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National Energy Authority

Energy Development in the Non-Connected Islands of the Aegean Sea

Internship report

Filippos Rodger Tsakiris

Prepared for the EDIN Steering Committee

OS-2010/08

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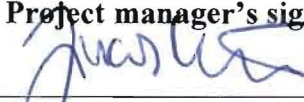
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Abstract: <p>The cost of sustaining diesel-fueled power plants in the Aegean Islands is significant in financial, social, and environmental terms. During the summer, cooling needs and tourist populations stretch island peak generation even further while the vital tourist industry is often hampered by the limited electricity and potable water supply of local island communities. Fortunately, most Aegean Islands have optimal wind and solar potential in addition to the substantial geothermal resources of the Aegean volcanic arch. Meanwhile, the current Greek government heavily supports RES investments through its legal frame and high feed-in tariffs. This report aims to provide an overview of the Greek and Aegean electricity sectors and present the energy potential, along with the financial and legal information related to the development of onshore wind, geothermal and solar plants in the non-connected Aegean Islands. The exploitation of the vast Aegean RES provides a clean and cost-saving substitute to diesel-fueled electricity generation, boosts local eco-tourism activities and helps the Greek government achieve its national and EU energy goals.</p>		
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1 INTRODUCTION

In December of 2008, the EU established the “20-20-20” goals leading the global transition towards renewable fuels and energy efficiency. Inside the EU energy scheme, Greece is obligated to meet 18% of its energy needs from renewable sources by 2020. To reinforce the country's commitment to green development, the current Greek government proclaimed renewable energy as one of its key priorities and raised its national goals to achieve both a 20% share of renewables in its gross energy usage and a 40% share in its electricity consumption by 2020. In fact, green development has been presented as capable of providing high quality jobs and global competitiveness and has been proposed as a partial solution to the current economic crisis the country faces. Following that direction, the government established the Ministry of Environment, Energy and Climate Change and published a new Law in June of 2010 aiming to accelerate the development of renewable energy sources (RES). This paper examines the role of the vast Aegean renewable energy resources in the national transition towards cleaner energy. A map of the Aegean Sea is presented in Figure 1.

As of today, most Aegean Islands are not connected to the mainland grid and thus rely on polluting and costly-inefficient diesel generation to fulfill their electricity demands. For that reason, islands contribute a significant share of the country's CO₂ emissions, despite the fact that their populations and economies are comparatively small in the national scheme. In addition, their diesel generation creates high costs which in turn are passed on to the mainland consumers through a nationally unified price system, thus raising electricity prices across the country. As the Aegean electricity sector follows a national trend of increasing consumption, these negative effects of island diesel generation are to become continuously more significant.

In addition, the predominant tourist industry of the Aegean Islands is directly linked to the electricity sector, demanding large loads to fulfill the cooling and service energy needs of visiting summer populations. While the tourist industry contributes a considerable share of the island and national income, tourist activities are often limited by the electricity and potable water supply of local communities. At the same time, Aegean tourist economies, relying on the large number of summer visitors, struggle to sustain their cultural and natural resources while competing internationally with much cheaper destinations. In many areas economic difficulties and limited working opportunities have forced Islanders to move to mainland cities or abroad. Under these terms, and with the entire country going through a phase of economic crisis and political transition, the financial and cultural survival of Aegean communities is at stake.

The green development of Aegean economies through the utilization of the vast renewable energy resources, could provide new working opportunities, enhance eco-tourism activities and secure the cultural, social and financial sustainability of Aegean societies. Fortunately, most islands have optimal wind potential with average wind speeds of 8-11 m/s at hub height and solar resources with a yearly sum of incident sunlight at 1800-2000 kWh/m² (assuming optimally inclined south-orienting modules) in addition to the substantial geothermal reservoirs being present in the Aegean volcanic arch. The exploitation of most of these resources provides a cheaper alternative to the current diesel generation and would result in significant savings and lower nationwide electricity prices. In addition, capital investment in the renewable electricity sector and new job opportunities would reinforce the weakening island

economies and prevent further immigration and city centralization. With a RES development similar to that of Samsø in Denmark or Gotland in Sweden, Aegean Islands could swiftly turn towards eco-tourism activities that provide high returns without over-exploiting the natural and cultural resources of their traditional and often sensitive societies. The energy development of Aegean RES brings a holistic solution for island communities while, at the same time, helps Greece fulfill its national and EU energy goals.

This report aims to provide an overview of the Greek and Aegean electricity sectors and present the energy potential, along with the financial, and legal information related to the development of onshore wind, geothermal and solar plants in the non-connected islands (NCIs) of the Aegean Sea. This document is addressed towards organizations, government officials, investors and individuals with an interest in the Aegean, or even Mediterranean, electricity sector and its future perspective. The paper was provided as an informational bridge linking Greek and Aegean institutions to the international organization EDIN (Energy Development in Island Nations).

This report was supported by and is part of a T.J. Watson Fellowship project focusing on sustainable energy development in islands around the world. The report was conducted through a two-month internship at the Icelandic National Energy Authority (NEA) and has received advice from this institution. However, the results and analysis presented in this document are generated by the author and do not necessarily represent the opinion of NEA. Comments, suggestions or any other feedback concerning this report may be sent directly to the author frtsakiris@gmail.com.



Figure 1: Map of the Aegean Sea (Graphic maps, 2010).

2 THE AEGEAN ISLANDS

The Aegean Sea, heart of the ancient Hellenic civilization, boasts over 2000 islands with a total population of 1.109.938 (Hellenic Statistical Authority, 2001). Rhodes and Crete are the most populated islands today, comprising 11% and 54% of the Aegean Island population respectively.

Today almost all of the Aegean Islands belong to Greece after seceding from the Ottoman Empire and other powers after consecutive wars in 1821, 1913, and 1947. Exceptions are the isles of Imbros (Turkish: Gökçeada), and Tenedos (Turkish: Bozcaada) which were ceded in 1923 and are now Turkish possessions.

The Aegean Islands are characterized by their extremely rich biodiversity and natural beauty, both threatened by large-scale tourism and environmental changes. The climate is dominated by cool, wet winters and hot, dry summers, and rainfall ranges from as little as 100 mm to as much as 3,000 mm. During the dry summer months, tankerships transfer potable water from the Greek mainland to many island communities covering the water demands of increased summer populations.

Geologically, most Aegean islands are peaks of extending mainland mountain ranges with many islands having volcanic origin. In the island highlands, limestone formations are common with a thin and relatively poor soil. The valley areas contain clay-like soils known as terra rossa, reddened earth that originates from limestone rock, which is adequate for farming. The most fertile regions are along coastal plains and besides rivers where clay and loam soils predominate. Forest cover varies greatly among the islands and in some cases, soil erosion is a serious problem.

The principal incomes of Aegean island communities derive from tourism, sailing, fishing, and high-price high-quality crops such as citrus fruits, olives, and grapes. The fact that successive Greek governments have focused mainly on Athens and mainland cities has left island economies underdeveloped and, combined with a poor national economy, has led many islanders to emigrate resulting in an island population decrease. As part of the Hellenic Republic, the Aegean Islands joined the EU in 1981 and have participated in the European Economic and Monetary Union since 2001.

3 GREEK ELECTRICITY SECTOR

The Greek electricity sector is characterized by increasing and accelerating consumption, mainly in the transportation and tertiary-domestic sectors, and by the inability of domestic production to satisfy demand, resulting in a dependence on electricity importation (Energy Outlook of Greece, 2009). In the year of 2006, the Greek electricity system had a total net capacity of 13,6 GW and a net generation of 57 TWh mainly from the use of lignite and hydroelectric plants. As of 2009, Greece had annual net electricity imports of 5,6 TWh accounting for approximately 9,4% of national consumption and heavily burdening the country's economy (CIA factbook, 2010).

The Greek wholesale electricity market is currently dominated by the Public Power Company (PPC), which covers 95% of it, even after the 1999 energy law reforms allowed private companies to enter the market. According to the energy reformation law, the electricity of Greece has to remain exclusively owned by PPC which is obligated to maintain the grid and ensure its operational and technical sufficiency (Ministry of Development, 2009).

The Regulatory Authority of Energy (RAE) is the country's independent, supervising authority on matters of energy sufficiency, market regulation and monopoly supervision. RAE regulates the energy production of both public and private plants and, exercises price control in cooperation with the Minister of Energy, Environment and Climate Change.

3.1 Historical Overview of the Greek Energy Development

Electricity services were first offered in Greece in 1889, when the General Construction Company built an electrical power plant to illuminate the king's palace in Athens. Very soon, electrical lighting spread to the historical center of the capital and surrounding areas. Thessaloniki, at the time still under Turkish occupation, received electricity in the same year, when a Belgian company built a power plant in order to power a tram network and illuminate the city.

In the next decade, multinational electricity companies made their appearance in Greece, with American Thomson Houston and the National Bank of Greece undertaking to provide the electricity supply of various major Greek cities. In the remote highlands and islands, where major companies found it unprofitable to build power plants, local authorities or individuals undertook the task by constructing small-scale power plants.

By 1950, there were about 400 companies involved in the generation of electrical energy in Greece, mainly utilizing imported fuel oil and coal. This fragmented power generation caused power outages to be commonplace, and combined with the import costs of fuel, made electricity a high-price luxury good. The industrial and rural needs imposed the uniform electrification of the country. The local power generators were largely unable to invest in domestic resource development and integration into a single interconnected power system seemed to be needed in order to ensure the distribution of loads on a national level (Public Power Company, 2010c).

Under these conditions, the Greek government founded the Public Power Company (PPC) in 1950, in order to apply a national energy policy which, through the exploitation of domestic resources, would distribute electric power to all Greek citizens. Backed by government funds, the PPC integrated most networks into a national energy system and heavily exploited the domestic lignite resources and hydroelectric potential. The Aegean islands, which were not connected to the national grid due to the high associated cost, were powered by fossil fuel engines. The establishment of the PPC as a single organization enabled the national management of energy loads and the spreading of costs between profit and loss making areas of the country. Throughout these years, PPC achieved provision of electrical power literally to all communities of Greece, from the most remote island to the most isolated mountain village (Public Power Company, 2010c).

In recent years, the liberalization of the internal electricity market has been one of the foundations of the energy policy adopted by the European Union. Like other Member States, Greece has incorporated European Directives and adjusted the structure of the Greek market taking approaches towards liberalization (Ministry of Development, 2009).

In 2001, complying to Law 2773/1999 and EU regulations, the electrical power market was deregulated and PPC became a public limited company entering the Athens and London stock exchange. A company independent of PPC, DESMIE S.A., Operator of the Greek Electrical Transmission System, was also created by Law 2773/1999 and received the operating responsibility of the electricity transmission system. However, following the same law, PPC ought to remain the exclusive owner of the Electrical Energy System of Greece and PPC, still today, dominates the energy market of the country owning about 89% of the installed electrical capacity in Greece.

3.2 Growth of Electricity Demand

After 1990, economic growth and widespread use of modern devices lead to a sharp increase in Greek electricity demand. The largest increase was in the consumption of the household and tertiary sectors which, in the period of 1990-2006, increased by 93.4% and 216% respectively. In recent years, the growth rate of household demand has been decreasing, possibly indicating a saturation of modern electrical needs. Due to the recent economic crisis in Greece, the growth of electricity demand is expected to remain in low levels at least for the next four years. The growth of electricity demand per capita is presented in the graph below:

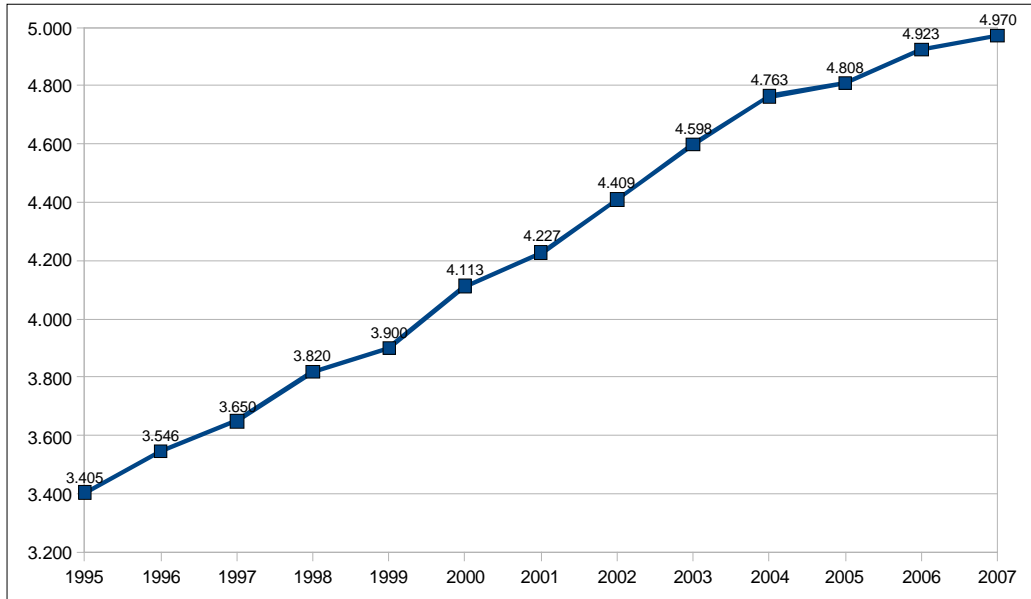


Figure 2: Yearly electricity consumption per capita in Greece for the period of 1995-2007 in kWh (Public Power Company, 2010a).

3.3 Comparison with Global Electricity Consumption

In comparison with the Balkan countries, Greece has the highest electricity consumption per capita, roughly twice that of Turkey and thrice that of Albania. Bulgaria is the only Balkan nation that has a similar level of electricity consumption. In comparison with other EU states and developed countries however, Greece presents a relatively low electricity consumption per capita as shown in Figure 3.

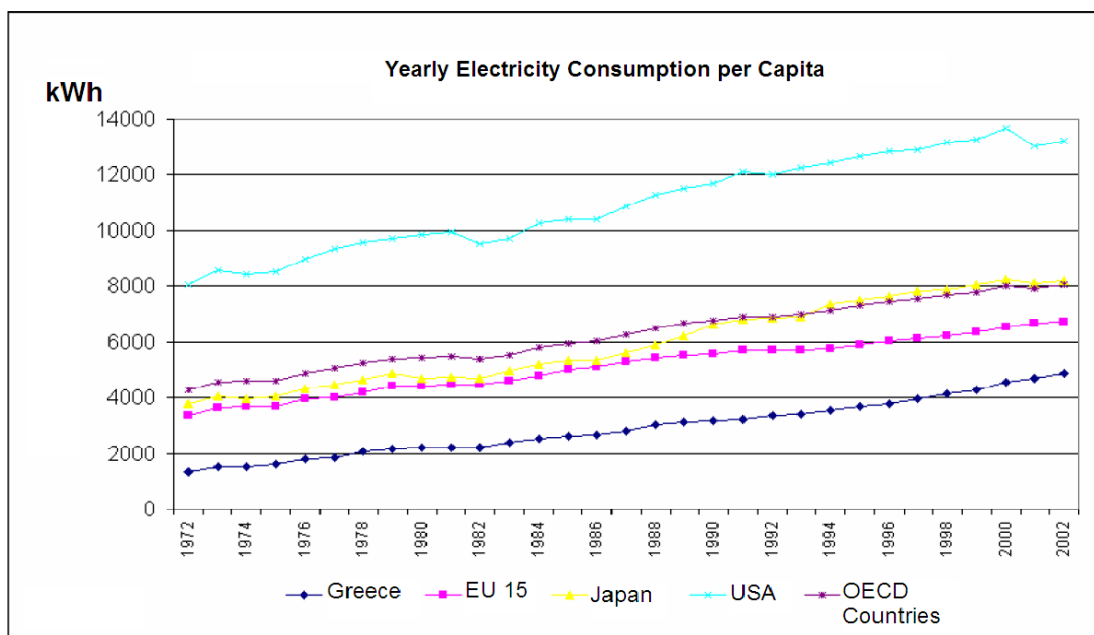


Figure 3: Electricity Consumption per Capita in various developed countries in kWh (Center of Renewable Energy Studies, 2002).

