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ELECTRICITY MARKET IN GREECE: THE PATH TOWARD LIBERALIZATION IN THE DIGITAL ERA

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ΕΛΛΗΝΙΚΗ ΗΛΕΚΤΡΙΚΗ ΑΓΟΡΑ ΕΝΕΡΓΕΙΑΣ : Η ΠΟΡΕΙΑ ΤΗΣ ΑΠΕΛΕΥΘΕΡΩΣΗΣ ΣΤΗΝ ΣΥΓΧΡΟΝΗ ΨΗΦΙΑΚΗ ΕΠΟΧΗ

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Abstract

Electricity market today faces dramatic changes such as evolution in customer behavior and expectations, policies regarding renewable and intermittent resources accompanied with technological advancements that need time to apply and return benefits.

“Electricity Market in Greece: the transition to liberalization“, is dedicated to review modern power frameworks around the world, analyze present energy policies and suggest certain guidelines to intensify electricity market reform in our country.

First chapter presents an introduction to the whole study, divided in four subcategories: background, production, transmission and distribution. Last three conform the phases of a power grid. Each one independently, initiates with historical references while proceeding with examples and technical analysis that provide a point of reference for evaluating the Greek perspective ultimately.

The second chapter presents case studies of modern power markets albeit with a historical background in order to better assess progress and efficiency. United States of America, France and Great Britain did install energy distribution systems for a long time and did face a lot of challenges and limitations. Currently, there are benefits by operational framework and reassuring future energy reforms.

Third chapter analyzes Greek electricity grid. Operational framework, European directives and corresponding inland legislation portray a contemporary pool market. Entities play an important role in current market operation and the corresponding relation inside European Union.

Fourth chapter includes research concerning limitations and challenges of the grid. Moreover, a comparison with other energy partners of European Union reveals potential market issues affecting efficiency and productivity.

Chapter number five, presents possible solutions and reforms that should be taken into consideration in order to achieve a better operational grid with profound benefits, both for market players and consumers.

Concluding the chapters, a brief recap of all chapters to remind that time is precious for Greece and the road to liberalization requires cost efficient measures and policies applied in a stable albeit constantly evolving competitive market model.

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Περιεχόμενα

Acknowledgements

My most sincere appreciation and blessing for the people who did support me

throughout the journey

Chapter 1 - An introduction to power grid systems

1.1 Introduction

The first documented alternate current power grid system was installed in 1886 . The basic infrastructure was comprised by certain stages such as power generation, power transmission, proper distribution and an early version of a demand-driven control system.

The interconnection of different grids in selected areas was first made possible in the first half of the 20th century due to technologic innovation of that era . Improvements were made to develop a better economic model and enhance reliability, especially during transmission. Metering accuracy was a field for improvement too and General Electric promoted changes in late 1960’s with the slogan “Time to retire old watt-hour meters” and stated the lost revenues as a direct effect of the slow-running meters (*IEEE Smart Grid forum, 2012*). Coal fired plants, oil generators and natural gas was the prime power for electrification.

From 1970’s and onwards, simple but significant changes shaped the evolution of the infrastructure of the power grid to smart grids of today. Power sources include nuclear power plants, albeit at a long but economic efficient distance from the demand centers .The tariff system evolved by including day and night billing. In detail, night rates were lower priced due to the better management of turbines at production plants, especially gas, which could be operated with longer forecasts for the burning cycles thus improving efficiency and approaching a lower cost dispatch for both ends.

The change of the decade brought the first serious power management problems. The high loads of demanded electricity during peak times such as the intense use of air conditioning machines at summer, could lead to blackouts. Brownouts were a rather elementary cause of action by the electric companies but the demand was still exceeding the production. The solution, among other measures, employed arrays of “peaking generators”. Mostly gas turbines, these generators are considered as low efficient but with improved response times. Another measure was the necessary redundancy cemented by increased reliability due to better servicing, inspection and materials.

Slowly but steadily, power grids kept advancing in technology to enhance function but also to manage peak loads in emergencies. It soon became apparent in 1970’s and onwards, that consumption should be matched to generation and meters ought to record during the day, not only summing up the consumption.

The fundamental element of the smart grid, the ability for the meter to read and send back the data to utility, was introduced at the time. Later on, a caller id technology was implemented by Theodore Paraskevakos, so it could monitor sensors and relay the data.

Italy’s Telegestor project at early 2000’s, was a full implementation of demand site management relying on smart meters communicating through P.L.C or Power Line Communication.

Similar projects are China's W.A.M.S system, Mesh Network of Austin, Texas (circa R003), P&GE California and Yellostrom implemented in Germany.

1.2 Electricity Generation

Electric power grid employs different type of generators for producing electricity, with a variety of capacity, fuel type and efficiency. Electricity generation is the basis in the process of delivering electricity to consumers with power stations, strategically located and responsible for the production of energy.

Central infrastructures has been operating since 1882, running on coal or waterpower. Through the ages, other sources like natural gas, oil and nuclear power were used. Today, there are also energy concepts from Renewable Energy Sources and geothermal derivatives. Renewable sources are becoming a major research initiative for the future and one of the core policies of smart grids: the seamless operation in tandem with other productive energy infrastructures.

Every country relies on individual sources to produce electricity according to its demand, economic strength, availability of sources and potential environmental pollution.

Statistics can show a pattern in last years :

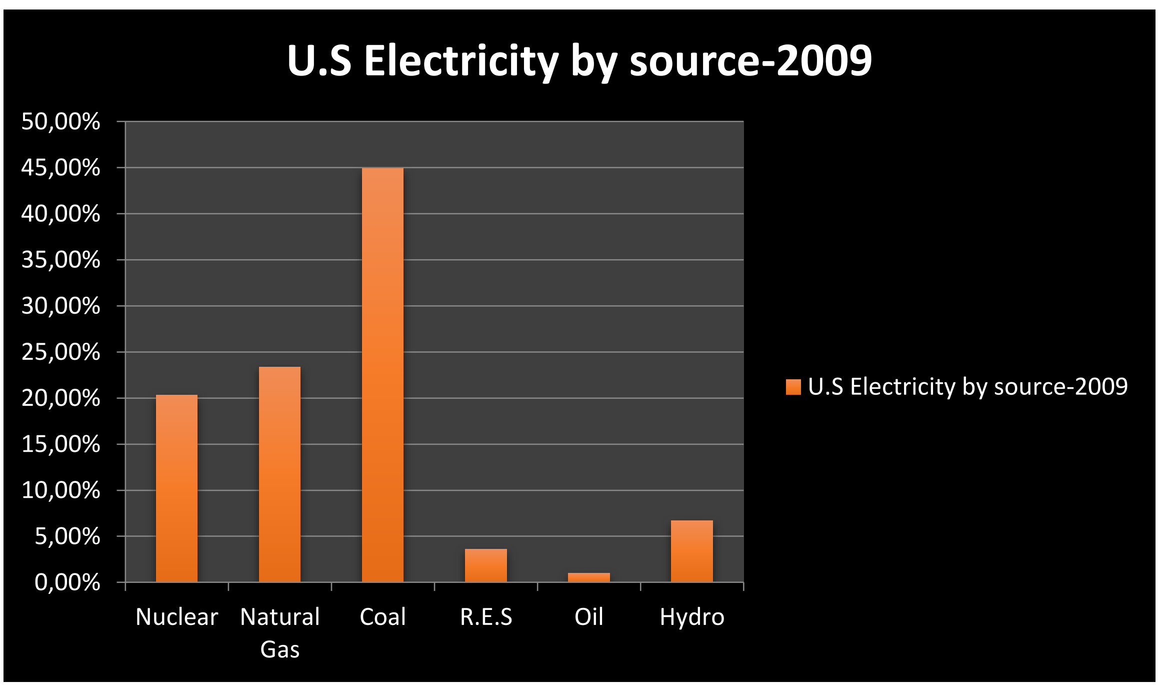


Figure 1: Electricity generated by various sources in U.S 2009

[Source: US Energy Information Administration]

It is evident that cheap sources of energy like coal, are used at large while glances at the future suggest that hydro, nuclear and R.E.S comprise the new energy policy.

Comparatively, we can see data collected in 2012 presenting different cases of electricity production in 4 different power grids:

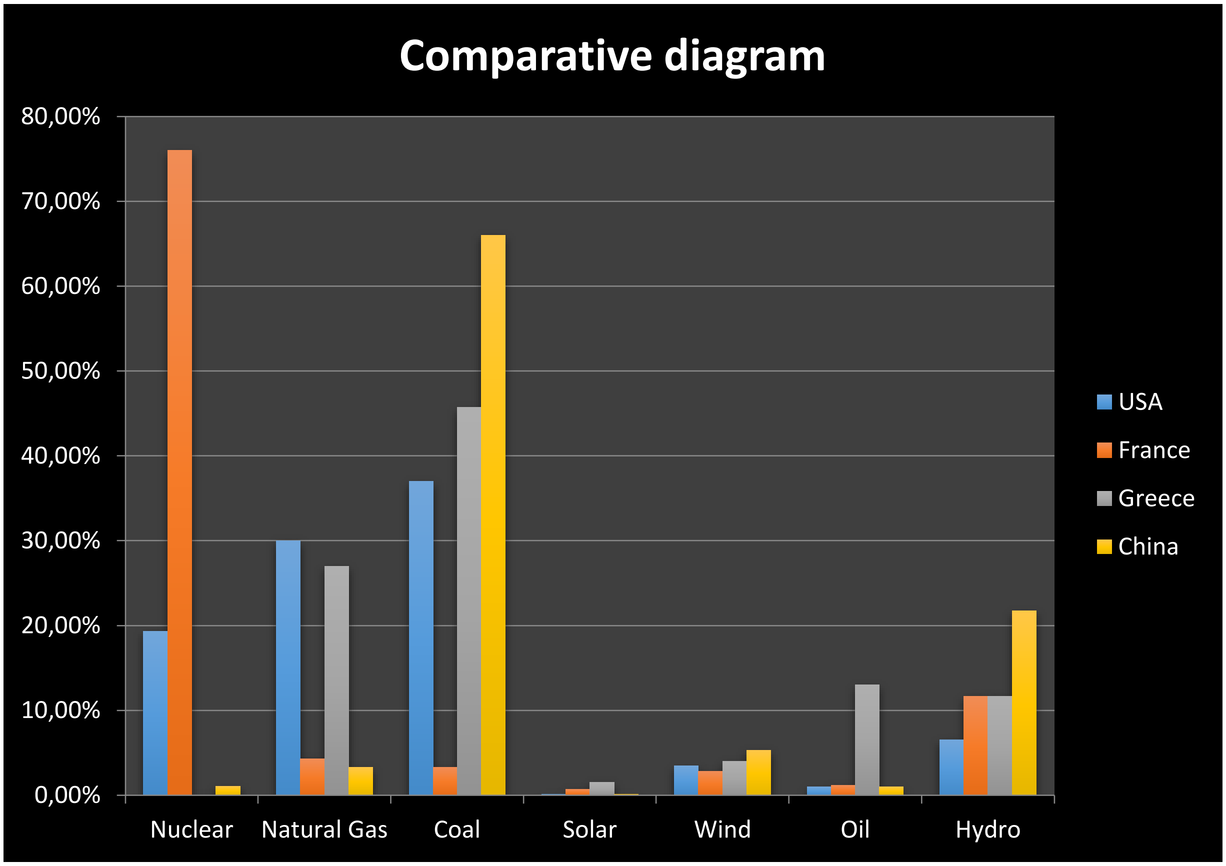


Figure 2: Comparative diagram of 4 different countries and their electricity generation by source in the year 2012 [source: IEA 2012, Eurostat, ADMIE,RTE Annual Report]]

United States of America relies heavily on fossil fuel but in last few years there is a clear turnaround. Natural gas can substitute a certain part of coal fired generators due to lower emissions and improved efficiency. Nuclear plants in France indicate the role of French power market as an exporter of energy in European counties, such as Germany. Despite the relatively smaller power market, Greece relies too in lignite operated plants due to lower cost and rich natural reserves. China's rapid industrialization was mostly fueled by coal , at approximately 70%. Future relies on RES though and there reforms and measures in soon to implement policies.

