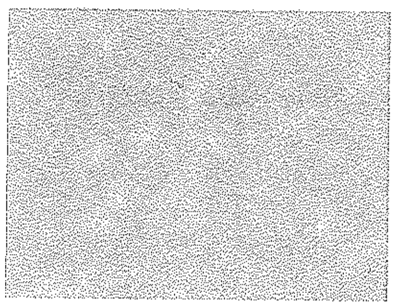
# FIVE – FORCES ANALYSIS OF THE GREEK WIND ENERGY FARM MARKET



## 1. Introduction

Promotion of electricity produced from renewable energy technologies is of high priority within the European Community for reasons related to security and diversification of energy supply, environmental protection and social and economic cohesion. During the last decade a continuously increasing interest in Renewable Energy Sources (RES) and especially in wind energy was noted in Greece. The factors that leaded in the construction of wind energy farms are three:

1. the favourable legal and financial measures that were implemented,
2. the rich potential existing in the country and
3. the rising envinonmental awareness.

According to the European Directive 2001/77/EC Greece is obligated to achieve 20.1% of the total electricity generation with means of RES. The achievement of this ambitious goal necessitates a drastic change towards RES and the construction of more wind energy farms.

The aim of this research is to perform a five – forces analysis of the Greek wind energy farms market.

## 2. Greek wind energy market then and now

Historically, the development of the wind energy farms market in Greece can be divided into two main phases:

1. 1985 – 1999: the wind energy utilisation fell within the responsibility of the state (the state owned Public Power Corporation – PPC and local authorities) not allowing for initiatives by private entrepreneurs
2. 1999 – Today: liberalisation of the market of renewable energy sources due to the adoption of the European Directive 1996/92/EC and the introduction of the Law 2773.

Although the results of the first phase were rather meagre, the second phase marked a remarkable growth of the wind energy sector. Currently, in Greece the production of electricity based on the wind attracts to many private investors since it is the only form of RES that can offer them significant profits.

critical for attracting investors.

Before the liberalisation took place when the Government was to develop a wind farm, it awarded through international tenders the construction to the firm whose feasibility plan exhibited the best technical and economical aspects. Since 1999, private investors submit applications in order to develop and run their own farms. In the second case, the firm – investor does not get paid by the Government for building the farm and the energy sold to the public grid consitutes its only source of revenues. Consequently, the firms that undertake the construction of the energy plants also are the sellers of the energy produced by the farm.

## 3. Market Definition

The product market we are investigating is the wind power – electricity produced in Greece. The analysis is confined to the firms that produce electricity through the construction and operation of large wind energy farms. In order to define the geographical market it is crucial to take into account that except from Greek firms many European ones play an active role in the Greek wind energy farms market.

## 4. Internal Rivalry

The Greek market of wind energy farms is very concentrated, it is an oligopolistic market. The joint venture of Rokas Renewables and the Spanish Irberdrola and the Greek company Terna Energy hold a leading position in the market with a share of about 35% and 28% respectively. The other three major players (Copelouzos Company, PPC Renewable SA, Technodomiki SA) hold the 22% of the market. Actually, the Greek firms are exploring opportunities for entering the wind energy generation markets in several developing countries in the S.E Europe, Asia and S. America. In Greece, the construction of wind energy farms (and as a result the production of electricity) is undertaken not only by Greek firms but also by Spanish, German and French Firms. Since 2006 many important European companies like the Spanish Gamesa and Cesa, the French EDF and the German Enercon have shown interest in investing in the Greek wind power market. As a result Greek companies don' t have to compete only with each other but they must face the competition arisen due to the interest of foreigners in the Greek wind energy market.

All the companies engaged in the wind energy market have to face significant costs: labour costs, capital costs including the cost of the turbines, the cost of the grid connection, the cost of the civil work, the development and licensing procedures, and variable costs, the most significant being the operation and maintenance of wind turbines. Although the Greek Government is subsidising the investment in this market, the costs remain significantly high.

Since all the wind energy farms – developed by different manufacturers/sellers – produce the same product, electricity, there is no product differentiation between different companies. Since it is obligated for all owners of the wind energy farms to sell all the energy produced to PPC through HTSO (Hellenic Transmission System Operator) at a fixed price which is not negotiated there is no pricing competition among the different firms. The HTSO has to grant priority to the electricity produced through the utilisation of renewable energy sources and consequently through the wind energy. As a result there is neither industry price elasticity of demand nor brand loyalty to existing sellers. What is more, the wind energy farms are relationship – specific investments and entail a large capital cost and as a result there are important exit barriers.

During the last two years, the rate of the industry growth has been equal to 33% since at the end of the year 2005, 486MW of wind energy generators were in operation while actually 650MW of wind energy generators are in operation.

Although there is no need for firms to use advertising in order to promote their construction activities and the production of electricity, firms try to have access to key – lands. The wind energy market is a higly competitive market. The competition among the firms is so fierce that in many cases firms that have made a substantial investment in the meteorology measurement and the measurement of the wind potential of a certain region, a time consuming and expensive procedure, find out that other firms have submitted for the same regions without proceeding in the measurement of its potential. As a result the market is characterised by fierce and intense nonprice competition.

but if there is a guaranteed buyer who pays the same price to everyone, do they really compete with each other?

## 5. Entry

In Greece, there is no Government protection of incumbents. The law 2773 (in 1999) foresaw the liberalisation of the RES market, guaranteed the buy – back rates for RES produced electricity and therefore marked a new phase for the development of RES utilisation in Greece. What is more, not only are there no legal barriers that can deter entry but also the Greek State is strongly subsidizing private investments in the area of wind energy applications. Subsidies come up to 35% — 40% of the initial investment cost. Although there is support of RES, in terms of tariffs and subsidies, there are other hidden barriers. Although the intense interest in developing wind parks that many investors have demonstrated, no tangible results can be argued to have resulted. Investors have submitted applications for a license for 23GW but only 845.5MW have been granted operation licenses. This is the result of the complicated licensing procedures for RES projects in Greece that constitutes the most important barrier that can deter entry. These bureaucratic procedures involve a multitude of central, regional, prefectural and local authorities (departments) interwoven in a lengthy and confusing licensing process. On the basis of the currently available data, the average duration of the entire process is estimated to be approximately three years and during this period of time is required the official expression of positive opinion of more than 35 public – sector entities and the check, in terms of conformity, of the installation with four National Laws and seven Ministerial Decrees. Consequently, taking into account that there is a large possibility of a negative decision regarding the installation, many investors are unwilling to wait until the decision is made and decide to invest in other markets.

What is more, another very important barrier that can deter entry are the limited capabilities of absorbing wind energy – generated power observed in many regions and the lack of the necessary infrastructure. These problems limit the potential surface that can be used to build wind farms excluding regions that exhibit an important wind potential and as a result making competition among firms more fierce. Additionally, incumbents enjoy experience – based advantages as well as advantages that result from the learning curve. The majority of the incumbents are also engaged in planning and construction of conventional power plants and in the utilisation of other forms of RES. As a result, they are very experienced and enjoy economies of scope. The fact that entrant' s access to favourable locations is difficult since incumbents have already submitted applications regarding the regions that have favourable wind potential poses a very important barrier to entrants. High development costs and the experience – based advantages of the incumbents combine to make entry into the Greek wind energy farm industry extremely difficult. Finally, the incumbents are able to construct big wind energy farms enjoying economies of scale that arise when the number and size of the wind turbines per wind farm increases. Wind turbines exhibit economies of scale in the terms of declining investment per KW with increasing turbine capacity.

### 6. The buyer power

The wind energy farms constitute a relationship – specific investment dedicated on the production of electrical energy. Consequently, the investors run the risk of hold – up if they cannot find potential buyers. As far as the Greek reality is concerned, the buyer' s industry is very concentrated since there is only one buyer, the PPC S.A. (Public Power Corporation S.A.) which consists the only industry in Greece that is responsible for the transmission and distribution of the electricity. According to the Renewable' s law 2244/94 the Greek Transmission System Operator (HTSO) is obligated to grant priority access to RESe installations. What is more, the HTSO is obligated to enter into a ten – year contract (Power Purchase Agreement) with the RESe producer, for the purchase of his electricity. The contract includes a renewal option. The PPC through HTSO is obligated to purchase the electricity production of the Renewable sources at a fixed percentage of the corresponding market price. Since June 2006 the respective rates for wind energy are as follows:

1. For the interconnected system and the islands linked to it, electricity price equals 73€/KWh and

2. For the insular system, electricity price equals 84.6€/KWh.

The price is not the result of competition but is decided by the Government. The purpose of the determination of these buy – back tariffs is to offer incentives to investors in order to invest in the Greek wind energy market. Since the only source of revenues for a wind energy farm is the energy sold to HTSO, the price plays a fundamental role for the economic viabiltity of the farm. It results that the pay – back period is remarkably diminished as the electricity price is increased. The determination of the buy – back tariffs aims at an average pay – back period equal to eight years. As a result the HTSO and consequently the PPC don' t have any bargaining power since they do not have the right to negotiate the price of the purchase. One price applies to all transactions. Although there are a lot of conventional power plants that produce electricity, the HTSO is obligated to buy all the electricity produced by the wind farms and the other forms of RES. In this way there is no competition between the electricity produced by wind energy farms and the conventionally generated energy range, even in the actual liberalised market.

Taking all the above into consideration, the Greek Government tries to ensure the economic viability of such investments offering to the farms the certainty of the absorption of all of their production by the PPC transmission grid.

As far as future prospects are concerned, it is doubtful that the legislation is going to change. Taking into account that Greece has not yet reached the goals of the Kyoto Protocol concerning the reduction of $CO_2$ emissions and the percentage of the total electricity consumed that must be produced by renewable energy sources, it is logical to assume that HTSO is going to continue purchasing the electricity produced by the Greek wind energy farms.

## 7. The Supplier Power

Wind energy is a capital – intensive technology. The capital cost can be as much as 80% of the total cost of the project over its entire life, with variations between models, markets and locations. The wind turbine because of the complexity of its sub – components and its structure constitutes the single largest cost.

Suppliers play a very important role in the market of wind energy farms since the capital cost of the investment is driven by the cost of the wind turbine and its different sub – components. As a result, suppliers have the power of eroding the profits of the firms. Since firms that construct wind energy farms are not able to set the price of the electricity they sell to the public grid, the importance of the capital cost, dedicated on the turbines, for the economic viability of the farm is obvious. During the last two years the booming demand for wind energy has put pressure on the supply chain. The cost of raw materials – steel, copper, lead, cement, aluminium and carbon– all of which are found in the major subcomponents of wind turbines has been pushed upward. As a result, the capital costs per KWh of wind energy have increased by 20% in the past three years.

Actually the firms that develop wind energy farms outsource the construction of the wind turbines since there are firms with an international presence in the construction of wind turbines. These firms enjoy economies of scale due to fact that they produce a large number of turbines for different companies around the world. Consequently, there is no reason for the Greek firms that are engaged in the wind energy market to develop their own wind turbines.

In the Greek market, there are four dominant suppliers of wind turbines, towers, motors and gearboxes: Vestas, Siemens, Enercon and Nordek with market shares equal to 40%, 30%, 10% and 5% respectively. The supplier market is very concentrated. It is an oligopolistic market. Taking into account the high cost of the wind turbines, the firms choose very carefully the supplier based on the price of the product. Since all the suppliers offer a variety of wind turbines that can be used, the firms choose the supplier that bids the lower price. What is more, in order not to be subject to a potential rise of the price firms not only use their bargaining power but they also set up long – term contracts in order to achieve a favourable for them price that cannot erode largely their profits. It is very interesting to mention that up to 1988 the high price of the wind turbines has played a negative role in the viability of the wind energy farms.

As far as the rest of the electromechanical equipment required (e.g. cables), there is a large number of suppliers whose products are homogeneous. As a result they don' t have the ability of negotiating high input prices with the firms in the industry.

## 8. Substitutes

The energy produced by conventional energy plants as well as by plants exploiting other forms of renewable energy sources constitute close substitutes for the energy produced by wind energy farms. Actually, thanks to the Renewable's Law, the energy produced by means of RES is granted priority and therefore there is no price competition with the electricity produced by conventional plants. Whether the price of the wind based electricity is higher than the price of the conventionally produced energy, its absorption by the grid is obligatory.

As far as photovoltaic plants are concerned, Greece is a country with an extremely high potential for solar and especially for PV applications since it has a very high insolation all year round (among the highest in Europe). Therefore, PV farms can contribute to the achievement of the goals of the Greek Government regarding the energy production based on RES.

However the Greek PV energy market is not adequately developed compared with other EU markets. During recent years, the Government has incentivized investment by providing for high tariffs and capital subsidies for photovoltaic energy. Nevertheless, total installed solar capacity is relatively small, equal to 5.44 MW in both autonomous and grid connected capacity as at December 31, 2006, and is produced principally by individuals. As a result, although the Greek PV market has grown rapidly during recent years supported by the existing European, national and regional programmes, it seems to be in an embryonic phase with some applications supporting the small number of companies in the sector contrary to the excellent solar conditions, which favour the PV applications. Consequently, the PV market has a great potential of development.

It is, however, a fact that the cost of production of electrical energy by Photovoltaic Parks is still very high compared to the cost of the electricity production by wind farms. It is important to mention that the construction of a wind energy farm of 10 MW demands the investment of 10 million € while the development of a photovoltaic park of just 172 kW requires the investment of 1.3 million €.

At present, it is obvious that as far as the construction of big energy plants based on renewable energy sources is concerned there is neither price competition nor price elasticity of demand among the energy produced by different types of RES since the Greek Government tries to exploit all the different renewable energy sources and HTSO buys the electricity produced by them at the same price.

As far as future prospects are concerned, reasons other than price competition can lead to a significant erosion of the profits of the firms engaged in the wind energy market because of the electricity produced by other means of RES. For example, if the Greek Government decides to promote more the photovoltaic energy or other means of RES and HTSO stops buying all the electricity production of the wind energy farms or reduces significantly its price, then the firms in the market will suffer losses of profits. These losses will not be the result of price sensitivity between the products but the result of the change of the current legislation. ✓

## 9. Summary

The table that follows summarizes the five – forces analysis of the Greek wind energy farms market. The Greek Government supports the electricity production based on the wind energy utilization guaranteeing its absorption.

There is no price competition with the conventional power plants. As far as future prospects are concerned, it is doubtful that the situation will change. The suppliers are the only that can erode the profits of the firms since the price of the electricity sold to the grid is fixed.

| FIVE - FORCES ANALYSIS | |
|---|---|
| **Force** | **Threat to profits** |
| Internal Rivalry | Low |
| Entry | Low |
| Substitutes | Low |
| Supplier Power | Medium |
| Buyer Power | Low |

There are very important barriers that deter entry (bureaucracy, lack of infrastructure, high development costs). Entrance will be easier only if the licensing process changes and the upgrading of the power transmission grid takes place – a procedure that requires a long period of materialization which exceeds 6 years.

interesting paper – good choice of a topic.
excellent research.

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Strategy

Our strategy is to leverage off our competitive strengths in the Greek RES market, and in the short term, to rapidly grow our generation capacity and consolidate our position as a leading RES electricity producer in Greece. Our strategy also involves taking advantage of opportunities in markets outside Greece, where we believe significant potential for developing these energy projects exists.

**Growing our RES generation capacity in Greece**

Our principal strategy is to continue developing our RES projects currently under construction and those for which we have either applied or received production licenses, in order to rapidly increase our total installed capacity in Greece in the short term. Although wind power will continue to contribute the dominant portion of our total installed capacity, we also plan to bring online a number of hydroelectric, solar power and biomass projects.

By exploiting the regulatory incentives and simplified licensing procedures provided by the Greek regulatory framework, as well as our established wind project development and construction expertise, we are confident that we will meet our objectives for expanding our wind park portfolio and achieving the substantial increases we are targeting in our total installed wind power capacity.

We are also developing a number of hydroelectric facilities, in some cases together with joint venture partners. Moreover, we have filed license applications for solar parks, to take advantage of the natural hydropower and solar potential made possible by the terrain and climate in Greece. Moreover, we have identified opportunities for developing projects involving the processing of biomass, arising in part from the need to address the historic problem of improper waste disposal in Greece.

**Entering foreign markets**

We have already begun exploring opportunities for entering the RES generation markets in several developing countries in the S.E Europe, Asia and S. America, with a view to supporting the long-term growth of our generation business as our home market approaches its RES targets and expansions of the Greek power grid will become necessary to take on additional capacity. We are in the process of conducting wind tests in S.E Europe to locate suitable sites for wind parks, and are in discussions with potential joint venture partners in Asia and S. America to explore future wind project developments in that area.

Hydroelectric Projects

The company is developing a number of small and large hydroelectric projects, for which production licenses have already been awarded in various regions of the country, with a total capacity of more than 120 MW. Moreover, another 93 MW are in the pipeline, for which the company has already applied for production licences.

Within 2006 the construction of the first two small hydroelectric projects begun, which have a total installed capacity of 15 MW.

Other hydroelectric projects are currently in the development stage, as far as licensing and techno economic planning is concerned.

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(3) Solar Energy

The Company showed an early interest in solar energy and photovoltaic systems. In April 2001, it successfully completed the construction of a Photovoltaic Park with capacity of 171,6 KW in Xerolimni (Lasithi),10 klm southeast of Sitia (Crete), which was one of the first projects of this scale in Greece. The overall budget of the project was approximately €1.3 million and was subsidized by 70% by the Operational Program for Energy (CFS II).

This Photovoltaic Park, which remains until today one of the largest in Greece, operates successfully and without serious damage or problems, demonstrating proof of its developed technology, and produces in fact more energy than was originally estimated.

It is, however, a fact that the cost of production of electrical energy by Photovoltaic Parks is still very high. The Company follows with interest the developments in the field of RES, and remains always ready to proceed to new investments in photovoltaic systems once conditions allow it.

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# Developments in the utilisation of wind energy in Greece

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**Abstract**

The utilisation of renewable energy sources, and wind energy in particular, can be described in Greece as a story of high expectations, intense initial entrepreneurial interest, delays in the start-up phase of projects and, some times, disappointments during the implementation procedure. Still, the current situation gives reasons for some optimism. This paper provides a review of the present technological background in wind generators, as found in the Greek market, as well as a detailed analysis of the legislative framework. Moreover, it aims to analyse the development of the process of granting investment and production permissions and their implementation since 1999. Thus, it is possible to identify the main reasons for the problems that occurred since the liberalisation of the electricity market and to account for the interest in wind energy. Finally, comments and proposals are formulated concerning the hidden barriers, the pertinent problems and the promising perspectives of the use of wind energy in Greece.


*Keywords:* Wind energy; Legislation; Investments; Market; Greece

## 1. Introduction

The case of modern wind generators begins in the early 1980s, as a consequence of the oil crises during the 1970s. On the one hand, the energy supply security and, on the other, the drive towards a more sustainable development since then fuelled a lasting interest in this particular form of renewable energy sources (RES). 25 years later, wind generators have become a success story, being a mature, cost effective technology, with reasonable efficiency rates, high reliability and availability values. The driving forces and prevailing trends in the design of contemporary wind generators are based in the variation of their aerodynamic characteristics with respect to the wind conditions, the improved compatibility with the power grid, the reduction of the noise disturbance level, the increase in the aerodynamic efficiency, the reduction of the visual disturbance and the adaptation to the tougher demands set by the increasingly popular off-shore applications [1,2].

As can be deduced from related bibliography, contemporary wind generators draw on an impressive combination of scientific progress, technological advances and entrepreneurial attitude [3,4]. In the past 20 years the nominal power of wind generators has increased by about two orders of magnitude, the cost of generated energy has been drastically reduced and the wind energy industry has developed into a leading branch of the electricity generation section. It is of interest to notice that 3 MW generators are already commercially viable systems, whilst generators with a nominal power rating of about 5 MW are in the final stages of trials [5]. Similar observations can be made with respect to components like blades, power control, system of power transmission as well as concerning the increasing degree of wind parks penetration in not interconnected electrical systems and weak power grids (e.g. non-interconnected insular systems).

The development of wind generators currently presents a strong momentum, as a series of technical challenges still have to be tackled and basic and applied research into their resolution is being carried out. In that sense, although, research focuses on big size wind generators, as they

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of the installed wing energy generators, it can be observed that the majority are constant pitch machines. However, the market begins to follow the trend mentioned towards wind energy generators with variable pitch control and variable revolution rate.

The main difficulty met in the propagation of big wind energy generators is the transport and installation of the systems in the windy areas, because of the rather poor, or sometimes entirely absent, infrastructure. This especially applies to the mountainous locations, where the exploitable wind energy potential could be very appealing. A second difficulty, also pointed out by investors being an obstacle to the installation of big size wind generators, is the lack of experience which is common in the cases of native investors and their financiers. To mention one reason, they were so far used to financing and installing small wind generators, with less power but trusted functional features. The aforementioned issues probably provide an explanation why in Greece the current average installed power of wind energy generators comes up to 576 kW, while in 2000 the respective figure was 450 kW, as is shown in Fig. 4.

Nevertheless, in the last year a rising trend can be observed, concerning the size of new installed wind energy generators. Hence, the average size of wind energy generators which was installed in 2004 came up to 1038 kW against 615 kW in the year 2000. In summer 2006 the first wind energy generators of 3 MW (Vestas N90) were made operational, and this signals an important step towards the technological maturity of the Greek market. As far as future projects are concerned, the tendency of using bigger wind generators can be observed, probably as a result of the recently granted production licences. This trend can be assumed to increase, especially as the locations with high wind potential are diminishing and therefore wind generators more efficient in low-wind conditions will have to be chosen. At the same time, efforts are being made to overcome the obstacles met today during the installation of big generators in infrastructurally weak locations. These include the use of divided blades, the local assembly or the already piloted construction of heavy subsystems with use of alternative materials. The application of such helpful solutions and the growing functional experience in the operation of big wind generators are expected to contribute to the Greek market's move towards using big generators on a broader scale.

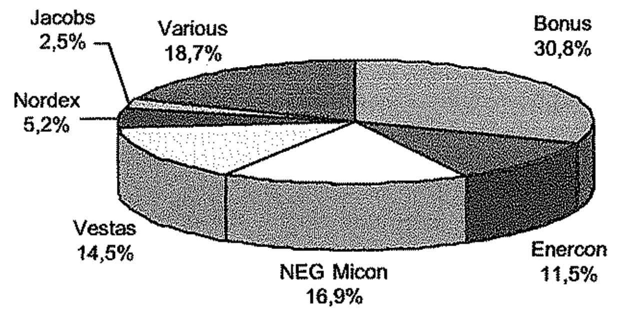


Fig. 2. Distribution of market shares with respect to the installed generators.

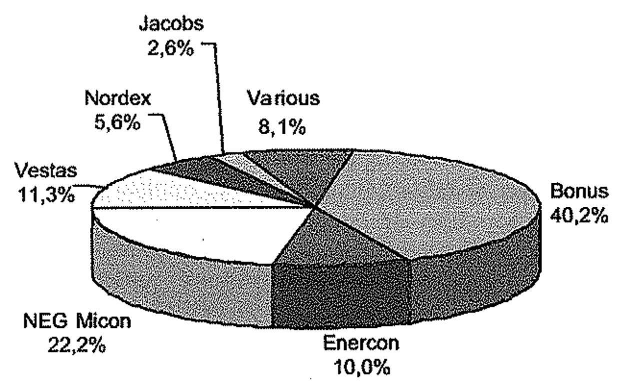


Fig. 3. Distribution of market shares with respect to the installed power.

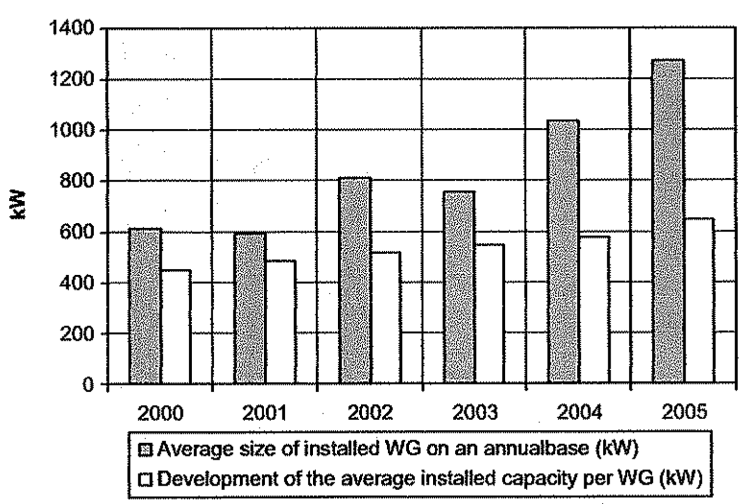


Fig. 4. Average power of installed wind energy generators in Greece and its annual development.