3.4 Renewable Electricity Generation in Greece

Conventional renewable electricity generation (large hydroelectric plants excluded) has indicated an average annual growth of 3,7% during the last decade, and today accounts for 4,3% of gross domestic electricity consumption. If hydroelectric plants are additionally considered, this percentage rises to 9%. Among the conventional green energy technologies, wind electricity is by far the most developed industry in Greece. The development of the various renewable energy sources and their respective shares can be viewed in Table 1 and Figure 1.

Table 1: RES Generation in Greece (Center of Renewable Energy Studies, 2009).

GWh	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
RES Total	3949	5028	4562	3560	4240	6459	6450	6999	8077	5356	6586
Hydroelectric Total	3876	4865	4111	2725	3463	5332	5205	5610	6292	3377	4149
Pump Systems	149	237	418	628	663	566	533	593	427	785	837
Hydro < 1MW	8	18	26	40	58	76	91	106	89	118	117
Hydro 1-10 MW	137	164	140	95	92	169	212	218	299	177	207
Hydro 10+ MW	3582	4446	3527	1962	2650	4521	4369	4693	5477	2297	2987
Wind	73	162	451	756	651	1021	1121	1266	1699	1818	2242
Biogas	0	1	0	79	126	105	123	122	85	160	191
Photovoltaics	0,1	0,2	0,2	0,2	0,5	0,6	0,8	0,9	1,3	1,4	5
Geothermal	0	0	0	0	0	0	0	0	0	0	0

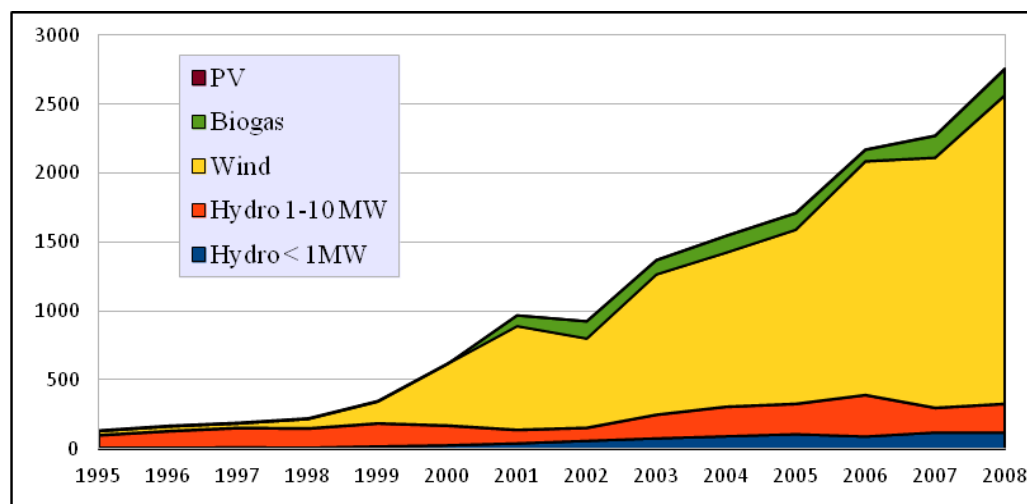


Figure 1: Yearly electricity generation from RES in Greece excluding large hydroelectric, GWh (Center of Renewable Energy Studies, 2009).

3.5 Electricity Prices

Electricity prices in Greece follow a system of increasing price blocks operated by the PPC, the sole electricity seller to mainland and island Greece. The price of household electricity is unified over the country and ranges from 7,17 to 18,9 eurocents/kWh depending on the volume of electricity used. The PPC further offers 3,9-5,9 €cents/kWh contracts for industrial purposes, and a 5,9 eurocents/kWh household rate for the low-consumption night period (Public Power Company, 2010b). The different price blocks are presented more analytically on Table 2 and Figure 2.

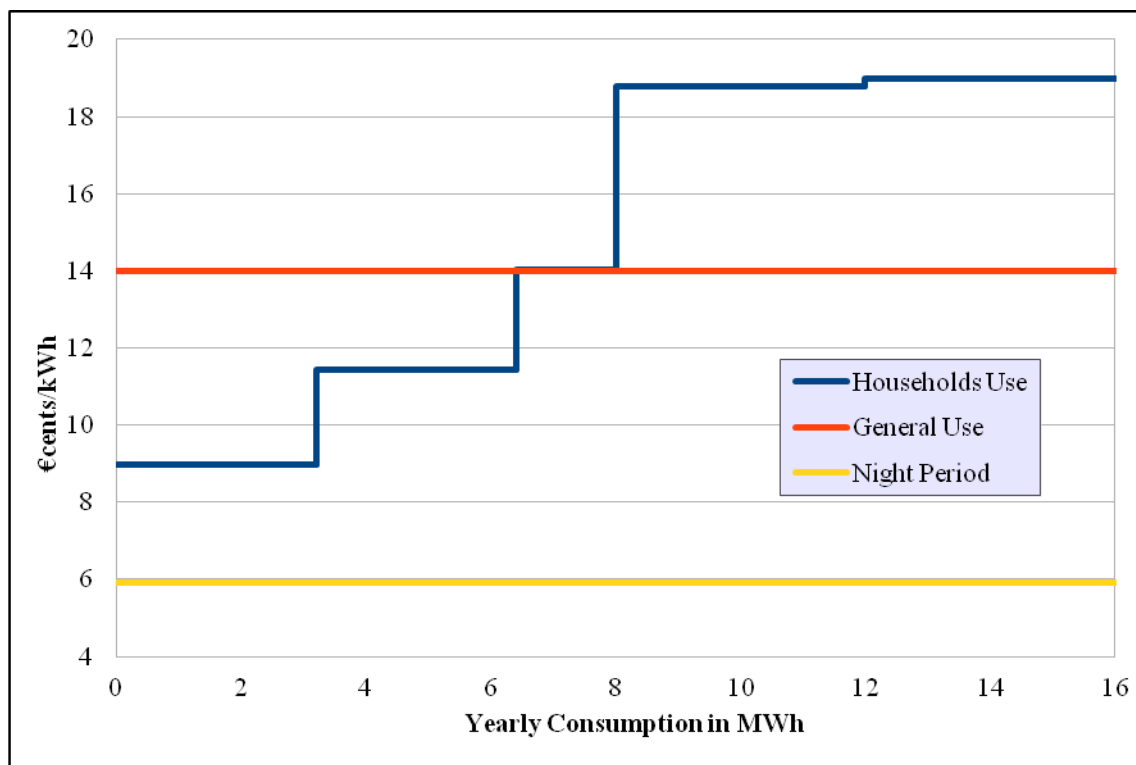


Figure 2: *Electricity prices in Greece for household and general purposes. Prices are geographically uniform throughout the country (Public Power Company, 2010b).*

Table 2: *Electricity Prices in Greece (Public Power Company, 2010b).*

	Price Block	Price		Unit
		Single Phase	Triple Phase	
Low Voltage Electricity for Household Purposes	Consumption 0-800 kWh / 4months 4-Month Fee Electricity	3,08 7,2	8,76 7,7	€ cents/kWh
	Consumption 801- 1600 kWh / 4months 4-Month Fee First 800 kWh Next 800 kWh	11,4 8,8 11,2	23,1 8,8 11,2	€ cents/kWh cents/kWh
	Consumption 1601 – 2000 kWh / 4months 4-Month Fee First 800 kWh Next 800 kWh Remaining 400 kWh	15,2 8,8 11,2 13,7	38,3 8,8 11,2 13,7	€ cents/kWh cents/kWh cents/kWh
	Consumption 2001 – 3000 kWh / 4months 4-Month Fee First 800 kWh Next 800 kWh Remaining 400 kWh Last 1000 kWh	8,9 11,4 14,0 18,7	8,9 11,4 14,0 18,7	€ cents/kWh cents/kWh cents/kWh
	Consumption 3001+ kWh / 4months 4-Month Fee First 800 kWh Next 800 kWh Remaining 400 kWh Last 1000 kWh Any additional kWh	9,0 11,4 14,0 18,8 19,0	9,0 11,4 14,0 18,8 19,0	€ cents/kWh cents/kWh cents/kWh cents/kWh
	Low Consumption Night Period All kWh		5,9	cents/kWh
	Low Voltage General Use	4-Month Fee All kWh	10,3 14,0	€ cents/kWh
	Middle Voltage Electricity for Industrial Purposes	Power Supply Fee / 4 months First 400 kWh per kW Additional kWh	10,0 5,9 3,9	€Kw cents/kWh cents/kWh

4 AEGEAN ELECTRICITY SECTOR: NON-CONNECTED ISLANDS

4.1 Characterization of Current Generation Mix in the NCIs

The energy market of Greek island communities is still greatly covered by oil-burning plants due to the lack of connection to the mainland grid. Today, diesel engines comprise 87,4% of electricity capacity and cover 90,7% of the NCI consumption. Most island power stations burn diesel, light and heavy oil fuels utilizing gas turbines, internal combustion engines, and steam turbines as well as several combined cycle units (Ministry of Development, 2009). The generation cost often reaches 22€cents/kWh as it ranges widely depending on the age of the plant and the technology used. Self-generation is cost-inefficient and negligible in the Aegean area, as the nationally unified price system provides low-priced electricity across the islands.

Rhodes and Crete are the biggest electricity consumers of the Aegean islands and significant economic centers of the area. For information on the diesel generation and the electricity demand per island please refer to Appendix I of this report. Based on data of 2006 provided by the Ministry of Development in the Energy Outlook of Greece, published in February of 2009, the following analysis of electricity capacity and generation can be given.

As of 2006, the Aegean NCIs had a total installed capacity of 1.617 MW representing 11,9% of the national capacity. The geographical allocation of electricity capacity is presented in the Table 3. In the same year, the NCIs generated a total of 5,2 TWh representing a 9,2% of the national electricity generation. The generation of the Greek islands is analyzed in Table 4.

Table 3: *Installed capacity in the NCIs in 2006 (MW).*

Fuel	Crete	Rhodes	Remaining Islands	Total Capacity	Share %
Oil	693	199	521	1414	87
Wind	136	15	51	202	12,4
Hydroelectric	0,6	-	-	0,6	0
Biomass	0,4	-	-	0,4	0
Total	830	214	572	1617	100
% of national capacity	6,1	1,6	4,2	11,9	

Table 4: *Electricity Generation in the NCIs in 2006 (GWh).*

Fuel	Crete	Rhodes	Remaining Islands	Total Generation	Share %
Oil	2.472	674	1.590	4.736	90,7
Wind	348	24	112	484	9,3
Biomass	0,5	-	-	0,5	0,0
Hydroelectric	0,2	-	-	0,2	0,0
Total	2.820	698	1.702	5.220	100
% of national generation	5,0	1,2	3,0	9,2	

4.2 Load Profile of an Aegean Island

Considering that Aegean islands vary in population size and economic activities, their peak demand can be generally approximated at 0,7 kW/capita during the summer and at 0,5kW/capita during the winter. In the same terms, the baseload approximately corresponds to 0,35kW/capita during the summer and 0,225kW/capita during the winter. Typical daily load profiles are illustrated in Figure 3 for the island of Crete.

It should be noted that the load factor is smaller for the island system than the mainland grid indicating that island economies have a much worse peak load problem, which is mainly due to the increased demand of the touristic summer months.

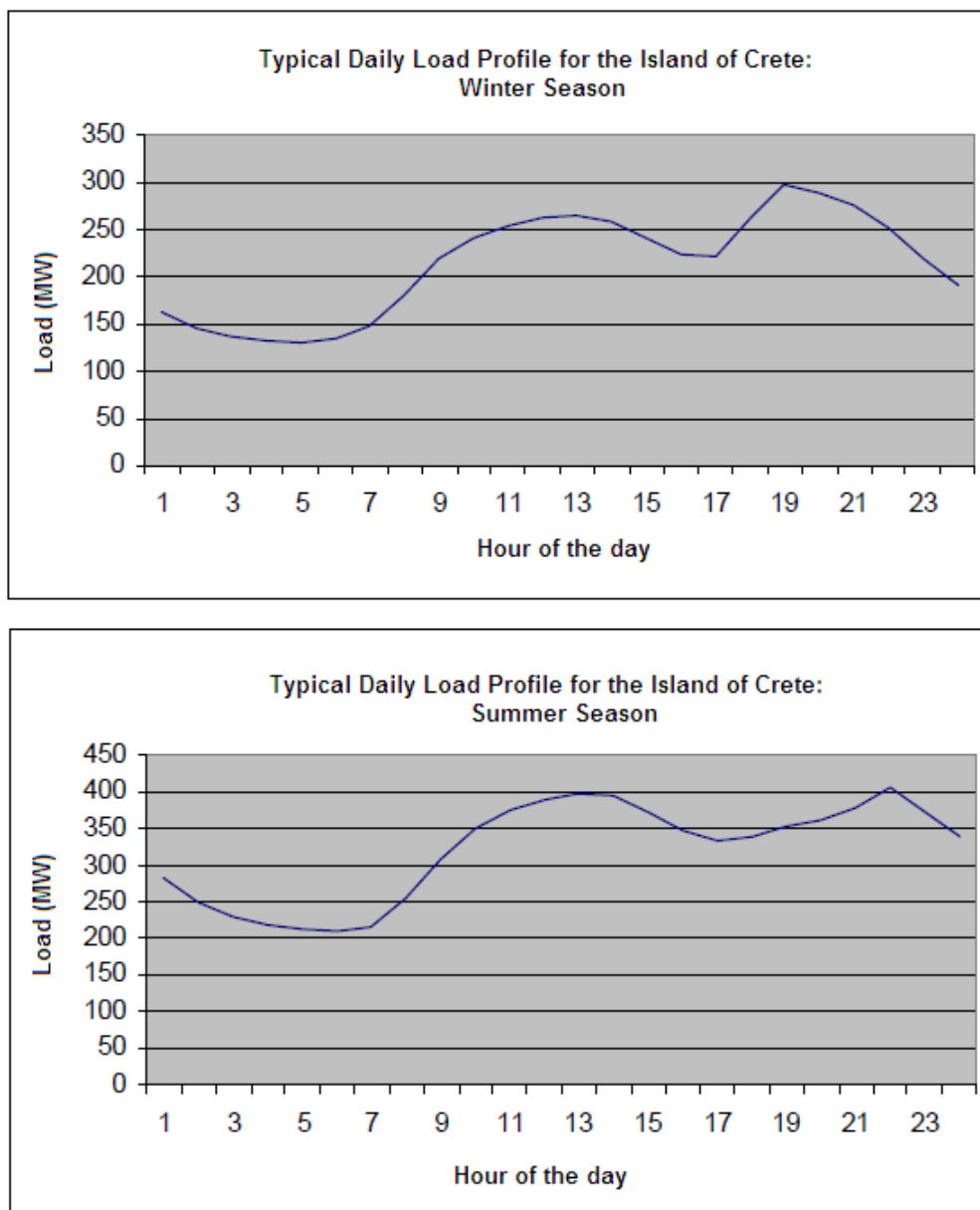


Figure 3: Typical load profiles in the island of Crete. A typical winter and summer day are indicated for the year of 2000 (Markoulakis, 2003).