1.3 Transmission

A power plant produces electrical energy in medium (2000V) or low (1000V) voltage which is then elevated to high voltage (up to 400V) by a step up substation.

The part of transmission can be illustrated:

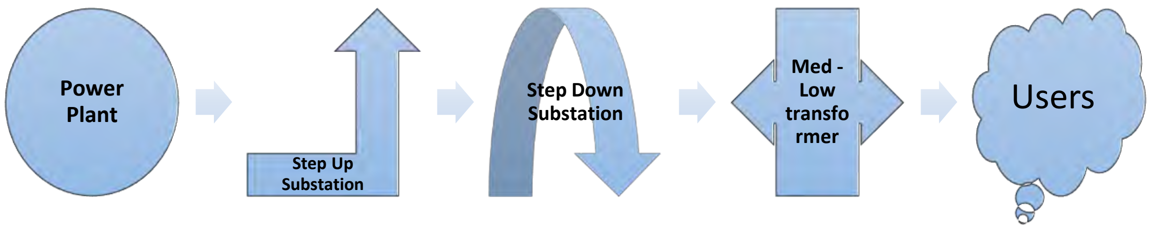


Figure 3: a schematic representation of a transmission cycle [source: IEC- D&T]

The main concept of a power plant is the production of electricity. A step up substation with high-tension power lines transmits high voltage output. Higher voltage on these lines indicates more power for retail customers. Next step includes a substation that converts the voltage to usable levels for consumers or factories, through a designated transformer.

The whole process of transmission requires certain techniques and measures to be taken, in order to provide quality and reduce losses. For starters, the distance between a step-up substation and a power plant is usually quite small, due to lesser losses and better response of the system. If the distance is short, the cables and the perplexed framework needed are limited and as a result, the cost is reduced.

The history of electricity transmission begins at 1883 when Thomas Edison [citation] introduced an economic and viable model for generating and distributing electric power. Today, we are speeding towards methods and approaches that can enhance the power grid to smart grid. Typical example of a transmission phase in a smart grid system can be seen in Sydney, Australia with the Basslink project.

The Basslink project is among few, examples using a High Voltage Direct Current (H.V.D.C). The adaptation of smart meters has already begun but admittedly, at a slow rate[citation]. The whole interconnection provides efficient and beneficial generation of electricity between the states and east coast but it is currently limited to areas.

As far as the Greek transmission phase is concerned, the electricity is generated mainly in northern Greece, in which the most coal mines can be found, with lignite proving the major energy source for the country. Power lines with 400kV of AC are the main transmission channel with 150kV of DC support. The system interconnects the main land but the islands of the country either are connected with submarine cables or depend on autonomous power plants. There are also cross border interconnections with Bulgaria, F.Y.R.O.M and Albania, mainly with 4 400kV AC lines.

1.4 Distribution

The next process in electricity market infrastructure is the distribution of power. After transmission is completed, power is being transformed, mainly for distribution purpose, to a lower voltage [Jan De Cock, Strauss, “Practical guide to Electrical Network].

The history of distribution system is long and its origins can be found in 1930’s[JDK]. There are more similarities than differences comparing redundant and present day distribution systems. It is only natural that progress is evident in devices such as transformers responsible for increasing or decreasing the levels of power voltage in the system, aiding efficiency. Cables responsible for channeling the power through the aforementioned power lines are being built with lower cost and prone to losses. From a structural perspective, modern distribution circuits operate at higher voltages and more underground circuits are in use.

The key evolution at the aforementioned systems is the extensive use of I.T technologies throughout the grid. Better communication between equipment with smarter switches and controllers is essential. These directives counter act power losses, increased peak demand and faulty management with inefficient pricing.

A detailed example of a modern and efficient distribution facility is the Greater New Town Transmission and Distribution project in Britain. Core principles of this project such as continuous current rating, line voltage regulation, fault rating, supply interference, supply security, construction hazards and standards, were considered from the early start of the project. In order to achieve overall efficiency and better energy consumption, computer aided modeling, smarter design and reliability statistics were used [C.Bayliss /T & D ,Report, 2006]

The Greek electricity distribution network consists of 102000 km medium voltage lines at 115000 low voltage lines. The system has been improved from 2000 and onwards. However there are certain reforms to be implemented in distribution system , now controlled by D.E.D.D.I.E , and power market in general. Competition levels are considered generally low and prices aren’t entirely cost reflective [IEA Report,2011].

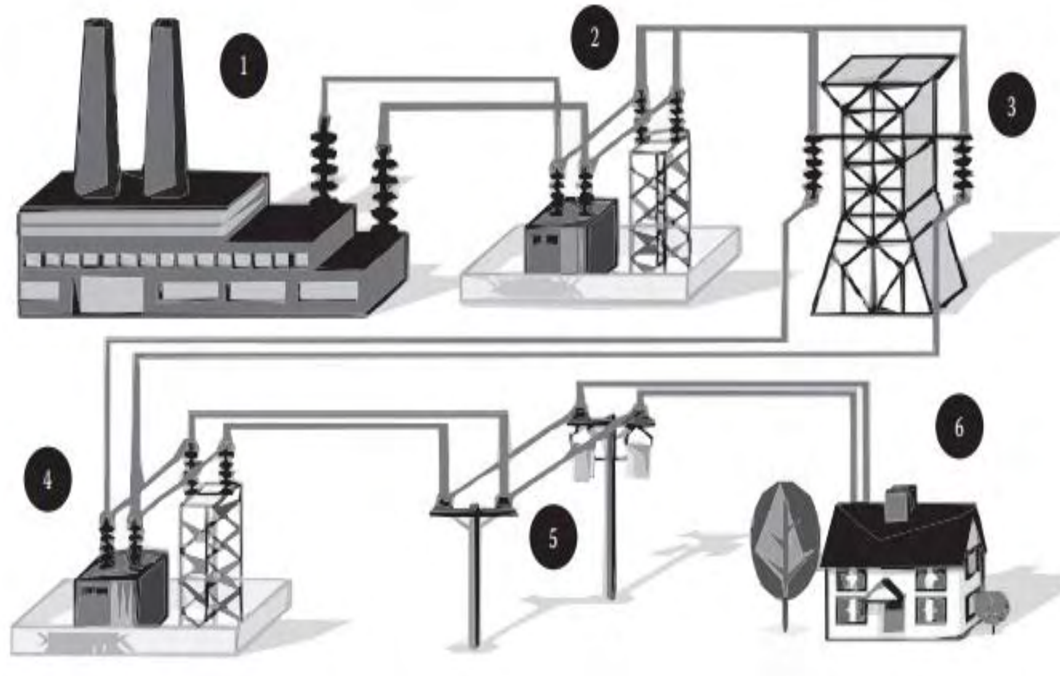


Figure 4: Electrical Grid stages of operation (SmartGrids,2011)

The contemporary electrical grid is comprised of individual stages. Number 4 signals the distribution phase of electricity to consumers. Smart grid applications and infrastructure aid the whole system in an efficient and seamless manner.

Chapter 2 - Foreign Power Markets

2.1 Overview

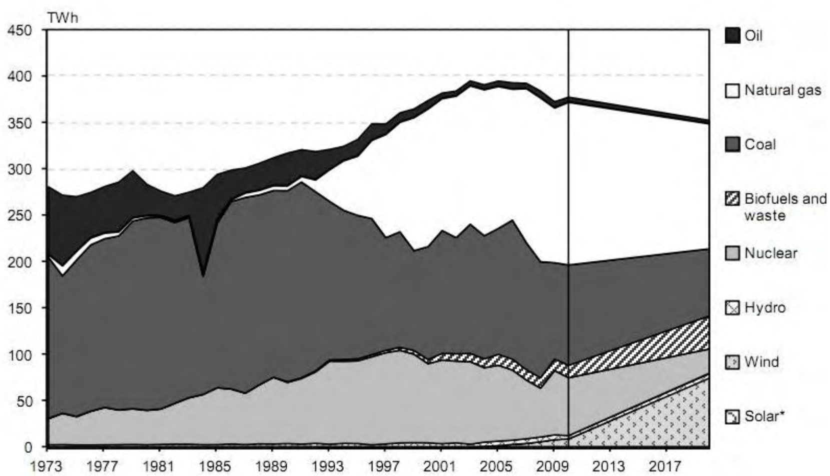
This chapter analyzes the basic structures of known electricity market systems from Great Britain, United States of America and France.
It is crucial for the market analysis and the economic aspect of electricity market and the full liberalization to study the aforementioned examples to an extent provided by facts, figures and analysis that is aiming to present the measures already taken but also the careful planning and strategies for the future. Eventually, a prologue of Greece's thesis and the in-depth study are being presented along the results.

Competition is the key word in the aforementioned markets. There are different levels of competition in these networks but it all began when the need for a coordinated operation of the major entities in an electricity network was deemed necessary otherwise the costs would be aggravated unexpectedly. Real competition where contracts were in place along with the possibility of a generator selling energy to a consumer or a distributor , came in motion in the 1990's [Ruff]
The electricity markets of United Kingdom, France and USA are similar and very different at the same time. These are markets that liberalization and deregulation was and still is , a primary target in order to improve competition, keep the prices in appropriate levels for wholesale and retail market and ensure future modernization of power networks in tandem with renewable resources. In Europe, the EU Directives, 96/92/EC and 2003/54/EC aim at specifically creating a single internal electricity market (I.E.M) with European members participating.