## 4. Difficulties and perspectives

The isolated interpretation of the data presented above could lead one to believe that the overall picture is a satisfactory one. However, should one carefully observe the data presented in Table 1, it could be concluded that despite the intense interest demonstrated by investors in developing wind parks, no tangible results can be argued to have resulted. Out of 23,000 MW, the total figure for which applications for a licence have been submitted, only 845.5 MW have been granted operation licences. In addition, no more than 485.5 MW were in operation in summer 2006. The distribution of projects with respect to their location shows that southern Greece (Evoia, Viotia, etc.) accumulates the highest investing interest, followed by Peloponnesus, east Macedonia and Thrace. It has to be pointed out that the figure of 23 GW also refers to applications in regions where implementation can be considered viable only in the future due to the poor existing local infrastructure [11,12].

The discrepancy between set objectives and reality can be argued to result from a series of problems relating to the majority of RES projects in Greece today. These include, amongst other:

- The complicated licensing procedure: A result of, firstly, the shared administrative authority between the RAE, the Ministry of Development and the regions and, secondly, of the involvement of many other public bodies and organisations. On the basis of the currently available data, the average duration of the entire procedure (from applying for the production licence until obtaining the installation licence) is estimated to be approximately 3 years.
- The immaturity of the investment plans: It needs to be pointed out that very often the applications, as initially submitted, are so poorly elaborated, that constant modifications concerning the final technical characteristics of the projects and the investment plan are needed, thus leading to an important delay in the projects' implementation [12].
- Communities are often unwilling to accept investments: This could be due to the inadequate information provided to the citizens in relation to the environmental impact and benefits of RES installations. Due to the absence of concrete land planning for RES, which is foreseen as a necessity by the Laws 2742/99 and 3468/06, the resulting legal processes may end at the Supreme Court. In such cases the project's kick-off can be postponed for more than 3 years and the final decision has been observed to be, as a rule, against the wind energy projects.
- The limited capabilities of absorbing RES-generated power: The need of upgrading existing grids, a time consuming and expensive procedure, especially in the case of high-voltage nets. These problems occur mainly in the regions of Thrace, Evoia and Lakonia, where there is a high investing interest due to the very favourable wind potential.
- Finally, it is of interest to notice that the same fragmentation met in the licensing procedure of projects occurs in monitoring their operation and performance: The turnkey cost of wind parks is monitored by the Ministry of Development, which is granting the production licences and is also responsible for managing the funding of the CSF in the energy sector. The monthly and annual energy output is monitored by the Hellenic Transmission System Operator (HTSO) which is responsible for the payment of energy producers. The RAE is monitoring the producers' compliance with the terms of the production licences, as well as the evolution of the electricity market as a whole. Although both HTSO and RAE are supervised by the Ministry of Development, this fragmentation does not enable a rundown of the data needed for the evaluation of the wind parks' energy performance and economic efficiency.

Table 1
Regional distribution of operational plants and licences at various stages

| Region | In operation capacity (MW) | Operational licences capacity (MW) | Production licence capacity (MW) | Requests for licences capacity (MW) |
|---|---|---|---|---|
| Eastern Macedonia—Thrace | 137.3 | 65.4 | 187.3 | 2614.2 |
| Attica | 0.1 | 31.5 | 110.3 | 1108.2 |
| Northern Aegean | 28.4 | 2.7 | 11.3 | 336.5 |
| Western Greece | 1.2 | 57 | 276.2 | 1517.7 |
| Western Macedonia | 0 | 0 | 74.8 | 864.3 |
| Epirus | 0 | 0 | 10.5 | 757.6 |
| Thessaly | 0 | 17 | 78.9 | 336.8 |
| Central Macedonia | 0 | 17 | 247.9 | 1379.1 |
| Crete | 96.4 | 53.4 | 71.9 | 693.8 |
| Ionian islands | 0 | 81.6 | 77.3 | 511.1 |
| Southern Aegean | 18.1 | 33.7 | 115.1 | 1264.3 |
| Peloponnesus | 0 | 246.2 | 490.9 | 5342.4 |
| Central Greece | 204 | 243 | 1363.9 | 6352.7 |
| Total capacity (MW) | 485.5 | 848.5 | 3116.3 | 23,078.7 |

In terms of the perspectives for the future, one can make the following remarks:

- In September 2005, the national land-planning frame for RES has been assigned to a contractor. According to the timetable provided by the Ministry of the Environment, Physical Planning and Public Works, it should have been completed by May 2006. As of the time this paper has been written (September 2006) this was not the case and a delay of a year (i.e. May 2007) was expected.

- In regions such as south Evoia, Andros, Tinos, south-east Peloponnesus and east Macedonia–Thrace, licensed wind energy parks (700–800 MW) are to be established after the fulfilment of the scheduled grid upgrading projects [13]. This will be completed, according to the official timetable, by 2007 in the cases of SE Peloponnesus and Thrace and by 2010 in the case of Evoia.
- There are approximately 2200 MW of licensed wind parks in areas for which there are no infrastructure problems. These are expected to be implemented without any serious problems and approximately 60% of them (about 1300–1400 MW) are expected to become operational within the next 3 years. This estimate is shaped by previous experience relating to sublime problems with local reactions, rejections on the grounds of environmental issues and the fact that some projects will not be able to obtain the necessary funding.

## 5. Conclusions

At the end of the year 2005, 486 MW of wind energy generators were in operation, another 90 MW had accomplished the functional tests and were in the process of becoming commercially operational and another 845 MW were in plants with installation licence. Thus, the capacity of wind generators to be operational by the end of the year 2006 is estimated to be at 900 MW. In order to accomplish the goal of a percentage of 12% RES use in the total amount of the national electricity consumption, as foreseen by the directive 2001/77/EC, it has been calculated that more than 3000 MW will have to be installed by the year 2010.

Technological developments, mainly by means of bigger wind generators, will enable a more feasible exploitation of less favourable locations. The new law about RES is expected to contribute to the acceleration of the licensing procedures. However, as long as the land-planning problem remains unsolved, there will still be significant difficulties in this process. In addition, given the delays in extending and upgrading the transmission grids, no access to some of the most suitable regions will be available. So, achieving the objective of "3000 MW by the year 2010" remains an important issue and time and practice will show how realistic it is.

## Disclaimer

The statements expressed in this paper are personal opinions of the authors and do therefore not necessarily represent their institutions.

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# An analysis of the Greek photovoltaic market

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**Abstract**

The number of photovoltaic applications has increased slightly over the last 10 years in Greece, with a forecasted 40% increase in the annual rate of sales over the next few years, a target similar to the rest of the EU Member States. This article: (i) presents an analysis of the current situation on the photovoltaic market in Greece and attempts to segment this market; (ii) investigates the existing incentives policy, as well as the crucial barriers for the wide dissemination of the photovoltaic applications, and (iii) records the market actors' aspects and predictions for the future. Furthermore, in order to supply essential information for business development, the current investment and legislative framework is presented.


**Contents**



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## 1. Introduction

During the last decade a continuously increasing interest in renewable energy sources (RES), was noted in Greece. This was a combined effect of (i) the favourable legal and financial measures that were implemented, (ii) the rich potential existing in the country and (iii) the rising environmental awareness.

In 2000 RES contributed a total of 1.403 ktoe to the Greek energy system. This corresponds to 5% of the Greek Total Primary Energy Supply (TPES), which was about 28.1 Mtoe. Electricity generation from RES (RESe) was 4.145 GWh in 2000 with a total installed capacity of 3.334 MW. The major contribution to the electricity generation was from hydros (3.693 GWh), while photovoltaic (PV) contributed only a small amount, mainly in installations that are not grid connected. Solar energy applications are almost exclusively used for water heating (Tables 1 and 2) [7].

Greece is a country with an extremely high potential for solar and especially for PV applications, mainly due to:

- the high insolation all year round (among the highest in Europe)
- the electricity needs in the islands are mostly covered by diesel/heavy oil generation units, thus resulting in high operation costs and environmental pollution
- the significant tourism activity during summer (environmental burdens in some islands increase by more than 100%), thus offering significant seasonal correlation between energy demand and PV power generation.

However the PV market is not adequately developed compared with other EU markets. In order to create more favorable conditions, nowadays a positive legislative and financing framework has been formulated (Operational Programme for Competitiveness—OPC, Operational Programme for Energy—OPE, deregulation of the energy market, new development law, etc).

This Greek PV market analysis aims:

- to identify the market potential of the PV technologies in the Greek market
- to depict the current situation in Greece and the market potential
- to assess the existing barriers for the wide dissemination of PV systems

Table 1
Energy produced from RES (2000)

| Source | ktoe |
|---|---|
| Biomass | 946 |
| Wind | 38.8 |
| Small hydro (<10 MW) | 14.28 |
| Large hydro[a] (>10 MW) | 303.5 |
| PV[b] | 0.024 |
| Solar heat | 99 |
| Geothermal heat[c] | 1.61 |
| Total | 1.403 |

[a] Production through pumping, 35.97 ktoe is excluded.
[b] Grid connected and autonomous island systems (non-connected systems for electricity supply).
[c] Sites with official permits.

Table 2
Current status of renewable energy technologies in Greece (2000)

| Technology | Status | | | | Current utilization and capacity | |
|---|---|---|---|---|---|---|
| | C[a] | D[a] | Planned | No | Output (ktoe) | Capacity (MW) |
| Wood | X | | | | 702 | N/A |
| CHP with biomass | X | | | | 0.8 | 2.1 $MW_{th}$<br>0.5 $MW_e$ |
| District heating with biomass | X | | | | 0 | 1.4 $MW_{th}$ |
| Wood, Vegetal waste in industry | X | | | | 242 | 510 |
| Biogas from agrofood and farm slurries | X | | | | 0.3 | 2.1 $MW_{th}$ |
| Landfill gas | X | | | | 0 | 0.240 $MW_e$ |
| Sludge/sewage gas | X | | | | 1.7 | 2.2 $MW_{th}$<br>0.359 $MW_e$ |
| Municipal waste | | | X | | | 10 $MW_{th}$<br>7.4 $MW_e$ |
| Bio-fuels | | | X | | | |
| Geothermal electricity | | | | X | | |
| Geothermal heat | X | | | | 1.61 | 29 $MW_{th}$ |
| Solar thermal | | | | X | | |
| Solar heat | X | | | | 99 | $2.94 \times 10^6$ $m^2$ |
| Hydro (>10MW) | X | | | | 303.5 | 3.052 |
| Small Hydro(1–10MW) | X | | | | 12.06 | 42 |
| Small Hydro (< 1 MW) | X | | | | 2.22 | 13.6 |
| Wind | X | | | | 38.8 | 226 |
| PV[b] | X | | | | 0.021 | 332 kWp |

[a] C: commercial, D: demonstration.
[b] Grid connected and non-connected systems in islands (does not include small scale isolated panels).

## 2. Policy framework

### 2.1. Laws

The basic law governing RESe is Law 2773/99. This law has incorporated the majority of provisions of the earlier Law 2244/94, which was devoted entirely to RESe matters. The key provisions of Law 2773/99 are:

- The Greek Transmission System Operator (HTSO) is obligated to grant priority access to RESe installations up to 50 $MW_{el}$.
- The HTSO is obligated to enter into a 10-yr contract (Power Purchase Agreement) with the RESe producer, for the purchase of his electricity. The contract always includes a renewal option.
- The RESe production of an independent power producer, or the surplus electricity production of a RES autoproducer, is sold to the HTSO at a pre-

determined buy-back rate, which is a fixed percentage of the corresponding consumer electricity rate.

- *The current* RESe *tariff system distinguishes between* 'autoproducers', i.e. producers consuming part of their RESe production themselves and selling the surplus to the grid, and 'independent power producers', i.e. producers selling their entire RESe production to the grid. The buy-back rates for both cases are *differentiated as follows:*

  (a) For autoproducers, the buy-back rate is set at 70% of the utility's domestic consumer tariff, for RESe produced and sold in the non-interconnected Greek islands, and at 70% of the utility's consumer tariff corresponding to the actual grid-connection voltage of the RES installation (be it low-, mid- or high-voltage), for RESe produced and sold in the Greek mainland.
  (b) For independent power producers, the buy-back rate is set at 90% of the utility's domestic consumer tariff (in the non-interconnected Greek islands), and at 90% of the utility's mid-voltage (commercial) consumer tariff (in the Greek mainland).

- Every RESe producer is subject to a special annual fee equal to 2% of the producer's electricity sales to the grid. This charge is collected by the HTSO and is given to the local authority, within the area of which the RESe generation unit operate, for the purpose of realizing local development projects.

At today's (2003) electricity consumer prices in Greece, an independent RESe producer is paid 0.063 €/kWh in the Greek mainland and 0.078 €/kWh in the non-interconnected islands. Law 2773/99 instituted a new license, the so-called electricity generation license, which is now the first license required to be obtained by any electricity-producing station, conventional or RES-based, in a long planning/licensing procedure that also includes preliminary environmental assessment, land-use permit, approval of environmental terms and conditions, installation license, operation license, etc. (see below).

Law 2941/01 supplemented Law 2773/99 with certain important provisions including: (a) the definition of the general terms and conditions, under which it is allowed to install RES stations in forests and forestry lands, and (b) the characterization of all RES projects as projects of public utility status, which give them the same rights and privileges in land expropriation procedures as those given to public works, independently of the legal status of the RES project owner (being private or public). Laws 2244/94, 2773/99 and 2941/01 on RES are supplemented by a number of Ministerial Decrees.

Finally, it is also important to mention here the legally binding EU Directive 2001/77/EC on RESe and its indicative target for Greece, i.e. 20.1% coverage of the country's total electricity demand by RES, until 2010. This target corresponds to about 2500 $MW_{el}$ of RES installations, an 8-fold increase over the currently installed RES capacity of about 320 $MW_{el}$.

### 2.2. Financial instruments

There are two main financial-support instruments that provide substantial public subsidies to RES investment projects (among others): (a) the so-called 'National Development Law' (Law 2601/98, currently under revision), and (b) the Greek OPC, one of the 11 National and the 13 Regional Operational Programmes, in which the 3rd Community Support Framework (CSF III; 2000–2006) for Greece is divided [4].

#### 2.2.1. National Development Law 2601/98

This is a financial instrument umbrella, covering all private investments in Greece. It has a strong regional character, since regions with high unemployment rates and low incomes per capita receive the highest investment subsidies from the State.

Investments in RESe installations have a special status under Law 2601/98, similar to the one bestowed to other selected categories of investments, such as investments in high technology, environmental protection, etc. More specifically:

- 40% public subsidy (grant) on the total eligible RES investment cost +40% subsidy on the interest of loans obtained for the purpose of financing the RES investment
- Alternatively, 40% subsidy on the loan interest +100% tax deduction on the RES investment cost
- Level of subsidy (40%) is independent of the RES technology and the geographical region
- Required own capital: 40% (min) of the total investment cost
- Minimum investment cost required: 176 k€
- Maximum subsidy granted: 14.7 M€
- Maximum investment cost subsidized: 36.7 M€

Law 2601/98 does not have any total budget cup, thus there is (theoretically) no limit in the number and budget of proposals that can be funded.

It should be noted that Law 2601/98 is currently under revision by the Ministry of National Economy and the new Law should become operational before the end of 2003. Preliminary information from the Ministry indicates that direct subsidies to investments will decrease, in favour of increased tax deductions. RES are expected to retain their special investment status, leading to increased subsidy rates, compared to most other types of investments.

#### 2.2.2. National operational programme for competitiveness/measure 2.1

The Measure 2.1 of Subprogramme 2 of the National OPC/CSF III (2000–2006) is devoted entirely to providing State support (grants) to private investments in: (a) RES, (b) rational use of energy (RUE) and (c) small-scale (<50 $MW_e$) cogeneration (CHP). The total budget of Measure 2.1, for the 2000–2006 period of CSF III, is 1.07 G€, of which 35.6% is the public subsidy available to RES/RUE/CHP investments; about 2/3 of the total available subsidy (~260 M€) is foreseen to be awarded specifically to RES investment projects.

The main provisions of Measure 2.1 of OPC, concerning public support of RES investments, are as follows, in particular for PV:

- Public subsidy (grant) on the total eligible PV investment cost: 40–50%
- Required own capital: 30% (min) of the total investment cost
- Minimum investment cost required: 44 k€
- Maximum investment cost subsidized: 44 M€

It should be mentioned that a RES investment–subsidy programme also existed in the 2nd Community Support Framework (CSF II; 1994–1999) for Greece. This CSF II programme granted cumulatively about 92 M€ of public subsidies to 78 RES investment projects, having a total budget of about 213 M€ (i.e. mean subsidy rate ~43%) and a total installed capacity of 161 $MW_e$ + 102 $MW_{th}$. This programme was very instrumental in generating substantial RES activity and in materializing a large number of commercial-scale RES projects in Greece, particularly in the period 1997–2000, as indicated in Table 5.

*2.2.3. Tax and other fiscal incentives*

The one legislative provision that was in effect until recently, in the area of tax incentives for domestic RES installations, was incorporated in Law 2364/95. This law, although dealing primarily with the importation, transmission, distribution and sales of natural gas in Greece, contained an important provision regarding the purchase and installation of domestic RES appliances. Up to 75% of the total cost for the purchase and installation of domestic RES appliances and systems could be deducted from the taxable income of natural persons. Such appliances and systems were deemed to include installations for the common use of the occupants of apartment buildings, in which case the deduction was calculated on the basis of the co-ownership percentage of each owner. For legal persons and companies, 75% of the total expenditure for the purchase and installation of the aforementioned appliances or systems was deductible from the total profit established by the application of the tax coefficient or the objective criteria.

Furthermore, a separate Presidential Decree had been planned, entitled 'Incentives for energy savings'. According to this Decree, an integrated set of financial, administrative and other incentives is to be instituted for domestic applications of techniques and systems, including RES that demonstrably contribute to energy savings in buildings. These planned incentives are outlined below:

(a) All expenses related to the purchase and installation of RES systems and materials in existing buildings can be deducted from the taxable income of owners/possessors/usufructuaries, up to a certain percent which will be defined, according to a specific set of criteria.
(b) Owners of existing or new buildings (domestic/commercial/tertiary) who, within a period of six years from the date of enactment of the above Presidential Decree, install RES exploitation systems in their buildings, for space heat-

ing and/or cooling, hot water production or lighting, demonstrably meeting at least 30% of their energy needs with RES, will be entitled to receive certain subsidies or attractive, low-interest loans from State or private banks, in order to cover their RES-related costs.

(c) In case the building owner opts for the low-interest loan, he will not be eligible for the income tax deduction of point (a) above.

(d) In regions with autonomous electricity networks (for example, in islands), or in regions of the interconnected system where the PPC is unable to cover the peak load, PPC can provide relevant subsidies or financial incentives, through mass purchases of domestic PV systems for interested customers. The PV systems will be selected by PPC to suit the specific load characteristics of the given residential area and will be offered to its customers at attractive low prices (due to mass-purchase discounts). Customers joining the programme through their electricity bills, in a number of equal instalments, will repay the system cost to PPC.

As far as tax incentives for corporation investments in RES are concerned, we note that such incentives are actually provided as alternative choices to capital subsidies in the National Development Law 2601/98. According to the law, investments and equipment-leasing programmes by corporations in RESe, can receive one (but not both) of the following subsidy packages:

| | | |
|---|---|---|
| (i) | Capital subsidy: | 40% of the total investment cost |
| | Interest-rate subsidy: | 40% of the interest paid on loans related to the RES investment |
| | Leasing subsidy: | 40% |
| (ii) | Tax deduction: | 100% of the total investment cost |
| | Interest-rate subsidy: | 40% of the interest paid on loans related to the RES investment |

The first subsidy package has already been discussed. The second subsidy package, for which a corporation may opt instead of the first one, contains two components of State financial support to RES investments: a 40% interest-rate subsidy and a tax deduction equalling 100% of the total investment cost (or equipment-leasing cost). This last form of financial support regards the exemption of the corporation from payment of income tax on the non-distributed net profits of the first decade following the materialization of the RES investment, by creating an untaxed (tax-exempt) reserve, equal in amount to the total RES investment cost. The 100% tax deduction is normally made from the profits of the particular tax year in which the RES investment is made. If there are insufficient or no profits in that year to cover the tax deduction, this deduction is made from the profits of subsequent tax years (and up to the tenth year), until the total RES investment cost is fully covered.

## 3. Existing market segments of the PV market

Trying to classify the current PV market worldwide we could distinguish some special segments [2,11] such as:

- the traditional market
- the off-grid market
- the urban grid-connected market
- the centralized utility market

### 3.1. The traditional market

This market segment, which includes applications for communications, water pumping, remote power and government demonstration projects, has an average annual growth of 15% over the past 20 years, regardless of the PV installation cost. This market segment is therefore obviously not price sensitive. Factors other than price, such as marketing and distribution, are much more important. Some companies in the past have not became conscious of this and have lowered their prices in order to create rapid market expansion and enlarge their market share. However, instead of achieving faster growth, they frequently made tremendous losses and most of them went out of business, doing a great disservice to the PV business. The traditional market needs to be seen as a cash market. It needs no subsidies, yet the availability of credit could substantially increase the size of the market.

### 3.2. The off-grid market

This market segment is not primarily price sensitive either, and its expansion depends on the available credit, rather than on prices or on the interest rates charged on loans. The off-grid market could experience explosive growth if credit for customers was available.

The expansion of the traditional and off-grid markets is strongly dependent on the PV global scale marketing and distribution. The development of a conventional distribution system started about 15 years ago. Up to then PV manufacturers had to open their own offices in most areas of the world to procure business. Today, a broad global PV industrial infrastructure exists and solar cells and panels are being manufactured as commodities. A great number of specialized companies have developed during this period specialized in components, system design, installations or building integration; a large number of these also became specialized installers, representatives, dealers, etc.

The PV marketing and distribution, like those of any other product—automobiles, electrical appliances or clothing—can only be effective and expand if the proper market development financing is available.

### 3.3. The urban grid-connected market

This market can be separated into two segments: *building facades* and *rooftop systems*.

Aesthetics and utility, rather than price, are usually the primary issues in the selection of materials for building facades. Since some of the companies specializing in this area realized this issue, it has become one of the fastest growing areas of the PV business. The problem is to obtain the proper mortgage and insurance facilities, not only for the buildings, but also for transportation and installation. Subsidies could certainly play a major role in the expansion of this market.

PV urban rooftop systems have become a fast-growing market, which exists as a result of subsidies, government regulations or people's interest in 'green' energy. In this case—in the same way as for the building-facade market—the availability of subsidies and financing is more important than pricing.

### 3.4. The centralized utility market

Unlike the previous three market segments, the central utility market is price sensitive and therefore, while the other segments can increase on the basis of current technologies, it is believed that the centralized utility market will not do so. It will only be viable when a new, very large-scale PV production technology emerges, guaranteeing a much lower price for PV. As soon as these reasonable prices will be achieved, the central utilities will be activated to finance new PV power plants.

## 4. Methodology of the market analysis

The realization of the analysis is based on an extensive research through questionnaires in combination with the use of data from other available sources.

All known data sources were used, such as: CRES unpublished data, proceedings from EU and international conferences, all major Greek market actors, local/regional agencies, accumulative experience from the PV marketing group, ministries, etc.

The market research by questionnaire aimed to identify the PV technologies potential in the Greek market and the existing barriers for their wide dissemination. The objective goal was the justification of the current limited number of such applications and the potential recommendations for a viable market strategy.

Through the questionnaire, the technical group contacted about 60 major market actors in Greece. They belong to the following categories:

- public bodies
- PV manufacturer suppliers
- main users
- others

The aim was to collect information about regions with great potentiality for PV applications and mark out the market segments that will be of great interest for future PV penetration.