4.3 Forecast of Energy Demand

The annual growth of electricity demand in the Aegean Islands is almost twice that of the mainland connected system (Hatziaargyriou et al., 2006). Taking into consideration the EU directives on energy and carbon emissions, the PPC has forecasted a 55% increase in the island electricity demand by 2020, requiring the additional generation of 3,62 TWh yearly. The forecast of the energy demand of the non-connected Aegean Islands is presented in the table below.

Table 5: *Energy forecast of the energy and power demand for the non-connected Aegean islands (Ministry of Development, 2009).*

Year	Crete			Rhodes			Remaining NCI	
	GWh	GGR% *	MW	GWh	GGR% *	MW	GWh	GGR %
2011	3.680	4,9	780	929	5,0	248	2.232	4,7
2012	3.875	5,3	820	972	4,6	259	2.337	4,7
2013	4.049	4,5	855	1.019	4,9	271	2.447	4,7
2014	4.224	4,3	890	1.066	4,6	283	2.557	4,5
2015	4.422	4,7	930	1.114	4,5	295	2.672	4,5
2016	4.621	4,5	970	1.167	4,7	308	2.779	4,0
2017	4.843	4,8	1015	1.219	4,5	321	2.895	4,2
2018	5.041	4,1	1055	1.272	4,3	334	3.017	4,2
2019	5.268	4,5	1100	1.329	4,5	348	3.141	4,1
2020	5.495	4,3	1145	1.385	4,2	362	3.270	4,1

**GGR % stands for yearly generation growth rate*

4.4 Effects of Price Unification

The geographically unified price system, established by the national energy policy, significantly supports the habituation and economic activity of the Aegean islands. Island electricity is particularly costly due to the summer peak generation, small load factor, and cost of diesel fuels which raise the average generation cost to 15,2 €/cents/kWh, much higher than that of the mainland grid (Ministry of Development, 2009). This cost difference, however, is not passed to consumers due to the unified pricing. Essentially, island consumers receive an indirect subsidy as a result of the price unification, the approximate size of which can be viewed in Figure 4.

On the negative side, the unified price system offers limited incentives for cost-efficient electricity production by and improvement of the island generation facilities. As a result, the additional costs have to be covered by the PPC raising national electricity prices. Thus, appropriate energy planning and development in the non-connected islands could lower energy prices across the country, while at the same time, ensuring the economic survival and well being of Aegean island communities.

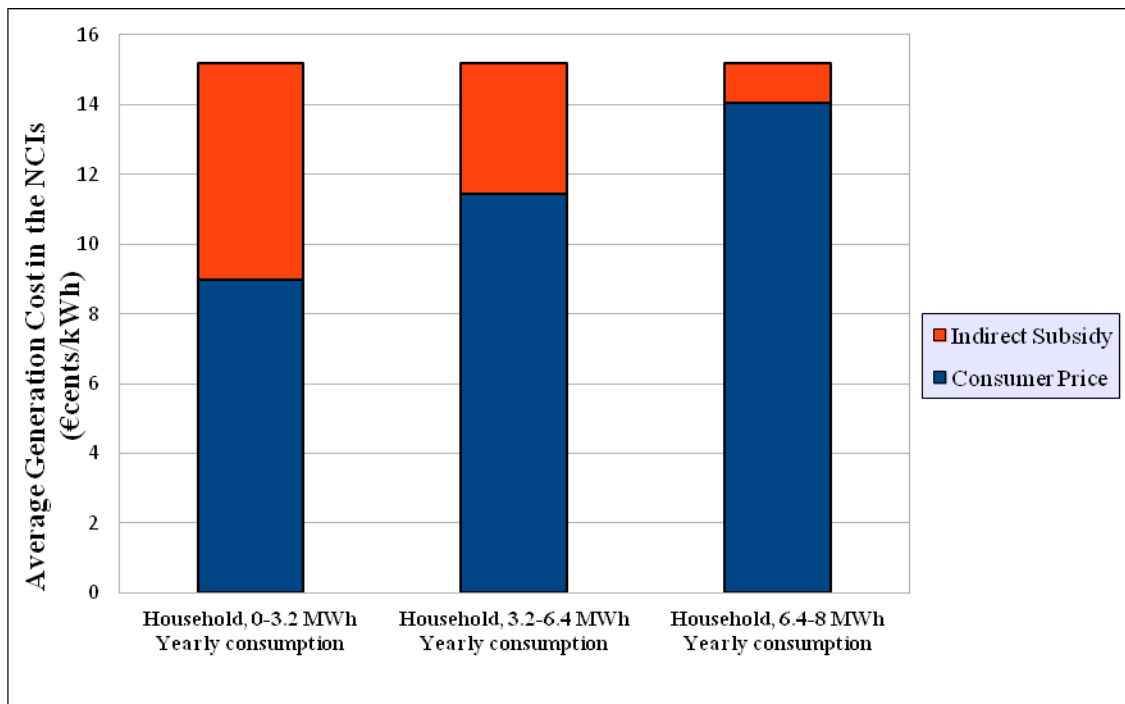


Figure 4: Cost distribution in the case of household electricity consumed in the NCIs. The indirect subsidy arises as a result of the unified price system. The average generation in the NCI is taken as 15,2 €/cents/kWh (based on data of the Ministry of Development, 2009 and the Public Power Company, 2010b).

4.5 Grid infrastructure and Further Expansion

Due to the grid isolation of the Aegean islands, local networks lack any external buffer system and have to individually secure adequate power supply at all times. When incorporating highly fluctuating energy sources, such as wind or solar energy, NCI grids can support a maximum penetration of 25-30% (Ministry of Development, 2005a) as the lack of grid connections does not allow the sale of electricity produced to other islands or to the mainland. As a result, wind farms currently operating in NCI grids are prone to output limitations when wind supply periodically exceeds total load demand.

The need to tap into the high renewable energy potential of the Aegean has led to the ambitious project of connecting most Aegean islands to the mainland grid. The aim is not only to cease the operation of costly diesel plants in the islands, but also to reduce the dependence on foreign fossil fuels in the entire country while, at the same time, moving towards national and E.U. clean energy goals (Regulatory Authority of Energy, 2007).

The installation of further renewable energy plants further requires the strengthening of local grid capacity. In recent years, the capacity of local island networks has not kept up with increases in electricity demands thus creating a significant bottleneck in the development of Aegean renewable energy sources (Kabouris and Perrakis, 2000).

Unfortunately, the grid expansion and the installation of extended power lines have faced resistance by locals of specific regions, who have taken the issue to the Council of

State, delaying its realization. The grid development can still be achieved through a rather costly alternative: abandoning the plan of transforming strategic islands to high-voltage distribution centers and instead, connecting the Aegean region solely through the use of underwater cables. This renewed project has already been initiated in the Northeast Aegean after all preliminary studies were completed in 2005 (Ministry of Development, 2005a).

The Regulatory Authority of Energy (RAE) has estimated the total cost of connecting all Aegean islands to be 1,5 billion euros, an expense that would be partially covered by EU funds. The preliminary cost-benefit analysis has concluded that the interconnection of the Aegean islands is a beneficial alternative to the current diesel generation, even without considering any additional developmental and environmental benefits. Thus, the Ministry of Development decided in favor of its incorporation in 2007, expecting that the project development will take 15 to 20 years to complete (Regulatory Authority of Energy, 2007). The interconnectivity of the Aegean islands will further bring environmental benefits and electricity security to the island communities and the country as a whole.

4.6 Renewable Generation in the Aegean Islands

As of 2010, wind and solar generation lead the RES development of the Aegean Islands providing an average load of 55,3 GWh/month and 1,86 GWh/month respectively, and covering together approximately 12% of the NCI electricity consumption. As an example, the wind and photovoltaic generation in the Aegean islands for the month of August is presented in Table 6.

As of today, there are 77 wind farms in the non-connected Aegean Islands contributing a total capacity of 256 MW. Further, 247 photovoltaic installations are in function adding 17,6 MW to the total renewable electricity capacity. The geographical distribution of these installations is presented in Table 7 as well as Figure 5 and Figure 6. Among the Aegean Islands, Crete and Rhodes have the most extended grids and the largest wind and solar energy productions.

Table 6: *Electricity generated from RES in August, 2010, in the non-connected Aegean Islands (Public Power Company, 2010a).*

Island	Electricity Generated by RE in August 2010 (GWh)		
	Wind	PV	RE Total
Crete	47,5	16,3	63,8
Rhodes	3,1	0,68	3,78
Lesbos	2,4	0,12	2,52
Naxos	3	0,04	3,04
Samos	1,7	0	1,7
Kos	1,1	0,04	1,14
Chios	1,1	0,44	1,54
Other	4	17,6	21,6
Total	63,9	35,26	99,16

Table 7: *Installed RE capacity in the non-connected islands of the Aegean Islands as of August 2010 (Public Power Company, 2010a).*

Island	Installed RE Capacity (MW)		
	Wind	PV	RE Total
Crete	166,6	16,3	182,9
Rhodes	26,4	0,7	27,0
Lesbos	11,9	0,1	12,0
Naxos	8,8	0,0	8,8
Samos	7,7	0,0	7,7
Kos	7,6	0,0	7,6
Chios	7,1	0,0	7,2
Other	19,2	0,4	19,6
Total	255,1	17,6	272,7

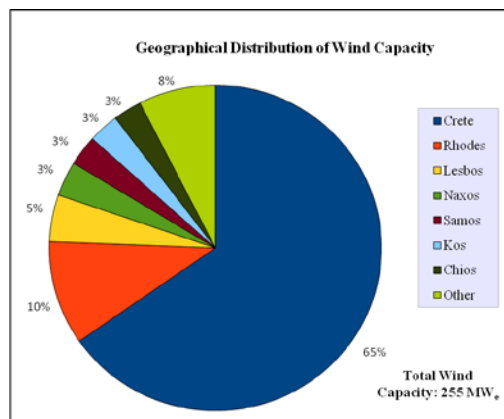


Figure 5: *Geographical distribution of wind energy capacity in the non-connected Aegean Islands. As of August of 2010, the NCIs had a total wind capacity of 255 MW (Public Power Company, 2010a).*

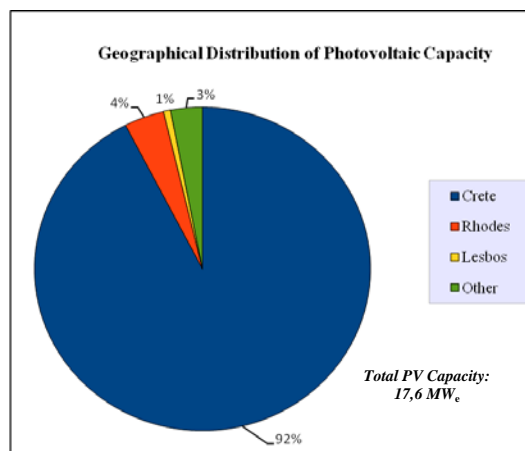


Figure 6: *Geographical distribution of photovoltaic (PV) capacity in the non-connected Aegean Islands. As of August of 2010, the NCIs had a total PV capacity of 17,6 MW (Public Power Company, 2010a).*

5 RENEWABLE RESOURCE ASSESSMENT

5.1 Wind Energy

While technical studies show a remarkable wind potential in the Aegean Islands, and cost-benefit analysis indicates that a plethora of wind-farm sites would be rational investments, national wind power penetration remains limited reaching 1185 MW as of June, 2010.

5.1.1 Wind potential in the Aegean Islands

The geographical position of the Aegean islands provides reliable wind resources throughout the year, with the Etesian winds in the summer and the Vardar winds in the winter months (Lalas et al., 1983). In the central Aegean region, where most islands are located, average wind speeds are 8-11 m/s at hub height (Kaldellis, 2005) offering optimal potential almost year round. Figure 7 presents the Aegean wind resources and indicates multiple sites with average wind speeds larger than 10 m/s. This potential, combined with the high cost of current diesel-generated electricity, makes the NCIs of the Aegean Sea an ideal candidate for wind-farm development.

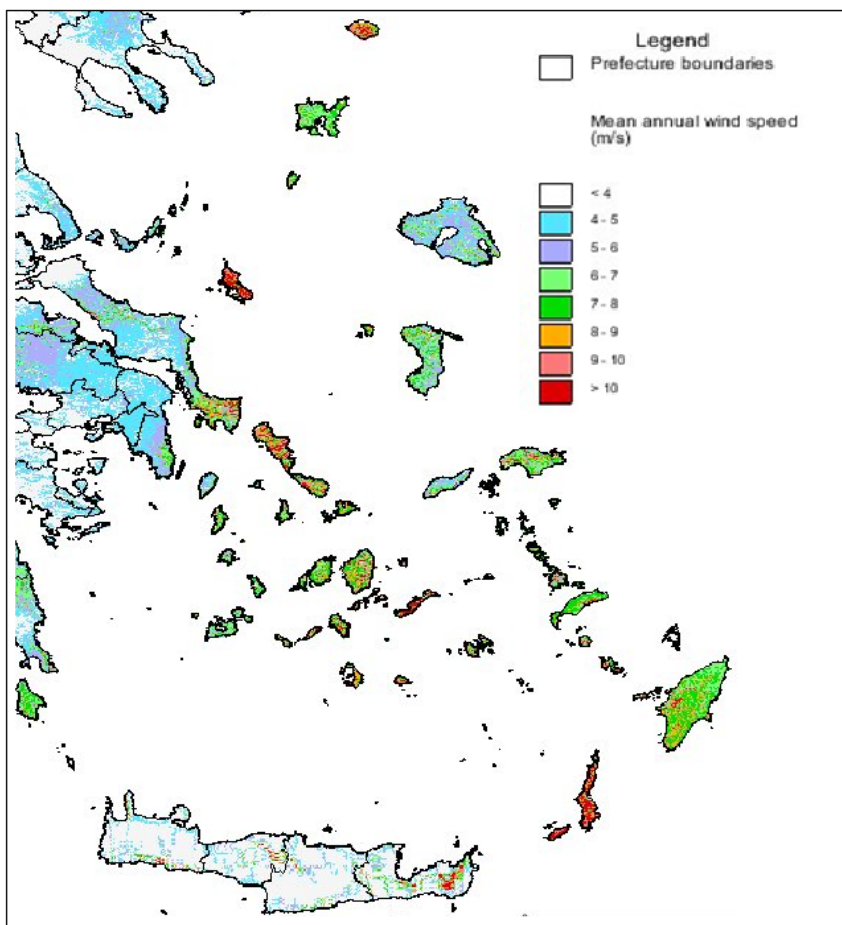


Figure 7: Mean annual wind speeds at hub height in the Aegean Islands (Center of Renewable Energy Studies, 2010).