2.2 United Kingdom

The case study of United Kingdom presents a market with many interesting points due to the nature of resources, the regulatory framework within the electricity market and the level of ambition and commitment towards low carbon technology. Critical factors can also be found in the interaction with the European Union Emissions Trading Scheme (EU-ETS) and the raise in the level of investment among private competitors in the wholesale market.

United Kingdom is considered a member of the European Union since 1973 and a pioneer in energy policy. The liberalization of electricity and gas markets by competition, privatization and broad deregulations regarding the access to power networks is considered as a milestone of the first among other members of EU.



* Negligible.

Sources: *Energy Balances of OECD Countries*, IEA/OECD Paris, 2011 and country submission.

Figure 5: Electricity Generation by source, 1973-2020 (*IEA, 2011*)

The electricity network relied heavily in coal electricity generation from 1973 until 1990's where the emissions and the efficiency of natural gas took place. Nuclear generation plants deemed important but with a lifespan of 50 years , the maintenance costs and possible precautions led to cease function in reactors and embody renewable sources in the last decade. From 2006, the government announced a new energy policy concerning less fossil fuels along with better legislation and an improved competition framework among power participants. These measures should help residential use, which occupies the 32% of UK demand and the transport sector with approximately 30%.

Britain’s electricity market consists of wholesale market, retail market and the necessary transmission and distribution networks. Wholesale market deregulated in 1990’s and the initial purpose was to create a competitive electricity system where prices are determined without administrative or other regulatory interventions. Real time unfettered movements in price and an actual freedom of market participants actions considered as the main investment drivers.

With the Energy Act of 2004, the reform of the old power grid started so the liberation movements and directives of previous years could finally work on full extent. Before 2001, the Central Electricity Generating Board Electricity Pool (CEGB) required all the electricity economic transactions (bidding selling) to go through a pool system. After the pool system, New Electricity Trading Arrangement System (NETA) was introduced with separated branches in Wales and Scotland.

The bilateral trading between traders, generators and general customers of the power grid offered diversity of selection thus improving competition. An improved version is seen on today’s system, British Electricity Trading and Transmission Arrangements (BETTA) which

- Unifies the GB as a single market operation system
- Defines rules for the access and use of the transmission network
- Introduces a System Operator for all Great Britain , independent of generation and supply interests.

The role of System Operator is crucial to liberated market. According to Hogan (1998), the operator needs to coordinate a short-term spot market with an elevated emphasis on security constrained economic dispatch. Reliability could be enhanced further more by the proper operation of S.O. Managing of events within each market periods and the operation in a special timeframe such as a “day ahead” scheme or hour ahead should be considered tasks for system operator.

B.E.T.T.A model works as a typical commodity market. Generators and suppliers interact through bilateral contracts. The trade of electricity is traded in 30 min blocks, known as settlement periods. The operation continues until 1 hour before the start of a settlement period known as gate closure. After gate closure, the responsibility of meeting the demand with the existing supply sources lays on National Grid Electricity Transmission hands, the current system operator. The S.O in this case, can take balancing actions to counteract possible implications and work with imbalance penalties. These can be used as incentives to market participants so they can ensure contractual and physical positions by creating contracts for supply ahead of time or by sustain the reliability of the power plant.

In retail market or the final distribution phase, the structure is characterized by the major 6 energy suppliers that are vertically integrated. The term is being used to describe the status quo detailing the suppliers who are part of larger corporate groups operating in wholesale and retail market too. Only 0.6% of the market is being supplied energy by independent suppliers.

Office of Gas and Electricity Markets is a government regulator who promotes the competition between participants in power network. The Retail Market Probe of 2008, commissioned by

Ofgem, did show hallmarks of a cartel situation among suppliers with tariff complexity, poor supplier behavior and lack of transparency.

The problematic situation by the lower state of competition, the consumer experiences and the low energy liquidity, which is one of the lowest in EU market areas such as (Benelux, Nordpool, Germany) points to another market reform, at least in specific areas.

In this case, from an economic point of view, the liquidity must be strengthened and the competition should be enhanced with more independent participants to the network. Ofgem in 2011, proposed an obligatory auction to forward market of up to 20% of generated output from the large vertically integrated entities and mandatory market arrangements so smaller independent players can participate with equal terms in the market.

2.3 France

France is the second-largest electricity consumer in OECD Europe after Germany.
The French electricity network in the last decade brought forward some irregularities due to the economic crisis but the current system did show remarkable adaptation to circumstances.

From 2000-2007 there was a 10.6% raise in electricity consumption but in 2007, peak load reduced to 89GW. Power demand is divided almost equally to commercial service with 31%, residential sector with 34% and industrial sector with 31%. Electricity market already shows signs of upturn with a growth rate of 0.8% in electricity demand every year.

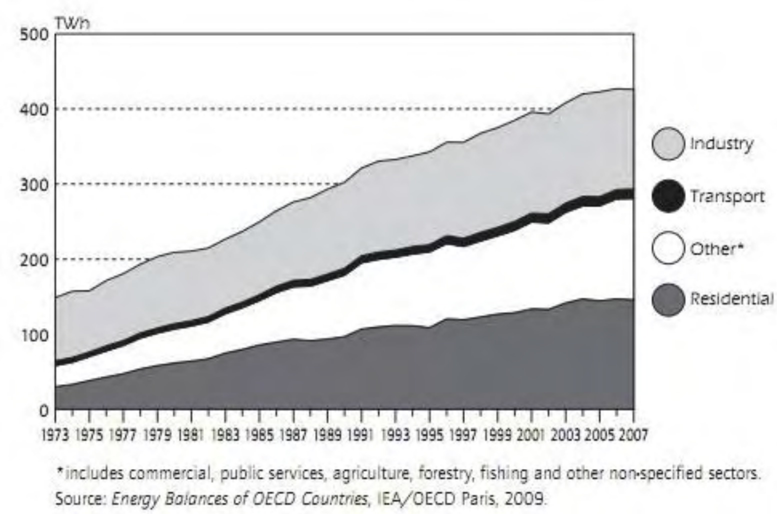


Figure 6 : Final Consumption of Electricity by Sector , 1973-2007 (*IEA, 2011*)

The use of nuclear power plants for generating electricity is the highest in the world with 77% generated electricity in 2011. There are plans for reduction towards 2020 due to the end of life circle of nuclear reactors. Fossil fuels account for a 10% generation with gas being the primary source and few supporting oil fired plants. Hydro –generated energy accounts for 10%

and intermitted energy sources such as wind and sun, accumulate a low 1%.

The use of renewable sources is an important matter to France's energy agenda, so there is a feed in tariff to current generation bills in order to accelerate investment in renewable energy technologies and in tandem with a 12year plan many facilities will have the option of renewing their feed in tariff and improve the generation footprint if possible.

The structure of the French electricity market consists of public or private entities. The major player in the generation sector is EDF, which is public by a 84.8% while generating the 88.1% of electricity in market. The 11.9% is divided by 7 smaller companies using various sources of generation but no nuclear. Transmission network is owned solely by the system operator, RTE, which is a subsidiary of EDF. RTE provides secure access for other utilities to the transmission network and plans the development of network. Commission de Regulation de l'energie assesses the legislation of the network and sets the transmission tariffs which will be approved by the government. Distribution is owned by ERDF , another subsidiary of EDF and a small percentage of local distribution companies own the remainder of retail market assets.

Inner structure is very important to electricity market but there is also an extensive hub of European interconnections for trading electricity. France is a member of the Pentalateral Energy Forum along with Spain, Benelux and Germany. The total growth of cross border electrical interconnection is 15750MW and involves other EU members as shown:

France - Belgium	3 200 MW
France - Italy	2 650 MW
France - Spain	1 400 MW
France - Germany	3 300 MW
France - Britain (undersea cable)	2 000 MW
France - Switzerland	3 200 MW

Source: MEEDDM.

Figure 7: Total Growth of Cross Border Interconnection (*IEA, 2011*)

France is operating as an arbitrage hub for German market, as seen the biggest exporter there. Actual prices in Germany power market are lower than French power market, which are in turn, at a lower standing point than Italy.

Electricity Exports and Imports, 2005 to 2009
(TWh)

	2005	2006	2007	2008	2009
Exports	90.9	89.9	83.0	81.4	68.0
Imports	32.3	28.0	27.5	34.8	43.4
Net exports	58.6	61.9	55.5	46.6	24.6

Source :Solde des échanges contractuels suivis par RTE.

Figure 8: French power market as an electricity hub, 2005-2009 (*IEA,2011*)

The French power grid policy responds differently during normal periods and in the middle of peak demand timeframe. More specifically, national grid is importing energy during peak times but exports electric power when a basic load is on demand. As a result, the system works more flexible and efficient with a healthy competition frame. France, Belgium and Netherland have formed a trilateral market coupling, converging prices of up to 66% in 2008 . A major player in this phase is Powernext, which works as an energy investment firm. The actual task is designing and operating electronic trading platforms for spot and derivative markets on energy platforms across Europe.

EU Directives and French Government legislate and measure the functionality of the market. EU Directives as member of European Union, also complies with 96/92/EC and 2003/54/EC , and as mentioned before, both aim in creating a single electricity market for Europe. The 3rd Energy Package that was implemented on 3 March, 2011, also includes 3 Regulations:

Regulation instituting a cooperation agency for energy regulators:

Regulation (CE) N°713/2009 of 13 July 2009

Regulation concerning the transport system access conditions for transborder electricity exchanges, abrogating Regulation (CE) n° 1228/2003:

Regulation (CE) N°714/2009 of 13 July 2009

Regulation concerning the natural gas transport system access conditions, abrogating Regulation (CE) n°1775/2005:

Regulation (CE) N°715/2009 of 13 July 2009

Figure 9: Basic regulations of 3rd Energy Efficiency Package by EU (*Source: CRE site*)

The Market Abuse Directive (MAD) and Markets ensure market Integrity in Financial Instruments directive (MiFiD). M.A.D refers to a community framework aim to prevent, detect and sanction economic dealings or manipulations inside the market. M.i.F.i.D, envisions guaranty of equal competition terms for all participants.

C*ommission de* ***r****egulation de l'****e****nergie* works under the regulatory framework of France. CRE possesses the authority to decide, approve, settle energy disputes between participants of network and approves the annual investment plan of the transmission grid operator.

In wholesale market, major activity of economic transactions is attributed to direct Over the Counter policies. Trading can proceed with direct dealings or through brokers and platforms. The OTC transactions in 2nd quarter of 2009 delivered56.3Twh, signaling a decrease of 4.5% compared to the 1st quarter. Volume of 2nd quarter represented approximately 53% of national consumption, marginally lesser to 41% of the first quarter.