Based on CRES' experience in Greece, Table 3 represents the most common PV applications. To cover the needs of the current market survey the following market segments were considered:

- electrification of remote villages and houses
- electrification of grid connected houses/settlements
- telecommunication transceivers, radio, TV
- public lighting
- pumping
- desalination
- educational kits
- marine signaling

Table 3
Current market segments

| Criteria | Description |
|---|---|
| PV system type | Grid connected systems |
| | Autonomous systems |
| End-user (application) type | Centralized, medium-to-large scale systems (for electrification of villages, islands, or connected to a large grid) |
| | Residential buildings (single houses, multi-store buildings, etc.) |
| | Commercial buildings (hotels, 'demo'/promotional systems, etc.) |
| | Electrification of small (possibly uninhabited) islands |
| | Tourist sector (small hotels, archeological sites, cantinas, etc.) |
| | Ecological applications |
| | Special applications (lighthouses, desalination, telecommunications, school kits) |
| Geographical region | Mainland |
| | Islands (big, small) |
| Ownership/decision making/ market control regime | Public |
| | Private |
| User's (or opinion leader's) previous PV experience | Already aware of the PV user |
| | Not aware of PVs |
| % coverage of user's energy needs | Full (autonomous systems) |
| | Partial (e.g. small hotels in electrified islands) |
| | Low (PV system serves mainly for demonstration or image purposes, for example PVs in large commercial buildings) |

The recipients of the questionnaire were:

- local services of Public Power Corporation (PPC) and Greek Telecommunication Organization (HTO)
- Marine Signaling Authority of Greek Navy
- responsibles of courthouses
- agencies of local administration
- PV suppliers
- main users
- other market actors

## 5. Questionnaire analysis

### *5.1. The correspondence*

The correspondence in the questionnaire of the market research was satisfactory. In order to be more specific, we can allocate the response on three criteria:

- the contacted market actors (answers 36%, refusals 41% due to various reasons, no PV activity 23%)
- the active market actors: (answers 46.5%, refusals 53.5%)
- the total installed power in Greece (answers 77%, refusals 23%)

### *5.2. The current status*

The PV market has expanded rapidly, especially in the recent years [6]. On the contrary to the weak first steps, PV applications have been remarkably accepted. This can be easily explained, if we take into account the high insolation during the year as well as the difficulties for the islands or some isolated areas to connect with the grid.

The current situation appears an unbalanced distribution (Fig. 1). The existence of company-leaders monopolizes the under-developed market, which consists of various SMEs.

The total installed power is about 1785 kW (2002), which indicates a strong change with reference to the 634 kW of 1998 (Table 4, Fig. 2).

### *5.3. PV categories*

Fig. 3 represents the basic segments of the Greek PV market and their position in market in 2002.

#### *5.3.1. Grid connected*

This segment represents about 51% of the total installed power.

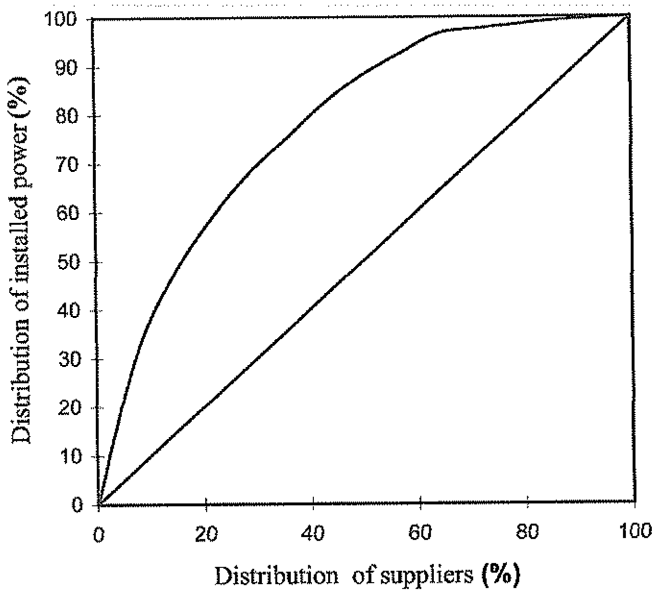


Fig. 1. Lorenz curve.

### *5.3.2. Autonomous applications*

This segment is consisted of isolated houses, mobile homes, farming houses, etc. Their installed power is about 533 kW, which represents the 30% of the total installed.

### *5.3.3. Autonomous agricultural applications*

The installed power of such applications is about 142 kW, which represents the 8% of the total installed.

Table 4
Market shares of the PV sales in Greece

| | CRES' survey 1998 | CRES' survey 1998 kWp | CRES' estimations, 2002 kWp |
|---|---|---|---|
| Autonomous houses | 45.03 | 286 | 533 |
| Grid connected | 24.15 | 154 | 904 |
| Autonomus rural applications | 12.60 | 80 | 142 |
| Telecommunications/repeaters | 8.01 | 51 | 91 |
| External lighting | 1.93 | 12 | 22 |
| Other applications | 8.28 | 53 | 93 |
| | 100 | 636 | 1785 |

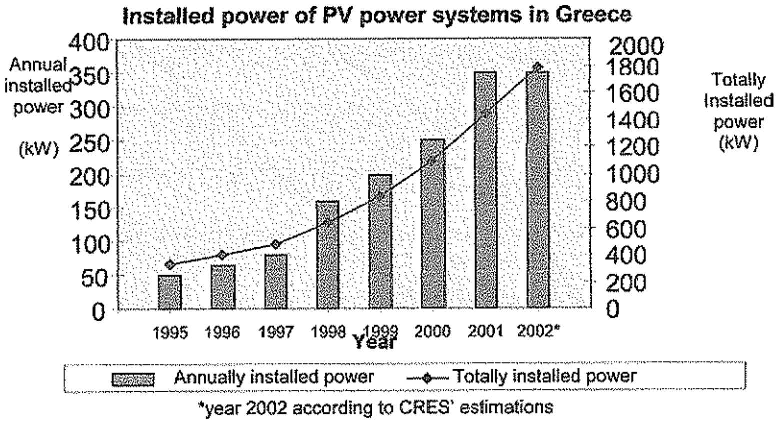


Fig. 2. Installed PV power in Greece.

*5.3.4. Telecommunications-repeaters*

On this segment the HTO is the leader. In recent years, radio/TV stations and mobile-phone companies have increased their activity. The installed power of 142 kW represents the 5% of total installed.

*5.3.5. External lighting*

This category represents only 1% of the total installed power.

*5.3.6. Other applications*

The lighthouses of the Greek Navy are the leaders on this category. Uses for navigation, training, research and demonstration are coming next. The installed power of 93 kW represents the 5% of total installed.

## 6. PV electricity market segmentation

Until 1998 most of the installed PV systems were stand-alone. During the last years the market has changed, since now most of them are *grid-connected*. In 1994

Table 5
Operational programme for energy, (CSF II, 1994–1999) RES funded projects

| RE technology | Number of projects | Electrical capacity ($MW_e$) | Thermal capacity ($MW_{th}$) | Total budget (M€) | Public funding (M€) |
|---|---|---|---|---|---|
| Wind | 17 | 125.1 | | 131.2 | 52.5 |
| Biomass | 9 | 20.4 | 94 | 47.7 | 22.5 |
| Small hydro | 11 | 14.3 | | 21.7 | 9.7 |
| Photovoltaic | 15 | 0.9 | | 7.0 | 4.8 |
| Active solar | 25 | | 8 | 5.1 | 2.5 |
| Passive solar | 1 | | | 0.3 | 0.1 |
| Total | 78 | 160.7 | 102 | 213.0 | 92.1 |

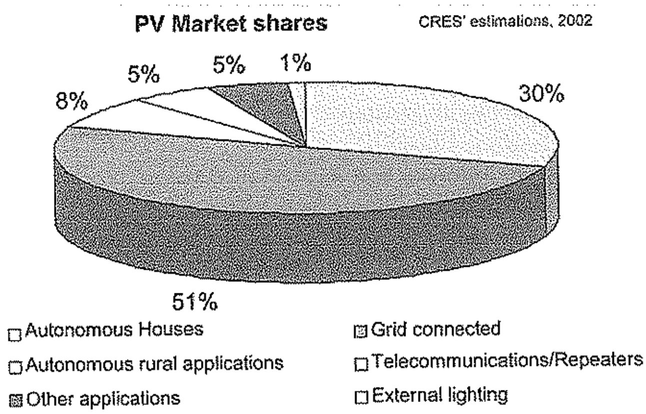


Fig. 3. Allocation of the PV installed power in Greece.

only 20% of the installed systems was grid-connected, while in 2001 this was more than 50%. Most of them are applications in the building sector [1].

### *6.1. Autonomous houses/settlements*

There is a range of such PV systems in terms of installed peak power. At this time many of those systems are made of a few panels (<500 Wp) and support basic needs such as lighting, small appliances and refrigerators.

Most of these systems are providing DC service, usually the small ones and some of them AC. The market segment above 500 Wp is quite small, at this time, due to PV system cost in relation to the buying power of the potential users [12].

In the population census conducted by the National Statistical Service in 1991, electrified houses were considered as those having an electricity source, i.e. utility grid, diesel generator, PV, wind generator, etc. Scattered non-electrified houses over the whole country that were seasonally or permanently occupied, isolated, or built in areas where building is not permitted are included.

Most of the non-electrified houses are located in rural areas. Those houses along with most of those located in semi-urban areas can be considered as the actual potential market of PV. A number of non-electrified houses are not scattered throughout the country but belong to small villages (settlements). These houses are occupied seasonally or permanently and are located in areas far away from the national electricity grid.

Taking into account the trend in electrifying non-grid-connected houses during the decade 1981–1991 and the results obtained from the analysis concerning the electrification of remote settlements, it can be concluded that the number of non-grid-connected houses since 1991 should have reduced by 20%. This means, that today there are 115,000 non-grid connected houses (permanently inhabited, seasonally inhabited and abandoned houses).

On the basis of the 1991 census data, the total number of inhabited non-electrified houses is 24,824, i.e. 0.79% of the total number of inhabited houses in Greece, while the number of non-electrified houses is 143,174 i.e. 3% of the total number of houses. This last number includes permanently and seasonally inhabited houses, as well as weekend and abandoned houses.

Most of the non-electrified houses are located in rural areas. Those houses along with most of those located in semi-urban areas can be considered as the actual PV market potential.

A number of non-electrified houses are not scattered throughout the country but belong to settlements. These houses are occupied seasonally or permanently and are located in areas far away from the national electricity grid in the last 27 years; the number of such settlements has been reduced from 1400 in 1981, to 873 in 1991 and recently (end of 1995) to 607; 373 of those settlements are inhabited by 8651 people (1991 census). One hundred of them have been already included in the future electrification program but most of them will remain without electricity because access by heavy-duty vehicles is not possible. The total estimated number of houses in those settlements is 14,000 and among those the inhabited are 2800.

Most of the non-grid-connected houses, permanently inhabited, are located in remote mountainous regions where the access is very difficult due to the lack of accessible roads. They are old houses, made of stones, bricks or concrete blocks and covered by tiles, flagstones, metal sheets or a concrete terrace. Most of them are south facing, non-shaded and have available roof area for a PV system or enough free space for ground installation. Their proprietors are poor people, mainly dealing with stock farming or agriculture, have a poor knowledge of PV systems and cannot afford a PV system. Conventional electric appliances are used when a diesel generator is available. DC appliances are used in combination with PV systems and batteries.

The most important electricity needs to be satisfied are: lighting, refrigeration and TV operating in DC mode. The theoretical potential for the application of PV in non-grid-connected houses in Greece is estimated to be about 32 MWp, assuming an average occupation of three inhabitants per house and 200 Wp per inhabitant (the abandoned houses are not included).

Although the theoretical potential is considerably high, the actual potential is lower considering that a significant number of non-grid-connected houses may be electrified after legalization and that most of the owners cannot afford the cost of a PV system without financial support.

### 6.2. *Autonomous small/rocky islands with development potential*

In this category of islands we include all those islands that have about 500 inhabitants or less, or are uninhabited for the winter season. There are at least 50 such islands that are inhabited and several hundreds that are not inhabited and have the potential for development in an environmentally friendly way. The main activities that may be undertaken in these islands are ecotourism, agriculture and fishing. The development of such islands using environmentally friendly technologies is very important for the improvement of the inhabitants' living conditions. The creation of a more stable economic environment will keep the inhabitants in their islands reversing the alarming abandoning trend [12].

An estimation of the permanent population in this category is 5000 people. During the summer months the population in these islands may be 2–3 times higher than the permanent population. The power service of the local grid is usually poor and power cuts are frequent. PV systems may improve the power service, increase the income of the islanders and stabilize their population. Assuming an average introduction of 200 Wp per permanent inhabitant, there is a potential PV market of 1 MWp. If the islanders have the scope to provide services to the summer tourists, then the potentially installed capacity may be a few times larger.

### *6.3. Telecommunications*

This is a market that is already economically viable around the world. In Greece, there are a few applications by the Greek telecommunication companies (Greek Telecommunication Organization, Panafon, Telestet). In most of these sites, where the telecommunication companies are planning to install relay stations, PV systems compete with the cost of electrification by grid line extension, except for the sites that are too far from grid lines or cannot be reached by trucks and where the cost of opening new roads is too high [5].

### *6.4. Public lighting of roads, signaling, billboards, powering small devices etc.*

This market is practically non-existent in Greece, although in other countries such as USA, Germany and Egypt there is a number of companies that are active in this field. Some bus stops had small PV applications.

### *6.5. Exterior road and park lighting and signaling*

The viability of such systems can be justified by:

- the possible extension of the grid by digging out several meters,
- the remediation of the grounds to their previous condition

The associated cost of the above actions may be too high with respect to an autonomous PV lighting/signaling system that could later be moved again with minimum cost.

The estimated market potential can be significant, if PV lighting is examined as one of the possible solutions by municipalities, whenever the lighting of roads, parks, squares, boat marinas, docks etc. is being planned. PV lighting will not always be the most appropriate solution, due to cost and to the possible combination of high power lighting applications and limited area availability of PV surface on a pole. A PV system for street lighting, with two 50–55 Wp modules, a 18–36 W low pressure sodium or fluorescent lamp and the associated electronics, battery, pole etc., cost from 2–3 k€ [2].

### *6.6. Advertising board lighting*

This is a market with considerable potential. Any given site that has potential for promotion of products and does not have reasonably easy access to the grid can be a moneymaking location for the advertising companies when lit by a PV system. Such PV systems could have a significant potential if the advertising companies become aware of such a possibility.

### *6.7. Small devices*

PV could power other possible devices such as: parking ticket issuing machines, lighting of public card-phones etc.

If for example, a telecommunication company decides to light 10,000 card-phones by PV, with an installed power of 30 Wp per card-phone, then the total PV power would be 300 kWp. The PV powered parking ticket machine introduction is a possible application that frees the local authorities from the electric grid and all the necessary groundwork to power the parking ticket machines.

The economic viability of many of the above PV applications has to be determined on a case-by-case basis.

## 7. The potential

The Greek PV market seems to be in an embryonic phase with some applications supporting the small number of companies in the sector contrary to the excellent solar conditions, which favor the PV applications. PV potential could cover 25–30% of domestic needs.

Furthermore, the use of PV for a noise barrier in high-speed roads and railroads could represent a potential of 6.2 MW for new roads and 13.4 MW for railroads [9].

Almost 40 companies are involved in the Greek sector (PV providers, studies, installations, etc). The bigger part installs annually only 20–250 kW [1].

The Greek PV market has grown rapidly during recent years supported by the existing European, national and regional programmes (OPC, OPE, THERMIE, VALOREN, ALTENER, OPRT, etc.) reinforcing the promotion of PV applications. These programmes provide support and information for the dissemination of know-how.

Similarly, the establishment of a favorable institutional and legislative framework (Energy Law 2244/94, the Development Law 2601/98, etc.) has created very positive conditions for PV technology and investments.

The houses/settlements in isolated areas (islands and/or continental) are presented as the most attractive application for the users (29%). Followed by the transceivers (19%), the agricultural applications (16%), the houses connected with the grid (14%) and the navigation applications (13%).

The above demand arises from the needs and the motives of users, which were recorded in the market analysis, are:

- electrification for isolated-faraway areas: 48%
- ecological sensitization: 20%
- electrification-connection with grid: 12%
- independence from PPC (power failure, taxes, etc.): 8%
- energy saving: 8%
- attractive financing: 4%

Additionally, the appearance of new PV manufacturers and a general mobility on PV technologies (national and European Programmes, institutions, universities, groups of scientists, etc.) depict a market ready for further expansion.

The market actors' forecasts are reliable, when 67% of them refer to an increase of between 10 and 40% per year (Fig. 4). This estimation is compatible with those of the world market growth (average annual market growth 40%).

On the other hand, there is an optimistic aspect (25%) which aims at a yearly increase of >40%. Finally, only 8% of the surveyed market actors believe that the dynamic of this market is too poor.

The response in the survey was very satisfactory (46% of the current active market actors), which means a great interest for cooperation in the sector. Actually, PV market research plays the role of pioneer for the Greek market, and we are positive that a focused market survey through each PV application would be even better (as a follow-up).

The first industrial facility producing PV in Greece (a-Si double junction 4th generation, production capacity 5 MW per year, with prospect to upgrade to 10 MW in the technology of CIGS-Copper indium gallium diselenide) has been constructed in Northern Greece by the HELIODOMI SA in cooperation with the American company EPV. The first PV production will start in early 2004 with a

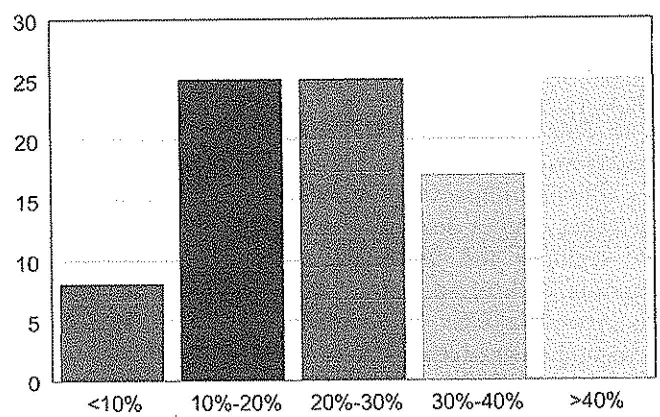


Fig. 4. Forecasts on sales (%/yr).

production cost of 2 €/W. This low production cost is estimated to lower the consumer prices. The PV systems will have a nominal power of 10–160 Wp. In the rooftop of the industrial plant a 400 kW grid will be installed and connected.

The procurement and installation cost of PV is 6000–10,500 €/kWp (typical price 9000 €/kWp) for grid connected and, on average, 11,000 €/kWp for autonomous. on average, during the last 4–5 years, there was a real reduction of the procurement cost by 15%.

## 8. The barriers

Generous public subsidies (grants, tax exemptions), available to RES investments through the National Development Law 2601/98 and Measure 2.1 of the National OPC/CSF III, coupled with satisfactory (and fixed) buy-back rates for RES electricity sold to the grid, have led in recent years to a blossoming of investment interest for RES in Greece. However, despite this particularly strong interest of Greek and foreign investors, that has resulted in hundreds of applications for commercial RES projects all over Greece, and has led to the issuing of more than 2700 $MW_{el}$ of RESe generation licenses by the Regulatory Authority for Energy [10], the pace of materialization of the corresponding investment projects has been slow. The most important obstacles are outlined below [14].

### *8.1. RES licensing procedures*

Undoubtedly, the complex licensing procedures for RESe projects, set by various Ministerial and Joint Ministerial Decrees constitute the single, most difficult obstacle today in the effective materialization of commercial-scale RES investments in Greece. These procedures involve a multitude of central, regional, prefectural and local authorities (departments, committees, councils, agencies, etc.), interwoven in a lengthy, bureaucratic and, at times, confusing licensing process, that invariably takes 1.5–2 years to complete. Any single RES installation license requires the official expression of (positive) opinion of more than 35 public-sector entities, at the central, regional, prefectural and local level, and needs to be checked, in terms of conformity, with four National Laws and seven Ministerial Decrees (Fig. 5).

The transfer, in late 1998 (Law 2647/98), of most RES licensing jurisdictions and competences, from the central to the regional and prefectural authorities, has compounded the already difficult situation, creating more problems than those it was supposed to solve. This is due to the structural and organizational weaknesses that still plague regional and local administrations in Greece, such as severe budgetary constraints, lack of specialized knowledge, RES-related experience and trained personnel, parochial ideas and conflicts, etc.

Revoking these administrative obstacles, Law 2941/01 and at the same time, Law 2773/99 are currently under revision in order to compensate for the slackness of the liberalization process of the electricity market mostly attributed to the dominant position held by PPC SA and also to reflect the modifications portended by

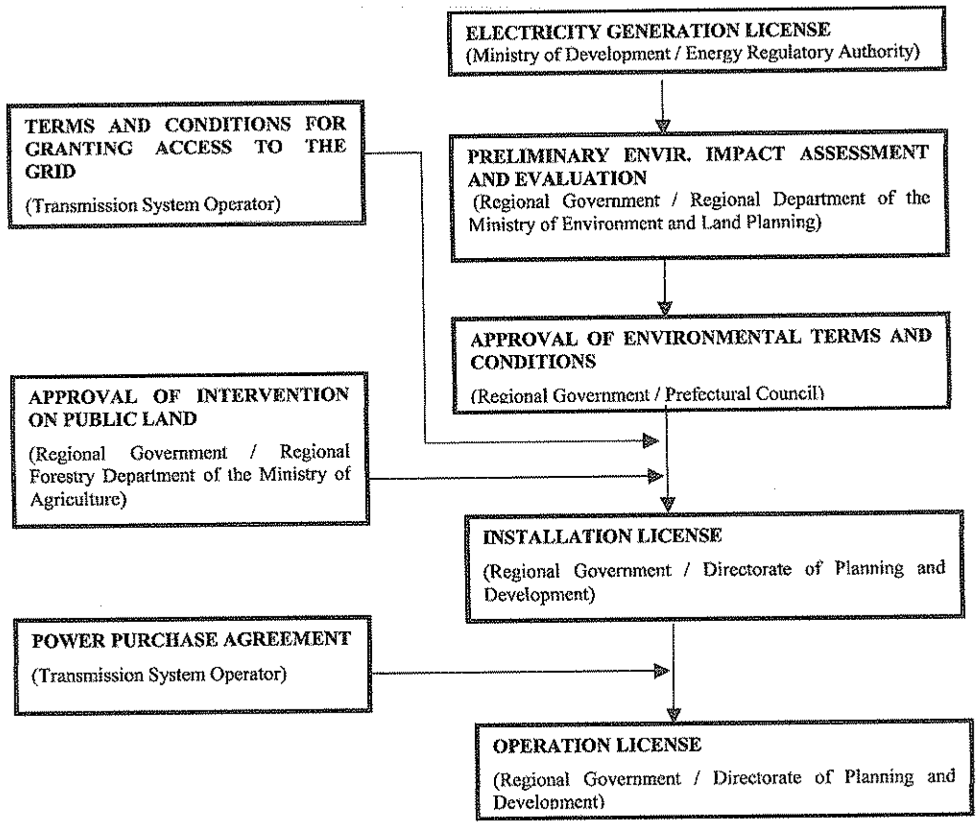


Fig. 5. RES licensing procedures and jurisdictions.

the ongoing revision of Directive 96/92/EC. At the regulatory level, a joint ministerial decision has been signed (JMD 1726 of 2003) in order to adjust the overall licensing procedure of RES projects to the environmental consent process introduced with the new Law 3010/02. Among the regulations introduced, it is worth mentioning the fixing of shortened time limits. Should no action be taken within these limits, the authority managing the licensing procedure is entitled to consider as positive the lacking interim approvals or opinions of other services and bodies and thus to urge forward to completion of the licensing process. This expedient fully reflects the requirements of article 6 of Directive 2001/77/EC [8].

