The Evolution of Renewable Energy Sources in the Electricity Sector of Greece *

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Abstract

This study assesses the status of renewable energy sources (RES) penetration in the electricity sector of Greece. Methodologically, we approach the topic by identifying the actual advancement of projects, from the date of initial licensing to the initiation of operational phase. Next, we investigate the institutional and social barriers for their further development. The evidence provided here records that throughout the previous decade RES penetration in the focal economy has been dramatically slow, since a considerable 87.6% of installations acquired production license in the period between 2001 and 2005, out of which a substantial 44.6% in 2001. We further show that an overwhelming portion of RES projects is targeted upon specific technologies and that RES installations are unevenly allocated among the different administrative Prefectures of the country. In this context, our trajectory indicates that the EU 2020 target which calls for a share of 18% of RES in final energy consumption is in question, unless bureaucratic barriers are removed, public acceptance is increased and a coherent national strategy aiming at the further development and competitiveness of the private sector will be consistently implemented.

Keywords: RES technologies; Greece; EU 2020 milestone; administrative Prefectures; institutional and social barriers of implementation.

1. Introduction

The most significant, long-term environmental challenge facing the world today is climate change that results from greenhouse gases' (GHGs) emissions. Historically, changes in climate resulted entirely from natural causes, such as changes in Earth's orbit, changes in solar activity and volcanic eruptions [1]. After the industrial revolution though, the growing global dependence on coal, oil and natural gas had a tremendous impact on climate, particularly by adding billions of tons of heat-trapping GHGs to the atmosphere [2]. Today, GHGs emissions have exceeded the atmospheric "cleansing capacity" [3], posing a fundamental threat to environmental and economic sustainability. Indeed, the scientific consensus of our times posits that GHGs are causing climate changes that include rising average national and global temperatures, extreme rainfalls, heat waves and storms, warming oceans, extinction of species and loss of biodiversity [4], [5].

Anthropogenic climate-related impacts occur across many industries' life cycle [6]. However, together with the transportation sector [7], the energy sector accounts for a large portion of GHGs, being at the root of climate change and air pollution [5]. Given that carbon dioxide (CO_2) emissions stemming from fossil-fuels' value chain contribute significantly to the climate issue, the challenge for global energy markets is to meet the simultaneous imperatives of economic development and environmental deterioration. This challenge derives from the positioning of energy at the interface between emissions and sustainability: demand for energy services to meet economic objectives and improve human welfare is increasing [8], [9]. Yet, for economic development to be sustainable, energy services need to be secure and have low environmental impacts [10], [11]. As a response to these considerations, renewable energy sources (RES) contribute significantly to both environmental protection and the elimination of the dependence on oil, addressing in that way effectively the concerns of our era about the 'limits of growth' [12].

Within this context, European Union (EU) is continuously working to address the effects of climate change and establish a common energy policy. In this vein, in March 2007, European political leaders had agreed on future binding targets, setting the pioneering vision to reduce GHGs emissions by 20%, improve energy efficiency by 20% and increase the share of renewable energy to 20%; the so-called 20-20-20 by 2020 target. In this regard, according to Directive 2009/28/EC each EU Member State (MS) should further increase the use of RES technologies in the electricity sector. This increase, which reflects differentiated RES potentials among EU countries, range from 10% in Malta to 49% in Sweden.

Against this background, the purpose of this study is to survey, report and evaluate the progress made by the EU peripheral economy of Greece towards RES penetration in the electricity sector. To achieve our research objectives a novel methodology is presented,

tracing the date of initial production license for each RES installation in the Interconnected Electrical System (IES) of the focal economy. Exploration and investigation of technologies and systems to tap and convert renewable energy into electricity energy is an important area of research worldwide [13]. Greece represents a unique case in this regard, as an EU economy facing a multi-dimensional challenge: its trajectory of economic growth (as a response to the ongoing financial crisis) will inevitably require increased electricity demand and a consequent rise in environmental concerns. In addition, compared to other EU countries, the country possesses enormous RES potentials due its idiosyncratic geographical distribution and favorable climatic conditions (over 1,000 islands with sea wind, an average wind speed exceeding 7.5 m/s, an average of about 3,000 hours of sunshine per year and an important number of geothermal fields). Yet, RES participation in the electricity sector still remains small and the country is overall characterized by a pollutant energy system, depending substantially on lignite and imported fuels, especially liquid fuels.

Our findings add to the existing evidence on the projection of EU countries' potential to achieve their 2020 RES targets. Further, by putting emphasis on social and institutional factors and assess the progress under which RES projects actually advance throughout the various administrative procedures, from the initial licensing requirements to production, we identify the most significant barriers to their implementation and further development. Finally, more important here for potential investors, Greece's strategic geo-economic location, between energy producers in the Middle East, North Africa and the Caspian Sea, as well as on the vital transport routes of the Aegean Sea and the Eastern Mediterranean, mark it as a very attractive energy hub between East and West. Thus, the allocation and development of RES installations and technologies in the different Prefectures of Greece, in combination with the local wide-ranging investment regulatory framework, may provide insights for investment opportunities in specific regions of the country.

The paper is organized as follows: a brief review of the main EU policies for RES development and the local regulatory framework will set the scene for assessing the evolution of RES projects in Greece. Next, we detail on our methodological approach and report the progress of RES in the country in relation to the 2010 intermediate milestone. Further, we record the key barriers of projects' implementation. Following this, we project RES evolution and identify the country's potential to achieve its 2020 national binding target. In the final section we conclude, by discussing the implications of our findings for research, public policy and private investments.

2. Setting the Scene: EU Renewable Policy and the Local Legislative Context

2.1 RES and the origins of EU energy policies for climate change

Following the 1972 UN conference on environment, Europe's environmental policy was initiated in 1973, addressing the ambitious aspiration to contain many elements of the 'sustainable development' imperative. Consequently, when climate change issues emerged at the top of political agendas in the beginning of the nineties, EU environmental policy had already witnessed more than a successful decade with common action in a growing number of areas [14]. Hence, there was a widespread optimism at that time that EU would also be able to implement a coherent energy and climate change strategy. At the core of that discussion was the acknowledgment that RES were insufficiently exploited throughout the Union [15]. Although many of them were abundantly available, RES recorded a disproportionally small contribution of less than 6% to the region's overall gross inland energy consumption; despite the benefits that clean, sustainable and secure energy supply would bring to environment, public health and the economy at large. In short, at the end of the eighties, one could only observe a patchwork of different, partially contradictory trends, with different environmental policy approaches being promoted simultaneously [16].