Retail market reflects the progressive liberalization of electricity grid. There are 7 major players who cover over 98% of total consumption. Since July 2007's EU directive, a customer is eligible to select their supplier. These selections are offered with a contractual agreement of various types:

- Under regulated tariffs.
- At market prices.
- Transitional Regulated Market Adjustment tariffs (T.a.R.T.A.M)

The first type of contract is offered by the major 7 , known as incumbent utilities. At market prices is a type of contract offered by incumbent and alternative suppliers too. TaRTAM , refers to a limited period where a customer transitions from a supplier at market prices to a new one.

Status of Retail Market Distribution, December 2008

	Residential sites		*Non-residential sites*	
	As of December 2008	*As of September 2008*	*As of December 2008*	*As of September 2008*
All sites (TWh)	140	139	292	295
Sites at market prices (TWh)	4	2.4	134	137
TaRTAM sites (TWh)	-	-	82	85
Altenative suppliers (TWh)	3.3	2.4	34	36
Share of alternative suppliers (%)	2.3	1.7	11.6	12.4

Source: CRE, Electricity and Gas Market Observatory, 4th Q 2008.

Figure 10: Retail market distribution analyzed into two categories (*Source: C.R.E*)

Alternative supplier's market share was 2.3% on December of 2008 and the historical/incumbent suppliers counted for the remainder. On the contrary, a 26.81% increase was recorded in September 2008 concerning customers with contracts at market prices.

The entire market infrastructure is reflected upon pricing. Under law, the regulated tariffs must cover full costs. Competition among participants, exports and the different conditions of each fiscal year led the wholesale market price of electricity to increase substantially while the retail market remained relatively stable. The result was tariffs for certain customers or groups that were actually a lot lower than actual wholesale market prices. A social rate was also established in 2004 (Decree No 2004-325) for the economically challenged residents.

The complex pricing system of TaRTAM , is also another issue of the power grid. It was impossible before 2007 for a customer who chose to be part of the liberalized market to return to regulated tariff system. In the following 2 years , law amend these situations by restate the possible right for a customer to reselect a supplier but introduced the Tartam rate which is equal to the regulated retail tariff exclusive of tax but increased with a percentage between 10%-23% . Levies were forced into customers and producers to relieve the market. The estimated pre-tax cost of the TaRTAM regime is approximately 2 billion Euros in the 2006-2010 periods.

Adjustments need to be made to ensure better market stability providing lower distortion parameters and enhanced future capabilities.

2.4 United States of America

The study of United States of America electricity market is prominent due to the reason that a whole history of changes, legislations, reforms and energy plans are distilled into current power market. In the timeframe from 1990-2005, electricity demand rose to 41%. The rise in population increased the peak demand considerably and the market reform deemed mandatory.

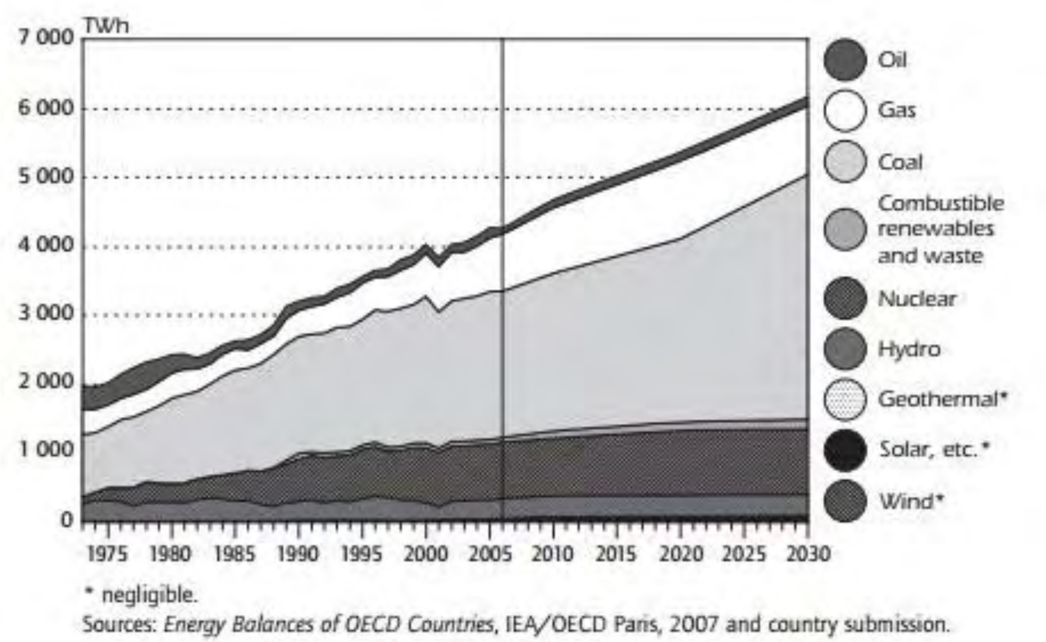


Figure 11: Electricity Generation by Source, 1973-2030, projected (*IEA, 2011*)

Statistics present a peak generating capacity of 906GW in 2006 as well as a net power production of 4065Twh. Figure 11 shows the dependency of electric generation on coal by 50% and nuclear along with natural gas share equally a 40% volume. As far as the renewable sector is concerned, hydro generation has risen to 9.5% while solar and wind sources conclude the electricity generation by source.

The transmission network is closely integrated with parts of the Canadian network. Private or public utilities own the majority of the network. However, there are vertically integrated utilities and independent system operators that actually manage the operation. Since the nature of the network is fragmented due to many different states, many sub-networks may be combined to ensure the creation of a Regional Transmission Operator.

Market structure and energy framework seem to vary from state to state but a basic layout can be drawn. Liberalization is present and there is little government presence on scene, mostly for security and arbitrary. Wholesale market is open to power marketers, energy service provides and Independent Power Producers (I.P.P). Investor owned utilities near 66% market share occupies the retail/distribution section.

The US electricity industry is subject to regulation at local, state and federal levels apart from certain exclusions. Commissions are formed in each state so they can approve distribution prices for specific jurisdictional electric utilities. When a utility activity needs to cross border for a transaction, then Federal Energy Regulation Commission is subjecting it to federal regulation.

F.E.R.C is major entity in electricity market of America. Liberalization is active in 14 States and the District of Columbia. Therefore, the tasks of the particular commission are many and very important.

- Regulation of interstate market related to wholesale transactions
- Promotion of competition schemes
- Providence of nondiscriminatory access to transmission facilities for competing electricity generators.

During the last market reform, in 2012, FERC was appointed to govern structure and operation of wholesale national power markets. For this purpose, the State Regulatory Commission of each state would assist the effort.

Transmission providers must include in the planning process all the tasks needed such as coordination, transparency , dispute resolution , regional coordination and info exchange in order to substantiate the security of supply and overall network efficiency. Consequently, the Demand Site Management activity was introduced. Electrical supply and security are still considered significant goals; however, the environmental impact of electricity use suggests actions taken to relieve the situation.

Legislation consists of numerous versions of National Energy Plan and Energy Policy Act.
The National Energy Plan of 2001, proposed the joint action of Department of Energy (D.O.E) and F.E.R.C towards:

- An improved transmission system with improved reliability and legislation concerning a new organization.
- The Office of Electricity Delivery and Energy Reliability were created, as self-regulatory entity that would enforce reliability and be subjected to F.E.R.C oversight.
- Federal Agencies would remove constraints on the transmission grid
- FERC considered of 51 recommendations to gather investment funds to power grid and especially in the inventive rate proposals, returning a higher rate for new grid investments to entitled owners.
- FERC finally approved the standardized procedures and agreement for the grid interconnection of electricity generators larger than 20 MW.
- A more stable market place and attraction of more investor’s capital to gas and power sectors was the epitome of market behavior rules of 2003 issued by F.E.R.C.

The Energy Policy Act of 2005, also known as EPAct 2005, through thorough examination and study by D.O.E had an enriched agenda:

- EPAct aims to solve the congestion issues of the transmission network in areas shown in the Figure [], due to potential large-scale development of wind, coal or nuclear capacity. A D.O.E designated national interest corridor designations might alleviate the issue.
- Address reliability issues by mandate new standards enforced by F.E.R.C
- Proposition of action plans for designating more than 6000miles of specific energy corridors so it can lessen the environment impact in the 11 Western States.

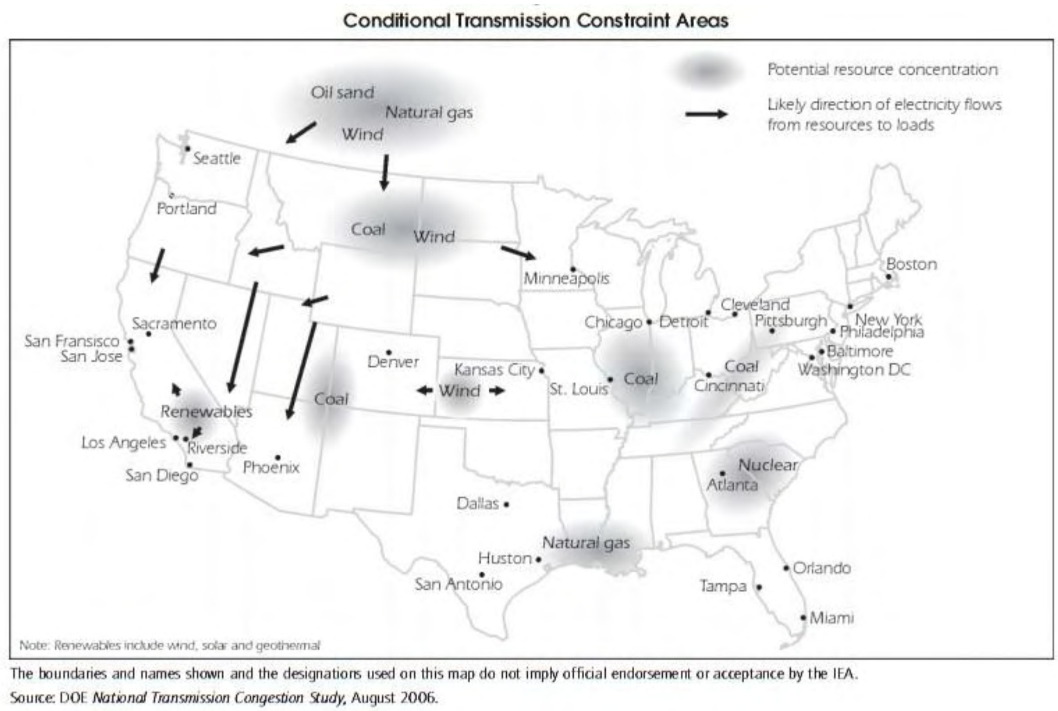


Figure 12: Transmission constraint areas in United States of America (*IEA, 2011*)

Measuring the main priorities of the current electricity market towards reliability and environmental impact while ensuring a healthy competition framework. Consequently, there is pressure to reduce the role of gas in generation and competition applies downward pressure on prices but if there is not a mandatory independent operator with security framework accompanied with cost-reflective wholesale to retail market prices, incidents like the California electricity market can always deviate the original scope. The crisis that happened in California electricity market in the summer 2000 did show a low efficient production scheme might occur in a market where a higher priced, competitive production will be superseded by lower priced production generated by firms with market power. There were also evidence of withholding by large firms in 2002 [Joskow and Kahn].

