CAREER AND BUSINESS OPPORTUNITIES IN MODERN ELECTRIC POWER SYSTEMS

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ABSTRACT

This paper presents the two major changes in the electric power systems, namely the deregulation of the electricity market and the growth in the production of electricity from renewable energy sources, mainly wind. These two changes form the so-called modern electric power systems. It is shown in this paper that the modern electric power systems create significant career and business opportunities.

Keywords: Electric power systems, electricity markets, deregulation, wind energy.

1. MODERN ELECTRIC POWER SYSTEMS

During the last decade of the 20th century, the electricity supply industry underwent major restructuring. In general, the restructuring of electric power industry creates different players in the market (the majority of which are new): vertically integrated utilities, generating companies, distribution companies, market operator, independent system operator, transmission companies, regulator, small consumers, and large consumers.

Another significant change in the electric power systems is the technological progress in the production of electricity from renewable energy sources, mainly wind. The oil crisis in 1973 stimulated a number of substantial Government-funded programs of research, development and demonstration of wind energy projects. Recent years have seen a growth in the implementation and economic viability of wind energy technology. As environmental concerns have focused attention on the generation of electricity from clean and renewable sources, wind energy become the world's fastest growing energy source. The operational wind power capacity worldwide from 4844 MW in 1995 was grown to 38706 MW in 2003, i.e. 700% increase in 8 years.

Deregulation and privatization in the electric power industry, growth of electricity production from wind and distributed generation systems form the evolution of traditional power systems to the so-called *modern electric power systems* [1], which result in significant career and business opportunities.

2. EVOLVEMENT OF THE ELECTRICITY SECTOR

For about a hundred years, the electricity supply industry was in the hands of vertically integrated monopoly utilities. During that time, engineers treated the management of this industry as a set of challenging optimization problems. Over the years, these optimization problems grew in size, complexity and scope. New algorithms were developed, and ever more powerful computers were deployed to refine the planning and the operation of power systems. With the introduction of competition in the electricity supply industry, a single organization is no longer in charge. Multiple actors with divergent or competing interests must interact to deliver electrical energy and keep the lights on. The evolvement of the electricity sector varies from one country, or region, to another but a general pattern of the following four phases developed [2].

2.1 Phase I

Private companies largely undertook the infrastructure investments in the late 19th and early 20th century. Private firms developed and commercialized the technologies for the production and delivery of electricity. Local monopolies, and national and international oligopolies that used their market power to extract economic rents from captive customers, dominated the new industry. Delivery to users was generally confined to urban communities, with limited development of distribution grids in rural areas. There was little competition in the sector during this period of rapid innovation and industry expansion.

2.2 Phase II

Around the time of World War II, a trend towards the nationalization of energy assets or at least strong government regulation of privately owned monopolies became the norm, in an attempt to limit abuses of market power. In many countries, governments also played an important role in rural electrification, since returns were too low to attract private capital. Elsewhere, state ownership of the electricity industry became the rule. Over time, however, public ownership and the absence of competition increasingly undermined effective management, innovation and operational efficiency. Governments used the power sector artificially to create employment and as an instrument to deliver hidden subsidies to parts of the economy.

2.3 Phase III

The economic costs of public ownership and monopolistic market structures became more and more apparent. In the 1970s, the United States began to experiment with power sector reform. By the 1980s, policy makers in Europe, the Americas and elsewhere realized that electricity, natural gas and telecommunications were no longer monopolies. Thanks to advances in technology, economic theory, and increasingly sophisticated regulatory instruments, it became feasible to introduce competition with the same effect as in other industries. Substantial improvements in operational and investment efficiency, the reduction of costs to end-users, an improvement of services, and a higher rate of innovation thus became possible. During the 1990s, electricity and natural gas sectors have been transformed through the overhaul of regulatory frameworks, the introduction of competition, and increasing private participation. These policy reforms have been implemented in developed and developing countries alike.