Against this background, the liberalization of EU electricity market started with Directive 1996/92/EC which was expired by Directive 2003/54/EC with the overall objective to set common rules for the internal market in electricity. As a parallel step towards a pan-European harmonization of the Community's strategy and action plans, in 1997 EU published the White Paper on renewable sources of energy, setting the goal to double their use (from 6% to 12%) within the EU-15 countries between 1996 and 2010. Following these legislative developments, the Directive 2001/77/EC on the promotion of electricity produced from RES was introduced. Under this Directive, EU countries were required to adopt indicative national targets so as to materialize the Union's target of 22% of electricity produced from RES by 2010. The Directive also encouraged the use of national support schemes, the elimination of administrative barriers and grid systems' integration. Further, it provided for the obligation to issue renewable energy producers with guarantees of origin upon request. Apart from environmental protection, the promotion of electricity from RES was a high EU priority for several other reasons too, including the security and diversification of energy supply, social cohesion and economic growth and sustainability. Finally, it also constituted an essential part of the measures aiming at complying with EU commitments under the Kyoto Protocol, i.e. the reduction of GHGs by 8%. During the 00's, EU has been continuously working on shaping appropriate policies to reduce the effects of climate change and establish a common energy policy. This vision is clearly reflected in Directive 2009/28/EC. According to the latter, RES should account for 20% of the EU's final energy consumption by 2020, from 8.5% in 2005. To address this target, each EU Member State needs to increase further the production and use of RES, primarily in the electricity sector, but also in heating, cooling and transportation.

The target for Greece is set at 18%, from just 6.9% in 2005, which in this case corresponds to an estimated share of RES in electricity gross consumption of approximately 35%.

2.2 Legislative framework in Greece

In Greece, the electricity market has undergone radical changes over the past three decades, the most prominent of which include the effort to open up the market to competition, improve the country's energy infrastructure and promote renewable sources. The first reforms to open the market have been introduced by Statute 1559/1985 (Regulations of Issues of Alternative Forms of Energy and Specific Issues of Power Production from Conventional Fuels), which essentially initiated in the country a favorable indirect endeavor towards energy production from RES. Drawing on this, the production of energy is permitted for individual producers *if and only if* the production procedure utilizes renewable sources and the output is being partially consumed by the producer. Evidently, the Law did not promote investments that were exclusively aimed at producing renewable energy for commercial purposes.

The inadequacies and drawbacks of Statute 1559/1985, which made licensing an almost impossible task, led to its amendment by Statute 2244/1994 (Regulation of Issues pertinent to the Generation of Electrical Energy Sources and Fossil Fuels), which became a landmark piece of legislation for the evolution of RES in Greece, imposing feed-in tariffs for renewable energy and opening the market to both public and private entities. Statute 2244/1994 introduced fixed tariffs and a guaranteed purchase of the energy produced under 10-year contracts. These provisions, coupled with support (in form of grants and subsidies) by investment Laws, have attracted a considerable number of investors, resulting in the first private wind farms which came in operation in 1998. Following this favorable environment shaping the competitive setting of renewable energy production, a total capacity of 368.6 MW of RES has been installed in Greece at the end of 2002, compared to 71 MW of RES capacity installed almost a decade ago (in 1994).

In 1999, the Statute 2773/1999 on the Liberalisation of the Electricity Market (the so called *Electricity Law*) aligned local legislation with Directive 96/92/EC. Electricity Law has incorporated the majority of provisions of the earlier Law 2244/1994, which was entirely referred to RES electricity issues. Within its provisions, the 'Electricity Law' introduced the new key entities of the market, namely the regulator (RAE) and the transmission system operator (HTSO), retained the fixed tariffs for electricity produced from RES and assigned emphasis on the crucial issue of RES priority access to the electrical grid. The Statute's provisions, coupled with the Licensing Code of December 2000, established the notion of 'Production Licence' as a fundamental prerequisite for all legal entities using RES in the electricity production. From 2000 and onwards, the production license became the mandatory entry point to the administrative procedure for anyone aiming to become an electricity

producer. It should be noted though that the very small RES installations (ranging from 20 to 500 kW of capacity) *are exempted* from the licensing procedure.

According to the Licensing Code, the production license is issued by the Ministry of Development, following a relevant application to RAE and a positive recommendation to the Ministry by this authority. The first 'Call for Expression of Interest' to apply for an "Electricity Generation Licence in Greece" was published on the 2nd of December, 2000 and the first production licenses have been issued by RAE from May to September, 2001. Between 2001 and early 2007, interested parties retained the option to apply for a RES production license at any time throughout the whole year. From June 2007 and onwards though, RAE accepts RES applications according to an annual, fixed schedule of six rounds of applications. However, for projects referred to electrically congested grid areas, such as the non-interconnected islands, investors can only file their applications after an official public 'Call for Application' which explicitly states the capacity requirements to be addressed.

Although it seems that a RES project is initiated with the production application to RAE, in reality the acquisition of the production license is considered as just a prerequisite step (Fig. 1). From this point and onwards, the RES project has to advance through a complex administrative procedure with the overall purpose to obtain two more administrative permits. First, the *Installation Permit* allows for the physical planning of the work and for that reason it is a very crucial step for the eventual implementation of the RES project. The installation permit involves getting a positive clearance from a number of administrative authorities with the final mandatory issuing responsibility lying at the different administrative Prefectures of the country (depending on the project's location).

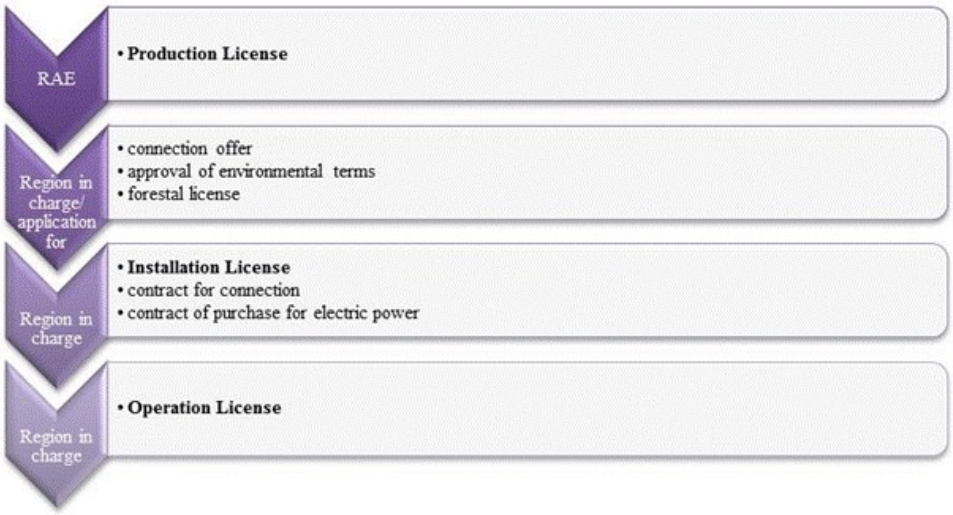

Fig. 1: From production to operation license (source: adapted from www.investingreece.gov.gr)

With the Statute 3468/2006, the environmental impact assessment of the RES project became also an integral part of the procedure of issuing the production license. After the installation is

finalized and its associated operating functions have been verified, especially in terms of network's integration, the final *Operating Permit* is granted. Throughout the description of the different phases of project's evolution, it can be inferred that obtaining the installation and operation permits is generally conceived as a complex decentralized administrative procedure, facing considerable bureaucratic barriers at the different levels of public governance authorities.