I.S.O and R.T.O should extend to cover larger areas and present clear incentives for transmission investment. Higher transparency in competition, especially in the bulk power sector, can always divert the market to a more appropriate channel. Cost reflective prices of wholesale market that can be met in retail market appears as promising guideline for the USA market.

Chapter 3 - Greek Power Market

3.1 Overview

Greek electricity sector has developed many irregularities since 1949 when the first national grid was established. The economic crisis in the last few years amplified the problematic situation and clarified the need for market reform. As a member of European Union, the Greek energy policy implement directives, the Emissions Trading System (EU-ETS) and antipollution-environmental standards legislated by the European Council. The aforementioned legislation and regulatory framework urges the de-carbonization of the mainly lignite powered electricity generation. Moreover, energy sector suffers from lack of competition, non-cost reflective prices due to monopoly of state controlled vertical integrated companies and the restrictive operational scheme concerning system operators.

3.2 European Union Legislative Framework

1996/92 EC: The 29 articles of this directive concerned common rules for the internal market of electricity among members.

It lays down the rules relating to the organization and functioning of the electricity sector, access to the market, the criteria and procedures applicable to calls for tender and the granting of authorizations and the operation of systems. Moreover, Greece, Portugal and Belgium were given 1-2 extra years as a transition period.

2001/77 EC: The purpose of this Directive is to promote an increase in the contribution of renewable energy sources to electricity production in the internal market for electricity and to create a basis for a future Community framework thereof. Especially, articles §3.2 and §3.4 suggest a report of progress in the generation of electricity by renewable sources shall take place every 5 years along with the status of public acceptance. Furthermore, the latter article suggests two targets: 12 % gross national energy consumption attributed to alternative non-fossil sources by 2010 and a 22.1% indicative share in Community electricity consumption.

2003/54/EC The directive of 1996 presented benefits from the internal market in electricity, efficiency gains, competitiveness and higher quality of service . Market dominance though, privacy concerns for consumers and possible predatory behavior arose as possible problems that this directive encounter. Introduction of cost-reflective balancing mechanisms, transmission system operators and regulatory authorities were amongst the countermeasures.

2003/1228 EC: Trans-border transmission of electricity in adjusted rates and an increase in inter market competition were the main objectives.

2009/72/EC: New rules for an improved function of internal markets were constituted. The regulatory and legal context as written on 2003/54 was considered inefficient for proprietary discrimination of the transmission and distribution activities from network operators.

2011/1227/EU : Main objective focuses in wholesale energy market integrity and transparency of fiscal transactions among members, consumers and companies. According to EC/714/2009 or EC/715/2009, inside information that could benefit trading and single entities, should be generally prohibited but data about participants plants and strategies are not considered as inside information. In general, the changes of the regulation ought to be implemented by participating by interlinked member states for cross-border effectiveness, better monitoring by appointed operators and overall productivity with a conscious approach to consumers and participants.

3.3 Greek adoption and Law provisions

Greek legislative framework homogenizes, sine qua non as an EU member, in accordance with the current European Union directives and regulations. Nevertheless, there are many more key articles and guidelines to consider. Greek laws were discussed about electricity market in 1985 although the specific articles refer to reorganization of Ministry of Energy rather and in quite the same way in 1994's law about the use of fossil fuels but also renewable sources of energy.

- ***Law 2773/1999***: Deregulation of Energy Market and regulation of matters pertaining to energy policy and other provisions. It is the cornerstone for using R.E.S electricity and complies with previous EC's. n the liberalization of the domestic electricity market, renewable energy is that arising from the exploitation of wind, solar, biomass, biogas, geothermal, sea (wave / tidal) and small (<10 MWe) hydro resources, or their combinations. The same working definition is used in both financial instruments currently utilized for State support of RES projects, namely the so-called National Development Law (Law 2601 of 1998, on the "State support of private investments") and the Greek Operational Program for Competitiveness (a sectorial program of the third Community Support Framework for Greece, covering the time period 2000-2006).
- ***Law 1726/2003*** : Legislative framework commencing procedures for the approval of preliminary environmental impact assessments , environmental terms and conditions, transfer of property or of the right to use forests and scrublands , in the context of issuing of installation permits for power plants using renewables.
- ***Law 4001 /2011***: Since 2007, the electricity market has been liberalized for all consumers and all customers in Greece are eligible to change their Electricity Supplier.

  The consumer enjoys the right to select its electricity supplier and to freely negotiate the energy prices and the terms and conditions of the related services.

The organization of the market after the deregulation, as per the Laws 2773/1999 and 4001/2011, is briefly depicted in the following diagram:

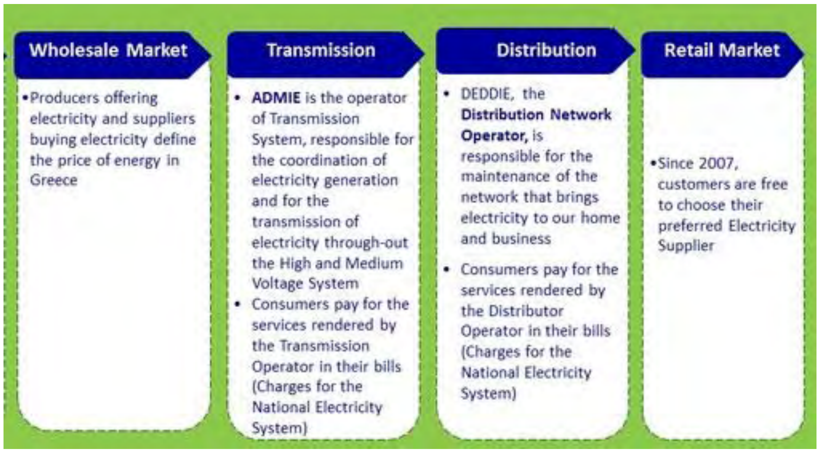


Figure 13: Current operation of Greek Power Market (*Elpedison, 2015*)

As of 2015 and during the negotiations for the 3rd bailout program, European Union, European Stability Mechanism , International Monetary Fund and European Central Bank proposed for stricter reformations in the energy department concerning electricity and natural gas. Especially, gas market, as told, is ought to be fully deregulated by 2018. Electricity factor A.D.M.I.E , also proposed by creditors, to fully deregulate the market by letting other companies participate in a healthy competitive framework. The results will be annually reviewed, according to the plan. Greek government is going to discuss further these measures and legislate by October 2015.

In order to evaluate efficiency and gain operational insight, an analysis of main entities in power market is the following :

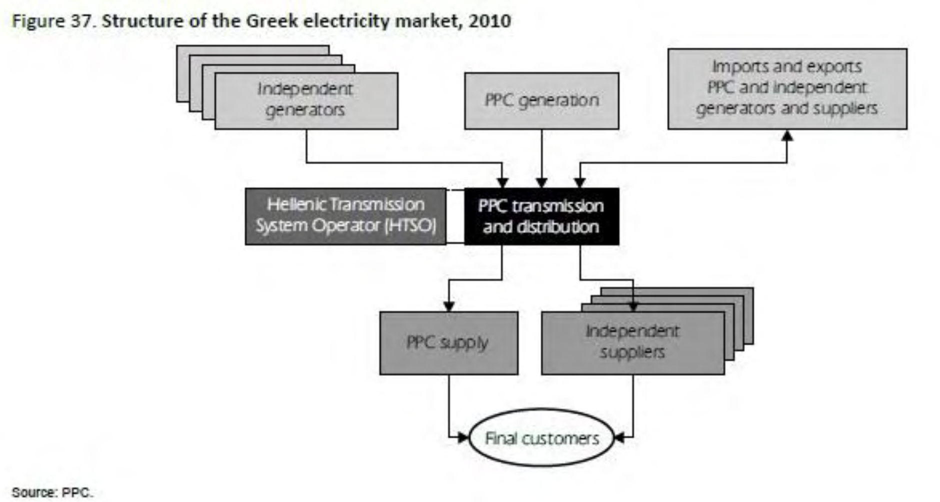


Figure 14: An analysis of the electricity market in Greece (*IEA, 2011*)

A.D.M.I.E or *I.P.T.O* : The Independent Power Transmission Operator (IPTO or ADMIE) S.A. was established in compliance with Law 4001/2011 and European Union Directive 2009/72/EC regarding the adoption of common rules in the organization of EU electricity markets. According to Law 4001 /2011, ADMIE undertakes the role of Transmission System Operator for the Hellenic Electricity Transmission System and as such performs the duties of System operation maintenance and development to ensure Greece's electricity supply in a safe, efficient and reliable manner.

Although a wholly owned subsidiary of PPC S.A., ADMIE is entirely independent from its parent company in terms of its management and operation, retaining effective decision-making rights, in compliance with all relevant independence requirements of Law 4001/2011 and Directive 2009/72/EC.

L.A.G.I.E or ***H.O.E.M***: as Hellenic Operator of Electricity Market was founded in the basis of operating the Greek electricity transfer network in a fair and trouble free manner. The dissolution of DESMIE resulted in the creation of two separate entities in the electricity market, ADMIE (as IPTO) and LAGIE (as OEM) . Stated by law 4001/2011 , the purpose of LAGIE was and still is the proper operation of energy markets , both electricity and natural gas and also managing the tasks of research, production including network of transfer amongst other tasks (by Government Paper 179/22-8-11). Moreover, it is clearly stated that, responsibilities legislated in article 99 of the aforementioned law 4001, are now solely delivered to ADMIE.

R.A.E or ***Regulatory Authority of Energy:*** The Regulatory Authority for Energy (RAE) is an independent administrative authority, which enjoys, by the provisions of the law establishing it, financial and administrative independence. RAE was established based on the provisions of **L. 2773/1999**, which was issued within the framework of the harmonization of the Hellenic Law to the provisions of **Directive 96/92/EC** for the liberalization of the electricity market.

