ESTIMATING THE RENEWABLE ENERGY CONTRIBUTION TO

Regional Energy Systems

This article describes a study done on the island of Lemnos, Greece, to analyse and estimate the extent to which Greece can comply with the European Directive of increasing the share of renewable energy sources, while at the same time trying to establish a reduction in the increase of greenhouse gas emissions.

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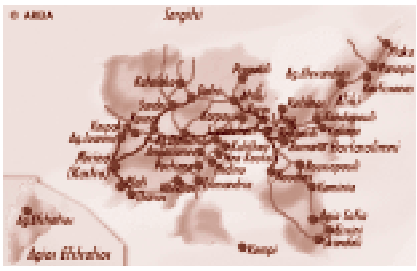
In compliance with the European Directive (2001/77/EC) on electricity generation from renewable energy sources (RES), Greece has to increase the share of RES contribution to electricity generation by 14% (excluding large hydro), or 20% (including large hydro) by 2010. In addition to this, the greenhouse gas emissions should not exceed the 1990 levels by more than 25% in the period up to 2012.

The objective of this work is to provide a framework for analysis and a method of estimating the extent to which these two goals can be met in the country. More specifically, the energy analysis of a regional system using the LEAP software, the forecast for the future energy demand, and the contribution of RES for different penetration levels in the local energy system will be carried out.

The base year for the analysis is 2003 and the proposed framework will be applied to a case study of the County of Lemnos, which is simple enough to present the main features of the method. Lemnos consists of two small islands located in the N.E. Aegean Sea (Figure 1) with a population of 17,852 according to the 2001 Census. This region has all the main features of the Greek national energy system, being at the same time a closed system.

Figure 1:
Location of the Study Region *[7]

Figure 2:
Detailed map of the County of Lemnos



METHODOLOGY

The proposed methodology consists of the following three steps:

First, the energy balance of the region that is being studied was determined for the base year. The energy consumption for each sector of the energy system was calculated by using a bottom-up approach. Simple energy models were created and energy demand was assumed to be built-up by energy consuming units in the main sectors of the region's energy system *[1,3]. The Long range Energy Alternatives Planning (LEAP) software was used to develop the region's energy balance. The necessary data was collected through local field research or from official sources, like the National Statistical Service *[6] and the Public Power Corporation.

In the second step the future energy demand was estimated. Towards this end, the following three alternative scenarios were created *[2], based on the assumption that the annual energy consumption per unit remains stable:

- Business As Usual (BAU)
- Higher Energy Demand (HED)
- Lower Energy Demand (LED)

The main variable is the number of energy consuming units. The BAU scenario, which was used as a guide for the other two, followed the Public Power Corporation's forecast for electricity demand, based mainly on historical data. In the HED scenario, the foundation of a University Department on Lemnos by the end of 2006 is assumed (currently under discussion). Finally, the LED scenario assumes that population increase declines and reduction in growth rates over the coming years will be observed. The growth rates used were entered into the LEAP model and the future demand is estimated.

The third step entails the selection of the best combination of RES technologies in order to meet energy demand. The method used is Cost Effectiveness Analysis, which evaluates the alternative energy plans according to both their costs and their energy supply, taking into account the island's specific needs and natural resources *[5]. Cost data for the renewable energy technologies were taken from RETScreen, a standardized and integrated renewable energy project analysis software. At this point, it should be noted that only costs relating to electricity were used in the analysis. Also, the electricity plants were dispatched according to a specified merit order. The fuel oil plants and the wind turbines were considered as base load and the diesel plants as peak load.

RESULTS

The results are presented in the tables and figure below. More specifically, Table 1 presents the energy balance of Lemnos for the base year. All the non-indigenously produced energy forms are imported from the mainland. It is seen that the domestic and transport sectors account for over 65% of the total energy consumption. Furthermore, the domestic sector accounts for over 50% of the total electricity consumed. Finally, it should be pointed out that the sector "Other" includes energy consumed in other public buildings, for the lighting of streets and squares and also for naval transport.

Table 2: Proposed Action Plan

Installation of Wind Turbines	
2006	2 Wind Turbines 600kW
2008	2 Wind Turbines 600kW
2010	2 Wind Turbines 600kW
2014	1 Wind Turbine 750kW
Installation of Solar Heated Boilers	
2020	2000 boilers to be installed by 2020 in the domestic sector

The proposed action plan is summarized in Table 2. These actions are mainly interventions into the existing infrastructure and, more specifically, the installation of extra wind turbines onto the grid. In practice, the wind turbines replace the diesel driven electricity generation units. The installation of 2000 solar heated boilers by 2020, mainly on newly built houses, is also suggested.

Through this action plan the contribution of RES to electricity generation will reach a share of 15% in 2010 and of 17% in 2014 (Figure 3) with an extra cost of $1,250,000 from 2010 and $1,500,000 from 2014 (Figure 4). It is obvious and