Statutes 2837/2000 and 2941/2001 amended the 'Electricity Law', yet it was Statute 3175/2003 that made the most significant changes by adopting some of the provisions introduced in Directive 54/2003/EC. In particular, Statue 2837/2000 regulated competition issues, whereas Statute 2941/2001 characterized RES projects as of a public benefit, regardless the legal status of the project's executor (i.e. public or private institution). Further, Statute 3175/2003 had set the framework for geothermal energy matters and hybrid RES installations. Following these developments, Statute 3468/2006 (also known as the '*RES Statute')* which has transposed the Directive 2001/77/EC on the promotion of electricity produced from RES into the national legislation, had extended the guaranteed purchase of RES electricity, increasing at the same time the level of feed-in tariffs. Further amendments to the existing legislation have been introduced in Law 3581/2010 on 'Sale and simultaneous Leasing of Public Sector Properties, Long-term Leases and Leasing for the Public Sector' with the overall objective to decrease the costs of RES production and provide attractive investment incentives in the local market. Specifically, the Law aims at accelerating the permitting procedure of the larger projects as much as possible, simplifying considerably the licensing of smaller projects, offering new attractive feed-in-tariffs for all RES technologies and introducing new clauses for offshore wind. It also established a RES agency under the Ministry of Environment, Energy and Climate Change for advising RES investors.

Finally, Law 4001/2011 "for the operation of Electricity and Natural Gas Energy Markets, for Exploration, Production and Transmission Networks of Hydrocarbons and other provisions" established rules for the internal markets in electricity and natural gas, according to the instructions of the European Parliament and Council of July 13 and considerably improved the procedure for phovoltaics' (PVs) licensing. Despite that the cost of power produced by PVs is still higher than the same size conventional generations and they normally require additional facilities to integrate and transfer the power to the grid [17: 924], after the Law's introduction, Greece plans to overpass 4% of the electricity demand with PV by 2020 which is very encouraging for the PV industry.

3. Research Design and Methods

3.1. Sampling, data sources and research instruments

The methodological strategy employed here is a combination of quantitative and qualitative research. In particular, based on archival data, we had performed a detailed longitudinal analysis by retrieving, analyzing and reporting the evolution of all RES installations (from initial licensing to actual production) operating in the IES of Greece in two different time periods, i.e. on December 2010 (EU intermediate milestone) and December 2008 (two years prior the closing date). In addition, we have conducted semi-structured field interviews with eleven public experts (one from each administrative Prefecture of the country) so as to identify the social and institutional barriers that impact on RES development and project their evolution towards the country's EU 2020 target. Due to their senior positions, we believe that our respondents are knowledgeable and the information provided reliable and accurate. All interviews were conducted by the lead author between January 2012 and April 2013. Each interview lasted approximately an hour and, following Ricci et al. [18], covered a variety of topics, including RES development in the administrative Prefectures of the country, projects' social acceptance, investors' difficulties in dispatching grid operations, policy legislation, the administrative burden and workload of the Prefectures and the direction of communication flows between central and peripheral administration.

The IES of Greece consists of the mainland and a number of islands connected to it by a submarine network. It has been selected as the geographical study area mainly because it is the part of the country's electrical system for which a detailed Registry of operating RES installations is publicly available. This Registry has been retrieved from the web site of the Independent Power Transmission Operator (IPTO), formerly known as Hellenic Transmission System Operator (HTSO). Both IPTO and HTSO databases are widely used as standard sources for researchers, since they are considered as original and reliable sources of information for the focal economy. December 2010 and 2008 Registries account for 93% and 99% respectively of the total installed capacity of RES in the IES of Greece [19], [20]. By analyzing the background information provided, one can trace the capacity, geographical location and type of RES technology. By further analyzing both Registries, we can evaluate the historical development of the installed RES capacity in the IES of the country, the contribution of electricity produced from RES installations at the national level, as well as project future trends.

3.2. Data collection and analysis

Mapping the evolution of RES projects has been initially planned to be addressed by quantifying the time elapsed between the dates of issue of the production permit and the operating license. However, all attempts to trace the relevant data from the administrative Prefectures were not successful, mainly due to the reluctance of public servants to provide relevant information. In particular, after three rounds of communication, the dates of issue of

the production permit and the operating license have been gathered from only two out of eleven Prefectures and for just a handful of projects. Lack of publicly available electronic records of installation and/or operating permits and severe difficulties in electronic communication simply added to the problem of data collection.

Alternatively, it has been decided to identify the year of issue of each of the production license of all currently operating RES installations and their capacity. In that way, we could statistically apportion the relevant information along the time period between 2001 and 2010. This would portray the distribution of the total operating capacity within the period of reference and, therefore, it would correspond to the 'maturity' of operating installations, providing us indirectly with a quite fair and secure representation for the progress of RES projects in Greece. However, although an electronic, regularly updated record on production licenses is available online (www.rae.gr/lic/), the site of RAE reports only the latest version of this record. Therefore, the original data set could not be retrieved. Further, a production license is distinguished by its unique 'License Number' and 'Date of Issue'. If any administrative, corporate or technical modification occurs, the production license record is subsequently amended. In our case, although, the record always keeps the original production license number, the date of issue appeared in the file corresponds to the day of last amendment. This means that, quite probably, the currently available date of issue of a production license may not correspond to the initial one. Tracing though the original date of issue for each production license was critical for achieving the objectives of our study.

In order to address the above methodological shortcomings, we have created a novel database including a chronological order of all production licenses' records (beginning from the 17th of February, 2004), derived from information officially released throughout this period. All the records of this file have been cross-checked against the announced amendments by RAE and have been adjusted accordingly. In that way, it became finally feasible to reveal the unique original initial date of issue of the production license for each of all the operating RES installations in the IES of Greece. Having identified the corresponding date of issue of each of the production licenses, the RES installations were then allocated to the pertinent eleven administrative Prefectures of the country so as to map the geographical distribution of the projects.

4. Results and Discussion of Findings

4.1 RES penetration in the IES of Greece

According to December's 2012 HTSO Registry, the installed capacity of RES in the IES of Greece totaled at 2,850 MW, while on January 2003, the relevant capacity summed up to 237 MW (calculated from Table 1). It can then be reasonably argued that throughout this decade we have witnessed a significant RES increase of approximately 1,200%. Though, according

to Directive 2001/77/EC, EU aimed to have 21% of its electricity produced from RES by 2010 (the 2010 milestone). The overall EU target was broken down to specifically-defined national, provisional targets for each MS, with the relevant target for Greece being set at 20.1%. According to evidence recorded, at the end of the previous decade Greece was behind in reaching this target, despite an increase over 40% two years prior to the closing date and considering also 3,000 MW of large hydro.

