with glass wool insulation, an electric black plate as an absorbing surface and a reflector in order to increase solar radiation on the plate. Solar cookers offer multiple benefits: they are environmental friendly, smoke free (they don't irritate lungs and eyes) and their moderate cooking temperatures preserve nutrients. Furthermore, solar cooking reduces risks associated with the fact that millions of women routinely walk for miles to collect woods for cooking. Thus it can be concluded that incorporating solar cookers into daily lives of rural, isolated areas can improve the living conditions of the population and is a cost-effective solution.

Solar Distillation

Essential oils that are produced by aromatic/medicinal plants are used in foods, medicines, cosmetics etc and are very expensive. Essential oils are extracted from various parts of a plant like flowers, seeds etc. Out of all extraction methods, distillation has advantages of extracting pure/refined essential oils by evaporating the volatile essence of the plant material. At present the large distillation units are located in cities, have high operating costs and are unmanageable by farmers. Thus, using SE as an alternative source of energy seems to be an attractive, environmental friendly and cost effective solution towards the development of decentralised (on-farm) solar-based distillation units. Munir and Hensel (2010) studied a solar distillation system that was installed at the solar campus, University of Kassel, Witzenhausen, Germany. The system includes a Scheffler concentrator which is a lateral part of a paraboloid and the results show that provides an excellent opportunity for essential oils extraction from herbs for decentralized applications.

2.2 Applications per sector

RES technologies in greenhouses

RES technologies have been applied in greenhouses and can provide attractive solutions for greenhouse owners with greenhouses located in isolated areas. Some of them are the following: Closed loop *underground earth-air heat exchangers* that regulate greenhouse air temperature (Mavrogianopoulos and Kyritsis, 1986). *Geostill,* that can be used for supplying greenhouse heating and pure water for irrigation from salty geothermal water (Mavrogianopoulos, 1991). *Passive, solar sleeves*: plastic, transparent sleeves filled with water are placed between plant rows, collect heat during day and provide this heat during the night (Mavrogianopoulos and Kyritsis, 1993). *Trombe wall* (passive solar) that can be used for heat absorption and storage and is placed inside the greenhouse near the south-facing windows in order to absorb heat and then radiate this heat into the greenhouse (Bellows,2010). Liquid-desiccant *solar cooling* system which is more efficient compared to simple fan ventilation system and is suitable for greenhouse food production in hot climates (Davies, 2005).

Tripanagnostopoulos et al. (2004) conducted a study on combining Fresnel lenses with PVs. Glass type Fresnel lenses can be mounted stationary on the greenhouse roof combined with linear absorbers (Fig. 4) to receive and convert the concentrated solar radiation into heat, electricity or both. The linear Fresnel lenses can separate the direct from the diffuse solar radiation and this advantage makes them suitable for lighting and temperature control of the greenhouse interior space, providing light of suitable intensity level and without sharp contrasts. The incident beam solar radiation is concentrated on the tracking absorbers and can be taken away from the glazed space. In this way, lower illumination level is achieved while avoiding overheating of the interior space. Furthermore, in low intensity solar radiation, the absorbers can be out of focus leaving the light to come in the interior space and keeping the irradiation at an acceptable level for the plants.

Fresnel lenses can also be combined with Stirling engines (simple, low cost thermodynamic devices) and can be used for applications such as water pumping, desalination, greenhouse ventilation etc (Tripanagnostopoulos et al., 2006). On the other hand, PV/Ts can be mounted on the roof of the greenhouse forming a kind of solar chimney and leaving most of the incoming solar radiation to go through the transparent roof (Fig. 5). The results of a case study for South Spain showed that the proposed system can contribute satisfactorily to the electrical load for the ventilation of a greenhouse, but it is not effective for covering the winter heat loads (Rocamora and Tripanagnostopoulos, 2006). Another application is drainage water disinfection by using an Integrated Collector Storage (ICS) system which combines collection and storage into a single unit. The experimental results of a study showed that a minimum time of 3 hrs is required for an effective disinfection treatment at 65^{o}C (Tripanagnostopoulos and Rocamora, 2007).

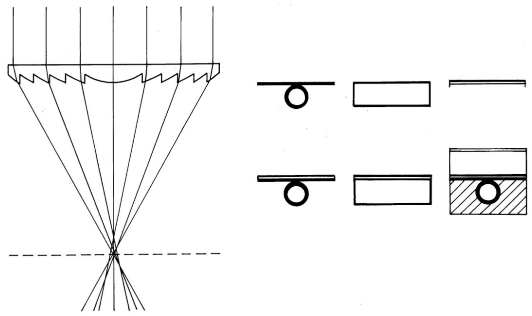

Figure 4: Linear Fresnel lens, with indication of the concentrating solar radiation (left) and alternative absorbers of Thermal, PV and hybrid PV/T (right) (Source: Tripanagnostopoulos et al., 2004).