5.1.2 Wind Generation: Costs and Subsidies

Wind energy costs have dropped significantly during the last 20 years making wind energy a competitor of diesel generation in the Aegean area. Wind electricity production is highly dependent on wind characteristics and thus appropriate site selection is crucial in achieving economic viability. Wind generation is a high-investment technology with installation costs typically varying from 900 €/kW to 1.150 €/kW and being allocated in the following manner:

Table 8: *Structure costs for a typical medium sized wind turbine of 850-1500 kW (European Wind Energy Association, 2009).*

	Share of Total Cost %	Typical Share of Other Costs %
Turbine (ex works ¹)	74-82	---
Foundation	1-6	20-25
Electric Installation	1-9	10-15
Grid-Connection	2-9	35-45
Consultancy	1-3	5-10
Land	1-3	5-10
Financial Costs	1-5	5-10
Road Construction	1-5	5-10
<i>Based on data from Germany, Denmark, Spain and the UK for 2001/02</i>		
¹ Ex Works costs include the wind turbine as provided by the manufacturer, incorporating the turbine, blades, tower, and transport to site.		

The average unit cost of generation can be calculated, taking into account that actual costs will be lower at the beginning of wind turbine lifetime and will slowly increase, as operation and management costs rise through the years. Assuming a medium installation cost of 1.100 €/kW, the average generation cost for the Aegean area can be calculated to approximately 5-6 €/cents/kWh (European Wind Energy Association, 2009)

Approximately 75% of these wind generation costs arises from capital costs (wind turbine, foundation, grid-connection, and electrical equipment). Operation and maintenance costs have an average share of 20-25% merely contributing 1,2-1,5 €/cents per kWh (European Wind Energy Association, 2009). Wind generation is characterized as an especially capital-intensive technology when compared with fossil fuel generation where 40-60% of the cost is related to fuel prices and operation costs.

Due to the need for large start-up investments, wind development can be greatly affected by the interest rates and the availability of capital. This so-called “cost of capital” varies substantially between countries and has reached high levels in Greece after the recent economic crisis. To indicate the importance of capital cost, a doubling of the interest rate, from 5% to 10%, increases the wind generation cost by approximately 1-1,5 €/cents/kWh.

To financially support the developing wind industry, the Greek government has used a mix of start-up subsidies and feed-in tariffs. As a rule of thumb, a Greek wind-park developer would receive an up-front subsidy of 25%, raise his own capital worth 20% and cover the remaining 55% using loans (Vlahakis, 2010).

Following recent policy changes, however, the up-front subsidy is no longer available imposing the need for further loans and possibly lower profits on the wind developer. To cover part of that difference, the Greek government increased the feed-in tariffs to 9,9 €cents/kWh for onshore wind farms and to 10,5 €cents/kWh for offshore. Even during the current economic crisis, wind farming remains a rapidly developing energy source, and one that Aegean islanders are highly familiar with.

5.1.3 Public Opinion

During the last decade, a rapid development of wind power has taken place in Greece, after the 1993-98 period of relative inactivity. Unfortunately, a big share of planned wind-farms is concentrated in few geographical areas, in an attempt to take advantage of existing electrical networks, thus raising complaints from local communities and bringing in the need for further public surveys. From a study conducted by Kaldellis in 2005, the following points can be made:

- In almost all islands examined the acceptability of existing wind-farms exceeds 80%. Characteristically, more than 90% of Crete islanders supported both existing and new projects. Acceptance levels are much lower among mainland communities where less than 40% of the inhabitants have a positive view of existing wind projects.
- The acceptability level of Aegean Islanders is slightly lower (~10%) towards the development of new wind parks than towards existing ones. Such a drop in public opinion is in agreement with, and can be explained by, the NIMBY (Not In My Back Yard) phenomenon.
- When referring to participation in upcoming wind projects, 39% of the interviewees require further financial information before personally investing. At the same time, a minority of 15% remains skeptical and would not invest even under proven financial benefits.

As presented above, Aegean Islanders have a much more welcoming attitude towards wind generation than their mainland co-patriots. This could be due to the historical use of wind-mills or the wind-turbine installations of the 90s throughout the Aegean Islands. Another explanation could be that rural mainlanders are mainly farmers or stock breeders and possibly more conservative than the seamen, traders, or tourist employees living in rural Aegean communities. Either way, wind generation has received the acceptance of Aegean Islanders, thus enabling the sustainable development of island economies while helping the Greek state achieve its national goals.

5.2 Geothermal Energy

As presented by projects in Iceland, New Zealand and USA, geothermal generation is a mature technology able to provide steady base-load electricity in a relatively low cost per kWh. The Aegean Islands lay in a geographic position that is favorable to high- and low-temperature geothermal resources with significant high-enthalpy reservoirs being present in the Aegean volcanic arc.

Due to the significant potential in the Aegean region, this report will partially focus on geothermal technology and aim to include geothermal power in the future Aegean energy mix. The islands of Milos, Lesbos and Nisyros will be presented as some of the best candidates for future geothermal energy development.

5.2.1 Plate Tectonic Movements of the Aegean Region

The Aegean plate tectonics involve complex slip patterns across the boundaries of several microplates. The intervening Aegean, Anatolian, and Apulian plates are small and rapidly moving, resulting in intense seismicity at their boundaries (Lort, 1971; Dewey and Sengor, 1979).

The Anatolian plate is moving westward consuming oceanic lithosphere of the Mediterranean and giving birth to the eastern Aegean geothermal activity (Figure 8b). The African plate is moving northward underthrusting the Hellenic microplate along the Crete and Calabrian island arc systems (Figure 8b). As a result, an island chain is created forming the South Aegean volcanic arc. Sediment deformation, magnetics, and heat flows, all suggest the existence of a compression zone in the eastern Mediterranean (Smith and Sandwell, 2009).

Southeastern Europe seems to have rotated anticlockwise relative to Eurasia during an extensional phase of the west. As a result, new oceanic crust developed accompanied by compression in the east. From the limited evidence that exists, the east Mediterranean crust is oceanic but does not present any magnetic stripes indicating the orientation of the mid-oceanic ridge from which it developed (Lort, 1971; Dewey and Sengor, 1979).

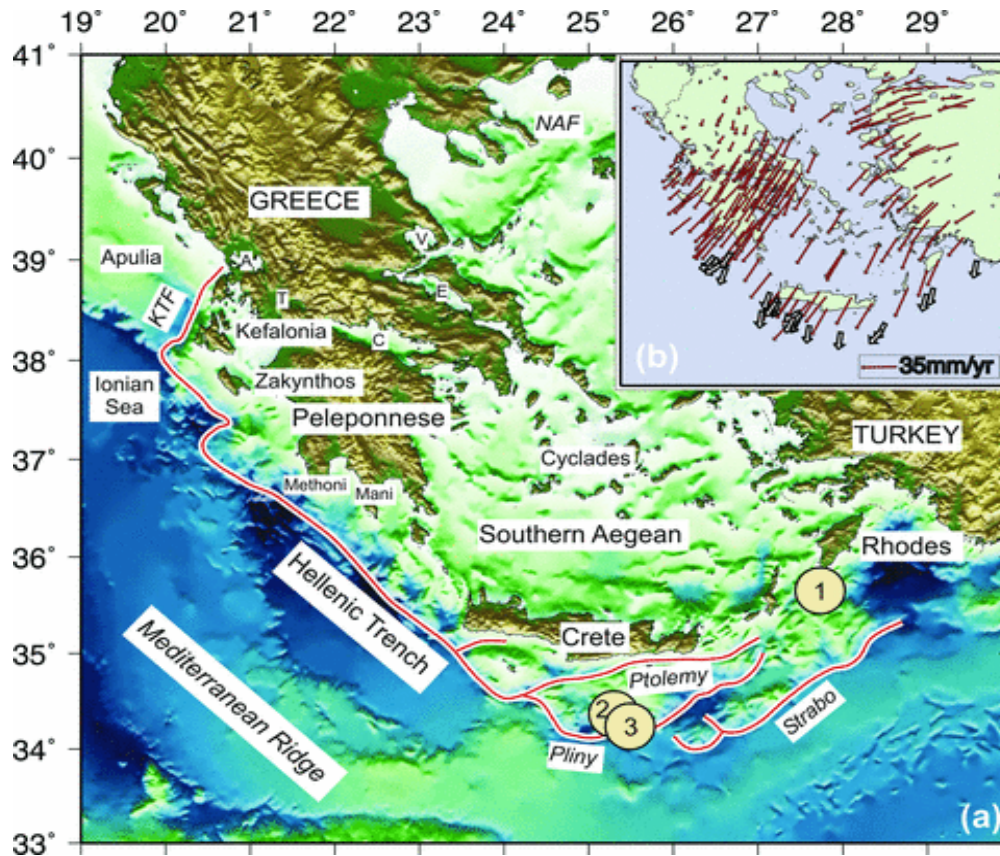


Figure 8: (a) The principal tectonic features and bathymetry-topography of the Hellenic subduction zone. The Hellenic Trench branches into three deep trenches in the east and terminates in the Kefalonia Transform Fault (KTF) in the west. The three yellow circles represent recent earthquakes. (b) Red arrows are GPS velocity vectors in the Aegean region relative to Nubia. Slip vectors of thrust-faulting earthquakes along the subduction interface are plotted as white arrows (Smith and Sandwell, 2009).

5.2.2 Regions of Geothermal Potential: An Overview

The Aegean geothermal activity originates in Quaternary or Miocene volcanism and in continental basins of high heat flows. An overview of Aegean geothermal resources is presented in Table 9, Figure 9 and the following summary:

- High-temperature ($>280\text{ }^{\circ}\text{C}$) resources, suitable for power generation coupled with heating and cooling, are found at depths of 1-2 km in the South Aegean volcanic arc. The total geothermal potential of Milos, Nisyros and Santorini islands accounts for at least 250 MW_e (Karytsas and Mendrinos, 2010).
- Medium-high temperature resources ($170\text{-}260\text{ }^{\circ}\text{C}$) at 2-3km are also suggested in the North-East Aegean islands of Samothraki, Chios and Lesbos but have not yet been identified (Mendrinos et al., 2010).
- Low temperature geothermal resources are indicated by the plethora of hot springs found in Lesbos, Chios and many other islands. Such resources could be

used for space heating, spas and agricultural purposes (greenhouse heating, the drying of fruits and vegetables, aquaculture and seawater desalination) providing an ideal synergy with other commercial ventures in the area.

Currently, none of the previously mentioned resources are being utilized for electricity generation. The PPC has received the developmental rights of specific high-enthalpy fields in the islands of Milos, Nisyros, and Lesbos, but has not proceeded in further steps. These delays are partially due to the opposition of local societies and due to the total lack of legal framework that has practically blocked any prospect of geothermal development during the past 20 years. It was not until 2003, that law 3175 “Exploitation of geothermal potential, district heating, and other provisions” was passed setting an operational framework for geothermal utilization.

Ground source heat pumps, which use a buried ground loop to transfer heat from the ground into a building to provide space heating, and in some cases hot water, have become a growing market in Greece.

Table 9: Overview of Aegean Island geothermal resources (Mendrinou et al., 2010).

Island	Geothermal Field	Map Symbol	Reservoir Depth (m)	Total flow		T _{max} Recorded	Equilibrium Temp*		TDS (g/kg)
				tones/ hour	litres/ min		T K-Na	T K-Mg	
Milos	East Milos	M1	1000-1400	340	5.668	323	322	334	80
Thera	Santorini		50-350	-	-	65	174	110	54
Nisyros	Caldera	N2	100-1900	75	1.250	350	256	225	80
Lesvos	Argenos	A2	150	300	5.001	90	217	127	12
	Stipsi		150-220	200	3.334	95	-	-	5
	Polichnitos		50-200	400	6.668	92	-	-	12
	Thermie	Th	50	200	3.334	60	175	110	36
Chios	Nenita well		300-500	60	1.000	82	210	152	75
	Ag. Markella Spring		-	-	-	35	217	139	38
	Agiasmata Spring		-	-	-	54	244	149	7
Samotharki	Therma wells		40-120	100	1.667	100	-	-	40
	Therma spring 1		-	-	-	55	257	171	13
	Therma spring 2		-	-	-	49	243	169	20

*The equilibrium temperatures were calculated using the ternary K-Na-Mg geothermometer of Giggenbach (1988).

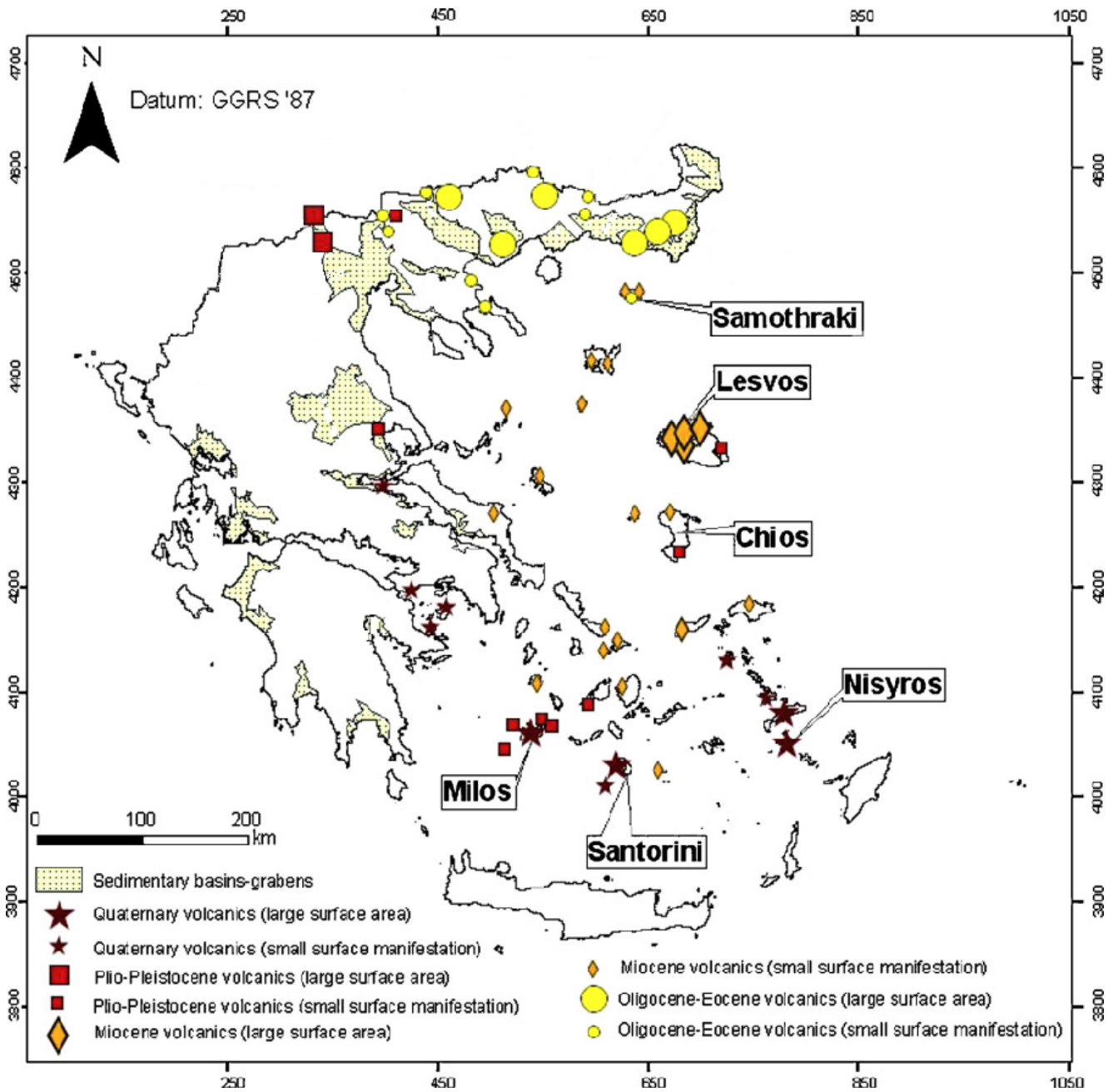


Figure 9: *Geology and location of geothermal areas in Greece (Mendrinou et al., 2010).*

5.2.3 Prospects for Development: Milos Island

Milos Island, positioned in the Cyclades island complex, is characterized by its Quaternary (0,1 to 1,5 million years old) volcanism. The geology of the island can be viewed in Figure 10. For further information on the stratigraphy of Milos, please refer to Mendrinis et al. (2009). Over the last century, earthquakes originating in the intense tectonic activity of the area have affected the thermal manifestations on the island. All the earthquakes were shallow, with hypocenters at about 5 km, and signal patterns characteristic of deep magmatic activity.