2.4 Phase IV

The fourth phase, which is now overlapping with the third, is characterized by convergence in the electricity, natural gas, and more generally the utility sector. ‘Multi-utilities’ are being formed to offer comprehensive service packages to clients and reap the associated economies of scale. As liberalization and privatization are taking hold, the industry is rapidly globalizing through international mergers and acquisitions, cross-border trade, and the creation of regional power pools. Another facet of the fourth phase is the emergence of a new ‘service’ sector in the power industry, quite distinct from physical distribution, classified now as the ‘wires’ business, involving electricity markets, and trade.

3. ELECTRICITY MARKETS

3.1 Specificities of Electrical Energy Trading

The development of electricity markets is based on the premise that electrical energy can be traded as a commodity. There are, however, the following three important differences between electrical energy and other commodities such as bushels of wheat, barrels of oil or even cubic meters of gas:

1. *Link with a fast physical system*: the most fundamental difference is that electrical energy is inextricably linked with a physical system that functions much faster than any market. In this physical power system, supply and demand – generation and load – must be balanced on a second-by-second basis. If this balance is not maintained, the system collapses with catastrophic consequences.
2. *Electrical energy cannot be stored* in large quantities, despite the recent technical advantages in electricity storage and microgeneration. This means that electrical energy cannot be stacked on a shelf – like kilograms of flour or television sets – ready to be used as soon as the consumer turns on the light or starts the industrial process.
3. *The electrical energy produced by one generator cannot be directed to a specific customer.* Conversely, a consumer cannot take energy from only one generator. Instead, the power produced by all generators is pooled on its way to the loads. This pooling is possible because units of electrical energy produced by different generators are indistinguishable. Pooling is desirable because it results in valuable economies of scale: the maximum generation capacity must be commensurate with the maximum aggregated demand rather than with the sum of the maximum individual demands. On the other hand, a breakdown in a system in which the commodity is pooled affects everybody, not just the parties to a particular transaction.

The above three main specificities of electrical energy trading have a profound effect on the organization and the rules of electricity markets.

3.2 Market Participants

The electricity industry throughout the world, which has long been dominated by vertically integrated utilities, is undergoing enormous changes. The electricity industry is evolving into a distributed and competitive industry in which market forces drive the price of electricity and reduce the net cost through increased competition.

Restructuring has necessitated the decomposition of the three components of electric power industry: generation, transmission, and distribution. This section presents the types of companies and organizations that play a role in the electricity markets. Since markets have evolved at different rates and in somewhat different directions in each country or regions, not all these entities will be found in each market. In some cases, one company or organization may perform more than one of the functions described below [3].

Vertically integrated utilities own generating plants as well as a transmission and distribution network. In a traditional regulated environment, such a company has a monopoly for the supply of electricity over a given geographical area. Following the liberalization of the electricity market, its generation and network activities are likely to be separated.

Generating companies produce and sell electrical energy. They may also sell services such as regulation, voltage control and reserve that the system operator needs to maintain the quality and security of the electricity supply. Generating companies that coexist with vertically integrated utilities are sometimes called *independent power producers*.

Distribution companies own and operate distribution networks. In a fully deregulated environment, the sale of energy to consumers is decoupled from the operation, maintenance, and development of the distribution network.

Retailers buy electrical energy on the wholesale market and resell it to consumers who do not wish, or are not allowed, to participate in this wholesale market. Retailers do not have to own any power generation, transmission or distribution assets.

A market operator typically runs a computer system that matches the bids and offers that buyers and sellers of electrical energy have submitted. It also takes care of the settlement of the accepted bids and offers, i.e. it forwards payments from buyers to sellers following delivery of the energy.

The independent system operator has the primary responsibility of maintaining the security of the power system. An independent system operator usually combines its system operation responsibility with the role of the operator of the market of the last resort.

Transmission companies own transmission assets such as lines, cables, transformers and reactive compensation devices. They operate this equipment according to the instructions of the independent system operator.