The financial independence of RAE, which is an essential condition in order to preserve the Authority's independence, was effectively ensured by the provisions of **L. 2837/2000**, through which it is anticipated that the Authority possesses its own resources, i.e. revenue bonds from the regulated industry, participation to research projects etc. These resources are managed in accordance with the **Presidential Decree 139/2001** "Regulation for the Internal Operation and Administration of RAE", while financial management is subject to ex-post auditing by Independent Auditors and the Court of Auditors.

P.P.C or ***Public Power Company*** (or D.E.I) : Public Power Corporation S.A. (PPC) is the biggest power producer and electricity supply company in Greece with approximately 7.4 million customers. PPC currently holds assets in lignite mines, power generation, transmission and distribution. PPC's current power portfolio consists of conventional thermal and hydroelectric power plants, as well as RES units, accounting for approximately 68% of the total installed capacity in the country.

After the spin-off of the Transmission and Distribution segments, two 100% subsidiaries of PPC were created, namely IPTO S.A. (Independent Power Transmission Operator S.A.) and HEDNO S.A. (Hellenic Electricity Distribution Network Operator S.A.). IPTO S.A. is responsible for the management, operation, maintenance and development of the Hellenic Electricity Transmission System and its interconnections, while HEDNO S.A. is responsible for the management, operation, development and maintenance of the Hellenic Electricity Distribution Network.

In 2012, the total installed capacity of PPC generation plants was 12.5 GW. At the end of 2012, the number of permanent employees amounted to 19.998.

PPC is active in the RES sector through its subsidiary company "PPC Renewables S.A." (PPCR), with a portfolio of wind farms, small scale hydroelectric plants and photovoltaic plants of total installed capacity of 116 MW (excluding the plants that PPCR participates through joint ventures, with 29 MW of their installed capacity accounting for PPCR).
Founded in 1950, PPC is listed on the Athens and London Stock Exchange as of December 2001.

HEDNO or **Hellenic Electricity Distribution Network Operator** (DEDIE) was formed by the separation of the Distribution Department from PPC S.A., according to L.4001/2011 and in compliance with 2009/72/EC EU Directive relative to the electricity market organization with the goal to undertake the tasks of the Hellenic Electricity Distribution Network Operator. It is a 100% subsidiary of PPC S.A., however, it is independent in operation and management retaining all the independence requirements that are incorporated within the above mentioned legislative framework.

Our company tasks include the operation, maintenance and development of the power distribution network in Greece, as well as the assurance of a transparent and impartial access of consumers and of all network users in general. We aim at providing reliable power supply to our Customers, quality of electricity voltage and constant improvement of quality in services.

Our mission and vision is the response to our Customers' expectations and the contribution to the development and welfare of our fellow citizens with respect to people and to the environment.

In the Meeting of the 12th of October 2010, the Board of Directors decided that the Power Distribution activities, that is, the network management and provision of services for the whole country, as well as the activities of the non-Interconnected islands Operator undertaken by PPC S.A. to be transferred as a whole (100%) to the subsidiary of PPC S.A..

3.4 Power Market operation

The electricity sector in Greece operates with a combination of a wholesale market and a capacity assurance market. Generators and suppliers can join the network if they hold a certain supply license or they can act as self-supplying customers obeying the current legislation.

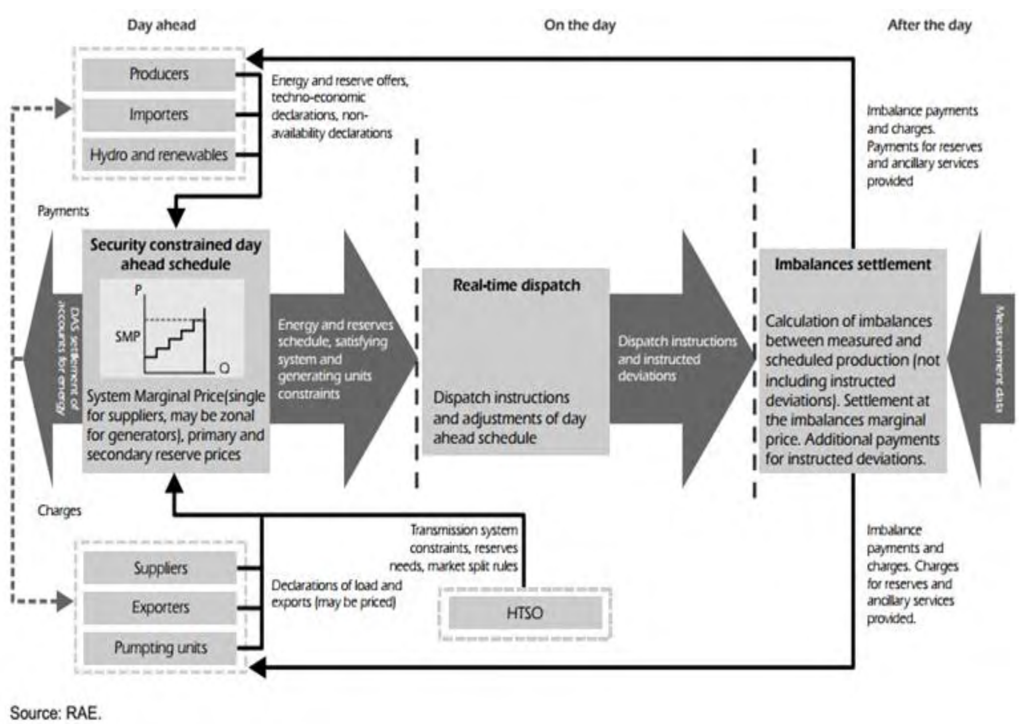


Figure 14: Day ahead, on the day, and After the Day phases of operation (*IEA, 2011*)

Supervising the market was administered to H.T.S.O but after the dissolution , ADMIE as an Independent Power Transmission Operator went forward with the task. The Grid and Market Operation Codes is the operational framework that ADMIE mandates for the safe and balanced function of the grid.

The **wholesale market** implements a mandatory pool with 3 specific key elements:

- ***Day Ahead scheduling****:* a Single Marginal Price (SMP) is generated for every participant, every hour. If the system falls into constraints, then the electricity grid divides into Northern Greece and South Greece represented as zones. Every zone will acquire a certain marginal price and the average of the two zones will establish the new SMP. The zone with a supply deficit as a result, connects with local generation if possible.
- **Real Time Dispatch**: In order to maintain a reliable and productive grid, between the day ahead scheduling and the real time supply, the real time dispatch element was introduced.
- ***Ex – Post imbalance settlement***: the IPTO in order to balance the dispatched units and the the price that they can hold, evaluates the marginal price that could result from imbalances of the system. This price is a penalty for those generators that could not keep their previous offer.

Finally, the **capacity assurance market** applies prudence from suppliers over their generating electricity agreements. More specific, generators issue a capacity availability ticket (CAT) which reflects their production in MW increments.

Each supplier must buy estimated production needs plus an additional reserve as a security precaution. If a shortfall of the system is recorded, I.P.T.O can always ask for an increase in capacity over an ad-hoc mechanism.

The main disadvantage, of the current system is the limited participation of other investors in these markets. As a result, previously HTSO had a counter-party role for regulated CAT prices.

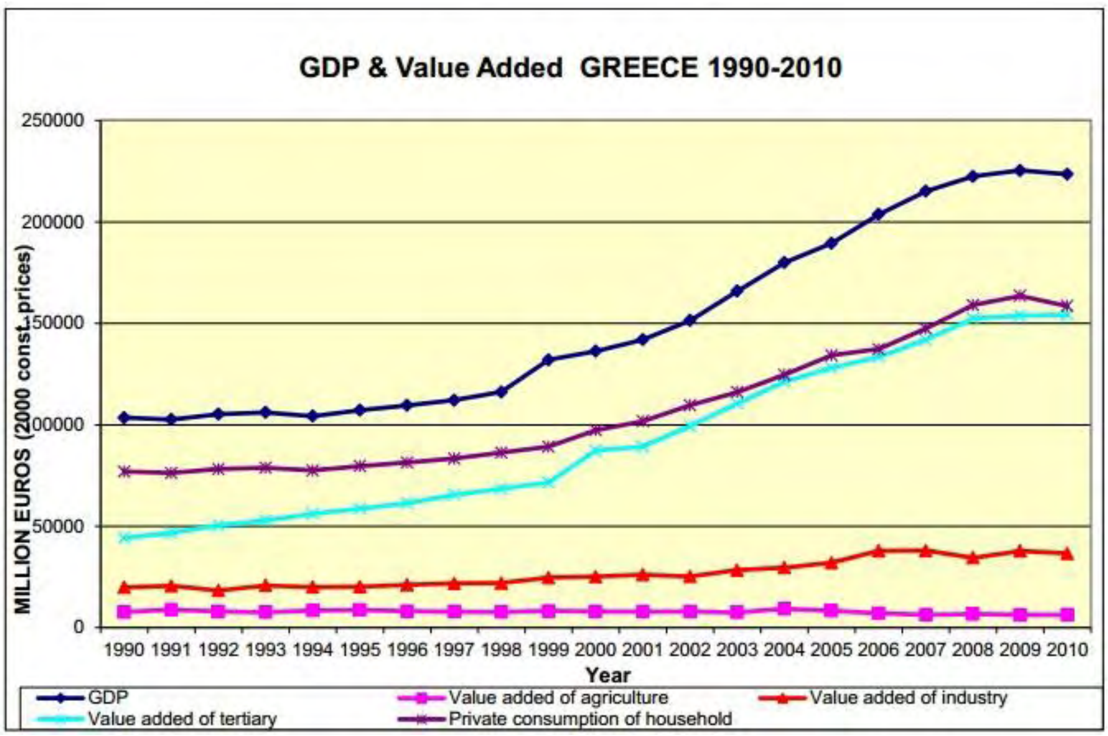
Chapter 4 - : Challenges in Efficiency of Greek Electricity Market

Overview

Effectiveness and productivity of an electricity grid can be measured by thorough reviewing the outcomes of energy policies currently in implementation. IEA uses a standard agenda for reviewing these policies which mainly focuses on installed capacity, electricity output and growth rates (*I.R.E.N.A , 2014*) . At this point, we should mention that in our opinion, productivity can be measured more accurately and sophisticated if entrust the measuring methods in energy output rather that plain growth. The measuring policies described need to be analyzed in economic and technological context of a specific installed grid. The predictive value of the system combined with an actual reason of effectiveness can lead to a more sophisticated and less prone to error approach.

In order to assess the current market policy and the goals that have been already set for productivity, we need to describe the context of Greek economy from 2000, amidst the start of economic crisis in 2008 until today.