The geothermal exploration of Milos began in 1971, with the Institute of Geological and Mineral Exploration of Greece (IGME) conducting the first geological mapping, geochemical analysis and thermal manifestation surveys. The first two exploration wells, depicted as MA1 and MZ1 in Figure 10, were drilled in 1975, reaching 1.163 m and 1.101 m respectively. In 1981, the PPC drilled deep wells M1, M2, and M3 with depths of 1.180 m, 1.381 m, and 1.017 m respectively. During the 90's, a plethora of international institutions got involved completing a wide range of geophysical explorations on the island (Mendrinis et al., 2010).

A model of heat and mass transfer of the Milos hydrothermal system was thus constructed estimating the high-enthalpy geothermal potential at 150 MW_e with a conductive heat loss at 77 MW_{th} over the island of Milos (Karytsas, 2010). Magneto-telluric surveys have also identified a deep zone of coherent low resistivity as shown in Figure 10 (Mendrinis et al., 2010).

Resistivity, geothermal gradient, and magneto-telluric data, all indicate that the south-central and eastern parts of Milos have the highest potential for geothermal development. Passive seismic surveys suggest that the hydrothermal system reaches 5 km deep through a complex of active faults and fracture zones (Mendrinis et al., 2010).

The only geothermal generation plant that has been constructed on the island is a 2 MW_e pilot plant established in 1987. Unfortunately, the plant was able to produce merely 10 GWh as it was shut down in 1988 due to public protest against its H₂S odor, excess steam venting, and loud noises. Considering that Aegean islanders have little to no familiarity with geothermal plants, public education and related surveys will have to play a key role in any future geothermal development.

Today, geothermal usage in Milos is limited to the heating of a few houses and a hotel. Development of a high-enthalpy reservoir could easily fulfill the heating (16 MW_{th}) and power (16 MW_e) needs of the island and further support its significant mining industry. It should be noted the mines of Milos are the largest producers of bentonite and perlite in the EU and a central sector of the Milos economy. Cooperation with this industry, and the local S&B Industrial Minerals, could be the key in the geothermal development of the island. Development of the reservoir to its full inferred potential of 150 MW_e would require a cable connection to the nearby Cyclades islands and eventually to the mainland Greece.

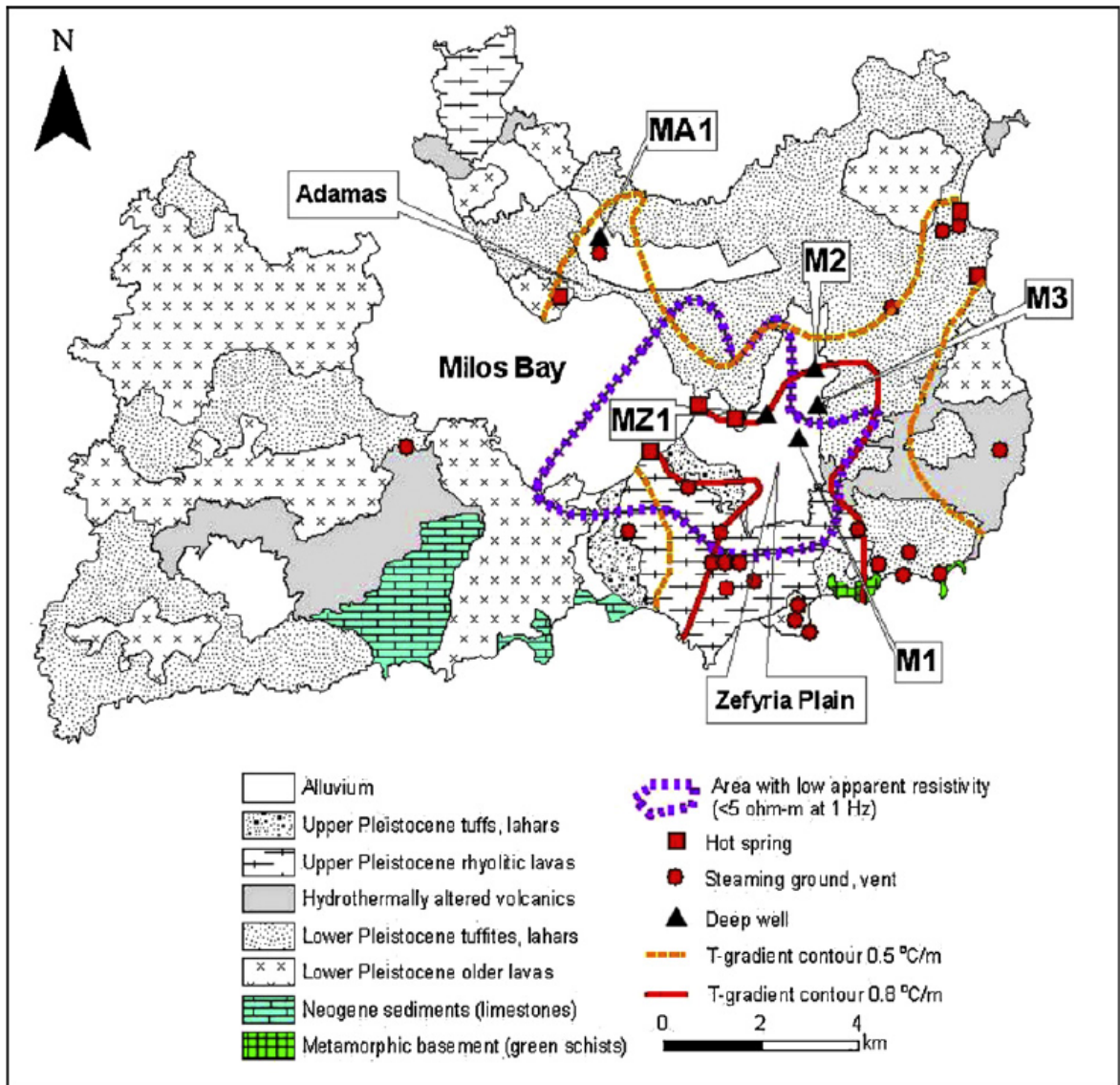


Figure 10: Geological map of Milos Island indicating the location of thermal manifestations, high-temperature gradient regions, low apparent resistivity areas and deep wells (Mendrinou et al., 2010).

5.2.4 Prospects for Development: Lesbos Island

Lesbos, also spelled as Lesvos, is located in the northeastern Aegean Sea, north of Chios Island and just 5,5 km east of the Turkish coast line. Lesbos is characterized by its deep gulf intrusions and Miocene volcanism. The geological profile of the island is presented in Figure 11.

The geothermal exploration of Lesbos began in the 1960s with geological mappings, thermal manifestation surveys and temperature measurements taken through shallow drilling. K-Na-Mg geothermometer measurements taken from Polichnitos spring indicate the existence of a deep NaCl-type water reservoir with K-Mg and K-Na equilibrium temperatures of 110°C and 175°C respectively. Similarly, geothermometer measurements from the spring of Argenos suggest K-Mg and K-Na equilibrium temperatures of 127°C and 217°C respectively. In 2009, a drilling conducted by the PPC 1,5km north-west of Stipsi reached 1,4 km deep finding a maximum temperature of 82°C. Six calderas are also visible through satellite imaging and may be suitable targets for further deep drilling exploration (Mendrinis et al., 2010).

Today, there are thermal spas and few green houses, in various parts of the island, that utilize hot water ranging from 40 to 90 °C depending on the area (Mendrinis et al., 2010). Although Lesbos has not yet presented high-enthalpy resources similar to that of Milos, it has multiple medium-temperature geothermal fields with large flows such that of Argennos and Polichnitos presented in Table 9. Further exploration, possibly through 2-3 km deep drilling, could thus result in large-scale utilization and significant social and economic benefits.

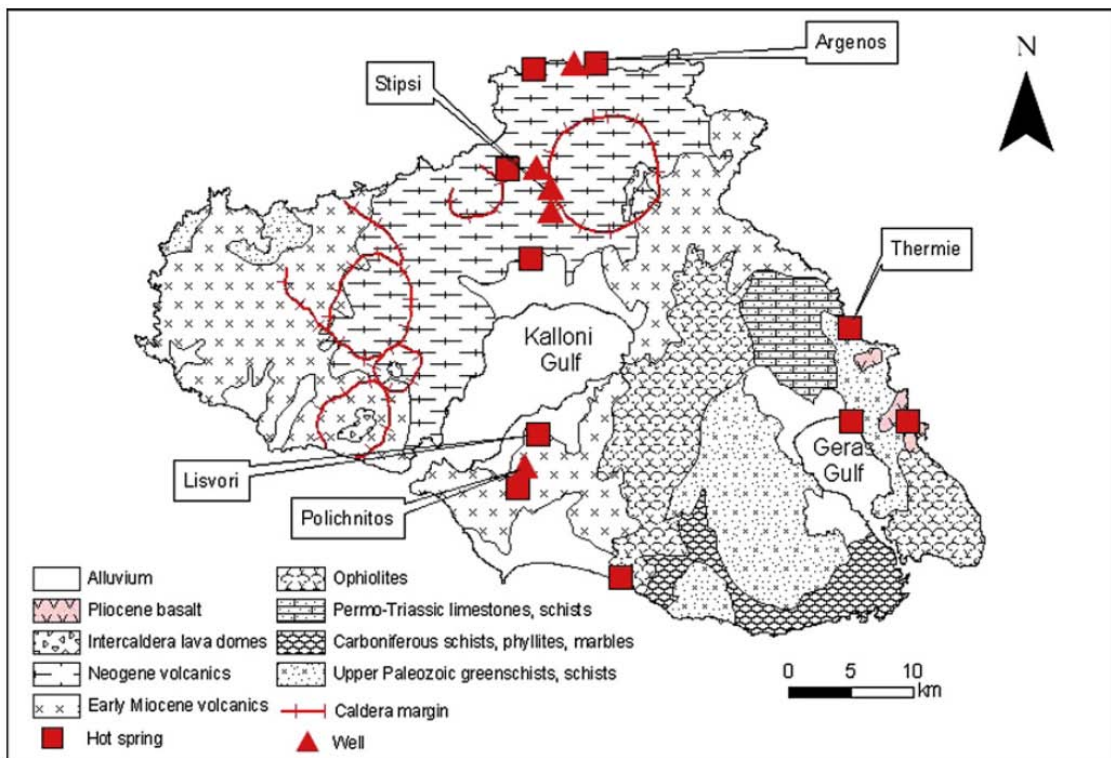


Figure 11: Geological map of Lesbos Island indicating the location of hot springs, calderas and thermal wells (Mendrinis et al., 2010).

5.2.5 Prospects for Development: Nisyros Island

Nisyros has a volcanic history characterized by hydrothermal eruptions which, through time, have formed multiple fumaroles and craters. The steam vents, located in the middle of the island, discharge at temperatures close to 100 °C leaving acid condensates of pH 1,5. Faults running through the island in an X shape, extending along the NE-SW and NW-SE axes, serve as fluid flow paths and feed the surface manifestations (Mendrinis et al., 2010). The geology of the island can be viewed in Figure 12.

Starting in 1973, multiple geochemical surveys have been completed sampling fluid discharged from the coastal hotspots and the mid-island fumaroles (Kavouridis et al., 1999). During the 1980s, DC resistivity, gravity, magnetotelluric and multiple geophysical surveys were conducted (Dawes and Lagios, 1991; Lagios and Apostolopoulos, 1995).

In 1982, the PPC drilled two deep exploration wells, Nis-1 and Nis-2, which reached 1800 m and 1550 m respectively. Well Nis-1 penetrated a hot aquifer (100°C) at 400-1000 m depth and a series of productive fractures, containing 300-350°C brines, at 1450-1800 m depth. Nis-2 also encountered a hot aquifer (150°C) at 370-470 m depth and two fracture zones, containing 250°C brines, at 1100-1300 m and 1500-1550°C depths. Two distinct fluid sources can thus be identified in Nisyros: a shallow aquifer of 120-170°C, extending beneath the whole island, and productive fractures beneath the caldera containing 275-350°C brines. The geological and geothermal findings of the two deep wells are collectively presented in Figure 13.

The geothermal potential of Nisyros has been estimated at 50 MW_e (Koutroupis, 1992) which is sufficient to cover the energy needs of Nisyros, neighboring Kos and several minor neighboring islands. A pilot geothermal plant of 20-25 MW_e capacity is currently under plan by the PPC. Further development is to be seen.

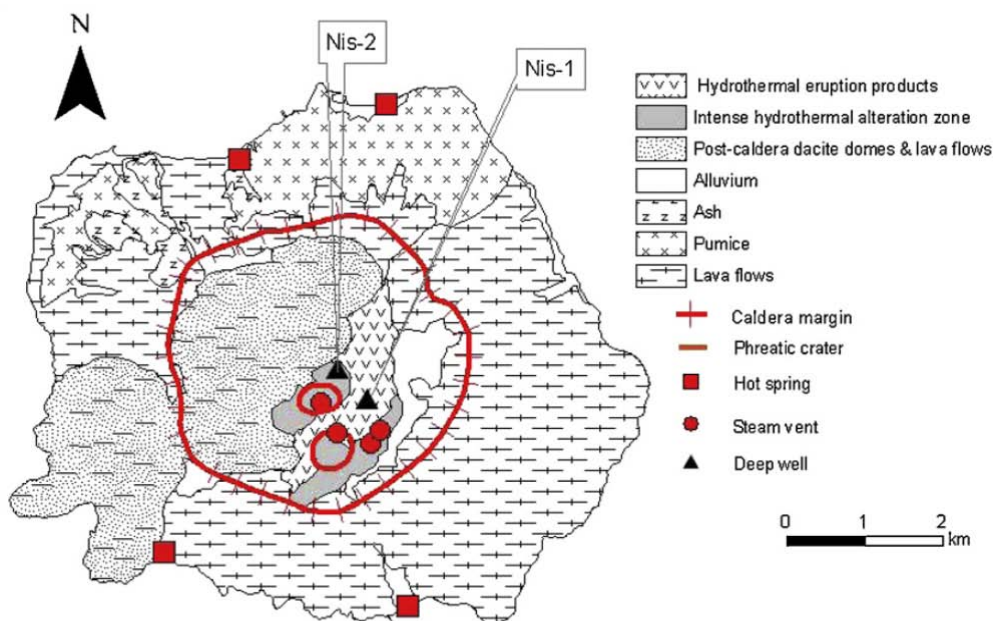


Figure 12: Geological map of Nisyros Island depicting geothermal characteristics and deep wells (Mendrinis et al., 2010).