### 8.2. *Limited capacity of the power transmission grid*

As of 2002, new RES capacity can no longer be connected to the existing grid (due to its capacity saturation). The upgrading of the power transmission grid has to face a crucial problem: their long period of materialization, which exceeds 5–6 years, due to difficulties (public reaction, etc.) in land expropriation and construction of high-voltage power lines through environmentally sensitive areas.

### *8.3. Public attitudes*

Although opinion polls in Greece invariably show a very positive attitude and support of the general public towards RES, this attitude seems to have a strong NIMBY ('Not In My Back Yard') component.

Reasons offered by local entities resisting RESe development in their areas include visual intrusion, noise, land devaluation, etc., but also perceived health problems to people and animals, negative impact on local tourism, deforestation, little or no benefit to the local economy (employment/added value), etc.

## 9. Conclusions and recommendations

Following the successful implementation of the OPE, the National OPC initiated in 2000 by the Ministry of Development is expected to have a significant impact on the development of RESe within the next few years [8].

The PV market will continue to expand rapidly in the future in its major market segments. The main obstacle to the explosive expansion of the PV market is neither technology nor price. It is focused on *financing* and *advertising*.

The need to develop financing methods, distribution mechanisms and infrastructure was realized a few years ago and the complex problems have been discussed in various studies and meetings. The result is that some progress is being achieved. However, the need for *advertising*, *training*, *promotion*, and *education* is only now being recognized. The lack of these basic elements is a formidable obstacle to the future of PV, and the PV community must focus on this matter urgently.

In addition to the previous barriers, the PV market analysis [11,12,13], various 1998, indicates the major parameters for the further PV market penetration in Greece:

- assured quality
- advertising, training, promotion, and education
- financing of PV products and systems

### *9.1. Quality of products and systems*

The issue of quality of PV products and systems is crucial. Many PV component and system failures have been reported, especially in off-grid rural electrification projects. This inconsistency of quality thus became an important issue, affecting not only the financing, but also the future of the entire PV business. The PV industry and its major customers, who established the PV Global Approval Programme, realized this issue.

#### *9.1.1. Public awareness and creating markets*

There is a great need for PV advertising, as well as for training, promotion and education. In the oil crisis era of the 1970s, when the terrestrial PV business began, media attention, focused on the then minuscule PV business, was significant and helped the establishment of PV in many market segments. However, the media attention stopped in the 1980s and today the public is not aware of the extent to which PV is already being utilized. The general belief is that PV is for the future. It is not widely known that without PV, there would be no global communication, no global email, Internet, TV, telephone, fax, because all the satellites used for these functions are 100% powered by PV.

There are no exact figures on how much the entire PV industry is spending on advertising, but as a first estimation the relevant budget is much less than 0.5% of the total revenues.

If it was clear that the PV market is not primarily price sensitive, and that a large market share could be obtained by advertising rather than by lowering prices, the PV industry would now be in a better condition. The PV industry today is not in the position to invest the necessary funds in advertising and in public awareness campaigns. Yet this is a crucial issue for the future of the PV business and should be addressed urgently. The enterprising spirit of the PV industry, and other interested parties, must mobilize resources for advertising, promotion and education/training. A discussion on the issue must take place as well as solutions have to be found.

#### *9.1.2. Finance and future*

Financing of PV installations is crucial for their future. The urban grid-connected and, to some extent, the off-grid markets are also dependent on subsidies. The merits and demerits of subsidies can be debated endlessly. If they apply for the long term, subsidies are necessary and beneficial. However, short-term subsidies would be detrimental for the PV business.

It is urgent to develop financing mechanisms for PV systems. The lack of financing available for customers is an enormous handicap to the development of the PV business. Much PV business in the developed countries and two billion potential customers in the developing countries need financing. This means that PV financing is a very complicated issue. Several interesting approaches are being tried and planned and various meetings have focused on this very complicated issue in an attempt to find solutions.

It is also essential that the effective consortia are set up to face these opportunities [3]. Experience indicates that the better the partners' fit, comprising social fit (trust and commitment), resource fit (competence and complementarity) and goal fit (goal clarity and compatibility), the better the projects will progress and succeed.

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# The economics of wind energy

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ABSTRACT

This article presents the outcomes of a recent study carried out among wind energy manufacturers and developers regarding the current generation costs of wind energy projects in Europe, the factors that most influence them, as well as the reasons behind their recent increase and their expected future evolution. The research finds that the generation costs of an onshore wind farm are between 4.5 and 8.7 €cent/kWh; 6–11.1 €cent/kWh when located offshore, with the number of full hours and the level of capital cost being the most influencing elements. Generation costs have increased by more than 20% over the last 3 years mainly due to a rise of the price of certain strategic raw materials at a time when the global demand has boomed. However, the competitive position of wind energy investments vis-à-vis other technologies has not been altered. In the long-term, one would expect production costs go down; whether this will be enough to offset the higher price of inputs will largely depend on the application of correct policies, like R&D in new materials, O&M with remote-control devices, offshore wind turbines and substructures; introduction of advanced siting and forecasting techniques; access to adequate funding; and long-term legal stability.



**Contents**



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## 1. Introduction

Wind energy is called to play a crucial role in the future energy supply of the European Union and of the world. By 2020, around 180 GW of onshore and offshore wind power could be installed in the European Union (estimates from the European Commission [1] and the European Wind Energy Association [2]); meaning between 10 and 15% of the total EU electricity demand. Worldwide, wind energy will also supply a sizeable amount of electricity – around 16% in 2020, according to the forecasts of the Global Wind Energy Council [3]. Yet the factors that determine the economics of a wind energy farm are not well known to many, and there has been an intense discussion on the reasons behind the recent increase of its generation costs after 20 years of steady reduction.

The objective of this article is to discuss the main cost categories of a wind energy investment, pointing out their relative weight and recent trends, and to propose a range of generation costs – both onshore and offshore. We also look into the supply chain constraints that affect the wind energy sector and discuss which the main elements are that have provoked a cost increase of around 20% in the last 3 years. The article places these increases into the more general context of growing generation costs of all electricity generation technologies and debates the usefulness of learning curves as a tool to predict the future trend of wind energy costs. Finally, we present a selection of policies that can reduce the generation cost of wind energy.

Thus, Section 2 of the article offers a range of generation costs for wind energy, both onshore and offshore, based on a consultation addressed to European Wind Energy Association members (EWEA comprises 80% of the wind energy manufacturers worldwide and the most important developers, sub-suppliers and research institutes in Europe) and on a comprehensive review of recent studies. The article makes a distinction between capital costs and variable costs, and analyses their evolution separately; it also carries out a sensitiveness analysis of the generation costs based on changes of the key variables (capacity factor, capital costs, variable costs, interest rate, etc.). This part ends with a discussion on the limited value of comparing the wind energy estimates found in the different studies and of comparing wind energy costs with the costs of other electricity generating technologies, due to an inconsistent selection of cost categories and basic assumptions.

Section 3 engages into the interesting debate of why the wind energy sector costs have increased in recent years and whether we can expect them to drop again. In order to do that, we explore the supply chain of some strategic raw materials and sub-components of wind turbines, and prove that most of the cost increase has been driven by the rise of their prices. The article states that cost increases do not only affect the wind energy sector, but also other electricity-generating technologies.

Some of the variables behind the cost growth can be considered as exogenous for wind turbine manufacturers and developers, a fact that limits the value of the learning curves that have been proposed. Yet, technological change still have a strong role to play in decreasing the overall cost of wind energy, provided that the future R&D efforts are put into the key areas. Also market policies, especially those that transform the level of risk for the developer, can help reduce the overall cost of wind energy through a lower risk premium and cheaper interest rates. These are the issues that we tackle in Section 4.

Section 5 finally concludes.

## 2. The generation cost of wind energy in Europe: current level and methodological issues

The key parameters that govern wind power costs are:

- Capital costs, including wind turbines, foundations, road construction and grid connection, which can be as much as 80% of the total cost of the project over its entire lifetime.
- Variable costs, the most significant being the operation and maintenance (O&M) of wind turbines, but also including other categories such as land rental, insurance and taxes or management and administration. Variable costs are relatively low and will oscillate around a level of 20% of the total investment.
- The electricity produced, which in turn depends on the local wind climate, wind turbine technical specifications, site characteristics and power generation reductions. The indicator that best characterizes the electricity-generating capacity of a wind farm is the capacity factor, which expresses the percentage of time that a wind energy farm produces electricity during a representative year.
- The discount rate and economic lifetime of the investment. These reflect the perceived risk of the project, the regulatory and investment climate in each country and the profitability of alternative investments.

It is important to differentiate between the costs of the wind farm in terms of capacity installed – total of capital costs and variable costs – and the cost of wind power per kWh produced, which takes into account the wind resource. This article focuses on the latter (cost in €/kWh produced), since it allows us to make a comparison between wind energy and other electricity generating technologies.

Wind farm fuel costs are obviously zero. This is the fundamental difference between electricity generated by wind power and most conventional electricity generation options. For example, in a natural gas power plant as much as 40–60% of the costs are related to fuel and O&M, compared to around 10% for an onshore wind farm.

On the other hand, the fact that wind energy projects require substantial capital investment affects the financial viability of the projects. A developer needs to have most of the funds available (around 80%) at the time the wind farm is built, so capital access and good repayment conditions become essential. Some projects may not come to fruition due to the finance needed during this initial stage, even though, over time, this may be a cheapest option. However, the distinct advantage of wind energy is that, after the installation process and provided that wind measurements have been calculated correctly, the generation cost of this technology is predictable. This reduces the overall risk of a company's or country's power portfolio.

The next sections look into the different costs categories of a wind farm investment and offer a choice of figures for onshore and offshore wind energy.

### 2.1. Capital costs

The capital costs of wind projects can be divided into several categories:

- the cost of the turbine itself (*ex works*),[1] which comprises the production, blades, transformer, transportation to the site and installation;
- the cost of grid connection, including cables, sub-station, connection and power evacuation systems (when they are specifically related to and purpose-built for the wind farm);

[1] 'Ex works' means that no balance of plant, i.e. site work, erection, foundation, or grid connection costs are included. Ex works costs comprise the turbine as provided by the manufacturer: the turbine itself, blades, tower, transport to the site and installation.

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- the cost of the civil work, including the foundations, road construction and buildings;
- other capital costs, including development and engineering costs, licensing procedures, consultancy and permits, SCADA (Supervisory, Control and Data Acquisition) and monitoring systems.

As explained in the previous sub-section, wind energy is a capital-intensive technology, so most of the outgoings will be made at this stage. The capital cost can be as much as 80% of the total cost of the project over its entire lifetime, with variations between models, markets and locations. The wind turbine constitutes the single largest cost component, followed by grid connection.

After more than two decades of steady reductions, the capital costs of a wind energy project have risen by around 20% over the past 3 years. The results of our survey show that they are in the range of 1100–1400 €/kW for newly-established projects in Europe. These costs are sensibly lower in some emerging markets, notably China and in the United States of America. There are also variations within the European Union.

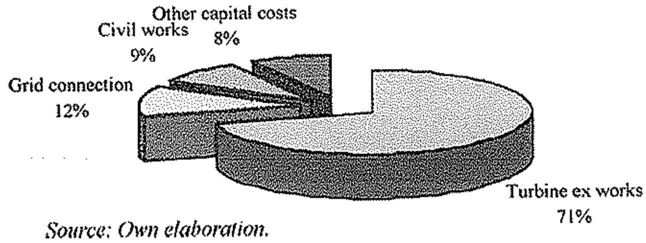
The reasons behind that spread of values lie on the impact of lower labor costs in some developing countries with manufacturing capacity, the degree of competition in a specific market, the bargaining power of market actors, the national regulation concerning the characteristics of the wind turbine (e.g. the existence of strict grid codes in some regions), the distance and modality of grid connection (including the possibility of having to finance all the cost of a grid upgrade) and the extent of the civil works (which in turn depend on factors such as the accessibility and geotechnical conditions of the site).

With all these limitations, Fig. 1 depicts a tentative cost breakdown of a wind energy investment in Europe.[2]

Fig. 2 illustrates the complexity of the sub-components that make up a wind turbine, and helps to explain why these are the most expensive elements of the investment. Note that the figure refers to an exceptionally large size in the current market (5 MW as opposed to the 2–3 MW machines that are being installed in most of the land sites). The relative weight of the sub-components varies depending on the model.

Other elements, apart from the wind turbine, are needed at the beginning of the project, and they can account for around 18–32% of the total capital costs for onshore projects. Their current level and trends can be summarized as follows:

- Grid connection costs. In the past, most wind farm projects have been connected to the distribution voltage grid (8–30 kV) through low to medium voltage transformers. However, it is becoming more common for wind farms to be connected to the transmission network, which results in higher costs. Additionally, the regulation defining who bears the connection cost and – if needed – the upgrade of the line differ in each country. In some places, the transmission system operator will take care of part or all the grid costs. In others, the developer will have to pay the full connection cost plus the upgrade of the line if the regulator considers that this is necessary. Grid connection prices can be regulated and transparent, or can be subject to substantial uncertainty. All this entails different levels of grid connection costs but a general upward tendency (e.g. around 115.24 €/kW in Spain in 2006 and a 13.8% increase in 2007/2008 [5]) has been found in most EU countries. As explained in Fig. 1, grid connection costs (including the electrical work, electricity lines and the connection point) are equivalent to around 12% of the total capital cost.
- Civil works. The situation is more heterogeneous for this category. Some countries, like Spain report a gradual reduction, which they attribute to the economies of scale that arise when the number and size of the wind turbines per wind farm increases. However, in the United Kingdom [4] the infrastructure costs, including civil works, are expected to remain stable in real terms up to 2020, whereas in other countries like France they are on the increase.
- Other capital costs. The elements that make up this category include development costs, land costs, health & safety measures, taxes, licenses and permits, etc. They may be quite high in some areas due to stringent requirements, such as environmental impact assessments. The institutional setting, particularly spatial planning and public permitting practices, have a significant impact on costs (as well as whether a wind farm is actually built). Generally speaking, there is a learning curve for the areas in which wind projects are developed and consequently many regions can benefit from substantial productivity increases if regulatory and administrative systems are adapted to accommodate wind power development.



*Source: Own elaboration.*

**Fig. 1.** Estimated capital cost distribution of a wind project in Europe.

### 2.2. Variable costs

Wind turbines, like any other industrial equipment, require operation and maintenance (O&M), which constitutes a sizeable share of the total annual costs – although the figure is substantially lower than for fossil fuel electricity generating technologies. In addition, other variable costs need to be incorporated to the analysis.

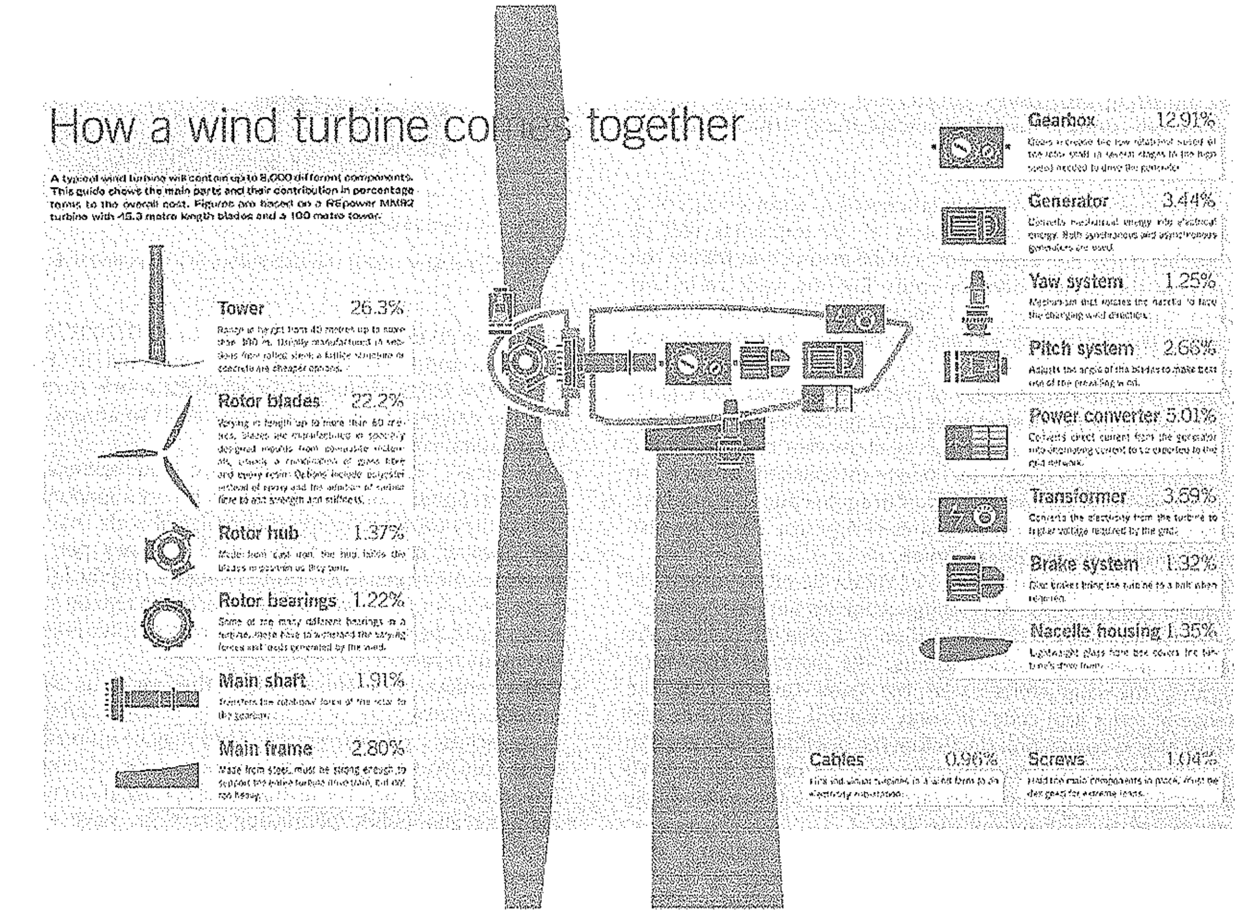
The most important variable costs of a wind energy investment are:

- O&M, including provisions for repair and spare parts and maintenance of the electric installation;
- land and sub-station rental;
- insurance and taxes;
- management and administration, including audits, management activities, forecasting services and remote-control measures.

Variable costs are not as well-known as capital costs, and our survey found significant variations between countries, regions and sites. Few turbines have reached the end of their lifetime, which would allow for a more thorough analysis in this respect.

Certain costs can be estimated easily. For insurance and regular O&M, it is possible to obtain standard contracts covering a considerable portion of the wind turbine's total lifetime. Costs for repair and related spare parts are much more difficult to assess, as this information is not readily available.

[2] The study carried out by the Department for Business, Enterprise and Regulatory Reform (United Kingdom) [4], claimed that turbine ex works accounted for 66% of the capital cost; grid infrastructure for 14%; other infrastructure 17% and planning 3%. The Spanish report from Intermoney-AEE [5] uses the following figures: 72% for the turbine ex works; 11% for grid connections; 9% for civil works and 8% for other auxiliary costs.




*Source: Wind Directions, January/February 2007.*

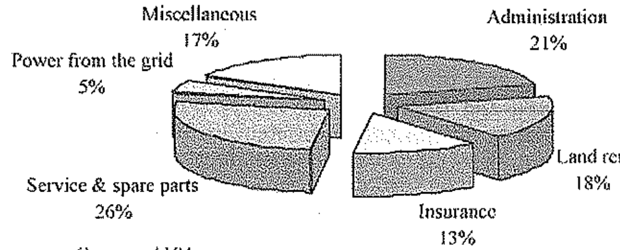
**Fig. 2.** Example of the main components of a wind turbine and their share to the overall cost in the 5 MW RE Power machine.

At present, one of the wind turbine manufacturers' priorities is to lower the variable costs, mainly those related to O&M, by *developing new turbine designs that require fewer service visits*, resulting in greater turbine productivity. It is important to note that the downtime of the machines is less than 2% annually.

Based on our own investigation and on a variety of reputable sources like the British Energy Wind Energy Association [6]; the Spanish Wind Energy Association [5]; Erik [7]; Milborrow [8] and [9], a prudent level of variable costs would be between 1 and 2 €cent/kWh over the lifetime of the wind turbine. This would mean between 10 and 20% of the total costs (around 10% in pure O&M activities). As with the other cost categories, the percentages are only indicative.

In Germany, the study carried out by the German Wind Energy Institute, DEWI in its German acronym [10] looked into the trends and distribution of variable costs for German wind turbines installed between 1997 and 2001. For the first 2 years of its lifetime, a turbine is usually covered by the manufacturer's warranty. So, the German study found fairly low total O&M costs (2–3% of the initial investment) over this period, corresponding to around 0.3–0.4 €cent/kWh. After 6 years, the O&M costs increased, accounting for just below 5% of the total investment. This is equivalent to approximately 0.6–0.7 €cent/kWh. Note that the figures were collated a few years ago, so fail to take into account recent price increases or requirements of the newest wind turbines (Fig. 3).

Finally, and with regard to the future development of variable costs, we must be careful when interpreting the results presented previously. Firstly, as *wind turbines exhibit economies of scale* in terms of declining investment per kW with increasing turbine capacity, similar economies of scale may exist for O&M costs. Secondly, the newer and larger wind turbines have reduced O&M requirements than the older, smaller turbines. Other costs, including those for replacing components, monitoring and insurance may go up, due to a rise in the cost of materials and the greater risks associated with some big wind turbine models. The overall trend, however, according to the limited number of studies that have addressed this issue (for example, the British




*Source: [10].*

**Fig. 3.** Variable costs for German turbines distributed into different categories as an average over the time-period 1997–2001.

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Department for Business, Enterprise and Regulatory Reform [4]) is of a decrease in costs.

*2.3. The wind resource and power generation*

The local wind resource is by far the most important factor affecting the profitability of wind energy investments and also explains most of the differences in the cost per kWh between countries and projects. Just as an oil pump is useless without a sizable oil field, wind turbines are useless without a powerful wind resource.

The correct micro location of each individual wind turbine is thus crucial for the economics of any wind energy project. In fact, it is widely recognised that during modern wind industry's infancy (1975–1985), the development of the European Wind Atlas Methodology was more important for productivity gains than advances in wind turbine design.[3] Wind turbines, whose size and characteristics are adapted to suit the observed wind regime, are sited after careful computer modeling, based on local topography and meteorology measurements.

The average number of full load hours varies from location to location and from country to country.[4] The range for onshore installations goes from 1700 to 3000 h/year (averaging 2342 in Spain, 2300 in Denmark and 2600 in the United Kingdom, to give some examples at national level). In general, good sites are the first to be exploited, although they can be located in areas that are difficult to reach.

Theoretical energy generation, based on wind turbine power curves and estimated wind regime, is reduced by a number of factors, like array losses – which occur due to wind turbines shadowing one another in a wind farm – blade soiling losses, electrical losses in transformers and cabling, and wind turbine downtime for schedule maintenance or technical failure. The net generation is usually estimated at 10–15% below the energy calculation based on the wind turbine power curves provided.

*2.4. The cost of onshore wind energy*

The level and distribution of costs between onshore and offshore wind farms are substantially different. In this section, we deal with generation costs for onshore wind projects. The following section will focus on offshore wind.

For onshore wind projects, and in terms of cost per kWh, an estimate has been made, based on a number of assumptions:

- the calculations are carried out for a new land-based 2 MW turbine;
- the capital investment cost is assumed to be around 1100–1400 €/kW, with a central value of 1250 €/kW;
- O&M costs are assumed to be between 1 and 1.5 €cent/kWh over the lifetime of the turbine; 1.2 €cent/kWh in the medium-term scenario;
- the lifetime of the turbine is set at 20 years;
- the debt/equity ratio is assumed to be 80% and 20%, respectively;
- the discount rate for equity is fixed at 7%, to be repaid over 20 years;
- the discount rate over debt is in the range of 5–10% per year; 7.5% in the medium-term scenario, to be repaid over 12 years;
- the inflation rate is forecast at 3%;
- the number of working hours are set between 1700 (19% capacity factor) and 3000 (35% capacity factor); 2100 in the medium-term scenario (23% capacity factor); and
- risk premium and taxes have not been taken into account.