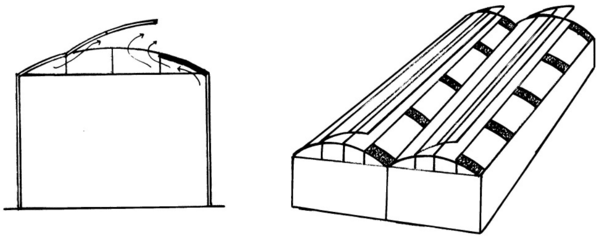

Figure 5: The suggested installation mode of hybrid PV/Ts on greenhouses for their ventilation (Source: Rocamora and Tripanagnostopoulos, 2006).

RES Technologies in agricultural buildings

Several RES technologies can be applied in agricultural buildings. Following are given some examples of literature review. Thorpe and Ahmad (1998) studied the performance of a *solar desiccant system for cooling* stored grains. In climates with high wet-bulb temperature of ambient air at night, it is preferable to reduce isothermally the humidity of ambient air before it enters the grains. Bazen and Brown (2009) conducted a study on feasibility of *PVs* in Tennessee poultry industry. The results show that under current incentives for PVs, solar energy can be economical feasible given that all state as well as federal incentives are actually obtained. Furthermore, space/water heating by using SE seems to be an attractive solution for rural areas because livestock and dairy operations often have substantial air/water heating requirements. For example modern pig and poultry farms raise animals in closed buildings and it is necessary to carefully control temperature/air quality to maximize the health of the animals. Thus, there is a need to replace the indoor air with fresh/ambient air. By using e.g. an air collector to preheat incoming fresh air substantial amount of energy can be saved. In addition, solar water heating systems can provide hot water for houses as well as for dairy operations such as cleaning of the farm equipments. Commercial dairy farms use large amounts of energy to heat water and therefore the use of a solar water heater can have a positive contribution towards their energy savings (US DOE, 2009).

Unglazed Transpired Collectors (UTC) (also known as perforated collectors or solar walls) are a relatively new development in solar collector technology and can be used for space heating e.g. of farm buildings and greenhouses as well as for drying, effecting considerable savings in energy. UTCs are a potential replacement for glazed flat plate collectors and reportedly offer the lowest cost and highest efficiency for air heating (Augustus Leon and Kumar, 2007). Building - Integrated *Concentrating PVs* (BICPV) can also be applied in agricultural buildings, offering advantages over convectional flat panel devices such as higher electrical conversion efficiency, better use of space etc. However, the viability of BICPVs depend on their ability to offer a comparative economic advantage over flat panel PVs, which market prices are decreasing from day to day and offer other advantages such as ease of structural elements replacement (Chemisana, 2010).

RES technologies for electricity supply in remote, insular, rural areas

Accelerating delivery of RES such as wind power, PVs etc for electricity supply to remote, insular and rural areas should be of high priority because they are a viable alternative compared to decentralised grid systems. A 50 kW_p PV rural electrification project was installed in La Garrotxa (Catalonia, Spain), a mountainous zone with scattered population part of which was not connected to the electric grid, promoted by the local authorities and included 65 sites with stand-alone PV systems. The results showed that there was a positive contribution to the development of these areas as well as considerable savings with respect to electric grid extension in a fragile mountain environment (Vallve and Serrasolses, 1997). Another PV rural electrification project was launched in Jordan (in 2002) where many remote/isolated areas are located far away from the national electricity grid. An important element of the program was the access of low-income, rural consumers to essential electricity. Users' satisfaction indicates that the PVs are capable of supplying the basic electricity needs with an acceptable level of quality. Furthermore, improvement of children's education, entertainment, and information through TV and radio are the prominent effects of PV electrification in that village. However, the sustainability of a successful rural PV electrification program in Jordan depends on factors such as market, technical, social and economic issues, as well as building up both the government and the user confidence in this new technology (Al-Soud and Hrayshat, 2004).

Another possibility is the adoption of hybrid RES systems such as the pilot one that was developed for electrification of remote villages in Thailand. Three hybrid systems PV /Microhydro/Diesel/Battery, PV/Diesel/Battery and PV battery-less grid connected power stations were installed to demonstrate and evaluate advanced RES technologies (Kruangpradit and Tayati, 1996).

Concentrating solar power (CSP) systems (e.g. solar dish/Stirling, parabolic troughs etc) can also be promising solutions for remote areas because CSPs can be combined with low cost storage systems such as two-tank molten salt. The results of a study regarding a 1.5 MW_e solar tower power plant in Julich (Germany) show that in countries with high solar potential such as Greece, the development of this competitive solar thermal technology is imperative, since it has already been implemented in other Mediterranean countries (Alexopoulos and Hoffschmidt, 2010).