Table 1: RES installed capacity in the IES of Greece (from January 2003 to December 2012)

	Wind Farms			Small Hydro			Biomass-Biogass			PV			Total
	MWh	MW	Δt (MWh)	MWh	MW	Δt (MWh)	MWh	MW	Δt (MWh)	MWh	MW	Δt (MWh)	Δt (MWh)
Jan-03	56.000	197		10.000	19		8.000	21					
Jan-04	57.433	283	86	14.706	34	15	8.449	21					101
Jan-05	73.881	341	57	14.322	43	9	8.083	20					66
Jan-06	130.432	429	88	25.509	48	5	8.121	20					93
Jan-07	130.532	552	123	15.293	76	28	9.538	37	17				168
Jan-08	122.671	667	115	28.780	97	21	15.262	37	0	77	1	1	137
Dec-08	211.749	791	124	38.821	158	62	14.894	39	2	915	11	10	197
Dec-09	220.850	917	126	78.270	183	24	15.498	41	1	4.062	46	35	187
Dec-10	243.084	1.039	122	72.803	197	14	16.444	41	0	12.889	153	107	244
Dec-11	287.343	1.363	324	39.298	205	9	17.091	45	3	37.754	439	286	622
Dec-12	312.014	1.466	103	82.921	213	8	17.652	45	0	88.566	1.126	687	798
Average to Dec-12			127			19			3			188	261

Source: HTSO registries (www.desmie.gr/nc/en/home/)

The performance of the country towards the EU 2010 milestone was not unexpected. To take one such example, in 2003 RAE had reported that a rational projection of wind farms' development towards 2010 would be 1,500 MW in 2006, 2,100 MW in 2007, 2,500 MW in 2008, 2,700 MW in 2009 and 2,873 MW in 2010. However, the regulatory authority had also stated its reservations for the successful accomplishment of the above scenario, having considered the slow pace of RES development, mainly due to the severe problems that the projects were facing at the implementation phase, such as grid problems, complicated administrative procedures and, to some extent, low degree of social acceptance from local communities. These reservations have been also reflected in both the 3rd and the 4th national reports on RES penetration up to 2010. Both reports have pointed out the need for a substantial increase of RES levels. More specifically, they pictured a required increase from the installed RES capacity of 3,764 MW on December, 2005 (large-scale hydro included) to an estimated capacity of 7,193 MW (3rd Report) and from 4,058 MW (on December, 2007) to an estimated required RES capacity of 7,652 MW (4th Report). In the latest available report (4th), the projections even of the conservative scenario that has set the target of RES penetration to 15.3% instead of 20.1% for 2010, indicate an increase of 41.51% of the RES installed capacity (from 4,062 to 5,748 MW) within three years. Evidently, at the end of 2010, despite a significant increase of RES investments, there is a notable divergence between actual and expected electricity production from RES.

In comparison to other EU countries, the performance of Greece could be characterized as moderate. EU monitored the 2010 target of introducing RES in the electricity mix by measuring the share (%) of RES electricity generation in the national gross electricity consumption. Taking 2009 data under consideration, Greece has achieved to cover 61.1% of its national target. Cyprus and Malta were still at an initial point of introducing RES, while Slovakia has achieved to cover 57.7% of its 2010 target. For the remaining EU countries, France, Luxemburg, UK, Poland and Lithuania have covered between 64.5% and 78.6% of their targets, Finland, Romania, Czech Republic, Portugal, Austria, Spain and Bulgaria between 81.8% and 89.2%, Italy, Sweden and Denmark between 91.1% and 94.4%, Latvia was at 99.9%, whereas Belgium, Netherlands, Ireland, Slovenia, Estonia and Hungary had fully covered their targets. 100%. The average coverage for all EU-27 MS target was 85.7%.

As for the evaluation of the EU 2020 objectives, the use of RES share (%) in final energy consumption (FEC) is considered as reliable indicator for monitoring the target described in Directive 2009/28/EC. Here, it should be mentioned that statistical techniques for incorporating some RES technologies in FEC are not yet adequately developed so as to fully comply with the requirements and indicators set by the above Directive. Though, for the time being, the contribution of these technologies is rather marginal. Hence, the current calculation of the index is conceived as relatively secure. According to data provided by Eurostat, in Greece, the share of RES in FEC and gross inland energy consumption in 2009, normalised for hydro contribution, was 8.1% and 6.1%, respectively. This performance diverges considerably from the relevant targets set by EU. The slow pace of RES installed capacity and the considerable time period required from the production to operation license (see section 4.3) raise concerns for the ability of the country to fully comply with EU 2020 requirements. To further conclude on the country's potential to achieve its 2020 target, the European Wind Energy Association (EWEA) has analyzed the EU-27 wind sector, which accounts for a large proportion of RES installations, concluding for the contribution of wind energy to the 2020 RES roadmap using a "Low" and a "High" scenario. According to this report, an estimated capacity of 985 MW of wind farms in Greece for 2008 should be increased to a level between 6,500 MW (low scenario) and 8,500 MW (high scenario) by 2020. That calls for an average annual capacity increase of 480-626 MW. In the IES of Greece the annual average RES capacity of 149 MW between 2003 and 2010 differs substantially from such levels. Though, the 798 MW installed capacity during 2012 is a promising achievement, which should be further exploited in order to compensate for the capacity "missed" during the previous decade.

4.2 Allocation of RES projects in the eleven administrative Prefectures of Greece

The mapping of RES operating capacity in the different administrative Prefectures of Greece is presented in Figure 2. According to evidence provided, in 2010 the "Sterea Ellada" Prefecture accommodates 417,627 MW (31.4% of the total country's capacity), "Peloponnisos" 231,031 MW (17.4% of total capacity) and "Anatoliki Makedonia and Thraki" 227,225 MW (17.1% of total capacity). Whereas it seems that RES development in these geographical locations is encouraging, in the remaining Prefectures RES projects are much less developed. A comparison between RES operating capacity in 2008 and 2010 (Fig. 3) does not reveal significant differences in the level of RES investments in the country's administrative Prefectures, with the exception of a minor increase in "Sterea Ellada" and a decrease in "Anatoliki Makedonia and Thraki" Prefectures. A detailed longitudinal analysis of RES capacity in the different Prefectures of the IES of Greece is presented in Appendix A.