Based on these hypotheses, the generation cost per kWh of an onshore wind farm today ranges from between 4.5 and 8.7 €cent/kWh. As explained in earlier sections, the wind resource is the factor that has a largest influence over the economics of wind energy. For instance, a wind farm with a capital cost of €1100 will be subject to an increase in generation costs of over 50% if the number of full hours decreases from 3000 to 1700. This percentage variation remains fairly stable regardless of the level of capital costs. If the lifetime of the investment is of only 16 years, and with a capital cost of €1100, the global cost will rise over 10%.

Table 1 shows some interesting figures on the impact caused by a 10% change in a number of key variables, as compared with the central case (capital cost of 1250 €/kWh, O&M of 1.2 €cent/kWh, lifetime of 20 years, interest rate over debt of 7.5% to be repaid in 12 years, capacity factor of 23%).

When increasing/decreasing each of the key parameters by a predetermined rate of 10% we find that it is the number of full hours – that is, the wind resource – which matters the most. A reduction the wind resources of 10% provokes an increase of the generation cost of 8.5%. It is interesting to observe that when the opposite happens (10% increase) the effect is a reduction of the cost of only 6.8%. That is because the cost curve is not a straight line, but a slightly concave one, thus showing marginal decreasing returns. The same can be observed for the other variables.

The second key variable is the capital cost, whose variation of 10% will entail a change of approximately 7.6% of the overall generation cost. This is hardly surprising, given that the wind turbine constitutes the lion share of a wind energy investment.

On the other extreme, the impact of the O&M costs seems to be small (±2.5%), but the percentage is somewhat misleading, because it does not take into account the (likely) circumstance that higher O&M costs will be accompanied by more frequent downtime of the machines. This will imply a lower number of production hours and, as explained above, a substantial negative impact on the cost per kWh.

*2.5. The cost of offshore wind energy*

At present, only a limited number of wind farms have been put into operation—22 offshore wind energy projects (1080 MW) and 3 near-shore projects (43 MW). However, there are many projects planned that will change this picture in the short and medium term (figures from EWEA [11]).

The different situations regarding distance from the shore, water depth, and grid construction and connection affect the cost of the offshore wind farm. In general, the greater energy production resulting from better wind conditions than on land does not compensate for the higher initial capital O&M costs. Offshore wind power is, therefore, more expensive than onshore wind power.

In order to understand the economics of offshore wind energy projects, the following key parameters need to be taken into account:

- foundations are considerably more expensive. Costs depend on both the water depth and the chosen construction principle. For a conventional turbine sited on land, the share of the total cost for the foundations is around 4–6%. In the two largest Danish offshore wind farms (Horns Rev and Nysted) this percentage is 21%, and may be even higher in deeper water or with less favorable soil conditions;

[3] The European Wind Atlas method developed by Erik Lundtang Petersen and Erik Troen was later formalised in the WAsP software for wind resource assessment by Risø National Laboratory in Denmark.

[4] Full load hours are calculated as the turbine's average annual production divided by its rated power.

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**Table 1**
Sensitiveness analysis (10% increase/decrease) applied to an onshore wind investment.

| Capital cost (€/KW) | O&M (€cent/kWh) | Lifetime | Interest rate (%) | Full hours eq. | % diff. with respect to medium scenario |
|---|---|---|---|---|---|
| 1250 | 1.2 | 20 | 7.5 | 2100 | |
| 1125 | 1.2 | 20 | 7.5 | 2100 | −7.6 |
| 1375 | 1.2 | 20 | 7.5 | 2100 | 7.7 |
| 1250 | 1.08 | 20 | 7.5 | 2100 | −2.4 |
| 1250 | 1.32 | 20 | 7.5 | 2100 | 2.5 |
| 1250 | 1.2 | 18 | 7.5 | 2100 | 5.1 |
| 1250 | 1.2 | 22 | 7.5 | 2100 | −4.0 |
| 1250 | 1.2 | 20 | 6.8 | 2100 | −2.1 |
| 1250 | 1.2 | 20 | 8.3 | 2100 | 2.2 |
| 1250 | 1.2 | 20 | 7.5 | 1890 | 8.5 |
| 1250 | 1.2 | 20 | 7.5 | 2310 | −6.8 |

- the construction and installation techniques are less developed than for onshore projects. This has an impact both in terms of cost and of reliability. The visible efforts that are being made in R&D are expected to bring these costs down;
- O&M costs are substantially higher than for onshore projects. The higher cost of transport, as well as reduced site access, due to wave and weather conditions are the main causes. Having an efficient O&M strategy is extremely important for keeping costs down. O&M costs can constitute up to 30% of overall costs for offshore wind farms;
- electrical connections between the turbines, and between the farm and the onshore grid, generate substantial additional costs compared to onshore wind projects. Going back to the example of Horns Rev and Nysted, they accounted for another 21% of the total investment costs. Again, this percentage will rise in deeper or more distant waters;
- environmental analyses tend to be more stringent, sometimes including R&D programs to monitor impact on mammals and other sea communities. With the generalization of offshore wind energy projects, these are expected to decrease in cost and complexity; and
- the investor faces higher risks, which translate into higher interest rates and premiums.

As a consequence, the uncertainty of cost calculation in the case of offshore wind is higher than for onshore wind. Today a range of between 1800 and 2500 €/kW can be used. This entails generation costs of 6–11.1 €cent/kWh.

The graph below shows a tentative cost breakdown for an offshore wind farm in the United Kingdom, and is based on a recent report published by the Department for Business, Enterprise and Regulatory Reform, formerly Department of Trade and Industry, DTI [12]; which took primary data from the existing offshore wind farms in that country. As always, these percentages will differ from country to country and from project to project (Fig. 4).

Economies of scale will play a fundamental role in the future evolution of costs and so the expected second round of investments in the United Kingdom and the announced plans in Germany, Denmark, Spain and Sweden will improve medium and long-term performance.

### 2.6. Some methodological issues

When trying to compare our results with those coming from other sources, we find major obstacles caused by the lack of a universally agreed set of cost categories and by the application of contradictory hypotheses regarding the items that should be included in the analysis and the ones that should be left out. The problem affects both capital and variable costs, although is more important for the latter.

For instance, under the heading of "variable costs" some studies only cover O&M costs, while others add the management and administration costs, the land rental, the forecasting services and the periodical taxes that need to be paid. As explained in Section 2.2 of this article, O&M explain around 50% of the variable costs – according to our classification – and thus the exclusion of one or all the other elements will have a noticeable impact on the global generation cost reported.

The national/regional/local policies will determine whether the wind energy developer has to pay the full cost of the grid connection and upgrade, the extent of the civil works, the content of the environmental impact assessment and the level of taxes. While it is fair that these different policies are reflected in the generation cost of a wind energy investment, they will make comparisons more difficult. Moreover, and with a view to ascertain the long-term cost tendency of wind energy, one would need to distinguish the cost elements that depend on the wind resource and on the technological improvements from those cost elements that are determined by the energy/taxation policy of the area where the wind farm is placed.

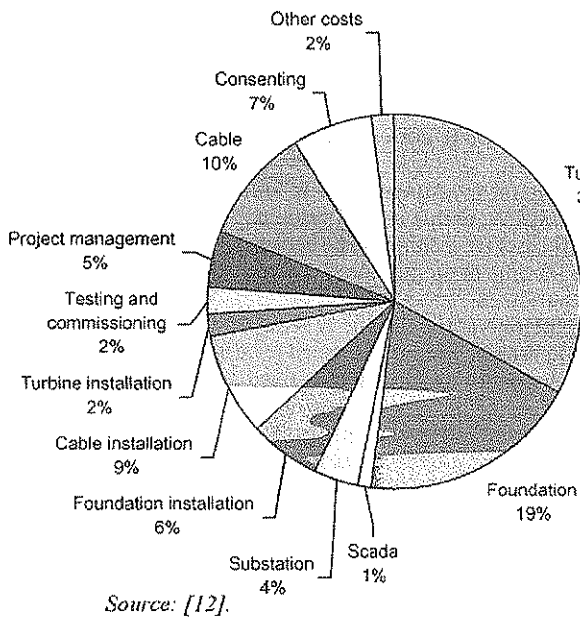


**Fig. 4.** Estimate of capital cost breakdown for an offshore wind farm.

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Other variables must also be discussed among the experts and an agreed baseline scenario should be worked out. The lifetime of an onshore wind farm is generally assumed to be 20 years, and 25–30 years for an offshore wind farm. However, some studies are based on different time-spans, or presume longer or shorter periods for individual components. The Dutch Research Institute ECN (http://www.ecn.nl/en/wind/additional/special-projects/) has got a public-access model which works with a 15 year lifetime. This contrasts with the International Energy Agency model and with our own model, which apply a 20 year lifetime. Other models use timeframes of between 16 and 24 years for onshore and up to 40 years for offshore wind energy.

Finally, we would like to draw the attention on a different problem, which is the cost comparison between electricity produced with wind energy and electricity produced with other sources. The elements that are incorporated to the cost calculation models tend to be slightly different and this has a large impact on the figures that are presented. For instance, very few cost calculations for coal, hydro and nuclear plants take into account the cost of dismantling the installation after the end of its operation. But dismantling costs are a major issue for those technologies, which in some instances have to include the recuperation of derelict land. It is simply not fair to leave them out of the analysis. In the case of nuclear plants, the treatment of radioactive waste is systematically deducted and this provokes a bias in the cost figures that they present.

More subtle is the method chosen to cope with the problem of long-term uncertainty, for instance in the future price of oil and natural gas. The traditional way to handle this uncertainty is to assume different discount rates for the investment. Low discount rates will reflect the higher risk of growing fuel costs, while high discount rates will reflect a low risk level. Institutions like the International Energy Agency [13] then present a list of generation costs for all technologies at a given discount rate, according to a set of pre-defined scenarios – low, medium and high risk scenario – and compare the generation cost of the different options when the discount rate is set at 3%, 8% or 13%.

But not all the technologies face the same uncertainty and so each technology should have its *own* discount rate. Wind energy, being a low-risk option, should have a high discount rate (thus a higher net present value and a lower generation cost); while natural gas plants and other fossil fuel options will have to reflect the higher likelihood that their generation cost will grow in the future. An abundant literature has looked into this issue (Awerbuch [14,15]; Bolinger and Wiser [16]; Bolinger et al. [17]; Kahn and Soft [18]; Roberts [19]). The aim of this article is not to review them in depth, but must at least point to the existence of this fundamental barrier to the cost comparison of electricity-generating technologies and express the convenience of addressing it as soon as possible.

## 3. The supply chain and its relation with the recent increase of wind energy costs

The booming demand for wind energy projects puts pressure on the supply chain. In addition, fast-growing economies such as China are pushing the cost of raw materials upwards. These include steel, copper, lead, cement, aluminum and carbon fiber, all of which are found in the major sub-components of wind turbines. Since 2004 copper prices have risen by over 200%; lead prices have increased by 367%; steel prices have doubled; aluminum prices have increased by 67%; and acrylonitrile, which is used to produce carbon fiber, has increased by 48% over the same period.[5]

[5] Data from the London Metal Exchange (LME). http://www.lme.co.uk/.

The objective of this section is to explain the role that these causative factors have played in the recent reversal of the cost trends of wind turbines and how and when they will be dealt with.

### 3.1. Supply chain

On the supply side, there have been bottlenecks in gearboxes and bearings, with a contributory factor being the dramatic increase in the size of turbines, which has severe implications for the supply chain. Another key factor is the price, availability and quality of raw materials. Examples of raw materials that have undergone substantial price increases are steel (used in towers, gearboxes and rotors), copper (used in generators and cables), carbon (used in rotor blades) and cement (used in foundations and towers).

The underlying issue here is that it was difficult to predict that so many world markets would enlarge simultaneously. Increases in component supply require a major investment in machinery, with up to 2 years lead-in time. Our survey found that most manufacturers are substantially expanding their production lines; in some cases, the reaction has been to vertically integrate supply-chain activities and to set up long-term contracts with sub-suppliers.

#### 3.1.1. Blades

These are a crucial component, requiring sophisticated production techniques. Global supply used to be dominated by an independent blade maker, although many major turbine manufacturers produce their own blades. There is no shortage of supply at present, but the availability and price of carbon fiber – a major sub-component for large blades – remains a problem. Several carbon companies have entered the wind energy market to address this problem.

#### 3.1.2. Gearboxes

Most turbine manufacturers have traditionally outsourced their gearboxes to a shortlist of six or seven independent companies. The situation changed somewhat in 2005 and 2006, with several acquisitions, as well as new players and concepts entering the market.

Nonetheless, gearboxes are the component for which most shortages of supply have occurred. The main reasons for this are the limited number of production facilities tailored to the wind energy market, a shortage of large bearings and a bottleneck caused by unexpected repairs to operating gearboxes, including the replacement of bearings. However, most of the manufacturers are already in the process of expanding their capacity and further improving the reliability of their components, with new production lines opening in both Europe and Asia. This should lead to a resolution of current delays in 2008.

#### 3.1.3. Bearings

There are some shortages of large bearings used in gearboxes and the main shaft. According to BTM-Consult [20], the delivery time for large bearings can be 16–18 months, when no long-term supply agreement is in place. One reason for the shortage is that the boom in the wind industry has coincided with a generally increased level of activity across all heavy industries. For bearings manufacturers, wind represents only a small fraction of their business.

Since 2007, several of the largest bearings suppliers to the wind industry have responded by expanding their production facilities.

#### 3.1.4. Generators

These are supplied to the wind industry by a number of large companies and there are no signs of a shortage. The main stress factor here is high and rising copper prices.

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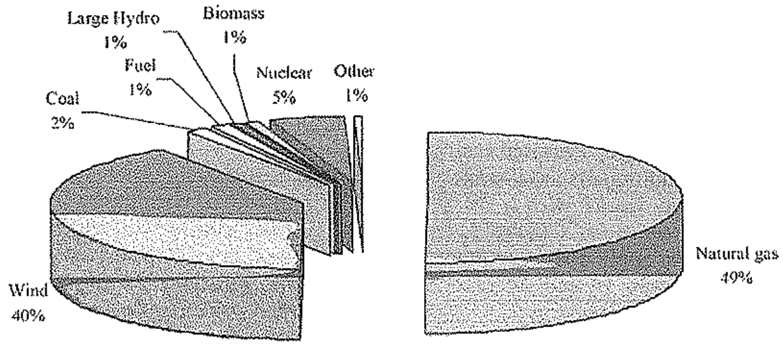


*SOURCE: [23].*
*NOTE: Other includes geothermal, small hydro, peat, waste and other gas.*

**Fig. 5.** New capacity installed in the European Union in 2007, MW.

### 3.1.5. Cast iron and forged components

This category includes the main frames used to support the rotor hub and nacelle, the hubs themselves and the main shaft, which links the rotor to the gearbox. The market has been affected by the high level of activity in the heavy industry sector, with increased demand for both forged steel and cast iron, whose price and quality have suffered.

### 3.1.6. Towers

Most turbine towers are made of rolled steel, although some manufacturers are turning increasingly to concrete as a cheaper alternative. Although manufacturing is an increasingly sophisticated process, the basic expertise is more widely available than for other components. Overall, towers are unlikely to create supply problems, but it is still important to keep a careful eye on the price of steel and cement and in the availability of quality steel.

## 3.2. Demand surges

The biggest factor on the demand side is the industry's dependence on national incentive programs whose shifting patterns are not always easy to predict. The most obvious example of this is the Production Tax Credit (PTC), which has been a major influence in encouraging the wind industry in the United States.

In 2004, the demand in the United States wind energy market was for just 389 MW of new capacity. The previous PTC period expired at the end of 2003. However, with the revival of the incentive at the end of that year, investment took off again, making 2005, 2006 and 2007 record years of 2500 MW, and creating a massive surge in global demand for wind turbines. The effect has also been to encourage turbine suppliers to target the US as a priority, effectively siphoning off turbines from European manufacturers, which could have been destined for other markets.

The growing interest in wind energy projects in many countries of America, Asia and Europe is reducing the impact that one specific legislation change may have on the industry, but can still put the production chain under stress. The recent policy developments, notably of the European Union with the approval of a target of 20% RE consumption by 2020 [21] should guarantee a sustained demand for wind energy farms in the short and medium term. This stable framework should foster the entry of new markets agents – something that we are already witnessing with the expansion of traditional energy companies, utilities, components manufacturers – thus increasing the global capacity of the industry and the competition among them.

## 3.3. Wind energy cost increases in the broader context of other electricity-generating technologies

Although this article is not intended to provide a comparative review of the generation costs across the electricity industries, the conclusions developed in Sections 3.1 and 3.2 will be better understood when inserted in a broader context.

Wind energy costs have augmented in the past 3 years but so have the other power generation technologies. The reasons are certainly not the same – fossil fuel plants suffer the effects of the doubling and tripling of oil and natural gas prices since 2004 – and their long-term behavior will probably diverge, but the fact remains that wind energy investments are as competitive as they were before 2004.

According to Milborrow [9] the generating costs of natural gas, coal and nuclear energy stood at around 4.9, 4.1 and 6.6 €cent/kWh respectively in 2007.[6] These are approximate figures, and may hide several methodological inconsistencies, as it was explained in Section 2.6. Also note that they do not take into account the environmental externalities caused by energy production, mainly but not only $CO_2$ emissions. Milborrow and to Blanco and Rodrígues [22] prove that the inclusion of a $CO_2$ price of around 30 €/ton would transform wind energy as the least-cost option.

Fig. 5 on new generating capacity installed in Europe reflects the attractiveness of wind energy, and shows that in 2007 (also in the 2000–2006 period) it was the second preferred investment option in Europe, after natural gas, with 40% of the total new capacity. The remaining technological options have since many years been lagging behind.

# 4. Long term trends of wind energy costs

## 4.1. Learning curves

Despite the recent increase in the capital costs of wind power generation, the long-term trends for wind energy have indicated a

[6] Other studies have looked into this issue. In 2004, BP Power carried out a comparative analysis on "the cost of generating electricity", which looked into the same issue. The values that they published were based on cost figures in the 1998–2002 period and thus fail to reflect the rapid changes that have taken place from 2005 onwards. The figures found by them were: 2.2 pence/kWh (3.19 €cent at a exchange rate of 1.45) for natural gas plants; 2.3 pence/kWh (3.33 €cent) for nuclear fission plants; between 2.2 and 2.6 pence/kWh (3.19 and 3.77 €cent) for coal plants – depending on the technology used; 3.7 pence/kWh (5.37 €cent) for onshore wind and 5.5 (7.98 €cent) for offshore wind farms [24].

**Table 2**
Capital cost of energy technologies assumed for the PRIMES baseline model (as applied in the impact assessment of the European Commission).

| | €/kW in 2020 | €/kW in 2030 | €/kW in 2040 | €/kW in 2050 |
|---|---|---|---|---|
| Onshore | 826 | 788 | 770 | 762 |
| Offshore | 1274 | 1206 | 1175 | 1161 |

substantial reduction. Today, a wind turbine produces 180 times more electricity, at less than half the cost per kWh than its equivalent 20 years ago (EWEA [1]).

A variety of models that analyze the long-term cost trend of wind, and other renewable energies, have been developed over the past decade, many of which supported by the European Union.[7] The European Commission, in its 2007 Strategic Energy Review [25] presented an amalgam of their main outcomes, as part of its impact assessment on renewables. It shows that the capital cost of wind energy is likely to fall to around 826 €/kW by 2020, 788 €/kW by 2030 and 762 €/kW by 2050. A similar pattern is expected for offshore wind energy (see Table 2).

In the same way, the British Department for Business, Enterprise and Regulatory Reform [12] has commissioned a study by Ernst and Young, which looks at the present and future costs of renewable technologies. For onshore and offshore wind energy, they predict that the upward trend will continue up until 2010. This will be followed by a decrease, once the supply chain bottlenecks are resolved.

A common way to look at the long-term cost trend is to apply the experience curve concept, which analyses the cost development of a product or technology as a function of cumulative production, based on recorded data. The experience curve is not a forecasting tool based on estimated relationships; it merely points out that if the existing trends continue in the future, then we may see the proposed decrease. Still, it is commonly used in most economic sectors, including the energy sector (for example, Harmonn [26] for solar photovoltaic; Claeson and Cornland [27] for combined cycle gas turbines).

Experience curves for wind energy have been drawn up in Denmark (Neij [28,29]), Germany (Durstewitz and Hoppe-Kilpper [30]), the United States (Mackay and Probert [31]) and in a mix of other countries (Milborrow [32]; Ibenholt [33]; Klaassen et al. [34]; Neij et al. [35]; EWEA and Greenpeace [36]; Junginger [37], Isles [38]). An excellent overview of the experience curves for wind and their usefulness can be found in Junginger et al. [39].

Unfortunately, some of these models use non-compatible specifications and so not all of these can be compared directly. Using the specific costs of energy as a basis (costs per kWh produced), the estimated progress ratios in these publications range from 0.83 to 0.91, corresponding to learning rates of 0.17 to 0.09. So, when total installed wind power capacity doubles, the costs per produced kWh for new turbines decrease by between 9 and 17%. The recent study carried out by the DTI [4] considers a 10% cost reduction every time the total installed capacity doubles.

Naturally, the level of R&D, both public and private, will have a significant impact on future costs, and this is where learning curves do not capture the importance of policy support. As it was detailed in Section 3 of this article, the evolution of steel, cast iron, copper and carbon fiber prices is and will likely remain on the rise, thus exerting a negative influence of the long-term costs of wind energy. Thus, the key question is to what extent technological improvements and economies of scale are able to compensate for these unfavorable factors, and what role public policies can play in this process.

[7] For example, TEEM, SAPIENT, SAPIENTIA, CASCADE-MINTS, co-funded by DG Research.

### 4.2. Policies to improve the cost effectiveness of wind energy

The aim of this section is to propose a choice of policy measures that can contribute to reduce the long-term generation costs of wind energy. Naturally, the measures should concentrate on the variables that most influence the global cost of a wind energy investment. According to Sections 2.4 and 2.5, these variables are:

- capacity factor;
- capital cost, which in turn is driven by the cost of the wind turbine and its different sub-components;
- improvement of remote-control O&M devices, more stable and cheap foundations and improved materials for offshore wind farms;
- access to capital finance, which depends on the maturity of the banking system, the existence of accurate information on the real risks and benefits of wind energy vis-à-vis other electricity generation options, and the stability of the political framework.

Wind farm capacity factors can be increased through the optimization of the size of the wind turbines, the application of advanced materials for blades, the improvement of forecasting and siting techniques, and the introduction of smartgrid technologies that allow higher amounts of wind electricity be put into the grid.

The level of capital cost is very sensitive to the availability and quality of the raw materials and also to the economies of scale of the production process. The capacity of policy makers to influence the quality and quantity of raw materials is limited, but some actions can be taken to promote free trade and competition in the relevant markets. Economies of scale can be achieved by using measures which support the installation of large-scale facilities, as has been done (with notable success) in Denmark, Germany and Spain, and more recently, in China and the US. R&D in new materials, drive-trains, blades, O&M, wind turbine design and increased efficiency will bring further cost reductions in this crucial investment item.

The reduction of offshore wind costs requires a special R&D effort. Offshore technology is newer than onshore and thus the rate of learning and advancement is relatively high. Areas of high priority for research include safety and access to offshore wind farms, new and improved wind turbine concepts, design and fabrication of substructures, new offshore cabling and connection techniques, and development of O&M solutions with remote control devices. In addition, policy measures have to be focused to create a solid offshore wind energy market, so that economies of scale can be exploited. Recent laws to promote this technology in Denmark, Germany, Spain and the United Kingdom (with differentiated feed-in tariffs, improved grid access, and in some cases, socialisation of the grid connection costs) can be cited as examples. In the future, the cost of offshore wind energy projects will largely depend on the existence of sufficient international interconnectors, which would permit the integration of this large-scale solution.

With regard to access to capital finance, policy makers can develop appropriate awareness campaigns to explain the benefits and the low risk of wind energy investments; this will encourage banks to fund more wind energy projects and at lower interest rates. They can also make funds available for the development of new initiatives, in the form of subsidized interest rates or preferential capital access. But the best policy measure by far consists of creating a stable policy framework, which improves the prediction of income streams for a wind farm. Long-term certainty on the revenue side is of crucial importance for a business in which approximately 80% of the global cost is spent during the first 2 years. A stable policy framework can be achieved through a renewable energy law (which stipulates aspects such as the

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remuneration level of wind-generated electricity, rules for connecting a wind farm to the grid, and the removal of administrative and grid access barriers) and through the approval of long-term targets that demonstrate the existence of a political commitment over the lifetime of the investment.