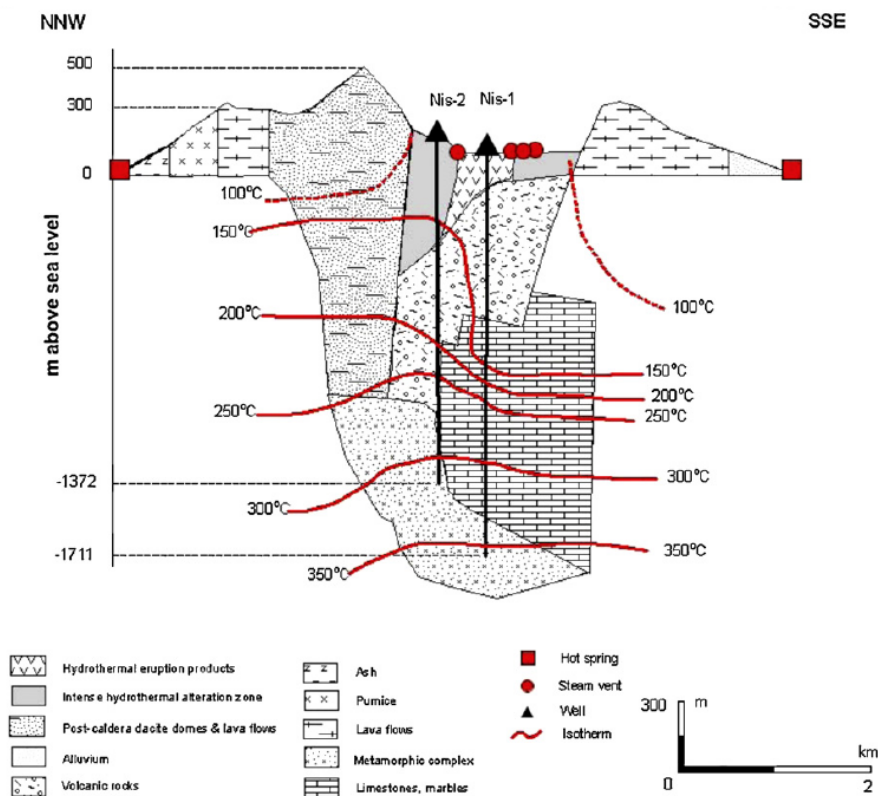


Figure 13: Cross-section of Nisyros depicting the local geology and temperature distribution as revealed by wells Nis-1 and Nis-2 (Mendrinou et al., 2010).

5.2.6 The Geothermal Development Plan of CRES

In 2010, geothermal experts of the Center of Renewable Energy Sources of Greece (CRES) published a 20-year national geothermal development plan, heavily incorporating the geothermal potential of the Aegean Islands (Karytsas and Mendrinou, 2010). A national goal was thus set to establish 400 MW_e of geothermal energy across Greece until 2020, 270 MW_e of which on Aegean Islands. The suggested time-schedule, along with the development sites, is presented in Table 10. The following steps were proposed:

Milos & Nisyros: 190 MW_e goal for 2020

Milos and Nisyros should receive priority as their high-enthalpy reservoirs have already been identified. As a first phase, the installation of 15 MW_e in Milos and 10 MW_e in Nisyros is advised in order to cover the local electricity demand. The generation plants will have to be ordered from abroad and they could be in full operation by 2013.

In a second phase, Milos should be connected to the mainland grid, through a 200 MW_e undersea cable, and Nisyros to Kos, through a 50 MW_e cable. The grid expansion will thus enable further geothermal installation reaching 150 MW_e in Milos and 40 MW_e in Nisyros by 2020.

Chios & Samothraki: 40 MW_e goal for 2020

It is recommended that the Ministry of Energy, Environment & Climate Change proceeds in the bidding process in order to allocate the developmental rights of geothermal fields in Chios and Samothraki. It should be noted that Italian company ENEL has already expressed interest in these areas. Chios and Samothraki can each support 20 MW_e until 2020. Further utilization of the Samothraki fields could be achieved by its connection to the nearby mainland grid.

Lesbos: 20 MW_e goal for 2020

The geothermal development of Lesbos has a relatively high risk as high-enthalpy resources have not yet been precisely identified. However, multiple fields in Lesbos have large flows (300 tones/hour at Argenos and Polichnitos) and geothermometer data indicates the presence of reservoirs with mid-high temperatures (> 170 °C) that could result in significant benefits and utilization. The geothermal development of Lesbos may thus require a higher price pilot plant (150 €/MWh) in order to cover the starting research costs.

Santorini: 10 MW_e goal for 2020

Santorini Island is essentially the tip of an active volcano and thus the presence of high-enthalpy reservoirs is inferred. However, geothermal exploration has not yet been conducted and development could prove particularly difficult due to the active volcanism. Thus, future development has a significant risk and would thus require higher electricity prices (150 €/MWh) to cover the costs of any first pilot plants.

Table 10: *The CRES geothermal development plan for the Aegean Islands. Developmental goals are set for the years of 2013, 2017, and 2020, with a five year window to 2025(Karytsas and Mendrinis 2010).*

Island	Inferred Peak T (° C)	MW _e Goal		
		2013	2017	2020-25
Milos	>300	15	15	150
Santorini	170-300	-	5	10
Nisyros	>300	10	10	40
Samothraki	240-260	-	5	20
Chios	210-240	-	20	20
Lesbos	170-200	-	5	20
Kos	160-190	-	5	10
Total		25	65	270

5.2.7 Geothermal Generation: Costs & Subsidies

After the drilling takes place, geothermal power requires no fuel and thus it is relatively immune to international fuel price fluctuations. It has low maintenance costs but it requires a moderate-high investment with drilling expenses comprising more than half of the start-up cost and having an average 20% failure rate (Glacier Partners Corp., 2009).

Geothermal installation costs range between 1,5 and 4 million € MW_e taking into account exploration costs and associated risks. Geothermal electricity generation costs are approximately 4-16 €cents/kWh with a 4-10 €cents/kWh range being more typical (Karytsas and Mendrinou, 2010). The economics of geothermal power become rather attractive when compared with the 16-22 €cents/kWh cost of diesel generation currently supplying the Aegean islands. It should be noted that the current feed-in tariff for high-temperature resources (>90°C) is 9,9 €cents/kWh and for low-temperature resources it is 15 €cents/kWh. These purchasing prices would be more than sufficient to develop the geothermal resources of Milos and Nisyros and even support pilot plants in the exploration zones of Lesbos, Chios, Samothraki and Santorini (Karytsas and Mendrinou, 2010).

Direct heating applications can use much shallower wells and lower fluid temperatures achieving lower costs and minimal risks. In the case of direct thermal uses, the installation costs drop to 0,2-1 million €/MW_{th} while heat generation costs range between 0,5 and 2,5 €cents/kW_{th}, much lower than diesel or even natural gas heating. As a result, geothermal energy can supply heat in a cost-efficient, secure and sustainable manner. In addition, geothermal energy can be used for absorption cooling and could thus cover both the cooling and heating needs of the vast Aegean tourist sector.

5.2.8 Public Opinion

In order to foster a positive attitude towards geothermal development in the Aegean, one must first understand the identity of the islanders and their positioning towards mainland Greece. In many cases, islanders view geothermal development as an exploitation of their natural resources in order to fulfill the needs and policies of the mainland city centers. Geothermal companies may similarly be seen as powerful external players with no particular interest in the traditional, and often sensitive, local communities of the Aegean. Under this viewpoint, and considering that islanders have had little to no familiarity with geothermal utilization, Aegean communities may take a negative position on the issue as it happened in Milos when the first geothermal projects were initiated in the 90s. It should thus be emphasized that information campaigns and opinion surveys will have to be incorporated into any future geothermal development in order to receive the so-much-needed approval of local communities.

Throughout the recent years, two public surveys have been completed on the Aegean regarding geothermal development. The first one was focused on Milos and was conducted in preparation of a geothermal desalination plant (Manologlou et al., 2004) while the second one collected information from both Milos and Nisyros in an attempt to get an accurate understanding of the public opinion (Polyzou and Stamataki, 2010).

Survey on Milos, 2004: Public opinion towards the current construction of geothermal desalination plant

According to research conducted by Manologlou et al. (2004), most Milos islanders perceive geothermal projects as beneficial for different sectors of the local development, and for everyday life, but remain reluctant about the exploitation of high-enthalpy resources. Further, 83% of the interviewees regarded that drinking water should be the first need to be fulfilled by geothermal utilization thus providing adequate quality and quantity of water to the anhydrous communities of Milos and neighboring islands.

Strong support for the plant's construction was expressed by the tourist sector with 98% of related participants believing that geothermal-powered desalination would positively affect the tourist industry. Interviewees involved in the agricultural sector also expressed a similar opinion with 91% of them supporting the construction of a geothermal desalination plant. It should be noted that the further development of tourist and agricultural activities is currently limited by the high costs and insufficient supply of water and energy. And, unfortunately, this is the case, not only in Milos, but in most of the Cyclades and Aegean islands in general.

Survey on Milos and Nisyros, 2010: Public opinion towards geothermal development

According to the most recent survey (Polyzou and Stamataki, 2010), the Milos and Nisyros populations have a mixed opinion towards geothermal exploitation. Most of negative opinions originate in lack of information and in mistrust towards effective project management. Based on the survey, the following points can be made:

- Personal experience and verbal communication are the main sources of related information (88% in Milos and 90% in Nisyros), indicating the total absence of official public education on geothermal utilization.
- The overwhelming majority considered geothermal energy as an environmentally polluting activity (80% in Milos and 85% in Nisyros) and regarded air pollution as the most important issue at hand (46% in Milos and 58% in Nisyros). Surprisingly, the interviewees did not account noise or visual impacts as significant issues.
- Approximately half of the interviewees of both islands considered that geothermal development would have a negative impact on their cultivations and fisheries.
- If geothermal utilization is to proceed, the interviewees regarded electricity generation as the first priority (57%) followed by water desalination (40%). The emphasis merely on these two choices reflects the significant energy and water needs of these communities, but also indicates an ignorance towards other geothermal applications. In fact, the majority of the interviewees (75%) did not even include other geothermal uses (fish farming, greenhouse heating, baths, drying, and heating/cooling) in their evaluation.
- Looking at the possibility of a geothermal plant installation, 73% of Milos and 51% of Nisyros inhabitants indicated a positive attitude towards such. The majority of the negative answers were based on health and environmental concerns (70% in Milos and 57% in Nisyros), while a significant percentage was due to a lack of confidence in proper operation and state-control of the project (16% and 23% respectively).

It should be noted that the reserve of Aegean islanders towards high-enthalpy geothermal power partly originates in events of the 1980s. It was during that period that the PPC attempted to establish a geothermal power plant on Milos which, in return, triggered active protests by local communities. The recollection of this event, combined with local myths and inadequate information, still affects the attitude of Milos and Aegean islanders. Learning from the Milos case, any future geothermal development in the Aegean should thus seriously consider the public opinion, provide adequate information, present the multifaceted benefits of geothermal development and involve local manpower before and during implementation.

5.3 Solar Energy

The Aegean Islands have a remarkable solar potential which increases during the summer months, thus conveniently matching the higher energy needs of the touristic period. Although solar applications remain expensive, their development is greatly supported by government programs and the reinforcement of the CO₂ permits in 2013. Greece has an increasing interest in photovoltaic (PV) plants and an already developed market for solar water heaters.

5.3.1 Solar Potential in the Aegean Islands

Due to excellent weather patterns and geographical position, most Aegean islands have a yearly sum of incident sunlight of 1800-2000 kWh/m², assuming optimally inclined south-orienting modules. As a comparison, Germany, the European leader in solar systems, presents a yearly sum of incident sunlight of 750-1000 kWh/m², again assuming optimal inclination. Figure 14 depicts the yearly irradiation sum in the Aegean area and indicates multiple sites with optimal solar potential. With such solar resources, a photovoltaic system generates electricity between 1350 and 1500 kWh/kW_{peak} yearly, assuming optimally-inclined modules and a performance ratio of 0,75. The high generation prices of the Aegean, combined with the ability of solar systems to provide increased output when most needed (hot mid-days and touristic summer months), makes solar applications part of the Aegean energy mix.

5.3.2 Solar Heating Systems

The use of solar heating systems (SHS) in Greece began in the mid 70's, when the oil crisis sharply increased the electricity prices and the operation cost of electric heaters. Throughout the years, various government programs and subsidies have supported the installation of solar heaters and boosted the associated industry. In 2000, there were

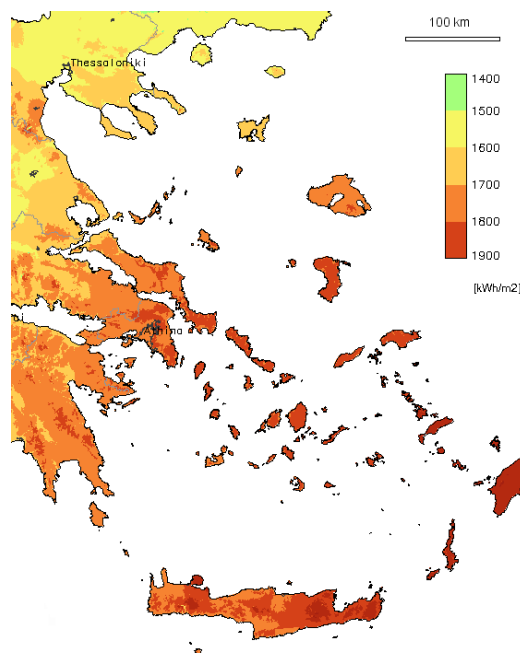


Figure 14: Yearly sum of sun irradiation in the Aegean region. Assuming optimally-inclined south-oriented modules (European Commission, 2010).

1,15 TWh of thermal energy produced from solar collectors substituting almost 8% of the electricity consumption of the residential sector (Kilias et al., 2000).

Today, the solar heating technology is qualified as quite mature and the corresponding Greek market is highly developed worldwide, having significant experience in the thermal market segment. More specifically, Greece plays a dominant role in the European solar thermal market, having 45 active manufacturers of solar collectors, and being the second largest user of solar heating in Europe with almost 3 GW_{th} installed (European Solar Thermal Industry Federation, 2009).

In recent years, however, the Greek solar heater market has been growing at a slow pace and seems saturated. At the same time, natural gas pipelines are established offering cheap heating fuel to the Greek mainland. Despite these conditions, the Aegean islands could remain a growing market segment, due to their high electricity generation costs and the excessive hot water demand during the summer months.