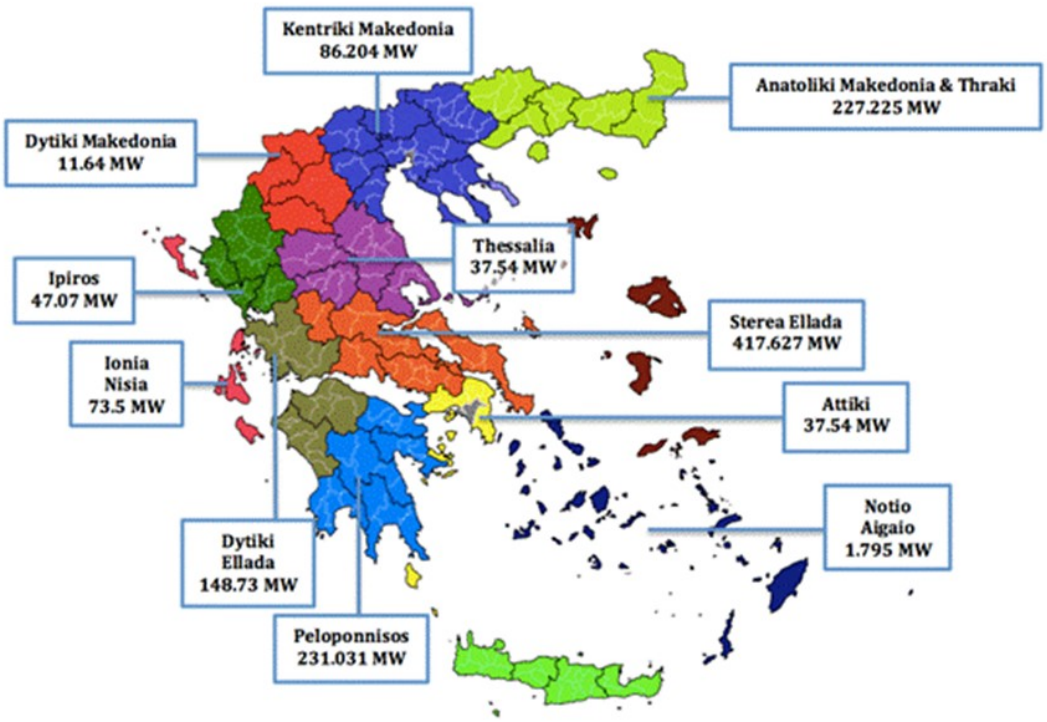

Fig. 2: Operating capacity (MW) of RES in the IES of Greece at the end of December 2010

A further segmentation of RES operating capacity according to RES technologies (Fig. 4) indicates that wind farms installations are by far the most prevalent, with an installed capacity accounting for 78.33% and 79.93% of the total installed RES capacity in 2008 and 2010 respectively. Small-scale hydro projects seem to develop at a satisfactory rate with "Ipiros" and "Kentriki Makedonia" Prefectures to accommodate considerable capacity (Appendix B). Surprisingly, in a country which is positioned in one of the most active volcanologically geotectonic environments of the world, maintained by the robust subduction of the African Tectonic Plate under the Eurasian one, the geothermal energy is marginally represented.

It can be concluded that despite the generous supporting schemes and incentives, RES projects advance extremely slow from the planning and designing period to the full implementation phase. According to evidence provided here, between 2008 and 2010, in the IES of Greece there have been added just 430 MW of RES capacity. Further, 87.6% of the installations operating at the end of 2010 had acquired their production license in the period between 2001 and 2005, out of which a substantial 44.6% in 2001. This implies that after obtaining a production license, a time period of up to 5 – 6 years is usually required for a RES installation to reach the operational stage.

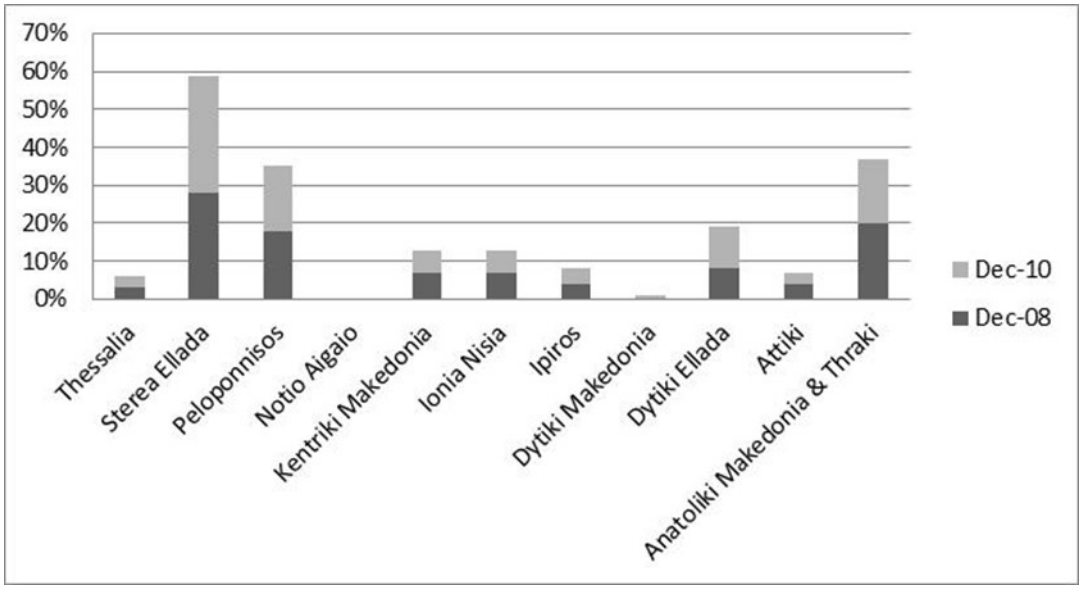

Fig. 3: Allocation of RES installed capacity in the administrative Prefectures of Greece, December 2010 and 2008

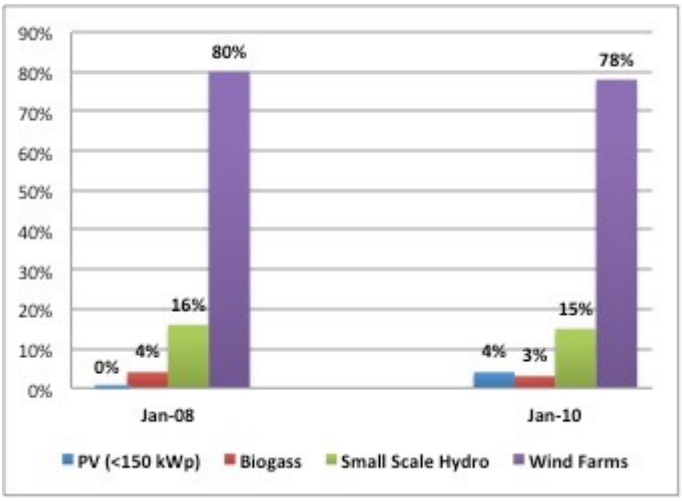

Fig. 4: RES technologies in the IES of Greece at the end of December 2008 and 2010

4.3 Barriers of implementation and further development

Apart from the limited grid capacity available for RES projects, interviews conducted with public administration experts have disclosed that the admittedly slow pace of renewables in the focal economy is due to the identified pre-elections and meta-elections slowdown (reported as a major barrier from four prefectures), bureaucracy (complicated administrative procedures, conflict of interests between the Ministry of Development and the Ministry of Interior, Public Administration and Decentralization), a misalignment of information technology infrastructure between the Prefectures and the Ministries (reported by six Prefectures), as well as low levels of social acceptance which cancel the projects or delay considerably their development (reported by seven Prefectures). As far as bureaucracy is concerned, which has been reported by all respondents as a major barrier of implementation, according to interviewees' responses, Greece is the country (together with Hungary) with the higher number of authorities involved in the procedure from production license to operation than most of the other European countries. In particular, our respondents stated that authorization to obtain an operation permit for a RES project requires the involvement of about 25 authorities.