## 5. Conclusions and the way forward

This paper has presented a range of current generation costs of wind energy investments in Europe, both onshore and offshore, based on a survey carried out among European Wind Energy Association members and the systematic review of available studies. It has also assessed the roles and tendencies of its individual cost components, the usefulness of learning curves as a tool to predict the long-term cost reduction potential of this industry and the role that public policies can play in the economics of wind energy. The next paragraphs summarise the main conclusions that have been reached:

Wind energy is a capital-intensive technology, with the fixed assets (wind turbine, grid connection and civil works) accounting for as much as 80% of the total cost. O&M make up another 10% of the expenditure, although there is substantial uncertainty around this category due to the fact that few wind turbines have reached the end of their lifetime, thus limiting the accuracy of any analysis.

The onshore wind energy generation cost is between 4.5 and 8.7 €cents/kWh, with the capacity factor and wind turbine cost being the most influential factors.

The offshore wind energy generation cost can be estimated at 6 to 11.1 €cents/kWh, with the distance from the shore, water depth, and grid construction and connection accounting for most of the cost divergences. Generally speaking, offshore wind energy is located higher in the learning curve and thus susceptible to greater cost reductions in the medium term.

The generation costs of wind energy have increased by 20% in the past 3 years, driven by a combination of rising prices of key raw materials and an unexpected surge in the demand for wind turbines, following the approval of favorable support policies in large markets like the US, China and a second round of European Member States. The growing interest in wind energy projects worldwide will reduce the impact that one specific legislation can have on the industry and keep demand high; the evolution of steel, cast iron, copper and carbon fiber prices is, and will likely remain, on the rise, since the demand for these materials from other economic sectors and geographical areas is not showing signs of exhaustion.

Under these conditions, the lessons that can be extracted from learning curves are of limited value, because they do not capture expected behavioral and structural changes of the industry, nor do they separate the influence of external variables from the internal factors.

An appropriate political framework can certainly decrease the generation cost of wind energy. R&D policies are decisive, and should focus on the optimization of the size of wind turbines, the application of advanced materials for blades, the improvement of forecasting and siting techniques, the introduction of drive-trains, O&M with remote-control devices, and the design of smart grids that accommodate higher amounts of wind energy. As a complement, market measures that increase investment certainty over the 20-year repayment period need to be put into practice: they must include the setting of long-term installation targets to give an order of magnitude of the investment effort needed, clear regulation on grid access and connection costs, the removal of the administrative barriers, and the articulation of an appropriate support payment mechanism.

Last but not least, this paper has identified some areas in which more research is needed: a new study on the costs of offshore wind energy, once more projects are operational; an initiative to agree upon the set of cost categories and basic hypotheses that should be included in analyses of wind generation costs, and comparisons against other electricity generation technologies; a careful assessment of the discount rate that should be applied to each electricity generation technology when trying to capture its long-term income risk; a new definition of learning curves, which makes a distinction between the role played by external variables and the role of economies of scale and R&D actions.

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## Appendix A. Publications and reports used for the preparation of the cost estimates

Tables A1 and A2.

**Table A1**
Summary of the main information sources that have been used in this article at the time of identifying the capital costs and the generation costs of an onshore wind farm.

| Study | Capital cost per kW installed | Cost per kWh |
|---|---|---|
| Erik (2007) | €900 to €1175 | n.a. |
| Milborrow (2006) | €869 to 1559 €/kW | n.a. |
| Intermoney-AEE (2006) | €971.67 and 1175.10 €/kW | n.a. |
| EER forVestas (2007) | 1050 €/kW to 1350 €/kW | n.a. |
| BWEA (2006) | 1.52 million €/MW | n.a. |
| IEA (2005) projected costs of generating electricity, 2005 update, IEA publications | 1000–1600 US$/kW onshore (€850–1360) and 1600–2600 US$/kW offshore | n.a. |
| IEA (2007) annual report, draft-data provided by Governments- | €1365 in Canada; €979 in Denmark; €1289 in Germany; €1050 in Greece; €1200 in Italy; €1209 in Japan; €1088 in Mexico; €1100 in Netherlands; €1216 in Norway; €1170 in Portugal; €1220 in Spain; €1242 in Switzerland; €1261 in UK; €11121 in US | n.a. |
| UKERC (2007) | n.a. | 5.9 €cent/kWh with a standard deviation of 2.5 €cent/kWh |
| DTI (2007b) | 1633 €/kW medium scenario; 1850 in the high scenario; 1422 in the low scenario. | 9.3–11.5 €cent/kWh – high and low wind |
| DTI (2007c) | n.a. | 8.1 €cent/kWh to 15.9 €cent/kWh |
| Bano, Lorenzoni for APER (2007) | 1400 €/kW | 9.4 €cent/kWh |
| Wiser, Bolinger for US DOE (2007) | 1480 US$/kW (1200 €/kW approximately) projects in 2006; 1680 US$/kW (1428 €/kW) for proposed in 2007 | n.a. |

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**Table A2**
Summary of the main information sources that have been used in this article at the time of identifying the variable costs of an onshore wind farm.

| Study | O&M costs | Other variable costs |
|---|---|---|
| Erik (2006) | 1.2 to 1.5 €cent/kWh | n.a. (not clear) |
| Milborrow (2006) | 15 to 40 €/kW; 1 to 1.5 €cent/kWh | n.a. (not clear) |
| Intermoney-AEE (2006) | 1.02 €cent/kWh | 1.03 €cent/kWh |
| EER for Vestas (2007) | 2.5 to 4 €/MWh; 0.25 to 0.4 €cent/kWh | n.a. |
| BWEA (2006) | 23.25 €cent/MWh | (check) |
| IEA (2005) | 12.50 to 33.8 €/kW | n.a. |
| DTI (2007b) | 61.5 €/kW | n.a. |
| Bano; Lorenzoni for APER (2007) | 1.8 €cent/kWh | n.a. |
| Wiser; Bolinger for US DOE (2007) | Partial data: 0.68 €cent/kWh for the most recent projects; 1.7 €cent/kWh for older projects. | n.a. |

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# Electricity sector reform in Greece

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ABSTRACT

This paper provides an outlook of the electricity market reform in Greece which started in 2001 and is still developing slowly. This is related to the persisting dominance of the incumbent company and the specificities of the electricity sector of Greece which is heavily dependent on indigenous lignite firing generation, while being located in the periphery of the EU internal electricity and gas markets. Competition through enhancing electricity trade in the region is limited to date, as the establishment of an internal market in South East Europe also progresses slowly. Development of competition through gas-firing generation by new entrants has been the priority adopted by State and Regulator's policies. However, the gas supply market in Greece and in the region still lags behind.



## 1. Introduction

For almost 50 years, the electricity sector in Greece has been organized according to the monopolistic model: a vertically integrated, 100% state owned company, namely the Public Power Corporation (PPC), was granted exclusive rights as regards all electricity activities.

Being a member state of the EU since 1981, Greece embarked on electricity market liberalization in February 2001, with Law 2773/1999. Subsequently, the legal framework was revised in order to comply with the provisions of Directive 2003/54/EC but also in order to incentivize private investment and competition. Moreover, a new electricity law established a mandatory pool system and a capacity assurance mechanism. In terms of customer eligibility, full market opening has applied since July 2007.

However, six years after the start of market liberalization, the former monopolistic company PPC, which was in the meantime converted to a share company and remains under state control, still holds a highly dominant position in both the electricity generation and power supply markets. More specifically, as regards electricity generation, with the exception of renewables that enjoy feed-in tariffs, there exist only two new independent power producers, representing a small percentage of the interconnected system's installed capacity. As regards electricity supply, all customer tariffs applied by PPC are regulated by the state and their structure still includes large cross-subsidizations among customer categories. It is also claimed that the level of regulated electricity prices is below power generation costs. As a result, PPC holds more than 98% of consumers.

In addition, compliance with the EU legislation on unbundling has been delayed and is still poorly developed. Legal unbundling was introduced only in relation to Transmission System Operation, while PPC remains the exclusive owner of the Transmission System and of the Distribution Network.

Insufficient power investment, needed to cover the fast growing electricity demand and to modernize power generation technology, is still a major issue for the Greek power system. Furthermore, there is scope for cost reductions and productivity improvements which evolve at rates slower than expected.

Further revisions of the existing legislation are currently under consideration in order to address the abovementioned issues and to comply fully with EU legislation. In addition, PPC is currently considering the application of a restructuring plan, which is based on the idea of creating a holding company owning separate subsidiaries that will be responsible for each electricity activity.[1]

## 2. Background to the electricity sector

Since 1889 when the lighting of the historical centre of Athens took place, several small power companies were created in order to supply restricted regions of the country with electricity.

In 1950, under the provisions of Law 1458/1950, the State united all these small companies and created the Public Power Corporation (PPC), a vertically integrated, state owned (at 100%) public company, which enjoyed exclusive rights and privileges as regards the construction, functioning and exploitation of hydroelectric and thermal power plants, as well as of the transmission and

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[1] For more information see the PPC Strategic Plan that was presented in November 2007, in http://www.dei.gr/Default.aspx?id=3942&nt=18&lang=2.

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distribution networks. At the same time, the Law prohibited any private business initiative or action in the electricity sector.[2]

Like other Greek public corporations, such as the Telecommunications Corporation, PPC was traditionally considered to be part of the public sector. Therefore, the operation of PPC was based on the basic principles governing the provision of public services, such as the principles of "continuity" (imposing the obligation of continuous service); of "adaptability" (imposing an obligation to monitor the evolution of the citizens' fundamental needs and to meet those needs); of "affordability" (imposing the obligation to ensure raising a minimal economic charge on the citizens); and of "universality" (imposing an obligation for equal service independently of location).

The exclusive right of PPC regarding electricity generation was limited for the first time by the provisions of Law 2244/1994 which permitted the operation of private power producers in exhaustively enumerated cases, namely the auto-producers, cogeneration and generation using Renewable Energy Sources (RES). The same Law imposed on those independent power producers the obligation to sell the entire electricity generated (except the self-used electricity by auto-producers) to PPC on the basis of regulated power purchase agreements. This is how the first privately owned generation units were constructed and started to operate in Greece.

The liberalisation of the market started in 2001 following the issuance of Law 2773/1999 to comply with EU legislation. That reform also aimed at improving the economic efficiency of the sector.

## 3. Political economy and regulatory environment

### *3.1. Geographical and population data*

Greece is located at the southernmost part of the Balkan Peninsula and has borders on the Ionian Sea in the west, on the Mediterranean Sea in the south, on the Aegean Sea in the east, on Turkey in the northeast, and on Bulgaria, F.Y.R.O.M. and Albania in the north. The country's land area is mountainous with ranges extending into the sea as peninsulas or chains of islands. Greece has extensive coastlines (15,021 km) and has also about 2000 islands most of which are not interconnected with the electricity grid of the continental part of the country and have small autonomous electricity systems. The biggest non-interconnected systems are those situated on Crete and on Rhodes.

Greece has a Mediterranean climate, with more than 2700 h of sunshine annually in most of the country, mild temperatures and limited rainfall, and different kinds of seasonal winds. The country's potential for renewable energy sources (RES) such as solar energy or wind power is therefore high. The weather of the islands of the Aegean and the Ionian seas is rather mild.

According to the latest census (2001),[3] the population of Greece is approximately 11 million, most of which lives in urban areas. Approximately 35.5% of the population lives in the Attica peninsula and mainly in the capital, Athens.

Because of the geographical concentration of the population, Greece has two main electricity load centres: one in Attica, which is the biggest, and one in Thessaloniki, which is the second largest city of the country and is located in the northern region.

The non-interconnected islands' electricity load represents approximately 8% of total electricity demand. However, electricity generation on such islands is based on oil and remains significantly costly. This fact, combined with the fundamental policy decision to ensure equal consumer prices throughout the whole territory of the country, is rather discouraging for new entrants. Therefore, PPC remains the sole electricity generator and supplier as regards such islands. According to a recent decision issued by the Minister of Development, electricity generation on non-interconnected islands constitutes a Public Service Obligation (PSO) that PPC is obliged to provide. However, the methodology for the calculation of PPC's remuneration for providing such PSO has not yet been adopted.

### *3.2. Political organization and general principles*

Since the end of the seven-year military dictatorship in 1974 and the adoption of the Constitution a year later, Greece has had a stable political system and is organized as a parliamentary republic.[4] The current conservative government came to power in 2004 and was re-elected in September 2007.[5] The institutional framework of the State includes a unicameral Parliament which is elected through direct general elections for a mandate of four years, the President of the Republic who is elected by the Parliament for a fixed term of five years, and the Government which is composed of the leader of the majority party in Parliament (or of the coalition that enjoys the confidence of the Parliament) as Prime Minister and his Cabinet. Usually, Greece has one-party Governments.

According to a decentralization principle, the country is divided into 13 administrative regions, each headed by an administrator who is appointed by the Government; then into 51 prefectures; and finally into many local communities, such as town municipalities and village communities, which are all headed by elected governors.

The central Government is responsible for defining and directing the general policy of the country, whereas the legislative function is entrusted to the Parliament which adopts the Laws by voting. Secondary legislation is issued on the basis of a delegation included in Law and has the form of a Presidential Decree or of a Ministerial Decision, depending on the issue that has to be regulated and the nature of the decision making institution. Other administrative authorities may also have the power to issue regulatory decisions for specific issues of technical, local and detailed nature depending on Law-based delegation. Administrative decisions may be challenged for annulment on legality reasons before the administrative courts and mainly before the Council of the State which is the Supreme Administrative Court.

The political organization of Greece relies on the principles of the rule of law and of the welfare state. Fundamental rights such as individual freedom, including economic freedom and free private economic activity (Article 5 of the Constitution) as well as private property rights (Article 17 of the Constitution) are protected by the Constitution. Restrictions of such rights apply only if they are considered necessary in order to protect human dignity and the general interest. This approach is reflected in paragraph 2 of Article 106 of the Constitution, which provides that "Private economic initiative shall not be permitted to develop at the expense of freedom and human dignity, or to the detriment of the national economy." Moreover, paragraph 3 of the same Article grants authorisation to the legislature to decide on the acquisition by purchase of enterprises or the compulsory participation therein of the State or other public agencies, in the event these enterprises are of the nature of a monopoly or are of vital importance to the development of sources of national wealth or are primarily intended to offer services to the community as a whole.

[2] For information see PPC website: www.dei.gr.

[3] For information see the official website of the General Secretariat of National Statistical Service of Greece: www.statistics.gr.

[4] See http://www.parliament.gr/english/politeuma/default.asp.

[5] See http://www.primeminister.gr.

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### 3.3. Economic information

Greece has been a member of the EU since 1981, became a member of the Eurozone in 2001 and applies a free market economy policy. GDP per capita is today equal to 75% of the average of leading Eurozone economies and is 82% of the EU-25 average. The public or state owned sector accounts for about 40% of GDP. Over the last 10 years annual GDP growth has been higher than the EU average.

According to latest statistics, the growth rate of the Greek GDP was 3.8% in 2005, more than 4% in 2006, and for 2007 it was expected to be also over 4%. Inflation rates, as measured by the Harmonised Index of Consumer Prices (HICP), rose to 3.4% in 2006 (in average annual terms), from 2.5% in 2004. At present, inflation is reduced to 2.6% per year, which is higher than the Eurozone average.

As a result of stringent policies aiming at reducing public expenditure, the deficit of the general government was reduced from 7.8% of GDP in 2004 to 2.6% of GDP in 2006; this is in line with Greece's commitments to the European Union's Growth and Stability Pact budget deficit criteria.

In order to overcome challenges such as covering the public debt, which is among the highest in the Eurozone, curbing inflation, and increasing employment, the current conservative Greek Government announced a series of reforms and other policy measures. These focus on rationalizing public expenditure, reducing the size of the public sector, and reforming the labor and pension systems. These reforms are challenged by the country's powerful labor unions and generally by public opinion.[6]

### 3.4. Institutional arrangements

The main responsibility with regard to the energy sector is entrusted to the Ministry of Development,[7] which includes a Department of Energy and Natural Resources. The Ministry plays a central role in energy policy making since it is responsible for elaborating the primary legislation, for defining market rules, for regulating the prices and for the issuance of administrative decisions such as market and technical codes, licenses and all kinds of authorizations of energy activities. Other Ministries involved in energy policy issues are the Ministry of Economy and Finance, which is responsible for financial policy and privatization issues, and the Ministry of Environment, Physical Planning and Public Works, which is responsible for environmental policy and licensing.

Other public institutions involved in energy issues are the Regulatory Authority for Energy (RAE), established as an independent administrative authority, which has been in operation since June 2000 and has responsibilities mainly towards market supervision and government advice;[8] and the National Energy Strategy Council (NESC) created in 2006 which has a solely advisory role on long-term strategic energy policy issues,[9] created with the purpose of assisting the Government in establishing a coherent energy policy. According to the Law 3438/2006 there shall be no overlap of the NESC competencies with RAE competencies and responsibilities.

In addition, local government institutions have power of decision regarding the issuance of environmental permits, as well as the installation and operation licences for electricity generation units from renewable energy sources (RES).

## 4. Institutional aspects of the electricity reform program

### 4.1. Electricity reform legislation

The liberalization of the Greek electricity sector started in 1999, with the enactment of Law 2773/1999, which aimed at compliance with the provisions of Directive 96/92/EC.

According to the provisions of that Law, the electricity sector was divided into two sub-sectors: the networks have remained monopolistic and regulated, whereas free market rules have been applied for electricity generation and supply to eligible customers. The law imposed, as a condition for any activity in the electricity sector, the issuance of a relative license, issued upon decision by the Minister of Development after a simple opinion of RAE. Furthermore, the Law adopted the basic rules for the organisation of system and market operation, and empowered the Minister of Development broadly to decide, after simple opinion of RAE, on secondary legislation deemed necessary for the regulation of specific organisational issues, including the regulation of prices. During the first years of market restructuring, the System Operation Code (2001), the Power Exchanges Code (2001), the Authorizations Regulation (2000) and the Supply Code (2001) were adopted. Only the issuance of the Distribution Network Code is still pending.

Substantial amendments aiming at the enhancement of market opening and competition in the electricity sector were included in Law 3175/2003. More specifically, according to the provisions of this Law:

- A Mandatory Pool System was introduced for power generation and wholesale supply, covering the entire market for the interconnected system. All suppliers acquired the obligation to purchase energy from the Pool and all generators can now operate only if selected by the market operator according to their economic bids to the Pool. The Pool was designed to operate on an hourly and daily basis.
- In order to allow for recovery of fixed and capital cost and therefore promote the construction of new power plants, generators acquired the right to submit free economic bids to the Pool, which have been restricted to reflect at least their variable costs.
- All consumers, with the only exception being households and consumers located on non-interconnected islands, became eligible from July 2004. By July 2007 all household customers, except those located on the islands, also became eligible.
- In addition, a capacity assurance mechanism has been adopted, based on the obligation of suppliers to hold capacity certificates and the obligation of generators to issue and market these certificates. To promote new investment, the Law provided for the possibility of organizing capacity tenders in Greece, which would guarantee part of the future revenues of new investors, in relation to the capacity certificate system.
- A delegation for the issuance of a new System Operation and Power Exchanges Code was also introduced. That Code would aim at setting the details of organization of the wholesale market and the establishment of a capacity assurance mechanism.
- Electricity traders were allowed to operate.
- Generators acquired the right to choose their natural gas supplier from July 2004.

The proposal for a new System Operation and Power Exchanges Code was prepared by RAE and was put to public consultation at the end of 2003; due to the governmental change in 2004 and

[6] See information published by the Ministry of Economics, Fact Sheet on the Prospects of the Greek Economy (January 2007), in: www.mnec.gr/en/economics/greek_economy_prospects.

[7] For more information see the official website of the Ministry of Development: www.ypan.gr.

[8] C. Ocana, International Journal of Regulation and Governance 3 (1), pp. 13–32 (22). For more information see RAE official website: www.rae.gr.

[9] The National Energy Strategy Council was established with the provisions of Law 3428/2006 and started to operate in July 2006.

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a long-term period of public consultation mainly with the Hellenic Transmission System Operator (HTSO) and PPC, the final Code was approved in May 2005. Compared to RAE's initial proposal, the final document contains several new provisions for a transition period which will apply until 1 July 2008 when the complete application of the Code is expected to start.

Further amendments to Law 2773/1999 were introduced with the provisions of Law 3426/2005 which was enacted for the purpose of implementing the provisions of the Electricity Directive 2003/54/EC. The provisions of this Law may be summarized as the following:

- It granted the right to choose supplier to all customers, by 1 July 2007, when household customers became eligible according to the EC Directive, with the exception of the customers situated on the non-interconnected islands.
- Reform of the licensing procedures regarding generation units of non-interconnected islands.
- Clarification of the Hellenic Transmission System Operator's duties and responsibilities, regarding the maintenance and expansion of the Transmission System; reinforcement of its independence vis-à-vis PPC's management and competencies.
- Legal unbundling of the Distribution Network Operator, by 1 July 2007.
- Clarification of the public service obligations regime.
- Delegation for the issuance of a non-interconnected islands' Operation Code, which shall include rules regarding the operation of the electricity generation units situated on such islands, as well as rules on dispatching and grid operation, aiming at promoting reliability and economic performance.
- Facilitation of the criteria for the granting of supply licenses.
- Enhancement of the Regulator's role and duties.

However, in 2006 the European Commission launched an infringement procedure, giving a reasoned opinion against Greece for failing to comply with the provisions of the Electricity Directive 2003/54/EC, mainly as regards the imposition of public service obligations (PSOs) and the conditions for granting supply licenses. This procedure is ongoing.

Finally, in October 2006 Law 3468/2006 was enacted with the purpose of further promoting the generation of electricity produced from renewable energy sources (RES) and high-efficiency cogeneration of electricity and heat. The Law included new incentives principally as regards photovoltaic plants as well as several facilitations of the complex administrative procedure for obtaining the operation permits.

Also for the purpose of simplification of administrative procedures, Law 3325/2005 was enacted, regulating the licensing procedures for industrial installations and operation, as well as energy-related infrastructure.

### *4.2. Establishment of an independent regulator*

The Regulatory Authority for Energy (RAE) was established under the provisions of Law 2773/1999 as an independent administrative authority, and started to operate in summer 2000.

According to the Law, RAE is a public body, composed of seven[10] members with a fixed term mandate. The members of RAE are selected on the basis of professional capacity and scientific excellence and are appointed by the Minister of Development. Three of the members, for the positions of the President and the two Vice-Presidents, are appointed by the Ministerial Council upon proposal of the Minister and opinion of the competent parliamentary committee.

RAE members enjoy personal and functional independence, are not obliged to comply with governmental orders and may not be dismissed for reasons that do not fall within the scope of strictly enumerated cases (mainly conviction for serious felonies during execution of their duties). Nevertheless, according to the opinion that was issued by the Legal Council of the State and accepted by the Minister of Development, RAE decisions are subject to ex ante legal control by the Minister itself.

RAE draws on its own economic resources, i.e. levies applied to the regulated industry, and has a budget which is independent from the State budget. The financial operation of RAE is subject to ex post control by the High Court of Audit.

In terms of administration, RAE is assisted by a Secretariat which is manned by two main staff categories: administrative staff and scientists. Currently RAE has approximately 60 employees.

RAE is not simply an advisory institution; besides its advisory responsibilities, regarding mainly the proposal to the responsible State institutions of any measures deemed necessary for energy market restructuring according to the principles of liberalization and consumer protection, RAE also has a set of specific competencies, as provided in the liberalization directives.

More specifically RAE duties and responsibilities may be summarized as the following:[11]

(i) Advisory duties:
   - Proposals for the adoption of measures regarding energy market restructuring according to the principles of liberalization and consumer protection.
   - Opinion (simple or binding) for the issuance of secondary legislation in the energy sector, according to specific delegations included in the Laws.
   - Simple opinion for the issuance of licenses.
   - Simple opinion for regulated tariffs.