The start-up cost is an important barrier, as SHSs are more expensive than conventional electric heaters. The average price of a family-sized SHS –hot water tank 150-170 liters and a collector surface of 2,5 m²– is 770 €. Thus, the effective cost of the substituted conventional energy is approximately 8 €/cents/kWh (Kaldellis et al., 2005). At the same time, the payback time of an Aegean moderately-used SHS is approximately 12 years, while its average service life is 12,5 years (+/- 3 years standard deviation) (Kilias et al., 2000). Under these conditions, SHSs are financially viable but not exceptionally attractive. With the current absence of state subsidizing, an island consumer may as well cover his hot water needs using a conventional oil-fired and electrical heater combination. If solar heaters are to continue being used in the average household of the Aegean Islands, further financial incentives will be needed.

It is in the interest of the government and the PPC to support SHSs as their unified price system is burdened by the high costs of island generation. Further use of SHS would decrease the costly electricity consumption of the Aegean economies and would help Greece achieve its national and EU energy goals. The payback period of a solar heating system is calculated for various subsidization percentages and presented in the following table.

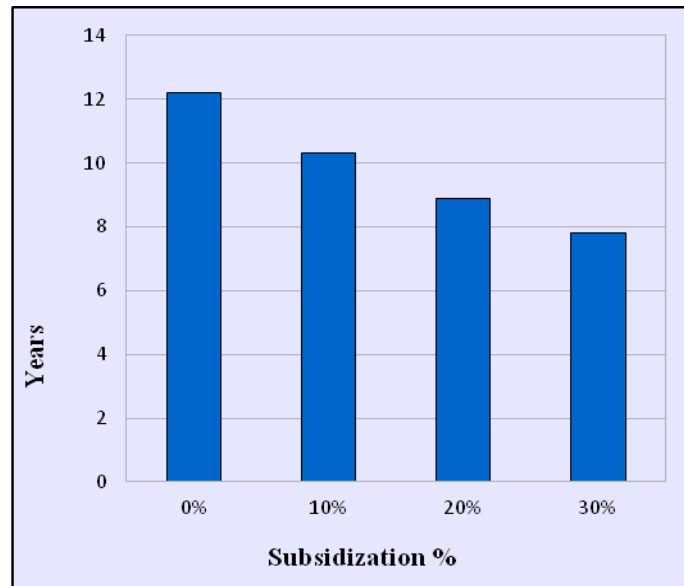


Figure 15: Payback period of a solar heater established on the island of Crete. Results are approximately identical in other Aegean islands due to similar solar potential (Kaldellis et al., 2005).

5.3.3 Photovoltaic Electricity

Photovoltaic (PV) electricity may become a significant component of the Aegean energy profile due to the superb sun radiation of the area and the synchronization of PV production with energy-demanding hot days and touristic summers. The Greek Government is encouraging PV development with high feed-in tariffs (presented in Table 11) and a number of small- and mid-sized companies have invested in this sector (Invest In Greece, 2010). As of 2009, Greece had the 8th highest PV utilization per capita in Europe with 4,9 W/capita (Euroobserver, 2010).

A considerable advantage of photovoltaic electricity is that it is predominantly produced in the peak hours of the day, when demand is high and electricity generation particularly costly. A qualitative comparison of the daily load with sunlight irradiation can be viewed in Figure 16. In addition, PV systems can be established sporadically throughout the islands thus producing electricity closer to the sites of demand. In this manner, transportation losses are minimized and PV installations can be connected straight to the grid, without additional capacity upgrades. Other benefits are improvement of voltage supply, reduction of CO₂ emissions, and increased variety of energy sources.

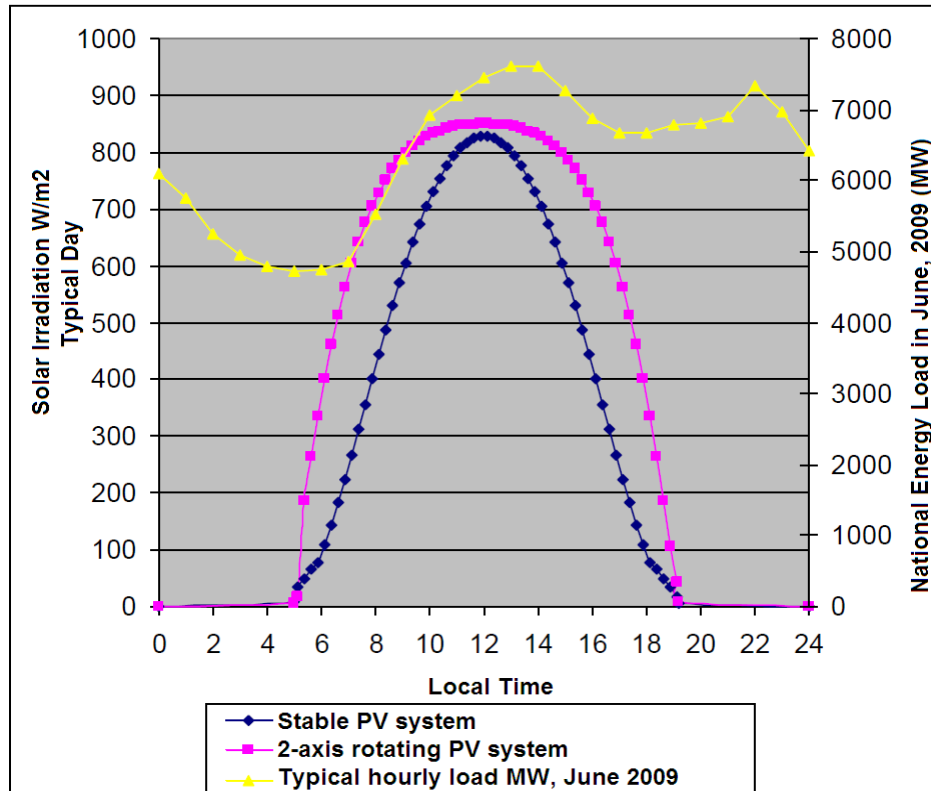


Figure 16: *Qualitative comparison of sunlight irradiation and typical daily load in January 2009 (Tselepis, 2010).*

The estimated lifetime of a photovoltaic module is 30 years, while the technology is very reliable, providing over 80% of the initial power after 25 years (European Photovoltaic Tech Platform, 2010). Most manufacturers offer performance guarantees on their modules ensuring 80% of initial output at 20 years of operation. Manufacturer guarantees of inverters and related electrical components are usually around 8 to 10 years.

Photovoltaic generation is characterized as extremely capital intensive with high start-up investment and low operation and maintenance costs (10-12 €/kW-yr). The turnkey price of photovoltaic systems varies greatly by country, plant size, and technology and ranges from 2.200 €/kW to 9.000 €/kW. In the case of large European PV plants, a 3.500 €/kW to 5.000 €/kW price would be considered typical (Tselepis, 2010). Referring to the Aegean solar potential, PV generation costs are calculated between 26 €/cents/kWh and 47 €/cents/kWh, assuming a 4.000 €/kW installation price, a system lifetime of 20 years, a performance ratio of 0,75, and a 5% interest rate on invested loan (European Photovoltaic Industry Association, 2008).

Investments in Aegean photovoltaic plants can have significant return for the investor, despite the high generation costs, as the Greek government offers strong financial incentives. The large feed-in tariffs established for the year of 2010 and onward are presented in Table 11.

Table 11: *Feed-in tariffs for photovoltaic systems installed in the non-interconnected islands of the Aegean (Invest In Greece, 2010).*

Feed-in Tariffs for Photovoltaic Systems in the Non Interconnected Islands		
Year-month		€cents/kWh
2010	February	45,0
2010	August	44,1
2011	February	41,9
2011	August	39,5
2012	February	37,6
2012	August	35,4
2013	February	33,6
2013	August	31,7
2014	February	30,3
2014	August	29,4
From 2015 and after for each year (v)		$1.4 * SMP(v-1)$
SMP(v-1): System's Mean Price the previous year v-1		

6 ENERGY POLICY AND LEGAL FRAMEWORK

6.1 Historical Overview of Related Legislation

Beginning in 1987, Greece established a legislation concerning renewable electricity generation in order to accompany pilot wind turbines constructed by the PPC. Since then, multiple modifications and additions have taken place as presented in Table 12, with the most significant being the liberalization of the Greek energy market in 1999 and the Law of Accelerated RES Development of 2010.

Table 12: *Overview of main regulations and legislation regarding renewable energy production in Greece.*

Date	Law	Description
31.12.1987	Ministerial decision	Regulations concerning the siting of first wind turbines.
07.10.1994	2244/94	Legislation concerning the production of electricity from Renewable energy sources.
10.05.1995	Ministerial decision	Regulations on licensing of private electricity companies As well their connection to the grid.
28.08.1996	Ministerial decision	Modification on regulations of 1995/385B regarding the sale of electricity by private producers.
26.05.1988	Ministerial decision	Further modification on regulations issued in 1995/385B
22.12.1999	2773/99	Liberalization of the Greek Electricity Sector. Legislation on electricity production licenses and the Development of renewable energy sources.
12.09.2001	2941/01	Updated legislation aiming to simplify the licensing of Renewable energy projects.
08.29.2003	3175/03	Legislation concerning geothermal exploration, district heating and other provisions
27.06.2006	3468/06	Legislation incorporating the use of feed-in tariffs in Renewable energy production.
04.06.2010	3851/10	Establishing the national energy goals for 2020. The Law aims to accelerate the licensing procedure and development of renewable energy projects.

6.2 Political Background

The current government was elected in October of 2009 and had little time before facing a deep economic crisis. Despite these conditions, Prime Minister Georgios Papandreou has identified green development as a key priority and has initiated a

legislation reformation in an attempt to remove significant bureaucratic obstacles that have hindered Greek RES development till today. During the cost-cutting reorganization of the government's structure, the Ministry of Environment, Energy and Climate Change was established by collecting all ministerial responsibilities related to environmental and energy policy and centralizing them into a single institution. The newly established ministry, in cooperation with the Regulatory Authority on Energy (RAE), aims to streamline the licensing process of renewable energy plants and assist investors by providing data and related information.

6.3 National and EU Energy Goals

As part of the 20/20/20 goals set by the European Commission, Greece is required to increase its share of renewable energy to 18% by 2020 (E. C. Directive 2009/28, Art.4, Par.3). To reinforce the country's commitment to green development, the current Greek government proclaimed renewable energy development as an environmental and energy priority of utmost importance and rose its national goals to achieve both a 20% share of renewables in its gross energy usage and a 40% share in its electricity consumption by 2020 as stated in law nr. 3851/10 for renewable energy. These pledges are now incorporated in in this law and will become the guiding principle.

It should be emphasized that, starting in year 2013, the EU will require utilities to purchase their allotment of CO₂ permits, thus imposing a considerable cost on the lignite-based electricity sector of Greece. As of today, the cost of CO₂ permits in the European market is approximately 20€/tn. In a business-as-usual scenario, the average estimated CO₂ emissions of a Greek power plant in 2015 will be 0,85kg/kWh which translates in an additional cost of 1,7 €/cent/kWh (Tselepis, 2010). As a result, the purchase of CO₂ permits will contribute a hefty national cost of at least 1.2 million euros annually unless RES development is to rapidly accelerate.

6.4 Licensing Procedure

The licensing procedure, until today, was characterized as costly, heavily bureaucratic and time consuming. The new Law No. 3851, established in June of 2010, aims to accelerate the development of RES through the simplification and streamlining of the licensing procedure and the establishment of significant financial incentives. Under the renewed legal framework, developers are required to acquire official documents roughly grouped in the following four categories: production license, installation license, grid connection license and power purchase agreement.

Production License

The production license is the first administrative step of any proposed project. In order to receive a production license, power developers must submit their business model, proof of financial capability, proposed site and study of available energy resources. The energy potential study may have to be certified by an accredited organization or company and include extensive field data. Based on this information, the Renewable Energy Authority (RAE) will examine the techno-economic capability of the particular project and accordingly grant, or not, a production license. Under the renewed law, RAE is obligated to issue its decision within two months of the submission of a

complete production license application. The production license is granted for 25 years with the possibility of renewal for up to 25 additional years.

RES installation of small capacity (lower than 1 or 0,5 MW_e depending on the source) are exempted from the requirement to obtain a production license and in fact any other confirmation. For details on the maximum limits of such projects, which depend on the utilized RES, please refer to Law 3851/2010.

Installation License, Operation License and Environmental Terms Approval

The stages of preliminary environmental studies are merged into the Environmental Terms Approval (known by its Greek initials as EPO). To acquire an EPO, a project must gather the approval of all opining authorities including the Archeological Authorities, the Forestry, the Ministry of Defense, the local municipality etc. The developer must submit an environmental impact study, with required supportive documentation, to all the opining authorities which in turn are obligated to reply within four months from the time of a complete application. After an EPO is received, an installation and operation license can be granted.

An EPO is valid for 10 years and may be renewed by application submitted six months before its expiry. The installation license is valid for two years and may be renewed for up to two years in case that additional time is needed. The operation license is valid for 20 years and may be extended for up to 20 years. Especially in the case of solar thermal stations, the operation license lasts for 25 years.

Photovoltaic stations and wind turbines installed on buildings or in industrial areas are exempted from the obligation to obtain an EPO.

Grid-Connection License

In the final licensing phase, the Transmission System Operator (alternatively named DESMIE from the Greek abbreviation) grants the connection license taking into account the projected demand for power and incorporating the proposed plant into the local grid capacity.

Power Purchase Agreement

The power purchase agreement (PPA) is also granted by the DESMIE establishing the volume and price in which generated electricity will be purchased. Under the new legislation, all power purchase agreements are valid for 20 years from the onset, rather than 10 years, with the possibility of a 20 year renewal. Especially in the case of solar thermal stations, PPAs are valid for 25 years with the possibility of further extensions. The purchasing prices defer between the various renewable energy sources and are presented in the following chapter of this report.

6.5 Feed-in Tariffs & Financial Incentives

In recent years, the Greek government has supported RES generation through a mix of feed-in tariffs and up-front subsidies. This mix resembled the RES promoting strategies of Germany and Spain. In the case of Greece, the up-front subsidies were not tied to the RES policy, but were part of a general EU investment package which will, unfortunately, cease being available in the coming year.

Table 13: *Feed-in tariffs for utility-scale RES projects installed in the non-connected islands of the Aegean (Law 3851/2010).*

Electricity Generated by	Cost €cents/kWh
Onshore Wind	9,9
Offshore Wind	10,5
Solar thermal stations	26,5
Solar thermal stations with storage system ensuring 2 hours of operation at nominal capacity	28,5
Geothermal resources of low temperature (25-90°C)	15
Geothermal resources of high temperature (>90°C)	9,9
Biomass stations 1-5 MW capacity	17,5
Biomass stations >5 MW capacity	15
Biogas from landfills & biomass > 2MW capacity	9,9
Biogas from feed stock organic waste < 3 MW capacity	22
Biogas from feed stock organic waste > 3 MW capacity	20

As established by Law 3851/2010, high feed-in tariffs are available for the majority of renewable energy sources as presented in Table 13. It should be noted that photovoltaic plants fall under a special scheme and will be discussed later among other exemptions.

The current legislation provides higher tariffs for emerging and technologically complex installations, such as solar thermal, geothermal and biomass plants, in order to facilitate the repayment of possibly higher investment costs. This is a significant opportunity for international corporations to enter the Greek energy market as their financial and technical experience abroad would offer them a comparative advantage to local start-up companies and significant profits.