The regulator is the governmental body responsible for ensuring the fair and efficient operation of the electricity sector. It determines or approves the rules of the electricity market and investigates suspected cases of abuse of market power. The regulator also sets the prices for the products and services that are provided by monopolies.

Small consumers buy electrical energy from a retailer and lease a connection to the power system from their local distribution company. Their participation in the electricity market usually amounts to no more than choosing one retailer among others when they have this option.

Large consumers often take an active role in electricity markets by buying their electrical energy directly through the market. The largest consumers are sometimes connected directly to the transmission system.

3.3 Competition

The evolution of the electricity supply industry from a deregulated monopoly to full competition can be described with the following four models [4]:

1. *Monopoly*: the vertical integrated utility integrates the generation, transmission and distribution of electricity.
2. *Purchasing agency*: the integrated utility no longer owns all the generation capacity. Independent power producers are connected to the network and sell their output to the utility that acts as a purchasing agent.
3. *Wholesale competition*: no central organization is responsible for the provision of electrical energy. Instead, distribution companies purchase the electrical energy consumed by their customers directly from generating companies. These transactions take place in a wholesale electricity market. The largest consumers are often allowed to purchase electrical energy directly on the wholesale market.

4. *Retail competition*: all consumers can choose their supplier, i.e. this is the ultimate form of competitive electricity market. Fig. 3.1 illustrates the retail competition model. Because of the transaction costs, only the largest consumers choose to purchase energy directly on the wholesale market. Most small and medium consumers purchase it from retailers, who in turn buy it in the wholesale market. In this model, the only remaining monopoly functions are thus the provision and operation of the transmission and distribution networks.

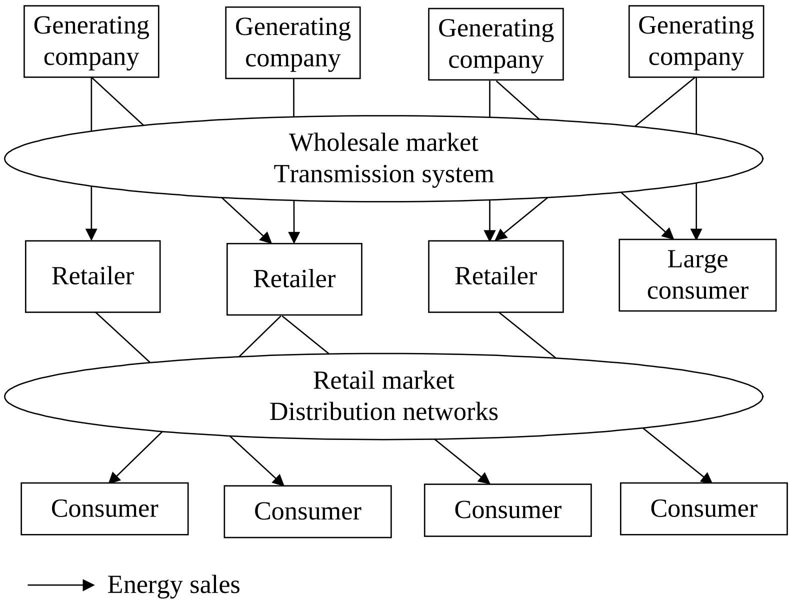

Fig. 3.1: retail competition model.

3.4 Status in Greece

The deregulation of the electricity market in Greece was introduced with the Greek law 2773/1999. More specifically, from the 19th of February 2001, the electricity market in Greece is fully deregulated in the production of electrical energy and partially deregulated in the supply of electrical energy where 7500 customers, connected in high and medium voltage, consuming 34% of the electrical energy in Greece, are characterized as 'eligible customers', since they have the opportunity to select their supplier [5].

The market participants in the Greek electricity market are the following:

1. *The Regulatory Authority for Energy (RAE)*. This organization is responsible for providing advice to the Minister of Development for the regulation of the electricity market.