An illustrative example for the above findings relates to the evolution of some wind farms projects, dated in 2003 (Table 2). On the 18th of March, 2003 RAE announced a call for applications for an available capacity of 18 MW in the Greek islands. Following this expression of interest, 53 applications were filed with an expected total capacity of 85.62 MW. On the 2nd of September, 2003 RAE announced that 17 wind farm projects, with a total capacity of 19.3 MW, have received a positive recommendation. All of these projects obtained production license from the Ministry of Development. In 2009, out of these 17 projects only 3 (17.6%) reached the operational stage (www.rae.gr/GIS/); representing 10.9% of the capacity licensed (total capacity of 2.1 MW). Also, one of these projects was actually an extension of a wind farm already operating. Hence, in order to have a more accurate representation of the evolution of RES projects throughout the period of reference, we should consider that a number of installations were probably already operating and/or having completed installation stage and were nearly ready to start operating by the end of 2001. These RES projects have followed the "prior to 1999" licensing framework, in terms of installation and operation permits, with the production license being for them just an additional final administrative prerequisite and not a factual necessity.

A typical example to illustrate this is the case of the "Sterea Ellada" Prefecture. This Prefecture includes the Euboea Island, the south-eastern area of which has considerable RES potentials. In Euboea, a wind farm of 5.10 MW capacity started operating in 1992. Between 1992 and 2000, several others wind farms with a total installed capacity of 39.35 MW were also operating in the island [21]. By juxtaposing the list of individual RES installations compiled by the Centre of Renewable Energy Sources (CRES) of Greece on December, 2001

(www.rae.gr/energysys) with the publicly available production permits records, we conclude that the total capacity of the wind farms operating in Euboea Island by the end of 2001 should range between 110 -130 MW. Evidently, the realization of these installations could not coincide with the first production permits issued from RAE between May and September, 2001. By further considering the capacity of the small-scale hydro installations also operating/installed by the end of 2001 in the other Prefectures of the IES of Greece, we estimate that installations with a capacity of 586 MW, albeit they have been granted with production licenses in 2001, were already operating or were close to operation by the end of 2001. We also estimate that some RES installations which operate today and have been recorded as holding a 2002 production license (totaling to 200 MW of capacity), have possibly covered lots of the ground of the licensing procedure during 1999-2001 and, thus, they cannot be considered as entirely new projects. By taking into account the above findings it can be reasonably argued that a notable part of the country's achievement in terms of RES capacity is based on the foundations grounded in the late nineties.

Table 2: Details of installation and operating permits' dates of issue for some wind farms and small-scale hydro RES installations in Greece

RES Technologies	Capacity (MW)	Production License	Installation Permit	Operating Permit
Wind Farms	10 < C < 20	2001	Oct - 03	Jan - 06
	20 < C < 30	2003	Oct - 05	Apr - 09
	20 < C < 30	2003	Oct - 05	Apr - 19
Small - scale Hydro	1 < C < 5	2002	Jul - 05	May - 10
	1 < C < 5	2003	Nov - 04	Sept - 08
	0.5 < C < 1	2003	Jan - 05	Oct - 06
	C < 0.5	2005	Aug - 06	Dec - 08

5. Conclusions

The Directive 2009/28/EC on the promotion of the use of energy from renewable sources sets mandatory national targets for the overall share of RES for each EU MS. In this regard, this study evaluates the status of RES penetration in the electricity sector of Greece. Methodologically, we approach the topic by retrieving the initial production license of each RES installation in the IES of the country. Next, we have allocated RES projects in the different administrative Prefectures and assessed the progress under which RES technologies

actually advance. This interaction of quantitative and qualitative methodological strategy was considered essential so as to monitor the actual evolution of RES in the focal economy and identify the most important institutional and social barriers to their implementation and further development. To the best of our knowledge, this is the first time that such an approach reflecting the pace of RES penetration and the perceptions of all the Prefectures of the country in relation to their evolution is adopted for Greece. The evidence provided here records that despite the considerable number of policies aiming at promoting the development of RES installations, their contribution in the electricity sector of Greece could be significantly improved. Consequently, Greece still relies on local lignite to power the mainland and on imported oil to power its islands. Further, RES installations are mainly targeted upon specific technologies (wind farms) and are unevenly allocated among the different administrative Prefectures of the country (two Prefectures accommodate nearly 50 percent of the total country's capacity), resulting in an unfortunate underutilization of the country's RES potentials. Subsequently, more needs to be done in order the country stays on track with its objectives set for 2020.

Our research has several implications. With regard to implications for public policy, admittedly the contribution of Greece to the global climate change problem is, in absolute terms, relatively small. Yet, the country still needs to pave its way in order to achieve its targets. In 2005, GHGs emissions had reached a level of increase up to 23.22% and in 2006 this increase was confined at a level of 19.72%. While this could be considered as a progress, data for 2007 report an emissions' increase at a level of 23.24%. As a result, despite the accepted wisdom on the advantages of RES for the focal economy [22], Greece could not comply with the prerequisites of the 2010 milestone. But, even more important here, the present research empirically shows that unless an unexpected change of pace occurs, Greece may stay short of its national, binding RES target for 2020. All of these sound a cautionary note to policy makers to reconsider the strategic direction, legislative context, administrative landscape and methodological approach towards RES development.

Strategically, considering the country's diversified RES sources and potential, political decision-makers should establish a common consensus to promote different technologies (e.g., wind energy, small hydropower, geothermal energy, PV and biomass) simultaneously. In theory, RES importance to the national economy as a means to secure energy supply, attract investments, exploit environmental friendly local energy sources, and, at the same time achieve GHGs emissions reduction is widely recognized. The diffusion of RES technologies in the energy system of Greece requires a change of systemic nature and demands for a holistic view of the entire technology system involved that should be prioritized (as is the case in pioneering countries, such as Germany and Sweden). Methodologically, we propose that the development of these technologies should adopt the 'long-distance runner' model, which

will further enable public authorities to continuously monitor the progress of RES projects on specific, pre-determined intermediate targets.