(ii) Decision making powers:
   - Imposition of administrative sanctions, mainly fines.
   - Approval of implementation details of the Codes.
   - Issuance of decisions in case of complaints against the companies that are involved in the monopolistic parts of the market.

(iii) Dispute settlement procedures, including arbitration in cases of disputes between consumers and market participants or between market participants and the companies having duties with regard to the networks.

(iv) Monitoring and reporting duties regarding the performance of energy enterprises.

(v) Monitoring duties regarding security of supply.

While exercising its duties, RAE is obliged to comply with the legality principle and its decisions, when not solely advisory, are subject to judicial review by the Athens Administrative Court of Appeals.

For the purpose of ensuring parliamentary control and accountability, RAE is obliged to publish and submit to the Parliament, via the Minister of Development, an annual report giving detailed information about its functioning and acts.

### *4.3. Regulatory reform, including adoption of incentive regulation for the natural monopoly network activities*

Due to difficulties faced in the past as regards compliance with accounting unbundling obligations, incentive regulation for the natural monopoly network activities is still not applicable in

[10] Initially RAE was composed of five members.

[11] See Annual Report 2006 to EC drafted by RAE – July 2006, pp. 4–6.

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Greece, since this model was considered more complex. Future application of incentive regulation is not excluded.

### 4.4. *Definition of rules concerning consumer protection, allocation of energy subsidies, and stranded costs*

Rules regarding consumer protection are included in the Supply Code that was issued in 2001 and includes two parts, that is for eligible and non-eligible customers. The provisions of these Codes have not been revised following the amendments of the initial provisions of Law 2773/1999 and this situation is a source of uncertainty and incompatibilities.

Specific rules as regards supply contracts apply to dominant suppliers and mainly to PPC for as long as it supplies more than 70% of eligible customers' total consumption. These rules include regulation of tariffs and of the contractual terms and conditions.

According to Article 26 of Law 2773/1999, PPC is supplier of last resort, having the obligation to supply all customers that cannot find another supplier. In such cases, PPC may request approval of special tariffs, enabling the recovery of eventual cost that is due to the fact that such customers previously had another supplier. Such tariffs have not been approved yet. In May 2007 RAE launched a public consultation with the purpose of granting an opinion to the Minister for the approval of such tariffs. This procedure is also ongoing.

## 5. Industry-related aspects of the electricity market reform program

### 5.1. *Corporatization of state owned utilities*

The state owned utility of the electricity sector, namely PPC, was created in 1950 as a vertically integrated company. Within the framework of a policy aiming at the reduction of the scope of the public sector in Greece and thus aiming at improving economic efficiency, partial privatization has been decided. However, privatisation of electricity assets is not foreseen.

According to the provisions of the Presidential Decree (PD) 360/1991, PPC was exempted from many special restrictions that are applicable to the public sector, such as restrictions regarding personnel hiring, procurement of goods, services and works.

With the Presidential Decree no. 333/2000 which was issued upon delegation of Law 2773/1999, PPC was converted in December 2000 to a "Société Anonyme" (PPC SA) that is, to a private law company. Subsequently PPC SA stocks have been introduced in the Athens and London stock exchanges.[12] After three public offerings, 49% of PPC shares belong to the general public, to institutional investors, and to the PPC's employee insurance fund (4%). The rest of the shares belong to the Greek State which, according to the legislation in force, must remain the majority shareholder.

PPC SA is still today a vertically integrated company, participating in all sub-sectors of the electricity market. PPC has approximately 26,200 employees, working in the distribution, mining and generation activities. It owns and operates 98 power generating units (95% of total power generation with the exception of RES; 12,695 MW) and is the exclusive owner of the transmission system and of the distribution network. It participates in the electricity supply business, supplying more than 98% of the electricity consumed in Greece. PPC actual basic organizational structure includes five business divisions: mines, generation, transmission, distribution and supply. The distribution and supply business are not yet fully unbundled.

PPC 100% owns four subsidiaries: PPC Telecommunications, PPC Crete S.A., PPC Rhodes S.A. and PPC Renewables S.A. A large subsidiary is the one active in the renewable energy sources business. The PPC Rhodes and Crete companies were created for the purpose of participating in the tendering procedure for new units in the respective islands which was launched in 2001. These subsidiaries are currently under liquidation. PPC Telecommunications holds 49% of the shares of the telecommunications company Wind-PPC Holding NV, whereas the remaining 51% is owned by Wind Spa. Wind-PPC Holding NV owns 100% of the shares of TELLAS A.E., a Greek telecommunications company. Furthermore, PPC owns 28.6% of LARKO S.A., a nickel production company, and 49% of the Hellenic Transmission System Operator (HTSO) S.A. Finally, "SENCAP S.A.", a registered Greek Société Anonyme, was incorporated in 2006 by PPC and ContourGlobal LLC, for acquiring and developing energy projects in South Eastern Europe.

### 5.2. *Unbundling of vertically integrated utilities*

According to the initial provisions of Law 2773/1999, legal unbundling was introduced only for the operation of the transmission system. The related responsibilities were assigned to Hellenic Transmission System Operator S.A. (HTSO),[13] a majority state-owned company, with 49% of its shares belonging to PPC.

As Law 3426/2005 provides, on 1 July 2007 the HTSO[14] should also acquire the responsibility for the operation of the distribution network, with the exception of the network that is located on the non-interconnected islands;[15] HTSO would then be renamed the Hellenic Transmission and Distribution Systems Operator (HTDSO), and will follow an organizational model of a combined transmission and distribution operator. However, even after such changes, the duties, financial resources and capabilities of this company will still remain relatively limited since it still will not obtain the ownership of the network and grid assets. The organizational changes prescribed by Law 3426/2005 have not taken place yet. A revision of the unbundling model is currently under consideration, in order to introduce a more efficient scheme.

In parallel, being the exclusive owner of the transmission system and of the distribution network, PPC remains responsible for their expansion and maintenance, and will be subject to the Operator's relevant plans and orders. According to the Law 3426/2005, such PPC duties shall be accomplished within the framework of specific contracts, concluded between PPC and the HTSO; such contracts have not been concluded yet.

In order to overcome potential incompatibilities with the EU directive in relation to the issue of unbundling, Article 27 of Law 3426/2005 comprises specific rules for the implementation of functional unbundling between the PPC divisions that are responsible for the networks and the divisions active in the competitive parts of the sector, i.e. generation and supply. These rules involve the obligation of PPC to create specialized business units for the network and the operation of non-interconnected islands, as well as the obligation to guarantee the independence of the management of these business units and the protection of the staff's professional independence. The same provisions also establish

[12] According to Article 15 of Law 3429/2005, PPC is also exempted from the provisions regarding the public sector in a broader sense, since its stocks are introduced in stock exchanges. Public sector rules apply only with respect to strictly enumerated cases in the same Article and refer mainly to personnel issues.

[13] See HTSO website: www.desmie.gr.

[14] According to the Law, until that date, for reasons related to functional unbundling, a special department of PPC has to undertake the responsibilities of the Distribution System Operator; this department will consequently be transferred to the HTSO.

[15] Due to the small size of the electrical systems of the non-interconnected islands, legal unbundling requirements are not applicable.

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a control mechanism, and authorize the Minister of Development upon opinion issued by RAE, to order structural changes if deemed appropriate.

As regards accounting unbundling, infringement procedures were launched by RAE against PPC because of non-compliance with the provisions of the Law 2773/1999 regarding unbundling and publication of separate accounts for the years 2000, 2001 and 2002 mainly with respect to its activity of lignite mining. These procedures led finally to the imposition of administrative fines against PPC. This was the reason for a lengthy period of dispute between RAE and PPC that ended in December 2005, as RAE after a long period of consultation finally accepted the submitted accounts for 2001–2002 and 2003.[16] Nevertheless, RAE stated that PPC should submit the unbundling methodology and its implementation for the Balance Sheet and Income Statement for 2004, 2005 and 2006 according to the provisions of the recently adopted Law 3426/2005.[17] During the first months of 2007 the unbundling methodology and the rules for the establishment of PPC separate accounts were approved by RAE.

### 5.3. Provision of third party access to networks

Since the beginning of market liberalization Greece adopted the regulated Third Party Access (TPA) regime. According to the Law, transmission system connection and usage tariffs are regulated by decision of the Minister of Development following opinion by RAE and according to a methodology that is also set by the Minister, following consenting opinion by RAE.

The TPA tariffs currently in place for the High Voltage Transmission System reflect a 30-year period of recovery of cost of capital, and apply an 8% annual rate of return. Similarly, the Distribution Network tariffs are also regulated by decision of the Minister following binding opinion by RAE. However, the tariffs for access to medium or low voltage systems have not been adopted yet.

According to the Law, the HTSO is responsible for ensuring TPA of generators, suppliers and eligible customers under equal and non-discriminatory rules that are included in the Transmission System (and the Network) Operation Codes. According to these provisions, upon application of the interested party, the HTSO shall prepare and submit a connection offer, which includes the design of the proposed connection and the budget. HTSO is obliged to select the most cost-effective and technically acceptable design of new connections.

Due to the exclusive ownership of the networks by PPC, TPA becomes practically effective through tripartite contracts between PPC, HTSO and the applicant for connection. The HTSO has limited capabilities and responsibilities as regards new connections, since these are constructed by PPC. This distribution of responsibilities has resulted in significant problems and delays during the construction of new connections. In order to overcome such problems, with the provisions of Law 3175/2003, the HTSO acquired similar rights as those entrusted to PPC and has the right to proceed with any expropriation that is eventually necessary for the construction of network installations. However, the situation has not changed significantly.

The new System Operation and Power Exchanges Code (2005) provides that when PPC demonstrably invokes reasons of inability to comply with the project implementation time schedule or to ensure project financing regarding new connections, the HTSO may, subject to RAE's approval, undertake itself or assign to third parties the construction of System projects, the expenses being borne either by the TSO or third parties through self-financing, or through any other suitable method to be decided by the TSO, subject to RAE's approval. The cost of such projects shall be recovered by the TSO or it shall ensure such recovery through charges for the use of the System. Similar provisions were also included in the first System Operation Code. However, the HTSO up to now has been hesitant in applying such provisions.

Finally, the northern interconnections of the electricity System are congested. The System Operation and Power Exchanges Code in force provides for the application of market-based mechanisms (explicit auctions) for long-term interconnection capacity allocation, and for implicit auctions as regards short-term capacity nomination. Rules of good management like the 'use-it-or-lose-it' principle and imports–exports netting also apply.

## 6. Consequences of the restructuring program

### 6.1. Establishment of a competitive wholesale market and capacity assurance mechanism

As mentioned above, after the enactment of Law 3175/2003, a new System Operation and Power Exchanges Code, providing for the organization of a competitive Day-Ahead Wholesale Market, was adopted in 2005. The applicable model is the one of the mandatory pool system (see Fig. 1).

The HTSO is granted the duties of the market operator. Within that framework, the HTSO:

- Collects (a) the demand declarations that are submitted by the load representatives and exporters, and (b) the generation offers that are submitted by the generators and the importers.
- Computes the system marginal price (SMP) for each hour of the next day by sorting in ascending order the economic bids.
- Determines the operation schedule for the next day applying least cost unit commitment based on economic offers and system constraints.
- Controls the operation of power plants and the use of interconnections.
- Settles financial transactions, and manages imbalances.
- Plans for and carries out the provision of ancillary services, such as voltage control, reactive power and power reserves.

- Generation offers include an economic bid (except renewable energy sources other than large hydro), which has 10 steps for each hour of the next day and must be equal to or higher than the unit fuel cost of the plant. A price cap is applicable (150 €/MWh).
- Withholding capacity is not permitted except in case of planned or unplanned outage; otherwise the HTSO is responsible for imposing penalties on generators.
- All financial transactions between the HTSO and generators and suppliers are carried out on the basis of the SMP.
- Bilateral contracts with physical delivery are not permitted; but, bilateral contracts about financial settlements (e.g. contracts for differences) are permitted and are uncontrolled.
- Capacity Certificate Obligations for load representatives, i.e. suppliers and auto-supplied customers, apply. More specifically, according to the capacity assurance mechanism:
  - Capacity Certificates are issued by all generators, refer to a future date and declare technical availability of certain power capacity (even future) from a specific power plant – generators may price their Certificates freely.

[16] On December 2004 the Commission launched an infringement procedure against the Greek State for not implementing correctly the provisions of Dir. 96/92/EC regarding accounting unbundling (case C-182/05) – IP/04/1498. After the approval of the accounts by RAE, the case was closed.

[17] See Annual Report 2006 to EC drafted by RAE – July 2006, pp. 31–33.

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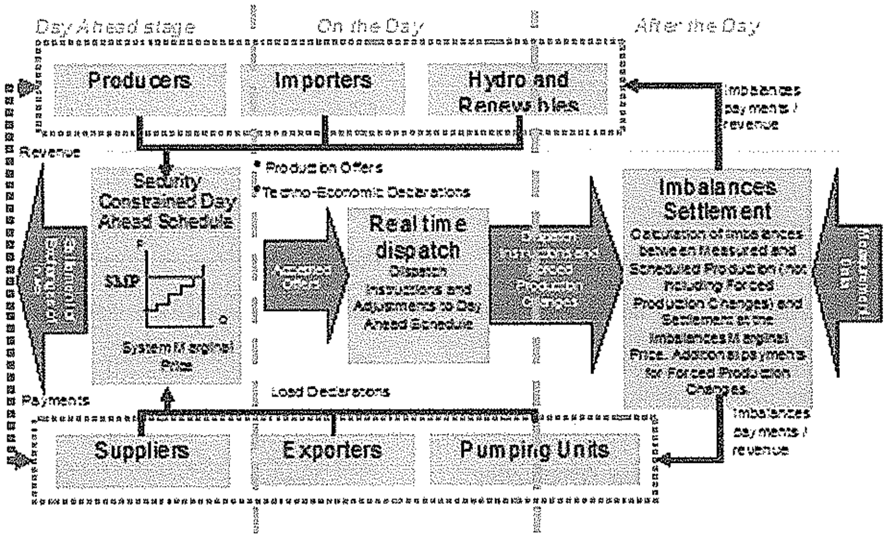


Fig. 1. Wholesale electricity market. Source: RAE.

- o Each supplier bears the obligation to submit to the HTSO Capacity Certificates up to a level covering the peak load of its customers; otherwise a penalty is applied by the HTSO.
- o Suppliers purchase their Certificates from Generators under bilateral financial agreements that are not regulated. Vertically integrated companies (e.g. PPC) are not obliged to enter into such financial agreements.
- o During a transitory period, in order to purchase power from the Day-Ahead Wholesale Market, suppliers other than PPC may just pay a fee which is currently set at 35,000 €/MW-year.
- o Total cost borne by suppliers is equal to system marginal price, plus capacity payments corresponding to Capacity Certificates.
- In case of inadequacy of supply, the HTSO may organize tenders for new capacity by granting capital revenue guarantees. The first tender was launched in 2006. This tender was stopped in summer 2007, since upon a complaint related to the tender rules and specifications the European Commission expressed doubts regarding compliance with the general principles of EU legislation.

Rights to use the interconnections for imports are granted after yearly and short term auctions for part (North) or the whole (Italy) of capacity. From 2007 PPC is also obliged to participate in such auctions, while up to December 2006 a capacity slot of the northern interconnections was granted directly to PPC. Exports are permitted only if the exporter is also a power generator in Greece, if the exporter holds Capacity Certificates, or if he is an importer.

### 6.2. *Liberalisation of the retail supply market*

The electricity market opening started on 19 February 2001, when consumers connected to the HV System or the MV Network acquired the right to choose supplier. Under the provisions of Law 3175/2003 from 1 July 2004 all non-household customers situated on the interconnected system (representing around 70% of the annual electricity consumption) became eligible. However, in 2003 still only five eligible customers were served partially by a supplier other than PPC, covering a small part of their load through imports.

According to Law 3426/2005, on 1 July 2007 all customers, including households, became eligible. Nevertheless, the practical consequences of market opening are rather negligible, since no one has changed supplier so far. This is mainly due to the regulated tariffs that PPC is obliged to apply: as explained below, these tariffs are often below cost, making new entry into the supply business almost impossible.

A request for derogation regarding the small non-interconnected islands (not including Crete and Rhodes) was submitted by the Greek Government to the European Commission. If such derogation remains in place, consumers situated on such islands will remain non-eligible for the purposes of the EC Electricity Directive, and PPC will remain the sole generator, distributor and supplier operating on such islands.

The condition for entering the supply business is the issuance of a supply license and proof of adequate power generation capacity through the capacity assurance mechanism. Licenses to Supply are restricted in terms of power. All licensed suppliers (29 licenses for a total capacity of about 4936 MW) other than PPC are currently traders selling imported electricity from the North interconnections mostly to the Day-Ahead Market, since market prices are more profitable compared to the regulated tariffs applicable by PPC (Table 1).

## 7. Recent performance of the electricity sector

### 7.1. *Investment*

#### 7.1.1. *Interconnected system*

Between 1995 and 2007 total nominal installed capacity of the electricity generation system in Greece rose from 9198 to 12,229 MW. However, because of high increase of electricity demand, Greece is currently lacking sufficient power capacity. Investment in power generation, particularly during the past seven years which coincide with the first steps of market liberalization, has not been sufficient to allow for a normal reserve margin. Electricity demand and in particular the growth of peak load has been growing at a rate of 4% per year on average.[18] Peak load is currently above 9960 MW and the reserve margin close to zero.

The main energy form used to generate power in the interconnected system is indigenous lignite which is extracted (mainly

[18] Historically, the demand for electricity increased from 80 kWh per capita in 1950 to 4808 kWh in 2005. Electricity per capita is still low compared with the EU average.

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**Table 1**
Market opening

| Year | Threshold (GWh/year) | % Market opening |
|---|---|---|
| 1999 | N/A | 0 |
| 2001 | 1 kV | 34 |
| 2005 | All except households and non-interconnected islands | 70 |
| 2007 | All except non-interconnected islands | 92 |

Source: Annual Report 2006 to EC drafted by RAE.

by PPC) from surface mines located mainly in the northwest part of Greece (Ptolemaida/Kozani) and secondarily in the Peloponnese (Megalopolis). Lignite plants cover mainly the base load. It is worth mentioning that 1150 MW of the 5288 installed MW of lignite power plants are very old; therefore PPC is currently considering their replacement.

Natural gas was introduced to the Greek energy system after 1996 (Law 2364/1995). Since then, the share of gas in total electricity generation has been continuously increasing. During the last decade, new combined cycle natural gas generation units were commissioned and part of the old oil-firing plants have been transformed to burn natural gas. As a result, the share of natural gas in total electricity generation increased significantly from 5.1% in 1999 up to 21% in 2007. At the same time, the share of oil-based power generation decreased from 18.8% down to 6%.

Oil-fired power plants installed in the mainland system are few and very old; they use residual fuel oil and operate mainly for supplying ancillary services and reserve power (e.g. PPC units in Lavrio and in Aliveri).

Hydroelectric plants are based on water reservoirs and operate so as to cover peak load. The installed capacity of renewable energy sources is still very small, despite the high potential of wind power and of solar energy. Hybrid schemes have not yet been constructed; however, the recently adopted Law 3468/2006 clarifies the energy tariff regime that is being produced in Hybrid energy sources and is therefore expected to stimulate anew the investment interest for particular projects that had been examined in the past (Fig. 2).[19]

Cogeneration plants (CHP) are few and small; their total installed capacity is 216.3 MW and they are linked with industrial applications. Only six distinct cases of CHP are operating. There also exists a small system of district heating with steam extracted from PPC's lignite plants. The first large CHP plant of 330 MW is expected to be commissioned in 2008 and belongs to the company Aluminium of Greece S.A (a large industrial company). That plant is linked with the production of raw material for aluminium melting.

The currently installed capacity of electricity generation of the interconnected System is shown in Table 2.

*7.1.2. Non-interconnected islands*

As mentioned in Section 3.1, most of the Greek islands in the Aegean Sea are not interconnected with the electricity grid of the mainland and have local autonomous systems. The biggest autonomous systems are those of the islands of Crete and Rhodes.

Oil is almost exclusively the energy form used for electricity production in the non-interconnected islands; oil-fired plants cover more than 99% of total electricity produced in these islands. The percentage of RES is still small (below 10% of nominal installed capacity).

Table 3 shows the currently installed capacity of electricity generation in the non-interconnected islands.

[19] For further information on RES see GREECE – Renewable Energy Fact Sheet, in ec.europa.eu/energy/energy_policy/doc/factsheets/renewables/renewables_el_en.pdf.

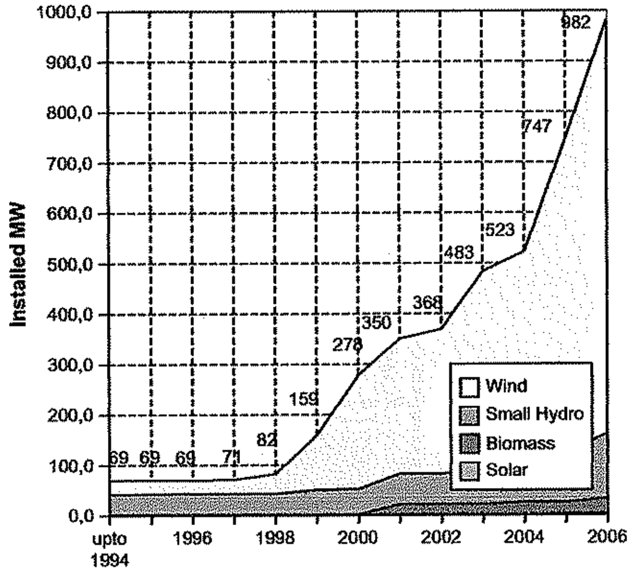


**Fig. 2.** The cumulative capacity of RES installed plants. Source: Ministry for Development 2005 – Third National Report regarding the penetration level of RES.

With the exception of RES, all generation licenses regarding the islands are held by PPC. PPC also holds licenses for two new oil-fired plants to be built on Rhodes (120 MW)[20] and on Crete (270 MW).

The introduction of natural gas on the island of Crete is still under consideration, although positive proposals had already been submitted by RAE in 2003. Furthermore, projects for large-scale interconnection of the islands with the electricity grid of the mainland are currently under consideration.

*7.2. Prices and consumer issues*

Total net electricity consumption in the Greek interconnected system is estimated to be about 54.586 TWh in 2004 and about 53.4 TWh in 2005, of which 1.34 TWh were transmission system losses.

Table 4 shows the increase of electricity sales in Greece since 1955, including exports and excluding electricity sales to lignite mines.

Residential and commercial customers represent approximately 66%, industry 28% and agriculture 6% of total demand. The average load factor of power demand is approximately 61.5% (Fig. 3).

As the law provides, PPC is obliged to supply non-eligible customers at prices that are regulated by decision of the Minister of Development issued upon opinion by RAE. Eligible customers have the right to negotiate prices with the supplier of their choice. However, aiming at mitigating the excessive market power of PPC, according to the provisions of the Eligible Customers Supply Code (2001), the tariffs applicable by PPC to eligible customers are also regulated for as long as the said company supplies more than 70% of

[20] The generation license for the island of Rhodes was granted by decision of the Minister of Development directly to PPC following an unfruitful tendering procedure. This license was annulled following a decision of the Council of the State, i. e. the Supreme Administrative Court. In August 2007 a new license was granted to PPC, according to the provisions of Law 3426/2007 that introduced a bottom–up procedure also for the non-interconnected islands.

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**Table 2**
Interconnected system installed capacity (2007)

| Type | Installed capacity (MW) | Percentage (%) |
|---|---|---|
| Lignite | 5288 | 43 |
| Natural gas | 2523 | 21 |
| Oil | 750 | 6 |
| Hydro-electric >10 MW | 3057 | 25 |
| RES | 611 | 5 |
| Total | 12,229 | 100 |

Source: PPC, HTSO.