2. *The Hellenic Transmission System Operator (HTSO)*. This body is responsible for the operation of the transmission network.

3. *The Public Power Corporation (PPC)*. A vertically integrated utility participating in the market as a producer of electrical energy and as a supplier for the eligible customers. Moreover, PPC has the exclusive rights to provide electrical energy to the 'non eligible customers'.

4. *Producers*. These are companies that own generating units. Their production is dispatched according to their economic offer.

5. *Produces from renewable energy sources and small cogeneration*. Their whole production is obligatorily absorbed by the HTSO and they are paid a fixed price for the energy (feed-in tariff model).
6. *Suppliers*. They sell energy to eligible customers.

3.5 Career and Business Opportunities

The deregulation of electricity markets offers significant career opportunities, such as:

- In the organizations that operate the market, i.e. the market operator, the independent system operator, and the regulator;
- In the generating companies as well as in the companies that undertake the design and manufacturing of the generating plants;
- In other market participants, i.e. transmission companies, distribution companies, retailers, large consumers.

It is obvious that in the electricity markets there is enough room for different scientists, for example, engineers, lawyers, regulators, and economists. The specialization is the key success factor for career development in the restructured electricity sector: personnel with good knowledge of economics, markets, and technology (e.g. operation of electricity markets) are in great demand nowadays.

In addition to career opportunities, the deregulation of electricity markets offers significant business opportunities, such as:

- Creation of new generating companies. This in turn increases the business opportunities for a number of other existing companies, such as:
  - companies that design and manufacture generating plants;
  - suppliers of electrical, mechanical and other equipment for the manufacturing of generating plants;
- Creation of new retailers.
- Creation of new distribution companies.
- Creation of energy service provider companies.

4. WIND ENERGY

4.1 Renewable Energy Sources

In Kyoto in 1997 agreements were reached on targets for greenhouse gas reductions for industrial nations and regions. The reductions are relative to emissions in 1990 and refer to a basket of six greenhouse gases dominated by CO_2. The targets are 8% for the European Union, 7% for the United States, 6% for Japan and 5.2% in average for the industrial world. The targets should be reached by 2012 and a second commitment period is expected to follow with stricter reduction targets. The main solutions for reaching the targets set by the Kyoto Protocol are energy conservation and the use of renewable energy sources.

Renewable energy sources include wind energy, solar energy, small hydro, fuel cells, geothermal, biomass, and wave power. Engineering for sustainability is an emerging theme for the twenty-first century, and the need for more environmentally benign electric power is a critical part of this new thrust. Renewable energy systems that won't diminish over time and are independent of fluctuations in price and availability are playing an ever-increasing role in modern power systems. Wind farms in Europe and the United States have become the fastest growing source of electric power; solar-powered photovoltaic systems are entering the marketplace; fuel cells that will generate electricity without pollution are on the horizon.

It should be noted that renewable energy sources have another role in energy policy besides contributing to reduction of CO_2 emissions. Fossil fuels, especially oil and natural gas, will be exhausted before the end of this century at the present rate of consumption. At the same time, the world population is approaching 10 billion people who will all need energy supply. The known alternatives are renewable energy sources and nuclear energy. There are many reasons why nuclear energy is not considered a desirable energy solution. This leaves renewable energy sources as the only sustainable energy supply in the longer perspective.

4.2 Promotion of Renewable Energy Sources

Due to relatively high costs of production, wind power and other renewable sources of electricity cannot compete in a free commercial market with mature technologies such as large hydro, combined cycle plants based on natural gas, efficient coal-fired combined heat and power plants or nuclear power plants. Therefore, special support systems are needed for the renewable energy sources until these technologies are commercially competitive. Two main promotional schemes have been applied in Europe [6]:

1. *Feed-in tariff model*: a long-term minimum price is guaranteed for electricity obtained from renewable sources. In combination with standardized costs for grid connections and short lead times, this pricing system has made it possible for developers to easily obtain bank financing for investments in wind power stations.
2. *Green certificates trading system*: introduces conditions of market competition into the production of green electricity for technologies that are not fully competitive with traditional supply systems.