An additional incentive, also incorporated in Law 3851/2010, encourages producers to develop their plants without a public grant. The electricity generated by such projects is priced on the basis of the feed-in tariffs, presented above, with an increase of 15-20% depending on the RES. It should be noted that PV and solar thermal stations are exempted from this incentive.

A special bonus is further offered to support undersea cable connections of Non-Connected Islands (NCIs) to the mainland system. Any RES stations established in NCIs and rocky islets, and then connected to the national grid at their own cost, receive a bonus on their pricing tariff. The increase varies from 10% to 25% depending on the length of the undersea cable connection and the installed capacity of the station. This bonus continues to apply after the interconnection takes place and adds up to other increases.

Photovoltaic power plants fall under a special scheme and receive significantly higher feed-in tariffs as presented in Table 11. The feed-in tariffs for photovoltaics decrease in time, assuming that experience and technological maturity will decrease costs through the years.

7 FINANCIAL COMPARISON & COST SAVINGS

Based on the previous information, one can compare the returns offered by the development of high-temperature geothermal, photovoltaic and onshore wind resources in the Aegean Islands. As presented in Table 14, all three RES offer significant returns per kWh and can be financially viable according to calculations of the author. Onshore wind farms are indicated as the most mature and less risky investment with a return of 2,9-9,9 €cents/kWh. Estimated returns range more widely for the case of geothermal plants, and even more for PV installations, as the limited applications of these technologies in the Aegean region have not yet given a precise estimation of utilities' costs. The introduction of geothermal and photovoltaic plants is a significant opportunity for international corporations to enter the Greek energy market as their financial and technical experience abroad would offer them a comparative advantage in risk evaluation and thus higher profits.

From the perspective of the Greek government and the PPC, one can also estimate the communal savings given by substituting NCI diesel-fuel power plants with high-temperature geothermal, photovoltaic and onshore wind installations. As presented in Table 15, geothermal plants and onshore wind farms could result in significant savings on the side of the government and the PPC at a time that they are mostly needed. On the other side, the development of PV stations is a costly-inefficient endeavor for the government due to the exceptionally high feed-in tariffs. The significant government support towards photovoltaics could be justified if most photovoltaic parts were to be domestically produced. In this manner, the high subsidies could stimulate a cluster of local industries resulting in consecutive social and economic returns to the Greek society.

When referring to thermal applications, the previously mentioned renewable sources are cost efficient and market competitive. Solar heaters run at an average cost of 8 €cents/kWh_{th} while low-temperature geothermal can be used for 0,5-2,5 €cents/ kWh_{th}.

Considering that many Aegean islands have geothermal resources, the low cost of geothermal heat could be utilized towards the development of spas, health services, recreational activities and the island tourist industry as a whole.

Table 14: *Approximate returns for photovoltaic, high-temperature geothermal and onshore wind plants installed in the non-connected islands of the Aegean Sea (€cents/kWh).*

	Installation Costs (million € MW _e)	Production Cost (€cents/kWh)	Feed in Tariff (€cents/kWh)	Approximate Returns (€cents/kWh)
Geothermal, high temperature	1,5 - 4	4 - 10	9,9	-0,1 - 5,9
Wind, onshore	0,9 - 1,2	5 - 7	9,9	2,9 - 9,9
Photovoltaic*	3,5 - 5	26 - 47	29,4 - 44,1	-17,6 - 18,1

* Referring to a maximum tariff in Aug 2010 and a minimum in Aug 2014

Table 15: Government and PPC savings per kWh by substituting NCI diesel generation by onshore wind, high-temperature geothermal and photovoltaic plants (€cents/kWh).

€cents/kWh	Feed in Tariff	CO ₂ Avoided Costs	Avoided Costs of Diesel Generation	Approximate Communal Savings
Geothermal, high temperature	9,9	1,7	22	13,8
Wind, onshore	9,9	1,7	22	13,8
Photovoltaic*	29,4 - 44,1	1,7	22	-20,4 - -5,7
* Referring to a maximum tariff in Aug 2010 and a minimum in Aug 2014				

Even if we exclude environmental benefits, the financial returns of utilizing the previous renewable resources are far bigger than these cost reductions. Unlike diesel-powered generation, the three RES technologies examined –geothermal, photovoltaics and wind— are all capital intensive technologies with minimal operational costs. Thus, the RES electricity prices mentioned above cover investments on local infrastructure, jobs, and national capital, instead of the purchase of instant-use fossil fuels from non-EU countries, which in turn harm exchange rates and leave little value in the country.

8 CONCLUSIONS & RECOMMENDATIONS

This report analyses the Greek and Aegean electricity sectors and presents the energy potential, along with the financial and legal information, related to the development of onshore wind, geothermal and solar plants in the Aegean Islands. The report was conducted through a two month internship at the Icelandic National Energy Authority and was supported by a grant of the T.J. Watson Foundation. The following conclusions represent the opinion of the author and not necessarily that of NEA.

The cost of sustaining diesel-fueled power plants in Aegean Islands is significant in financial, social, and environmental terms. Pressed by EU goals and the upcoming imposition of CO₂ permits, the country, as a whole, needs to tap to the vast renewable energy resources of the Aegean. Considering solely the cost of CO₂ permits after 2013, Greek utilities will be burdened by 1,2 million euros yearly, corresponding to a 30-40% electricity price increase if the penetration of Renewable Energy Source (RES) is not to rapidly increase.

The current government has reinforced its commitment to green development by setting high RES goals for 2020, establishing the Ministry of Energy, Environment and Climate Change and accelerating the licensing procedure of RES projects through Law 3851/2010. Under this new legal framework, most RES receive high feed-in tariffs and electricity purchase agreements valid for 20 years with the possibility of renewal. In addition, technologies that were previously not allowed or considered –such as offshore wind or geothermal- are now strongly supported in an attempt to attract the first investments in these fields. This is a significant opportunity for international corporations to enter the Greek energy market as their financial and technical experience would offer them improved risk evaluation and a comparative advantage to local start-up companies.

When referring to the RES development of the Aegean Islands, three main issues can be identified: the isolation of island grids, the formerly bureaucratic licensing procedure and the lack of incentives for local population to support RES projects.

The following conclusions and recommendations of the author are addressed towards the Greek Ministry of Environment, Energy & Climate Change, the Center of Renewable Energy Studies, the EDIN organization and any relevant institutions, companies and individuals. The following are conclusions of the author and do not necessarily represent the opinion of NEA.

Diesel Generators

- The utilization of fluctuating power sources, such as solar and wind power, requires the presence of a supplementing provider to cover the times of low power output from RES. It will thus be necessary to interconnect the islands to the mainland grid, if diesel generators are to be phased out.
- A significant share of established diesel generators has been in operation for many years and has not always been well maintained. This reduces the generation efficiency and often increases the cost up to 22 €cents/kWh. For the

time period that diesel generators remain necessary, any further installations should use high-efficiency low-speed generators. The Ministry could enforce this measure in the legal framework.

Geothermal Development

- Under the renewed and supportive legal frame, geothermal development should be rapidly initiated utilizing the large resources of the Aegean volcanic arc and the significant feed-in tariffs. As presented by power plants in Iceland, New Zealand and the USA, geothermal electricity generation is a mature technology able to provide steady base-load power at low cost/kWh.
- The geothermal development of Milos should receive utmost priority considering that its resources are well identified and pose a large potential of 180 MW_e. A 6 MW_e power plant would sufficiently cover the needs of the local community. If cooperation with the significant mining industry of Milos is established, a plant of up to 16 MW_e can be foreseen. For further exploitation of the geothermal resource, grid connection to other Cyclades Islands and the mainland grid will be necessary.
- The Center of Renewable Energy of Greece (CRES) has completed extended research on high- and low-temperature reservoirs of the Aegean and would cooperate with companies in the exploitation of these resources.
- It is suggested that the Regulatory Authority of Energy (RAE), or a government authority specifically focusing on geothermal resources, requests the regular submission of data by all geothermal developers. Since the geothermal resources are owned by the state, these data should be made public possibly in the form of an annual report. The recommended list of data is presented in Appendix II.

Solar Development

- The comparative advantage of using photovoltaic and solar thermal electricity systems is that they produce predominantly during the summer months, and the peak hours of the day, when island demand is high and electricity generation particularly costly.
- The installation of such systems, however, remains rather expensive, resulting in a cost/kWh that is higher than that of most RES. Taking advantage of an already established solar heater industry in Greece, the development of a domestic solar electricity sector could contribute in lowering these cost.
- The current feed-in tariffs for solar electricity generation are exceptionally high and indicate a significant cost on behalf of the government. In order to support such a policy, a cost-benefit analysis should estimate the economic value of solar energy development in the national economy. The expansion of domestic solar industry, the creation of jobs and the avoidance of CO₂ permits should be taken into consideration.

Wind Development

- Wind is currently the most widely used RES in the Aegean Islands and its development continues to be, and should be, strongly supported. Major international corporations, such as Spanish Endesa and Iberdola, have already invested in the Aegean wind sector and further interest has been expressed.
- Due to the grid isolation of island networks, the penetration of fluctuating power sources, such as wind, is limited to a maximum of approximately 30%. Thus, grid non-connectivity forms a bottleneck to the exploitation of the vast Aegean wind resources.
- Hydro-pump mechanisms can offer a partial solution to the issue by storing generated energy for later use. These hydro-storage systems could be further combined with desalination plants providing potable water to the anhydrous Aegean communities.

Grid Expansion

- In order to exploit the Aegean RES on a national level the grid-connection of the Aegean Islands will be necessary. It is obvious that the mainland energy market is close by and could absorb the vast power output of Aegean RES. Specifically, in the case of Milos, a 150 MW_e geothermal power plant interconnected to the Cyclades and the mainland grid is a feasible choice for all stakeholders.
- The total cost of connecting all Aegean islands is estimated to be 1,5 billion euros; an expense that can be partially covered by EU funds. The preliminary cost-benefit analysis has concluded that the interconnection of the Aegean islands is a beneficial alternative to the current diesel-fueled electricity generation, even without considering any additional developmental and environmental benefits.
- The Ministry of Development decided in favor of interconnection, expecting that the project development will take 15 to 20 years to complete starting in 2007. The interconnectivity of the Aegean islands will further bring environmental benefits and electricity security to the island communities and the country as a whole. Considering that Greece entered a deep economic crisis in 2010, it is strongly advised that the project is not halted as its incorporation can play a key role in the economic development of the Aegean communities and the national energy sector.

Looking Ahead

As Greek developing companies and government authorities may lack technical know-how in large-scale geothermal, offshore wind and solar thermal electricity plants, it is recommended that the Ministry of Environment, Energy and Climate Change and the Regulatory Authority of Energy seek independent peer review. The peer review panel would assist authorities to take measures as to secure the proper renewable resource exploitation for the next few decades. The cost of this peer review can be incorporated into the license fee.

Referring to geothermal technologies, employees in the Greek Regulatory Authority of Energy; the Center of Renewable Energy Studies; and the Ministry of Environment, Energy and Climate Change could seek training in the Geothermal Training Program of

the United Nations University in Iceland. This six month postgraduate program accepts qualified candidates from countries that present significant geothermal resources and have supporting energy policies. The government institutions mentioned above could greatly benefit from the Geothermal Training Program. It is thus recommended that they come in contact with the United Nations University in Iceland.

It should be emphasized that the interconnection of the Aegean islands reaches vast renewable energy resources in a geographically strategic position; it strengthens Greece's position on the global energy map while it could offer the long-run capability to largely produce and possibly export RES electricity to the neighboring Italy, Turkey and Balkan states.

The renewable energy development of the Aegean Islands is a holistic solution addressing a plethora of financial, developmental and cultural problems of the Aegean region. This endeavor should be conjointly undertaken by investors, municipalities, and government officials while using a mixture of RES, whilst always remembering that no single technology or corporation can alone serve as the golden solution.

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APPENDIX I: FOSSIL FUEL POWER PLANTS IN THE NON-CONNECTED ISLANDS OF THE AEGEAN SEA

Data were received from the Public Power Company and refer to year 2001. The islands are presented in order of descending installed capacity.

Supplying Island	Power Station	Installed Capacity (MW)	Peak Demand (MW)	Yearly Electricity Use (GWh)
Crete	Chania	328		
	Linoperamata	193		
	Total	521	407	1.925
Rhodes	Soroni	206	127	
Kalimnos, Kos and Nisyros	Kalimnos	70	57	218
	Kos**	61	-	-
Lesbos	Lesbos	50	46	210
Samos	Samos	46	24	99
Paros and neighboring islands	Paros	43	36	118
Chios and Psara	Chios	39	30	136
	Psara*	0,35	-	-
Thira and Thirasia	Thira	22	23	67
Mykonos	Mykonos	21	18	52
Syros	Syros	20	19	85
Andros	Andros	9,4	9,3	33
Karpathos and Kasos	Karpathos	9,0	6,5	24
Limnos	Limnos	8,9	12	47
Milos and Kimolos	Milos	7,6	6,0	24
Ikaria	Ikaria	6,9	5,4	19
Skyros	Skyros	4,5	3,8	12
Patmos	Patmos	4,4	3,6	11
Symi	Symi	4,4	2,0	7,8
Sifnos	Sifnos	4,3	3,4	9,4
Ios, Sikinos and Folegandros	Ios	3,7	4,4	12,6
Amorgos	Amorgos	2,7	2,2	6,3
Kithnos	Kithnos	2,3	2,0	5,2
Samothraki	Samothraki	2,2	2,4	7,1
Serifos	Serifos	2,0	1,9	4,8
Astipalea	Astipalea	1,6	1,4	3,8
Megisti	Megisti	0,39	0,32	1,2
Ag. Eustratios	Ag. Eustratios	0,36	0,22	0,76
Anafi	Anafi	0,36	0,34	0,61
Ereikousa	Epeikousa	0,27	0,20	0,41
Othoni	Othoni	0,27	0,24	0,50
Agathonisi	Agathonisi	0,24	0,10	0,28
Donousa	Donousa	0,21	0,15	0,28
Anikythira	Anikythira	0,14	0,04	0,10
*Back-up station not currently in operation				
**Station is operating as a supplement to Kalimnos station				

APPENDIX II: SUGGESTED DATA COLLECTION FROM GEOTHERMAL POWER PLANTS

Following the Icelandic regulatory system, it is suggested that any future geothermal projects in Greece should turn in the following data to the Greek Regulatory Authority of Energy or the appropriate government institutions. Since the geothermal resources are owned by the state the following data should be made public possibly in the form of an annual report:

- a. The amount of fluid extracted from or reinjected into each well in the geothermal field, each month.
- b. The temperature of the water reinjected into the geothermal reservoir each month.
- c. Results of water level measurements in wells in which the water level can be measured and are within the geothermal field.
- d. The pressure changes or drawdown determined in the geothermal reservoir.
- e. The results of measurements of the enthalpy of the fluid from every production well in the geothermal field.
- f. Chemical analysis of the geothermal water (and steam, if appropriate).
- g. Results from simulations of the geothermal reservoir.
- h. Results of measurements made to monitor changes in the geothermal reservoir.
- i. Information on drilling in the industrial area.
- j. A resume of improved understanding of the physical characteristic of the geothermal reservoir based on the results of the latest drilling.