For the case of RES systems for electricity production, it is important the selection of systems/appliances with lowest consumption for equal rendered services. This is called rational use of energy (RUE). Synergy between RUE and RES allows a decrease in total cost of production and consumption of RES-based electricity and facilitating greater penetration of RES-based electrification options (Chabot, 1992).

3. Energy policy aspects regarding remote/rural areas

Especially for rural areas, climate change policies have commonly been framed as an emergency topic for international governance. Nevertheless, a decade of experience following the Kyoto Protocol back in 1997 suggests that this governance is a far more complex procedure and a very interesting negotiation process, involving a wide range of actors, options and varied engagement by multiple levels of governance systems (Rabe, 2007). It has been argued that for regional areas and especially for countries that are located in the regional area of Continents local factors and local criteria mainly should be taken into consideration when a transition towards a new energy situation is taking place (Michalena, 2009). This is especially true for the transition to a sustainable energy environment when challenges are high and costs are discouraging.

In this section we will provide some recommendations that will support remote regions to further expand their capacity to adopt some new technologies or the ones presented above and that will lead the European ambitions towards a new energy era.

Three factors should be taken into consideration for the compatibility of energy projects in remote areas (Butler, 1986): spatial factor, environmental factor and cultural factor. This is especially true for regional countries with restricted geographic conditions and with exceptional beauties of landscape. In such countries Spatial Planning for renewable energy projects should consider all renewable energy technologies particularities as well as the carrying capacity of remote areas (Decleris, 2000). Strategic approach of the State should be funded on the following principles: The protection of vulnerable zones, the potential economic and social results, the promotion of the welfare of remote local communities, the degree of local acceptance for innovation, the existence of technical and financial

infrastructure, the dynamics of economic activities (i.e. tourism), the degree of natural processes understanding and the absorption capacity of ecosystems on the basis of shared responsibilities.
Towards this aim of new solar energy technologies adoption, participative governance is welcome. End users should not only have the possibility to follow the operation of the renewable energy projects (Dalianis et al., 1997), but also to participate through their engagement in energy projects. This engagement depends among other factors, by politic, economic and local circumstances (Nilsson and Martensoon, 2003). Reduction of social risks is equally important as the reduction of other technical risks in the context of a local community (Ragueneau and Teule, 2006). For the local people to be engaged in energy projects, familiarization of local actors with new energy projects is a time-demanding procedure. For well leading such a procedure, one should approach the specific interests of local actors and their degree of traditionalism. Local population should also be as more informed and trained as possible and ready to interact with private investors so as to face potential risks from the erection of new projects. For the case of adoption sustainable energy systems (SES) for the domestic sector, the design of effective policies aiming to encourage the uptake of SES needs an improved understanding of behavioural factors that influence householders' decisions to invest into SES (Claudy, 2008).
For well diffusing information related to renewable energy systems (especially when innovations are concerned), an important step is to segment the existing energy market depending on geographic criteria, or others. On this, innovative technologies need some time to be adopted, but there are parameters that might influence this adoption (Rogers, 1995). Also, the creation of platforms "learning by doing" (Smits and Kuhlmann, 2004) is important for the creation of "application nests on site" (Kemp et al., 1998). Towards this goal, the creation of "local laboratories" is helpful and the State should motivate funds towards this aim. Academics should be invited so as to relate sustainability with *intercommunal structure* (Clarimont and Vles, 2006). Demonstration based on pilot projects is equally helpful. Mechanisms that would facilitate collaboration and coordination between central authorities, local societies, private investors and actors of other countries should exist.
A special attention should be awarded on the evaluation of actions to be taken on site (Michalena, 2009). For this evaluation some indicators to be used are the rate of population increase (Fitzerald, 2005), the complexity of administrative procedures, etc. In any case, quantitative indicators should be accompanied by qualitative ones that will allow comparisons. Through this procedure, young people would be trained on how to build and operate renewable energy projects, and the islands would attract worldwide scientific interest, to maintain young populations on the remote areas (Michalena et al., 2005). Regulatory framework should emphasize on the use of innovative technologies and energy storage systems especially in remote areas where transfer of best practices from the mainland is not such an easy task. In all national policies, there must be a vision, specific and measurable objectives (Smith and Sheate, 2001; Pope et al., 2004), prior identification of possible barriers, preventive development of alternative solutions and specific action plan.

5. Conclusions

Under specific conditions, RES technologies have the possibility to provide an efficient and environmental friendly solution to the agricultural sector. Among RES technologies, Solar Energy has many applications such as solar drying, cooking, desalination, space heating/cooling, solar electric systems for lighting etc. Some recent developments in SE technologies can have various applications (drying, space heating, solar water heating etc) and are promising solutions provided they are used in a cost-effective way. Factors such as thermal energy storage, combined use and rational use of energy should be taken into account so as the proposed RES-based systems to be attractive commercial solutions and contribute positive towards the sustainable development of rural communities. A special emphasis should be given on the design of local and national regulatory and political framework to attract investments on solar energy applications.

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