In promoting the use of electricity produced from renewable energy sources, the greatest success have been obtained by the application of the feed-in tariff model in Denmark, Germany and Spain. Thus, if highest priority is given to fulfilling ambitious goals for the penetration of renewable energy sources, the natural conclusion would be to rely on the feed-in tariff model. The burden on the government budget can be reduced, by sharing the premium tariff between the electricity consumers. Competitive features may be introduced by using benchmarking principles. However, the feed-in tariff model does not fully conform to the principles of market competition.

The creation of efficient markets for green electricity is a complex process. Throwing renewable technologies into an uncertain commercial market may cause serious setbacks in extending the use of clean energy sources.

4.3 Development of Wind Turbines

A wind turbine is a machine that converts the power in the wind into electricity. This is in contrast to a 'windmill', which is a machine that converts the wind's power into mechanical power. Wind energy is the electrical energy produced by wind turbines. Wind energy has become the fastest growing energy source worldwide.

Wind energy technology itself moved very fast in new dimensions. At the end of 1989, a 300 kW wind turbine with a 30-meter rotor diameter was state of the art. Only 10 years later, 2000 kW turbines with a rotor diameter of around 80 meters were available from many manufacturers. The first demonstration projects using 3 MW wind turbines with a rotor diameter of 90 meters were installed before the turn of the 20th century. Now, 3 to 3.6 MW turbines are commercially available. Table 4.1 presents the development of wind turbine size between 1985 and 2004 [7].

Table 4.1: development of wind turbine size.

Year	Capacity (kW)	Rotor diameter (m)
1985	50	15
1989	300	30
1992	500	37
1994	600	46
1998	1500	70
2003	3000-3600	90-104
2004	4500-5000	112-128

4.4 Wind Power Economics

The cost of electricity from wind power has fallen to about one sixth of the cost in the early 1980s and the trend seems to continue. Over the past 10 years, the cost of manufacturing wind turbines has declined by about 20% each time the number of manufactured turbines has doubled. Currently, the production of large-scale, grid-connected wind turbines doubles almost every three years. The Danish Energy Agency predicts that a further cost reduction of 50% can be achieved until 2020 [8]. The European Union Commission estimates in its White Book that energy costs from wind power will be reduced by at least 30% between 1998 and 2010 [9]. Other authors emphasize, though, that the potential for further cost reduction is not unlimited and is very difficult to estimate [10].

A general comparison of electricity production costs is very difficult as production costs vary significantly between countries, because of the differing availability of resources, different tax structures and other reasons. In particular, the impact of wind speed on the economics of wind power must be stressed: a 10% increase in wind speed, achieved at a better location for example, will in principal result in 30% higher energy production at a wind farm.

4.5 Installed Wind Power Capacity

Wind energy was the fastest growing energy technology in the 1990s, in terms of percentage of yearly growth of installed capacity per technology source. However, it is concluded from Table 4.2 that the growth of wind energy has not been evenly distributed around the world. By the end of 2003, around 74% of the worldwide wind energy capacity was installed in Europe, a further 18% in North America and 8% in Asia and the Pacific.

Table 4.2: operational wind power capacity worldwide.