Greek economy has seen an annually rise in GDP in the range of 2.5%-9% , mainly due to development funds, various constructive infrastructure and investment plans towards the 2004



Olympic Games . (*Energy Efficiency Greece,2012)*

Figure 15: Greek GDP 1990-2010 (*IRENA,2014)*

Starting at 2008, the economic crisis had an ongoing multilayered impact that affects directly the energy sector and the economy. Official statistics did estimate lowered annual gdp rate at an average 3% for 2009 and 2010 and small , almost incremental improvements in the next years.[ELSTAT]

Greek energy sector averages a 30% increase of energy consumption since 1990 , using 4.7Mtoe more than the 14.7 before. Electricity market recorded the highest increase of approximately 86.3% , from 2.45Mtoe to 4.6Mtoe in 2010. The market structure, defined by the presence of PPC and the pool system , resulted in the aforementioned numbers until 2008 . It was the economic crisis but also the slow denounce of oil use for electricity at a rate of 2.16% annually that led to the higher by 4% electricity consumption.

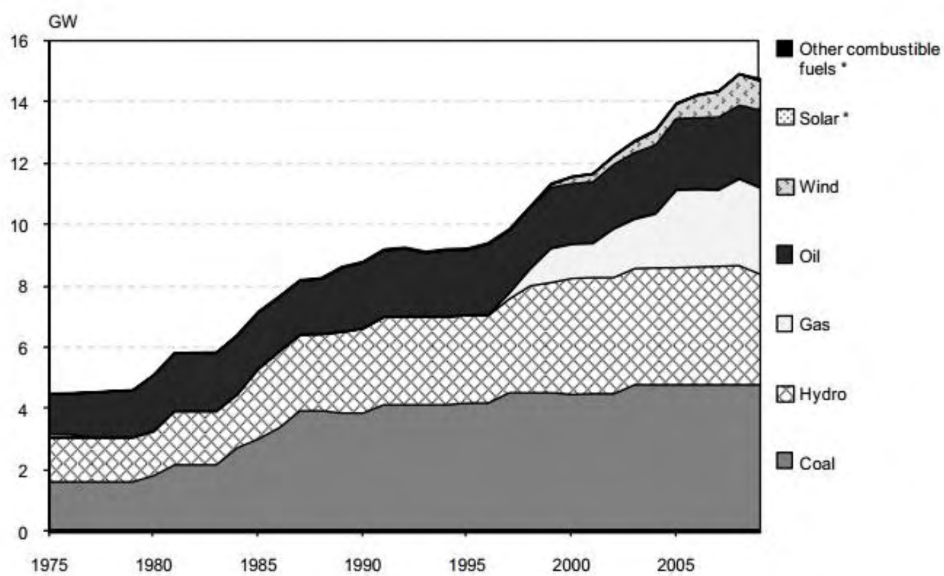


Figure 16: Net Electricity capacity by source 1975-2010 (*IEA Report 2011)*

Coal being a dominant source of electricity production but is steadily declining while hydro since 1990 is the stepping-stone of primary energy source. After supporting legislation was voted in Parliament, res gain momentum, if only the economic recession of the country would not affect heavily the install and expansion of new age systems across the country.

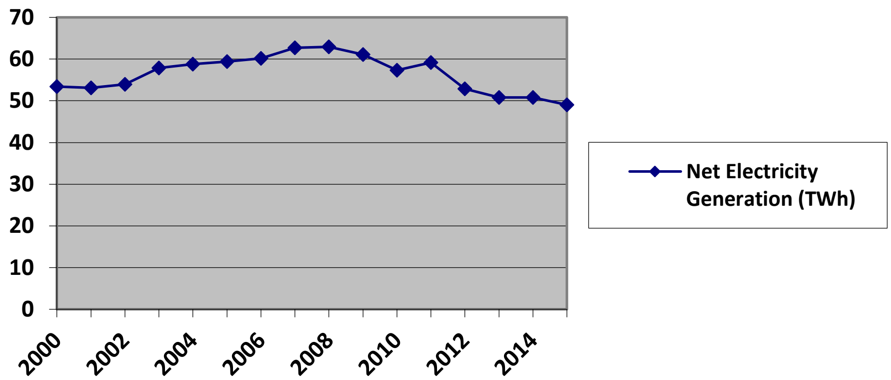


Figure 17: Net Electricity Generation 2000-2014 in TWh (*PPC,EUSTAT,2015*)

The last decade set the bar for electricity output for Greece. While increasing at small increments near Olympic Games 2004, for most of the time annual production did remain relatively constant. Since 2009 , there is a clear drop due to lower demand afflicted by recession.

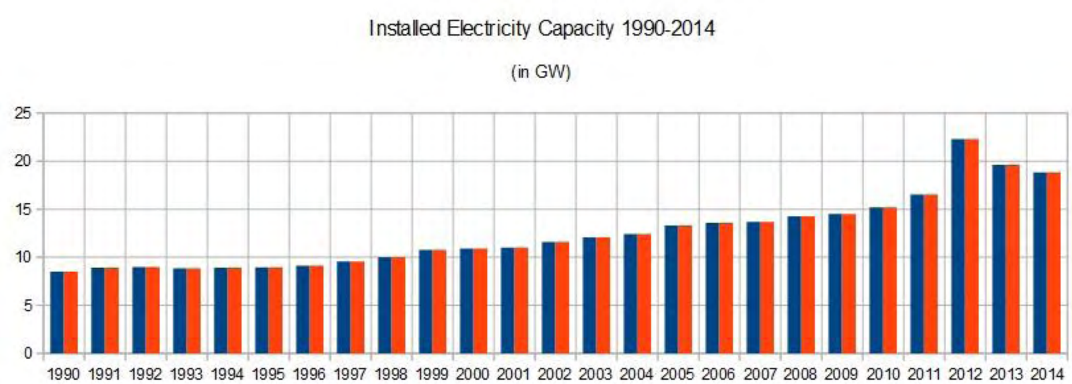


Figure 18 : Installed electricity capacity 1990-2014 (*ELSTAT, 2014*)

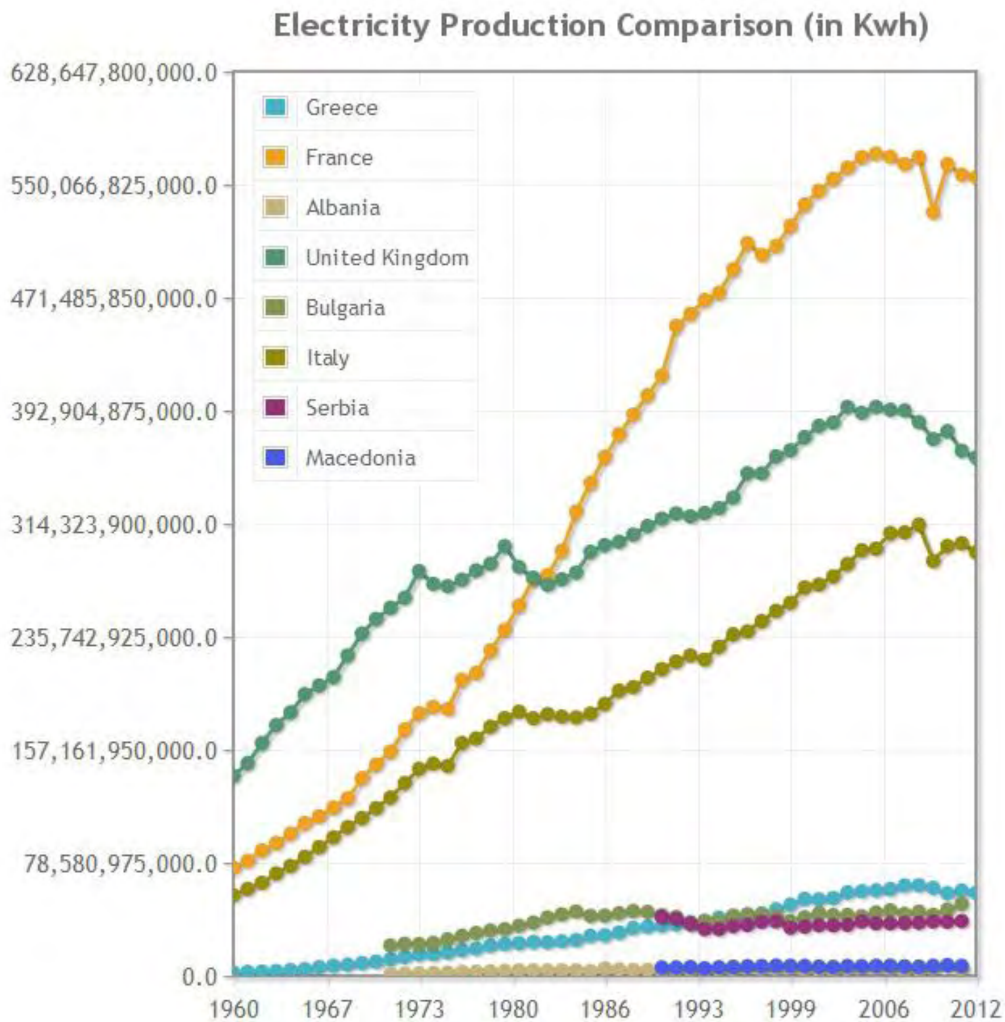


Figure 19: Comparison of electricity generation (*IRENA, 2014)*

According to net electricity generation and installed electricity capacity diagrams for the years 1990-2014 as far as Greece is concerned, first analysis on the growth output of the market can be established.

Since 1990, we can apprehend a relatively unchanged electricity production, indicating a stable economy but without strong development initiatives, a trend clearly stated by the almost same pattern in the GDP diagram. Towards the end of the decade, electricity production rises by 2.5%/year, a considerable growth output , followed by a 2009 stagnating 0.3% and in the last few years , an interchangeable rise and drop, reciprocating the European EU-28 pattern.

As we can apprehend from the statistical data , the growth output is conservative and shows to be in tandem with EU28.However, without the extensive liberalization, unbundling and foreseeable implementation of efficient energy measures, in context with an economic challenged era, the annual GDP percentage spent on energy , an approximate 18%, is going to have a stronger negative impact each year.