In the regulatory context, a variety of contradictory legal provisions concerning RES development and the protection of the environment calls for an urgent need for codification of the entire framework on licensing, construction and operation of RES projects, as the consecutive amendments of the legislation lead to delays, conflicts between regulations and create legal uncertainty. We propose that priority should be given to the pathogenic "modus operandi" of the administrative structure of Greece, namely the issue of "Encyclicals". Encyclicals can be defined as administrative, often binding, working documents providing instructions for the implementation of official legal acts. Since "Encyclicals" are not officially published, private investors may not be aware of their existence and the additional, or even different, administrative requirements they set. We argue that these documents could be included in the Official Gazette of Greece in a new Part. Further, the licensing procedures remain complex, involving a multitude of central, regional, prefectural and local authorities. As a result, this highly bureaucratic administrative structure with many levels of managerial authority and strictly defined hierarchies, deter the interdependence among different organizations, institutions and interested parties; leading to misallocation of valuable resources and capabilities. In order the evolution of RES projects to be the responsibility of a limited number of authorities, we propose a transition towards a socio-economic decomposition of the decision-making process, i.e. the more active involvement of regional authorities in the design and implementation of RES strategies. Lower level public managers in each Prefecture are often equipped with better and more accurate information and can provide valuable insights on the social acceptance of policy measures; enhancing the awareness of environmental, economic and social benefits [18], [23]. In this vein, top government officials can be concentrated on strategy, on higher level decision-making and the overall coordination and monitoring of action plans.

Finally, as the world addresses diverse and challenging questions related to energy production and supply, Greece is in a pivotal position to chart its energy future, emerging as a strategic energy hub in Southeast Europe and a desirable location for investment. It is estimated by the World Bank that investment of more than 30 billion Euro will be required by 2020 in the upgrade and building of power plants, in transmission and distribution and in RES. Energy policy in Greece could make a significant contribution to the country's economic recovery. In recession periods, RES development goes hand in hand with the creation of sustainable jobs and economic prosperity. By providing evidence on the allocation of RES projects in the various administrative Prefectures of the country and the key barriers to their further development, we argue that the ideal conditions for wind and solar energy coupled with attractive investment incentives may lead to new projects with strong cash flows

and attractive returns on investment in “Ipiros” and “Sterea Ellada” Prefectures, as well as the islands of the country.

References

[1] IPCC (Intergovernmental Panel on Climate Change) (2013), *Climate Change 2013: The Physical Science Basis*, Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Ed. T.F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P.M. Midgley. Cambridge, United Kingdom, and New York, NY: Cambridge University Press.

[2] Barry, M.M., Agbim, K.A., Chyu, M.
Performance of thermoelectric devise with integrated heat exchanges
Journal of Electronic Materials, 44(6) (2015), pp. 1394-1401.
doi: 10.1007/s11664-014-3380-2

[3] Prinn, R.
The cleansing capacity of the atmosphere
Annual Review of Environment and Resources, 28 (2003), pp. 29-57.
doi: 10.1146/annurev.energy.28.011503.163425

[4] Pourtouiserkani, A., Rakhshandehroo, Gh.
Investigating climate change impact on extreme rainfall events
Scientia Iranica, 21(3) (2014), pp. 525-533.

[5] IPCC (Intergovernmental Panel on Climate Change) (2007), *Climate Change 2007: The Physical Science Basis*, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Ed. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller. Cambridge, UK: Cambridge University Press.

[6] Berndes, G., Hoogwijk, M., van den Broek, R.
The contribution of biomass in the future global energy supply: A review of 17 studies
Biomass and Bioenergy, 25(1) (2003), pp. 1-28
doi: 10.1016/S0961-9534(02)00185

[7] Ball, M., Wietschel, M.
The future of hydrogen: Opportunities and challenges
International Journal of Hydrogen Energy, 34(2) (2009), pp. 615-627
doi: 10.1016/j.ijhydene.2008.11.014

[8] Muradou, N.Z., Veziroğlu, T.N.
“Green” path from fossil based to hydrogen economy: An overview of carbon-neutral technologies

International Journal of Hydrogen Energy, 33 (2008), pp. 6804-6839
doi.org/10.1016/j.ijhydene.2008.08.054

[9] Acar, C., Dincer, I.
Comparative assessment of hydrogen production methods from renewable and non-renewable sources
International Journal of Hydrogen Energy, 39 (2) (2013), pp. 1-12
doi:10.1016/j.ijhydene.2013.10.060

[10] Winter, C.J.
Hydrogen energy - Abundant, efficient, clean: A debate over the energy system of change
International Journal of Hydrogen Energy, 34(14) (2009), pp. S1-S52
doi: 10.1016/j.ijhydene.2009.05.063

[11] Clark, B., York, R.Y.
Carbon metabolism: Global capitalism climate change and the biospheric rift
Theory and Society, 34(4) (2005), pp. 391–428.

[12] Kaldellis J.K., Zarifakis, D., Kavadias, K.
Minimum cost solution of wind-photovoltaic based-alone power systems for remote consumers
Energy Policy, 42 (2012), pp. 105-117
doi.org/10.1016/j.enpol.2011.11.054

[13] Fan, H., Singh, R., Akbarzadeh, A.
Electric power generation from thermoelectric cells using a solar dish concentrator
Journal of Electronic Materials, 40(5) (2011), pp. 1311-1320
doi: 10.1007/s11664-011-1625-x

[14] Montini, M.
Reshaping climate governance for post-2012
European Journal of Legal Studies, 4(1) (2011), pp. 7-24

[15] Capello, R., Fratesi, U., Resmini, L. Globalization and Regional Growth in Europe: Past Trends and Future Scenarios. Springer: Berlin; 2011

[16] Liefferin, D., Skou-Andersen, M.
Strategies of the 'green' member states in EU environmental policy-making
Journal of European Public Policy, 5(2) (1998), pp. 254-270

[17] Ghaedi, A., Abbaspour, A., Fotuhi-Firuzabad, and Parvania, M. (2014),
Incorporating large photovoltaic farms in power generation system adequacy assessment
Scientia Iranica, 21(3) (2014), pp. 924-934

[18] Ricci, M., Bellaby, P., Flynn, R.

What do we know about public perceptions and acceptance of hydrogen? A critical review and new case study evidence
International Journal of Hydrogen Energy, 33(21) (2008), pp. 5868-5880
doi:10.1016/j.ijhydene.2008.07.106

[19] Hellenic Transmission System Operator. Synoptic RES and CHP Monthly Bulletin. Greece, December; 2010

[20] Hellenic Transmission System Operator. Synoptic RES and CHP Monthly Bulletin. Greece, December; 2008

[21] Kaldellis, J.K.
Investigation of Greek wind energy market time-evolution
Energy Policy, 32 (2004), pp. 865-879
doi: 10.1016/S0301-4215(03)00013-2

[22] Tsoutsos, T.D., Stamboulis, Y.A.
The sustainable diffusion of renewable energy technologies as an example of an innovation-focused policy
Technovation, 25(7) (2004), 753-761
doi.org/10.1016/j.technovation.2003.12.003

[23] Polatidis, H., Haralambopoulos, D.A.
Renewable energy systems: A societal and technological platform
Renewable Energy, 32(2), (2007), pp. 329-341.
doi.org/10.1016/j.renene.2006.02.016