	Installed capacity (MW) by the end of year						
Region	**1995**	**1997**	**1999**	**2000**	**2001**	**2002**	**2003**
Europe	2518	4766	9307	12972	17500	21319	28751
North America	1576	1611	2619	2695	4245	4708	6677
South and Central America	11	38	87	103	135	137	139
Asia and Pacific	626	1149	1403	1795	2330	2606	3034
Middle East and Africa	13	24	39	141	147	149	150

Table 4.3 shows that, in Europe, the countries with the largest installed wind power capacity are Germany, Denmark and Spain. In these countries, the main driver of wind power development has been the feed-in tariff model. In Germany, for instance, the renewable energy sources act (EEG) defines the purchase price (feed-in tariffs) for wind energy installation in 2004 as follows: 8.8 eurocents per kWh for the first five years and 5.9 eurocents per kWh for the following years. The German government currently works at changing the EEG and the power purchase price. The aim is to introduce incentives for offshore wind power development through higher power purchase prices. At the same time, onshore wind power is expected to be forced to become more competitive by decreasing power purchase prices over the next years. It is also important to mention that the EEG and similar laws in other countries require network companies to connect wind turbines or wind farms whenever technically feasible.

Table 4.3: operational wind power capacity in Europe.

	Installed wind power (MW)	
Country	**1995**	**2003**
Germany	1136	14609
Spain	145	6202
Denmark	619	3110
Netherlands	236	912
Italy	25	904
UK	200	649
Greece	28	420
Austria	3	415
Sweden	67	399
Other countries	59	1131
Total	**2518**	**28751**

4.6 Status in Greece

4.6.1 Promotion of Renewable Energy Sources

Greece follows the feed-in tariff model, according to Greek laws 2244/1994 and 2773/1999. The main points of the legal framework for renewable energy sources (RES) installations in Greece are the following [5]:

- RES and combined heat and power (CHP) installations do not participate in the electricity market, they are priority dispatched and their energy is sold at fixed tariffs.
- RES electricity is remunerated at price linked to the general medium voltage customer tariffs. Energy is paid 90% of the respective retail price for island systems and 70% for the mainland.
- In mainland, the produced power is compensated at 50% of the applicable consumer tariff. In island power systems, no such credit is applicable.
- For CHP using non-renewable sources, similar tariff system applies as well as for self-producers.

The financing of RES installations in Greece is as follows:

- Wind Energy: 30% of the installation costs
- Photovoltaics: more than 40% of the installation costs
- Geothermal: more than 50% of the installation costs
- Biomass energy: more than 50% of the installation costs
- Energy saving programmes: more than 40% of the installation costs
- CHP: more than 35% of the installation costs.

The licensing procedures for RES installations in Greece are as follows:

- Each prefecture gives the necessary permissions for installing RES in its territory
- Regulatory Authority for Energy approves or not the investment plan and gives permissions for signature to Ministry of Development
- Ministry of Development signs authorizations.

The so far experience of Greece in regulatory framework to support renewable energy sources penetration has shown that [11]:

- There is a need for speeding up licensing procedures
- The licensing procedure should be differentiated according to the RES type of installation
- Effective co-operation of the local authorities with the investors was the key for speeding-up the procedure (e.g. Crete and Thrace).

The main barriers to the development of renewable energy sources in Greece are the following [12]:

- Most important is the complexity of the legal framework and particularly the licensing procedure, frustrating for many small investors;
- The often inhibitive cost for the interconnection to the grid (mostly reinforcement or construction of new network lines);
- For larger stations (more than ~20 MW) and in certain areas with very high wind potential, lack of sufficient high voltage system capacity. Due to environmental restrictions and local community protests, expansion of the high voltage system is in some cases completely blocked;
- In the case of wind farms, public acceptability has also been an issue in certain cases, basically due to visual impact or other reasons.

4.6.2 The Current Regime of Public Subsidies for RES Investments

RES projects of total budget of €1.061 billion were financed by the 2nd European Community Support Framework which was terminated at the end of 2002. Financial cost and energy data for Greece of the Operational Energy Program (sub-program 3) are presented in Table 4.4.

Table 4.4: Brief cost and production elements for RES installations that are financed by resources of the 2nd European Community Support Framework.