Figure 3: Electricity Generation Planning for the PPC Forecast Scenario

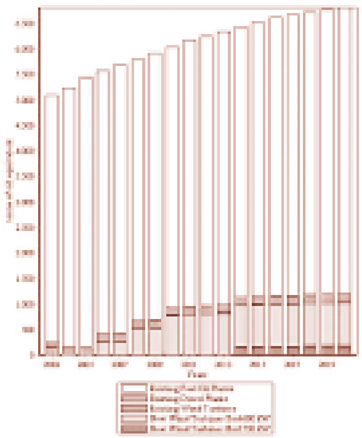


Table 1: Energy balance of the region for the base year (2003) in TOE

Energy System Sectors	Electricity	Gasoline	Diesel	Fuel Oil	LPG	Wind	Solar	Biomass	Total
Production	0	0	0	0	0	164	581	0	745
Imports	0	3287	8402	11829	244	0	0	2031	27684
Exports	0	0	0	0	0	0	0	0	0
From Stock Change	0	0	0	0	0	0	0	0	0
Total Primary Supply	0	3287	8402	11829	244	0	0	2031	28428
Electricity Generation	4840	0	-232	-11829	0	-164	0	0	-7386
Electricity Distribution	-381	0	0	0	0	0	0	0	-381
Total Transformation	4458	0	-232	-11829	0	-164	0	0	-7767
Statistical Differences	0	0	0	0	0	0	0	0	0
Domestic	1979	0	2585	0	244	0	370	2031	7210
Tourism	264	0	54	0	0	0	211	0	529
Commercial	504	0	160	0	0	0	0	0	665
Schools	225	0	160	0	0	0	0	0	385
Hospitals	18	0	37	0	0	0	0	0	55
Public Buildings	131	0	64	0	0	0	0	0	195
Agriculture	56	0	1760	0	0	0	0	0	3707
Transport	0	3287	1348	0	0	0	0	0	4635
Industry	189	0	500	0	0	0	0	0	689
Other	1092	0	1500	0	0	0	0	0	2592
Total Demand	4458	3287	8168	0	244	0	581	2031	20661
Unmet Demand	0	0	0	0	0	0	0	0	0

Figure 4: Extra costs due to the new wind turbines

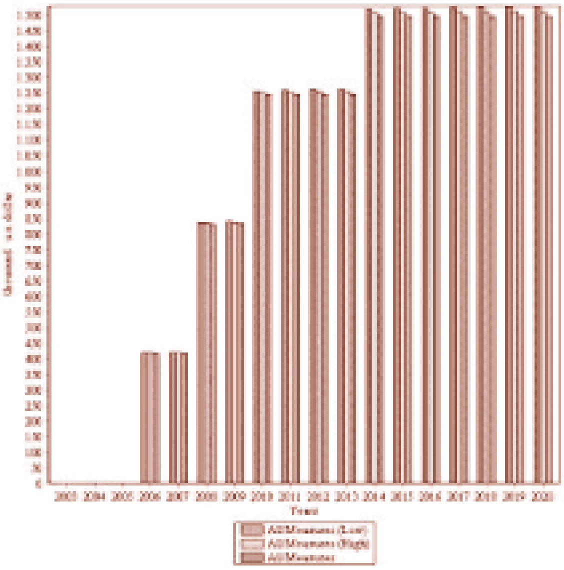
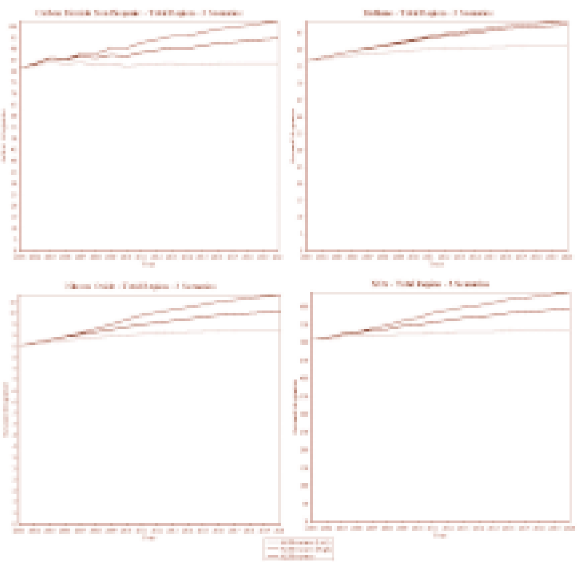


Figure 5: Greenhouse gas emissions (2003-2020)



expected that the use of renewable sources of energy leads to a significant cost increase.

On the other hand, the reduction in greenhouse gas emissions is not sufficient, despite the decrease of pollutants transmitted from the power generation plants (Figure 5). The two sectors which cause the most severe environmental impacts are the domestic and transport sectors. The action plan may be extended to include some interventions in these sectors such as ground-source heat pumps or biomass heaters for the heating of households, and the upgrading of the public transport.

SUGGESTIONS FOR FURTHER RESEARCH

The results presented in the previous section show that the proposed methodology meets the set objectives in a very satisfactory way. However, there are a number of points, as presented below, which may be further elaborated and improved.

In modeling energy consumption and estimating future energy demand the following important parameters were not taken into account:

- The rise in the standard of living, since both the annual energy consumption per unit and the fuel shares were considered to remain constant over time.
- The technological progress, since the efficiency of the used appliances also remains constant.

For a more realistic approach these two parameters should be also taken into account in the various alternative scenarios.

In modeling electricity distribution, a unique transmission and distribution losses coefficient was used, irrespective of where electricity was generated. Differentiating this coefficient and using a smaller value in the case of renewable energy sources would lead to cost reduction.

In modeling electricity generation, the load factor was used instead of the load curve, which was not available at that time. As a result, seasonal peaks in electricity demand were not taken into account, the satisfaction of which may require a different electricity generation planning. Taking this point into account would lead to a much more realistic simulation and to better results.

Cost data for the demand sector and not only for the electricity generation should be included in the analysis in order to have a complete cost analysis of the proposed action plan. Finally, further optimization of the proposed actions and measures may be attempted and different action plans for each scenario can be proposed to examine if the costs are reduced.

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For more information

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