List of Appendices

Appendix A: A longitudinal analysis of RES operating capacity in the IES of Greece at the end of December 2007 and 2010

A. DEC 2007	Prefecture	Anatoliki Makedonia & Thraki	Attiki	Dytiki Ellada	Dytiki Makedonia	Ipiros	Ionia Nisia	Kentriki Makedonia	Notio Aigaio	Peloponnisos	Sterea Ellada	Thessalia	Total		
		Operating Capacity (MW)												%	Cumulative %
Equivalent Year of Installation: 1990-1992	Wind Farms	0,220	-	-	-	-	-	-	1,575	-	5,100	-	**6,895**	**0,7**	
Equivalent Year of Installation: 1992-1998	Hydro	-	-	9,900	-	10,300	-	13,200	-	-	8,500	-	**41,90**	**4,2**	**4,9**
Year of Production License	2001	182,400	25,030	6,720	-	29,095	13,600	46,723	-	42,990	197,790	21,940	**566,288**	**57,3**	
	2002	14,850	9,500	61,350	-	2,255	-	1,480	-	54,000	18,725	-	**162,16**	**16,4**	
	2003	-	3,010	0,830	3,980	2,400	57,200	5,422	-	63,000	45,000	4,550	**185,392**	**18,8**	**92,5**
	2004	0,940	-	-	-	-	-	-	-	-	-	-	**0,94**	**0,1**	
	2005	-	-	-	0,490	-	-	0,431	-	15,000	2,550	2,350	**20,821**	**2,1**	**2,6**
	2006	-	-	-	-	-	-	-	-	-	2,085	-	**2,085**	**0,2**	
	2007	-	-	-	-	-	-	1,544	-	-	-	-	**1,544**	**0,2**	
Total RES		**198,41**	**37,54**	**78,80**	**4,47**	**44,05**	**70,80**	**68,80**	**1,575**	**174,99**	**279,75**	**28,84**	**988,025**	**100**	**100**

B. DEC 2010	Prefecture	Anatoliki Makedonia & Thraki	Attiki	Dytiki Ellada	Dytiki Makedonia	Ipiros	Ionia Nisia	Kentriki Makedonia	Notio Aigaio	Peloponnisos	Sterea Ellada	Thessalia	Total		
		Operating Capacity (MW)												%	Cumulative %
Equivalent Year of Installation: 1990-1992	Wind Farms	0,220	-	-	-	-	-	-	1,575	-	5,100	-	**6,895**	**0,5**	**3,7**
Equivalent Year of Installation: 1992-1998	Hydro	-	-	9,900	-	10,300	-	13,200	-	-	8,500	-	**41,90**	**3,2**	
Year of Production License	2001	182,400	25,030	13,040	-	29,095	13,600	47,348	0,400	55,740	202,740	22,690	**592,083**	**44,6**	
	2002	14,850	9,500	88,744	1,360	2,255	-	1,480	-	63,000	20,625	-	**201,81**	**15,2**	
	2003	-	3,010	2,030	4,480	4,210	59,900	15,422	-	63,000	71,000	15,330	**238,382**	**18,0**	**87,6**
	2004	20,740	-	19,915	-	0,270	-	-	-	-	0,163	-	**41,09**	**3,1**	
	2005	1,250	-	13,600	0,490	0,940	-	1,571	-	15,000	54,178	2,350	**89,379**	**6,7**	
	2006	0,780	-	-	-	-	-	1,530	-	20,000	43,085	-	**65,395**	**4,9**	
	2007	-	-	-	-	-	-	2,698	-	4,566	3,242	2,947	**13,453**	**1,0**	
	2008	-	-	1,004	4,316	-	-	1,500	-	7,050	-	-	**13,870**	**1,0**	**8,7**
	2009	6,985	-	0,499	0,994	-	-	1,205	-	2,675	8,994	1,006	**22,358**	**1,7**	
	2010							0,250					**0,250**	**0,02**	
Total RES		**227,225**	**37,540**	**148,732**	**11,640**	**47,070**	**73,500**	**86,204**	**1,975**	**231,031**	**417,627**	**44,323**	**1.326,867**	**100**	**100**

Notes: *Installed power in MW. The operating capacity is allocated by Administrative Prefecture and year of production license. The RES installations in the IES of Greece, which were included in the Ministerial Decision 1085/24-01-2002 (Hellenic Republic, 2002) are also shown. In the "Notio Aigaio" Prefecture only the inter-connected Andros and Tinos islands are included.*

Source: Authors' survey

Appendix B. Operating capacity of RES in the IES of Greece at the end of December 2007 and 2010 (by RES technology)

A. DEC 2007	Prefecture	Anatoliki Makedonia & Thraki	Attiki	Dytiki Ellada	Dytiki Makedonia	Ipiros	Ionia Nisia	Kentriki Makedonia	Notio Aigaio	Peloponnisos	Sterea Ellada	Thessalia	Total	
		Operating Capacity (MW)												%
RES Technologies														
Wind Farms		197,470	3,010	60,050	-	-	70,800	17,000	1,575	171,000	251,850	17,000	**789,755**	**79,93**
Small-scale Hydro		0,940	0,630	18,750	4,470	44,050	-	45,208	-	3,990	27,900	9,990	**155,928**	**15,78**
PV (>150 kWp)		-	-	-	-	-	-	1,544	-	-	-	-	**1,544**	**0,16**
Biogass		-	33,900	-	-	-	-	5,048	-	-	-	1,850	**40,798**	**4,13**
		198,41	**37,54**	**78,80**	**4,47**	**44,05**	**70,80**	**68,80**	**1,575**	**174,99**	**279,75**	**28,84**	**988,025**	**100**

B. DEC 2010	Prefecture	Anatoliki Makedonia & Thraki	Attiki	Dytiki Ellada	Dytiki Makedonia	Ipiros	Ionia Nisia	Kentriki Makedonia	Notio Aigaio	Peloponnisos	Sterea Ellada	Thessalia	Total	
		Operating Capacity (MW)												%
RES Technologies														
Wind Farms		217,270	3,010	113,350	-	-	73,500	27,000	1,975	212,750	373,450	17,000	**1.039,305**	**78,33**
Small-scale Hydro		2,970	0,630	33,879	6,330	47,070	-	48,503	-	3,990	31,941	21,520	**196,833**	**14,83**
PV (>150 kWp)		6,985	-	1,503	5,310	-	-	5,403	-	14,291	12,236	3,953	**49,681**	**3,74**
Biogass		-	33,900	-	-	-	-	5,298	-	-	-	1,850	**41,048**	**3,09**
		227,23	**37,54**	**148,73**	**11,64**	**47,07**	**73,50**	**86,20**	**1,975**	**231,03**	**417,63**	**44,32**	**1.326,867**	**100**

Notes: *Installed power in MW. The operating capacity is allocated by Administrative Prefecture, year of production license and type of technology. Other RES, exempt from Production Licensing and cogeneration are not included.*

Source: Authors' survey