	Wind	**Small-hydro**	**PV**	**Biomass**	**Total**
Number of applications	14	9	15	13	**51**
Final budget (in million €)	124.5	17.2	6.1	48.5	**196.3**
Total public cost (in million €)	49.8	7.7	4.2	22.9	**84.6**
Total installed power capacity (MW)	116	11.5	0.74	8.74	**136.98**
Annual power production (TWh)	0.335	0.053	0.001	0.168	**0.557**

In addition, the projects were co-financed by the Greek Ministry of Economy in the framework of law 1892/1990 and law 2601/1998. National resources have financed approximately one third of the operating RES power stations.

The Operational Program "Competitiveness" of the Greek Ministry of Development uses resources from the 3rd European Support Framework and provides public aid for RES, energy conservation, energy substitution and other energy activities of €1.02 billion in total. The percentage of public aid is 30% of the eligible cost and can reach 50% in the case of electric networks connecting RES installations to main electric transmission networks.

4.6.3 Installed Renewable Energy Sources

Installed RES power capacity in which large-hydro systems have been included are presented in Table 4.5 [13].

Table 4.5: installed RES power capacity by the year 2003.

RES type	**Installed capacity (MW)**
Wind	420
Small hydro	66
Large hydro	3060
Biomass	8
Geothermal	0
Photovoltaics	0
Total	**3554**

4.6.4 Future Development of Renewable Energy Sources

In the respective Greek Annex, European Union Directive 2001/77 on “Power production from renewable energy sources in the local power market” foresees for Greece an indicative target of 20.1% coverage of the gross power consumption from RES including large-hydro, by the year 2010. This target is compatible with the international requirements against Greece deriving from Kyoto Protocol signed in 1997, in the convention-framework of the United Nations for climate change. Kyoto Protocol foresees for Greece restraint of greenhouse-gases increment by 25% in relation to the base-year 1990. By the year 2010, it is foreseen that the gross power consumption in Greece will have reached 72 TWh, so there is a need of RES participation at a level of 14.47 TWh (i.e. 20.1% of the gross power consumption).

In the near future, the realization of works for the enforcement of the networks is expected. In parallel, an estimate of the RES penetration potential by year 2010 can be drawn, based on the RES economic potential and the consequent investors’ interest. The estimated results are shown in Table 4.6. It is concluded from Table 4.6 that if all the foreseen investments will be realized, the target of EU Directive 2001/77 will be reached.

Table 4.6: optimistic estimation of RES power production by the year 2010.

RES type	**Installed capacity in year 2003 (MW)**	**Installed capacity estimation for 2010 (MW)**	**Power production by 2010 (TWh)**	**% per RES type by 2010**
Wind	420	2170	6.08	8.45
S-hydro	66	475	1.66	2.31
Large hydro	3060	3680	5.47	7.59
Biomass	8	125	0.99	1.37
Geothermal	0	8	0.06	0.09
Photovoltaics	0	5	0.01	0.01
Total	**3554**	**6463**	**14.27**	**19.82**

In case that only capital subsidy will be provided, the RES penetration levels will approach 14.5%, the target of EU Directive will not be achievable and the conservative estimation of Table 4.7 would be closer to the reality.

Table 4.7: conservative estimation of RES power production by the year 2010.

RES type	**Installed capacity in year 2003 (MW)**	**Installed capacity estimation for 2010 (MW)**	**Power production by 2010 (TWh)**	**% per RES type by 2010**
Wind	420	1200	3.36	4.67
S-hydro	66	200	0.70	0.97
Large hydro	3060	3680	5.47	7.59
Biomass	8	100	0.79	1.10
Geothermal	0	8	0.06	0.09
Photovoltaics	0	5	0.01	0.01
Total	**3554**	**5193**	**10.39**	**14.43**

4.6.5 Payback of Wind Power Installations in Crete

Table 4.8 presents the payback of wind park installations in Crete. For the calculations in Table 4.8, the following elements were used:

a) 7.5% payback interest rate (EWEA) [14]
b) The production and the tariff for each year of the installation for the wind park
c) The worst production year for the wind park
d) Constant value for wind production compensation (81.5 €/MWh)
e) 531000 €/600 kW wind turbine installation cost [15]
f) For parks with available (published) economic data, this economic data was used.