**Table 3**
Non-interconnected islands installed capacity (2007)

| Region | Fossil capacity (MW) | RES (incl. Hydro) (MW) | Total (MW) | % RES |
|---|---|---|---|---|
| Crete | 730 | 18 | 748 | 2.4 |
| Rhodes | 206 | 0 | 206 | 0 |
| Rest non-interconnected islands | 581 | 13 | 594 | 2.2 |
| Total | 1517 | 31 | 1548 | 2 |

Source: Ministry of Development.

total electricity consumption of eligible customers of Greece.[21] Currently PPC supplies more than 98% of total electricity consumption in Greece, i.e. approximately 7.1 million customers.

The structure of PPC tariffs, that is, the rules defining tariffs as applied per sector, has remained unaltered since the beginning of the monopoly period, i.e. for almost 40 years. Only the numerical values of total tariff levels per sector are changed every year as a result of government's regulations. These tariffs are applied in a uniform manner for all customers independently of their geographic location in Greece. The tariffs vary per connection voltage level and sector to which the consumer belongs (for example industry, residential, etc.). Recently RAE launched a procedure for the revision and rationalization of PPC tariffs. This procedure is ongoing. Furthermore, PPC recently elaborated and presented an unbundled tariff structure, separating the regulated from the competitive charges.[22]

Low tariffs are exceptionally applied for agriculture, PPC employees and families with more than three children.

The High Voltage (HV) and the Medium Voltage (MV) tariffs are binomial: they are based on separate charges for power and for energy. The tariffs apply a generally higher price on the power component (MW) than on the energy component (MWh). The related supply contracts apply 'take-or-pay' obligation clauses regarding the power component, based on mentioning in the contracts per customer the volume of power on which take-or-pay obligations apply.

The Low Voltage (LV) tariffs are based only on an energy component and include a fixed payment term. The residential tariffs vary stepwise and follow an upwards increasing slope; the first step is almost half the fourth and the subsequent steps.

Commercial and small industry electricity prices are significantly higher than average electricity cost, whereas the High Voltage prices as well as the residential and agriculture tariffs are below average cost.[23] Therefore, cross-subsidizations between different consumer categories exist in Greece. Also cross-subsidizations apply to the benefit of consumers located in non-interconnected islands.

Interruptible tariffs are not applied. However, in order to overcome supply shortages during the summer, over the last few years, PPC, upon decision by the Minister of Development and opinion by RAE, designed and offered to consumers specific economic incentives, so as to incentivise interruption of electricity consumption during peak hours. Covering peak demand has been a problem over the past years, particularly in summer and specifically in July. This is related to the high use of air conditioning installations.

Finally, as regards the contractual relations with its customers, PPC still applies the supply contract forms that were applicable during the monopoly period. The supply contracts are not negotiable. These contracts are indefinitely renewed, without any negotiation between customers and PPC. The contracts also include terms and payments regarding the connection to the grid. This practice raises uncertainties as regards the relationships between PPC and its customers and for these reasons PPC services are currently reviewing the stipulations of the old contract forms.

### 7.3. *Financial performance*

PPC tariffs are regulated according to a cost-plus methodology: Every year, PPC submits request claiming coverage of all kinds of cost incurred plus profit. The currently applied PPC tariffs were approved in summer 2006 (Fig. 4).

In March 2007 the Government decided to increase the industrial tariffs at a rate of 4%. Further increases were approved in December 2007.

Over the last two years, PPC has seen its costs growing as a result of high fuel prices, including the prices of natural gas and oil and the payments for purchasing $CO_2$ emission allowances, which are related to the EU Emission Trading Scheme (EU ETS). PPC claims that these additional costs have not been reflected in the regulated tariffs and is asking for revision or even for an automatic system for revision of electricity prices. However, the government has not yet accepted such a system.

Current customer supply electricity prices (average across all customers 81 €/MWh) are below estimated total cost of PPC (83 €/MWh) including a low rate of return on capital (below 5%). In addition, the lignite mining productivity is deteriorating and the generation fleet is old and a source of pollution.

As a consequence, PPC profitability has been decreasing during the last two years (from €502 million in 2004, to only €42 million in 2006), as operating costs are steadily increasing more than the increase of revenues. The current effective rate of return on capital of PPC is small and is estimated to be between 1% and 3%. New management has been appointed recently and therefore measures are expected to cope with the decreasing profitability trends.

### 7.4. *Efficiency*

As far as energy efficiency is concerned, power generation in Greece is characterized by low thermal efficiency on average. This is

**Table 4**
Increase of electricity sales

| Year | 1955 | 1960 | 1970 | 1980 | 1990 | 2000 | 2005 |
|---|---|---|---|---|---|---|---|
| GWh | 551 | 1422 | 8358 | 20,065 | 28,337 | 43,263 | 50,719 |

Source: PPC.

[21] In November 2007 RAE submitted a proposal to the Minister of Development in order to modify the Eligible Customers Supply Code. According to this proposal which is still under consideration, only MV and LV PPC tariffs shall remain regulated.

[22] For further details see the Strategic Plan of PPC that was presented in November 2007, in http://www.dei.gr/Default.aspx?id=3942&nt=18&lang=2.

[23] According to IEA recent studies, Greece has the lowest EU-15 household and industrial electricity tariffs: IEA, Energy policies of IEA Countries – Greece, 2006 Review, 2006, p. 128.

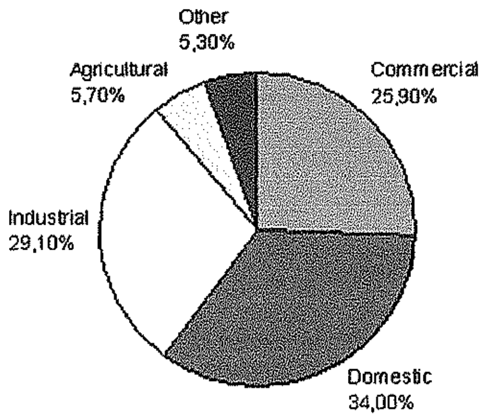


Fig. 3. Analysis of Greek electricity consumption (2003). Source: PPC.

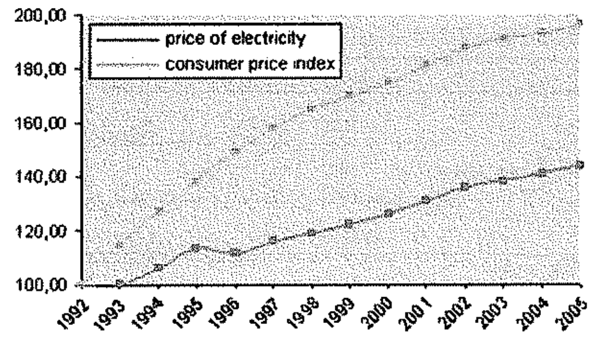


Fig. 4. Comparison of average price of electricity/consumer price index. Source: PPC.

due to the ageing of power plants owned by PPC, notably the lignite plants and the old open cycle oil and gas plants which are still in operation.

The new power plants built over the few past years are based on Combined Cycle Gas Turbine (CCGT) technology and therefore display high thermal efficiency rates. Since it is expected that most new investment will mainly apply the CCGT technology, average thermal efficiency of power generation in Greece is expected to rise. The average thermal efficiency of old plants is in a range between 0.31 and 0.33 which obviously is very low compared to state of the art technology. New power plants have an average thermal efficiency in the order of 0.50.

Concerning economic efficiency, the Greek power generation system is taking benefits from exploiting the low cost indigenous resources, namely lignite. For this reason, the ratio of fuel cost over total generation cost is among the lowest in Europe. However, this ratio is deteriorating, because of the increasing marginal cost of lignite.

Non-fuel components of operation costs as a ratio to total power cost is largely inefficient. Ratios such as labor costs per MW, operation and maintenance costs per MW and network costs per MW are all clearly above the European average.

### 7.5. Network coverage

The Greek mainland has a well-developed electricity transmission system which is interconnected with the transmission systems of the neighboring countries in the north and through a DC 400 kV direct-current submarine cable, with the Italian transmission system; an interconnection at the border with Turkey is currently under construction. Greece operates under the UCTE[24] system.

However, the electrical stability of the Greek electricity system is vulnerable because of the high concentration of generation units in the northwest part of the country and the high distance from the south where most of the load is concentrated. In addition, the synchronous and the high capacity interconnections with other countries are also located at the northern borders.

Transporting electricity to the main demand load which is situated in the South and principally in the Attica peninsula involves losses, high needs for reactive power and instability of voltage. Due to this high geographical imbalance between generation and demand, it is necessary to transfer large quantities of capacity along the North–South axis, through four long-distance High Voltage (HV) lines, which operate in parallel.

The interconnected Transmission System consists of the High Voltage (HV) lines of 149–400 kV, including the interconnections with neighboring countries, and of the 66 kV submarine connections to some of the islands. It has currently a length of approximately 11,300 km. Table 5 provides information regarding the expansion of the length of the Transmission System since 1955.

The (interconnected) Distribution Network consists of the Medium (MV) and Low Voltage (LV) lines, has approximately 7 million metering points and a length of 207,300 km, covering the whole population. Part of the Distribution Network is also the autonomous networks of the approximately 2000 non-interconnected islands of the Aegean Sea. Table 6 provides information regarding expansion of the length of the Distribution Network since 1955.

The exclusive owner of both the Transmission System and the Distribution Network is PPC. Within the framework of the unbundling requirements, however, the operation of the Transmission System was granted in 2000 to a separate company, namely the Hellenic Transmission System Operator S.A. (HTSO S.A.), mentioned first in Section 4.1, which from 1 July 2007 also became responsible for the operation of the Distribution Network. The HTSO does not own the grid assets.

As the law and the System Operation Code provide, the Transmission System expands according to a five-year Electricity System Development Plan, which is yearly prepared by the HTSO and approved by the Minister of Development following an opinion by RAE. The currently approved plan is applicable for the period 2005–2010 and aims at increasing reliability and the transmission capacity of the System. It includes the construction of the 400 kV interconnection with the Turkish system, the expansion of the 400 kV System to the southern part of the Peloponnese, the installation of submarine cables for the interconnection of some islands in the Aegean Sea, as well as new high voltage transformer centres (Patra, Rouf, Korinthos, Argyroupoli).[25] As an exclusive owner of the Transmission System, PPC is responsible – within the framework of contracts concluded with the HTSO – for the expansion of the system as well as for planning and carrying out the maintenance, the daily operation and its functionality. Such contracts have not been signed yet.

Detailed provisions regarding the expansion and maintenance of the Distribution Network will be included in the Distribution Network Code that has not yet been issued. The general provisions included in the law provide for the responsibility of PPC as exclusive owner of the Network to ensure the reliability, functionality and efficiency of the Distribution Network, and to provide undistorted third party access.

[24] Union for the coordination of transmission of electricity.

[25] For related information, see the HTSO website: http://www.desmie.gr.

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**Table 5**
Transmission system (HV)

| Year | 1955 | 1960 | 1970 | 1980 | 1990 | 2000 | 2005 |
|---|---|---|---|---|---|---|---|
| km | 1125 | 1960 | 4286 | 6612 | 9098 | 10,551 | 11,373 |

Source: PPC.

**Table 6**
Distribution network (MV & LV)

| Year | 1955 | 1960 | 1970 | 1980 | 1990 | 2000 | 2005 |
|---|---|---|---|---|---|---|---|
| km | 1480 | 9300 | 58,450 | 109,566 | 151,548 | 190,211 | 207,299 |

Source: PPC.

### 7.6. *Quality of supply*

Regarding the Transmission System, operating standards and obligations of the HTSO for ensuring and monitoring network performance are included in the System Operation Code. RAE is entrusted with the responsibility to control compliance with these rules.

In September 2006, a tendering procedure was launched by RAE for "Recording of the electric energy quality provided to consumers", in order to specify quality standards in compliance with the legal provisions in force. This study will collect data about the quality of the voltage system as provided at 500 metering points, according to the specific standards applicable according to the Standard EN 50160. The tendering procedure for the study is ongoing.

With respect to the Distribution Network, quality standards have not yet been set, due to the absence of the Distribution Network Code which is currently under preparation.[26]

## 8. Assessment of the impact of reforms

As we have seen, the market restructuring rules applicable since 1999 have not led to substantial changes in the market structure.

More specifically, although generation licenses for about 5500 MW were granted to independent power producers (IPPs), with the exception of RES that enjoy feed-in tariffs and small CHP, only two power plants were constructed and currently operate and both either belong to a state owned company or are financially covered by a state contract:

(a) The first significant IPP unit was a 150 MW gas-fired plant owned by HERON S.A. and located in Viotia (southern system). This unit was commissioned in 2004, after a call for tender launched by the HTSO for the provision of ancillary services regarding reserve capacity. The duration of the contract with the HTSO expired in summer 2007. Immediately after this, HERON S.A. signed a contract with PPC, according to which PPC becomes responsible also for the operation of this unit for a three-year period. This contract was notified to the Competition Commission and to RAE.

(b) The second IPP unit was a 400 MW CCGT gas-fired located in Thessaloniki (northern system), which has been in operation since December 2005. It belongs to T-Power, a subsidiary of the Hellenic Petroleum S.A., the state controlled petroleum company.

According to RAE reports and studies, the main reasons explaining the reluctance of new investors were related to high investment risk due to the market concentration and the institutional and regulatory framework in place.[27]

The establishment of the mandatory pool and the capacity certificate system are expected to facilitate new investment in CCGT plants. Most important, however, are the provisions of the legislation in force since 2003 about the tenders which would grant investment incentives, namely revenue guarantees, by the HTSO to new power plants. The first such tender was launched in summer 2006 and four bids were submitted in February 2007. The procedure is still pending due to a complaint that was submitted to the European Commission. However, it should be noted that investors already declared officially their willingness to construct new power plants even in the absence of any investment incentives.

Regarding RES, impediments to the construction of new energy infrastructure in Greece were the opposition of local communities and the excessive administrative burden. The administrative procedures regarding licensing are rather complex and time-consuming, while the respective decisions are often challenged for annulment before the competent administrative Courts, mainly on environmental grounds.

Again with the exemption of RES, all installed capacity on the non-interconnected islands belongs to PPC. According to the initial provisions of Law 2773/1999, a tendering procedure was provided for in order to grant generation licenses for new power plants on non-interconnected islands. Two tenders were launched in 2003 for the islands of Rhodes and Crete. Following an RAE decision according to which PPC bidding practices in the Rhodes tender were found to be predatory, the Minister of Development considered this tender unfruitful and granted directly to PPC the related license. The Crete tender was equally considered unfruitful, since only PPC submitted a bid.

With the provisions of Law 3426/2005, the bottom–up approach for also granting generation licenses for the non-interconnected islands was introduced. However, it is not expected that private investors will be interested in entering the generation business in such areas, since it is doubtful if such investment would be profitable due to the applicable PPC supply tariffs (cross-subsidization of customers located on non-interconnected islands).

As regards electricity supply, since the market organization was principally based on bilateral contracts between power generators and suppliers and due to the absence of any measures introducing a virtual IPP mechanism or other capacity or energy release measures, competition was limited to imports. However, the capacity of the northern interconnections of the Greek Transmission System is limited, compared to the size of the market, and additionally, until December 2006 a significant part of this capacity was allocated directly to PPC (for the purposes of ensuring supply to non-eligible customers).[27]

## 9. Political issues and political economy issues arising out of reforms

The main political issues that are currently under consideration are the eventual increase in PPC tariffs in order to reflect costs, and the rationalization of PPC cost, mainly with respect to labour costs. For the longer term, a matter of political concern is the eventuality that PPC loses significant market share which may create instability in PPC's finances and threaten its capability to cover its debt.

## 10. Suggestions for further reform

The current considerations for further reforms may be summarized as the following:

First of all, it is considered absolutely necessary to reform PPC prices, so as to reflect true costs and therefore to ensure profitability and viability of the company. Rationalization and reduction of PPC costs is another issue that has to be addressed.

[26] For further information see Annual Report 2006 to EC drafted by RAE – July 2006, pp. 25–26.

[27] See Annual Report 2006 to EC drafted by RAE, pp. 33–34.

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Promotion of competition in the retail market for the benefit of consumers is an objective that is often combined with the restructuring and rationalization of PPC tariffs.

A clear and coherent unbundling model, based mainly on efficiency considerations, has to be introduced, in order to avoid further delays as regards compliance with the EU acquis. This is also one of the main issues of the recently presented Strategic Plan of PPC.[28]

Promotion of new investment in order to ensure adequacy of power supply is the crucial issue for the Greek electricity market. Experience proves that this objective presupposes a stable regulatory framework and coherent regulatory decisions. Full application of the New Grid Operation and Power Exchanges Code is expected to play a significant role in enhancing new investment. However, the Code provides for the issuance of many Handbooks that shall contain detailed rules as regards the application of its provisions. It is therefore necessary to accelerate the publication of such Handbooks.

Finally, it is necessary to complete the regulatory framework by issuing all secondary legislation. The main regulatory gap that actually exists is related to the absence of a Distribution Network Code.

[28] For more information see the official site of PPC: www.dei.gr/Default.aspx?id=3942&;nt=18&lang=2.

***Policy Background***

*A European energy policy must pursue the objective of a sustainable, competitive and secure supply of energy. If the EU continues on its present course, this key objective will not be attained. In January 2007, the European Commission adopted an energy policy for Europe. This was supported by several documents on different aspects of energy and included an action plan to meet the major energy challenges Europe faces. Each European citizen must be informed of these challenges and the role they should play in meeting them.*

*Renewable energies help combat climate change while increasing security of supply.*

**Key Issues**

Hydro power has traditionally been important in Greece, and the markets for wind energy and active solar thermal systems have grown in recent years. Geothermal heat is also a popular source of energy. The Greek parliament has recently revised the RES policy framework partly to reduce administrative burdens on the renewable energy sector.

**Current national RES target**

The RES-E target to be achieved by Greece according to the EU Directive is 20.1% of gross electricity consumption by 2010. For biofuels, the following national targets have been set: 0.7% by 2005, 3% by 2007, 4% by 2008, 5% by 2009 and 5.57% by 2010.

**Progress towards meeting national targets**

In terms of RES-E share of gross electricity consumption, the 1997 figure of 8.6% had risen to 9.56% by 2004.

**Main supporting policies**

General policies relevant to RES include a measure related to investment support, a 20% reduction of taxable income on expenses for domestic appliances or systems using RES, and a concrete bidding procedure to ensure the rational use of geothermal energy. In addition, an inter-ministerial decision was taken in order to reduce the administrative burden associated with RES installations.

Greece has introduced the following mechanisms to stimulate the growth of RES-E:

- *Feed-in tariffs* were introduced in 1994 and amended by the recently approved Feed-in Law. Tariffs are now technology specific, instead of uniform, and a guarantee of 12 years is given, with a possibility of extension to up to 20 years.
- *Liberalisation* of RES-E development is the subject of Law 2773/1999.

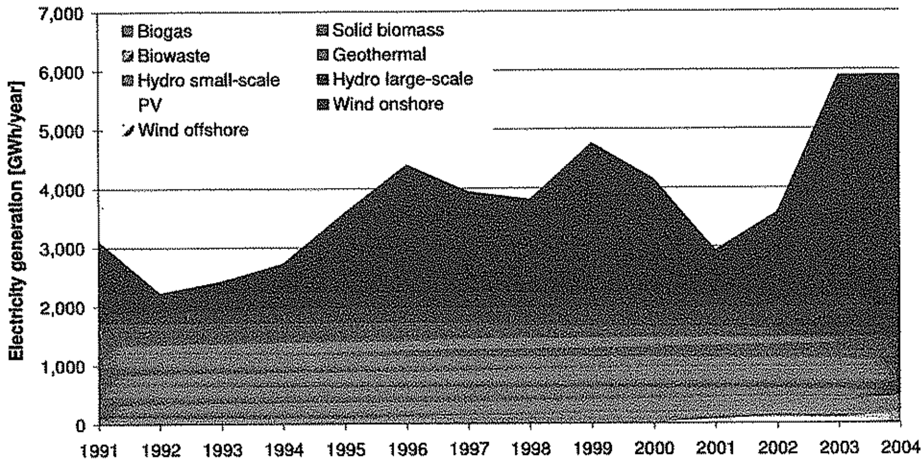
Fossil fuel taxes are not applied to biofuels.

Tax incentives were in place to promote RES-H, but these have been suspended for budgetary reasons.

**Key renewable energy statistics**

*Electricity from RES*: Large-scale hydro power continues to hold the largest share of the RES-E market (4,369 GWh in 2004). Onshore wind power accounted for 1,041 GWh in 2004, and grew at an average annual rate of 61% between 1997 and 2004. The level of production registered in 2005 was 1,243 GWh. PV accounted for 1 GWh in 2004, and grew annually, on average, by 27% between 1997 and 2004.

**Electricity generation from renewable energy sources by type (GWh)**




Source: European Commission
http://ec.europa.eu/energy/res/legislation/share_res_eu_en.htm

*Biofuels*: Production in the biofuels sector stood at 3 ktoe in 2005.

*Heating and cooling*: Biomass provides most of the RES-H in Greece (920 ktoe out of 1051 ktoe in 2004). Production has increased in the solar thermal sector, and the highest average annual growth, is that of heat from geothermal sources which stood at 28% between 1997 and 2004.

| | Penetration 1997 (ktoe) | Penetration 2004 (ktoe) | Av. Annual growth [%] |
|---|---|---|---|
| Biomass heat | 911 | 920 | 0% |
| Solar thermal heat | 101 | 128 | 3% |
| Geothermal heat incl. heat pumps | 2 | 13 | 28% |

Source: European Commission
http://ec.europa.eu/energy/res/legislation/share_res_eu_en.htm

**Good example: Project "5 MW WIND FARM IN COMPLEX TERRAIN"**

A 5 MW wind farm, with 10 wind turbines of 500 kW each, has been constructed on rough terrain in Sitia, on Crete. The wind turbines are produced by different manufacturers and come in two different forms, with different design and control concepts. The installation of the wind turbines on the same site enabled performance comparisons to be made under the same climatic conditions. In addition, the rough terrain in the area offered the opportunity of monitoring of the response of the wind turbines to a particularly turbulent wind flow. The results could be put to use in similar applications. The project was coordinated by the Organisation for the Development of Sitia.

**For further information**

To find out more about renewable energy, go to: http://ec.europa.eu/energy/res/index_en.htm

http://ec.europa.eu/energy/intelligent/index_en.html

To find out more about the current situation of renewable energy in the Member States, go to http://ec.europa.eu/energy/res/legislation/electricity_member_states_en.htm

http://ec.europa.eu/energy/res/legislation/share_res_eu_en.htm

To find out more about support measures, go to http://ec.europa.eu/energy/res/legislation/support_electricity_en.htm

To find out about a project or contact an energy agency in your region, go to http://www.managenergy.net/emap/maphome.html

Further fact sheets on Greece and other Member States can be found on:
http://ec.europa.eu/energy/energy_policy/facts_en.htm

**What is meant by.....?**

*RES:* Renewable energy sources
*RES-E*: Electricity production from renewable energy sources
*RES-H*: Production of heat and cold from renewable energy sources
*Biofuels*: Mainly includes biodiesel and bioethanol
*Biomass*: Includes solid biomass, biowaste and biogas
*CHP*: Combined Heat and Power
*GWh:* Gigawatthour
*ktoe*: Thousand tonnes of oil equivalent
*PV*: Photo-voltaic – technology for the production of electricity from solar energy

***Disclaimer***

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**Summary of a Greek article , published by the Newspaper "TA NEA" , 04/03/2006**

The Greek wind energy farm market attracts not only greek investors but also foreigners. This increasing interest is a result of the fact that the government is largely subsidizing the investments ensuring the absorption of the produced electricity. A lot of Eurpean firms like the Spanish Gamesa and Cesa, the French EDF and the German Enercon are going to invest in the Greek market.
The non-price competition is very intense since the firms use unfair means in order to achieve their purposes (access to key-lands).
The following tables depict the leading companies in relation to their wind-power producing capacity

| Companies | WindFrams Capacity |
|---|---|
| Rokas-Ibertrola | 200 MW |
| Terna Energy | 170MW |
| Copelouzos | 70MW |
| P.P.C. | 36,4 MW |
| Technodomiki | 24 MW |
| Others | 126 MW |
| **Total** | 615MW |

| Wind Turbines Manufacturers | Installed Power |
|---|---|
| Vestas | 243 MW |
| Siemens | 188 MW |
| Enercon | 53 MW |
| Nordek | 28,5MW |