It can be concluded from Table 4.8 that the subsidy helps in having payback in less than 6.5 years. For the wind parks of PPC, similar results are foreseen, although it is possible that the payback is even shorter due to the fuel consumption reduction that is higher than the income for the wind producers.

Table 4.8: Payback of investments for wind parks in Crete.

Wind farm name	Installed capacity (MW)	Production start	Payback (years)	
			With Subsidy	Without Subsidy
ROKAS	10.20	May 1998	3.3	4.3
AIOLOS	9.90	May 1999	4.9	6.1
IWECO	4.95	May 1999	4.9	6.1
MARONIA	25.00	December 1999	5.3	7.8
WRE	2.40	August 2003	6.2	9.5
PLASTIKA	5.94	June 2003	2.6	3.6

4.6.6 Economic and Environmental Impact of Wind Production in Crete

For the economic assessment of the wind power production in Crete, the actual cost of the fuel consumed for the operation of the system during 2000 including the compensation of the wind power producers is compared to the cost obtained if the thermal units alone would cover the same load. It is not considered any effect wind power might have on personnel, capital and management costs, interests, etc.

Comparison between the actual cost of operation including the compensation of wind power producers and the cost of purely thermal operation under the same load and maintenance conditions, calculated optimally, is shown in Table 4.9.

Table 4.9: comparison of actual operation cost versus cost of purely thermal operation for the year 2000.

	Heavy Oil (tn)	Diesel Oil (klt)	Cost (k€)
Actual	263,166.5	283,303	178,505.6
Purely thermal	269,014.3	324,499	181,099.3
Difference	5,847.76	41,196	2,593.7
Percentage savings	2.22%	14.54%	1.45%

It can be seen from Table 4.9 that in 2000 annual savings of 1.45% are obtained amounting to a total cost of 2.6 million €. It should be noted that these costs do not include the costs incurred in the system by possible intentional load shedding due to security reasons. For example, with the current thermal installed capacity, if the Wind Parks were not installed, the unserved energy would reach 11.6 MWh in the periods (24/10/2000 at 13:05-13:20) and (10/12/2000 at 17:50-19:40) with a maximum load shed of 8.1 MW for 5 minutes. The evaluation of this cost is very complex and can include compensation by the Utility imposed by regulatory measures, special reliability tariffs, etc. A related issue is the economic gains obtained by the postponement of capital investments for the installation of new thermal units or the construction of new thermal stations, in order to maintain a satisfactory degree of reliability in order to cover the load.

Moreover, it is interesting to calculate the environmental benefits from the wind power penetration in the energy production of the Crete power system in 2000. These benefits are summarized in Table 4.10. In view of the EU commitments to reduce Greenhouse Gas Emissions and other pollutants in the near future, the above effect alone would possibly justify support for a wide exploitation of wind power resources in isolated, island systems and other regions in Europe.

Table 4.10: annual (2000) reduction of pollutants due to wind power production.

	Tn	**%**
Pollutant Particles	60.07	7.27
SO_2	368.49	2.41
NO_X	260.7	6.03
CO_2	119,42	7.78

4.7 Career and Business Opportunities

The fast development of wind energy industry offers career and business opportunities and has large implications for a number of people and institutions, for instance:

- for scientists who research and teach wind power, and engineers at the universities;
- for professionals at electric utilities who really need to understand the complexity of the positive and negative effects that wind energy can have on the electric power system;
- for wind turbine manufactures;
- and for developers of wind energy projects who need to develop feasible, modern and cost-effective wind energy projects.

5. CONCLUSIONS

Deregulation and privatization in the electric power industry and growth of electricity production from wind and distributed generation systems form the evolution of traditional power systems to the so-called modern electric power systems, which result in significant career and business opportunities.

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