More specific, according to Eurostat, there is a reduction among EU28 in electricity generation after 2009. Moreover, nuclear generated electricity in 2011-2012 dropped by 2.8%, due to stagnating overall generation. Thus confirmed, the fossil fuel generation dropped by -4% while natural gas by -23%. All combined, EU-28 members saw an average -4.9% in electricity generation, which was reduced to -1.1% in 2012-2013. The gas-fired generators did record a reduction in favor of coal-fired generation during the same period. Although Greece remained within the average reduction percentage, Norway, Turkey and Switzerland recorded a 15%, 10% and 9% increase respectively. [Warwick]

At this point, we should mention that the electricity generation by itself is not the sole purpose of the market but it is how more efficient this energy can be spent, motivating the economy of a nation not just sustain it. Also, in a lignite oriented generation, the Carbon Capture Technology to new licensed power plants can reduce the emissions level and the fines related since 2013 [90419.pdf]

Moreover, we can benchmark the Greek electricity market by its pricing per Kwh, in household and industry, and in greater detail by introducing the measurement of liberalization level. A commonly accepted technique is the Herfindahl-Hirschman Index (H.H.I), as a mean to average the concentration level of the market (*Sianni, 2011*)

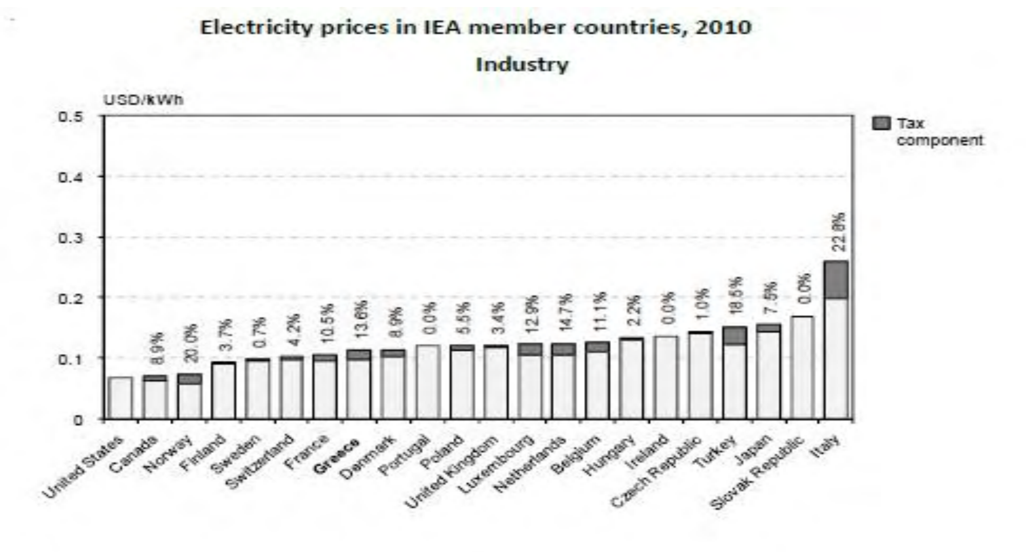


Figure 20: Electricity prices concerning industry consumers *(IEA, 2011)*

Greek market possess a low price compared with similar economies, such as Ireland and Portugal but with a higher tax. Prices do not reflect fully their cost due to specific arrangements with heavy industry users.

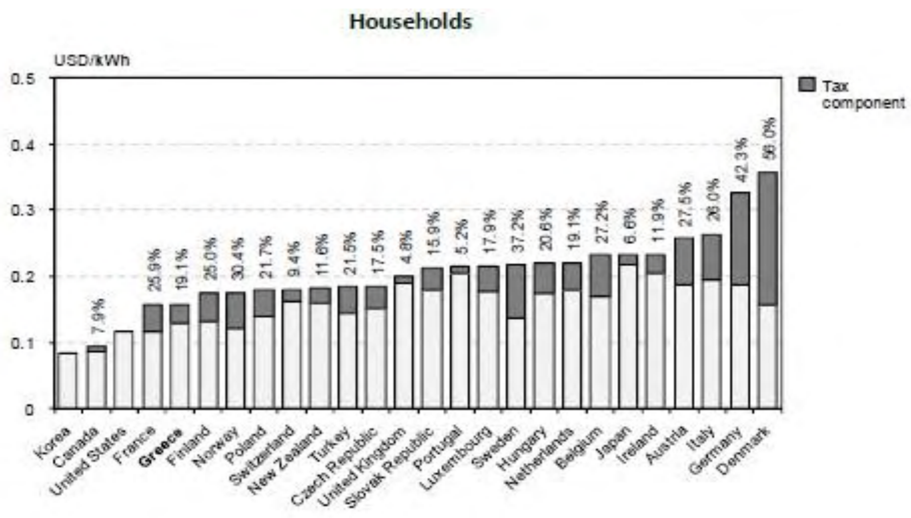


Figure 21: Household consumers and price per kWh (*IEA, 2011*)

On household consumption, prices are among the lowest in European Union with a heavy taxation scheme towards consumers.

Current energy necessities of Greece, acquire a certain amount of electricity to be imported by nearby transmission. Established connections with Bulgaria and FYROM while PPC maintains subsidiaries in FYROM and Turkey. Eurostat measures the dependency level with

Index = net imports / gross inland energy consumption

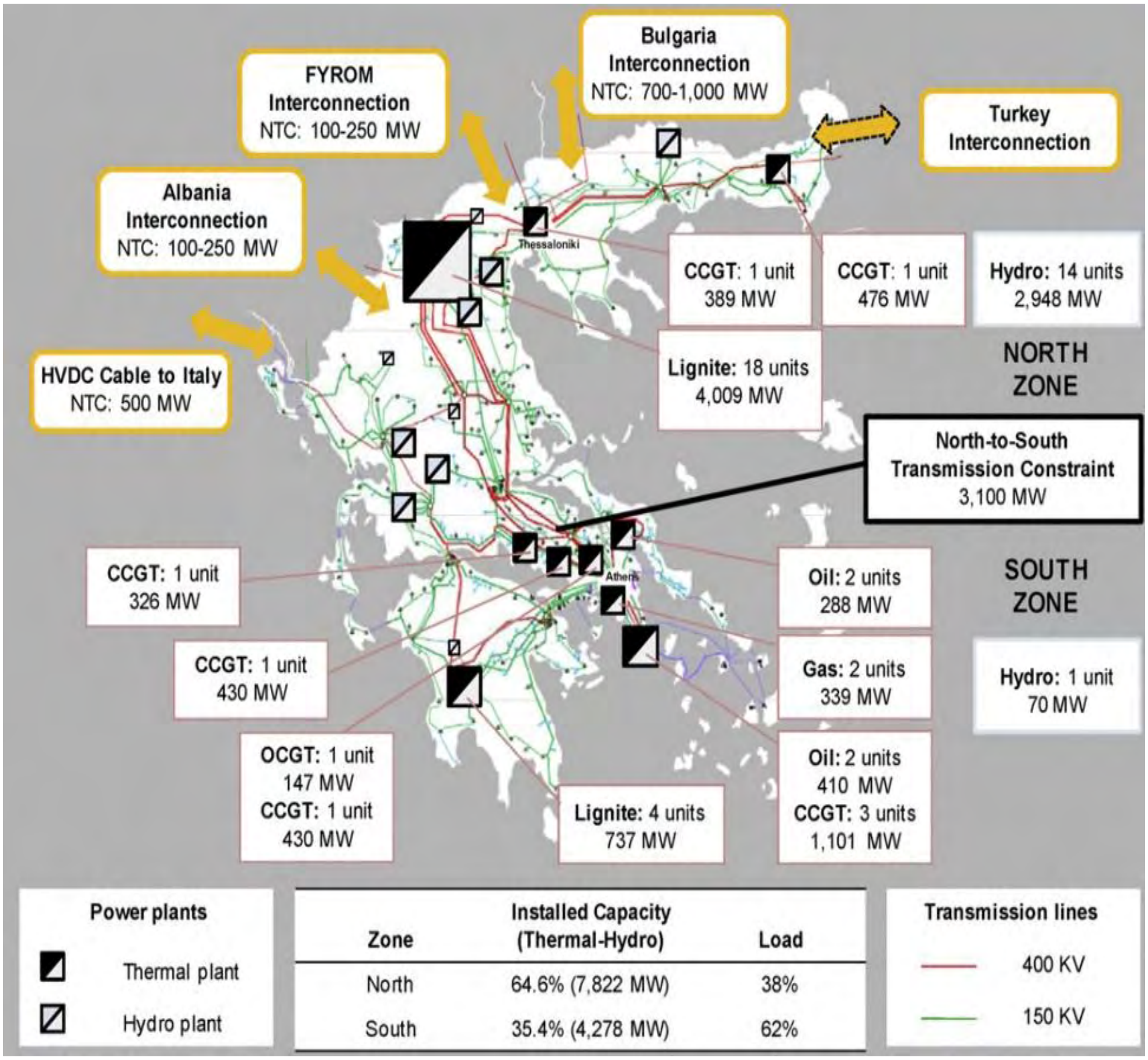


Figure 22: Main grid and non-connected plants. Interconnections included. (*HTSO, Andrianesis, 2011*)

Cost is also rising because of the low efficiency of aging lignite-powered plants. Efficiency is approximately 0.33 while newer plants achieve a higher rating of 0.40-0.50 (*Iliadou, 2008*).

At this point, the liberalization level measured by HHI is the portrayal of the concentrated aging problems of Greek power market.

	Number of companies with more than 5% share of capacity (%)			Share of 3 biggest companies (by capacity) (%)			HHI (by capacity)		
	2007	2008	Δ	2007	2008	Δ	2007	2008	Δ
Belgium	2	2	0	99.9	97.5	-2.4	8390	7206	-1184
France	1	1	0	93	93	0	6960	NA	
Germany	4	4	0	85.4	84.7	-0.7	NA	2008	
Gr. Britain	8	8	0	41	42	1	986	901	-85
Greece	1	1	0	NA	NA		10000	10000	0
Hungary	5	5	0	67	67.9	0.9	2119	1911	-208
Italy	5	5	0	61.2	57.6	-3.6	2126	1351	-775
Latvia	1	1	0	93	94	1	8110	8110	0
Lithuania	3	3	0	84	85	1	3160	3095	-65
Luxembourg	3	3	0	80	79	-1	5843	5682	-161
Portugal	2	2	0	72.5	72.2	-0.3	4472	4521	49
Romania	5	5	0	63.7	70.98	7.28	1813	2116	303
Spain	5	5	0	76	72.9	-3.1	1827	1716	-111
Netherlands	6	4	-2	61	69.9	8.9	1592	1551	-41

Source: European Commission (2010)

Figure 23: Wholesale market position in electricity 2007/2008

In order to assimilate the meaning of the above diagram, there are classes of HHI index

- HHI = 10,000 → The market is a total monopoly
- 5,000 < HHI < 10,000 → The market is highly concentrated
- 1,800 < HHI < 5,000 → The market is moderately concentrated
- 1,000 < HHI ≤ 1,800 → The market is sufficiently competitive
- HHI ≤ 1,000 → The market is highly competitive.

Figure 24 : HHI grade (*Siani,2011)*

Combined, HHI and the position amidst the grading indicate a highly concentrated market amongst other countries and comparable economies such as Portugal present a more competent scheme. With a mark almost reaching total monopoly, in 2008, power market is need of reforms. We should underline though that full liberalization of electricity prices and improved market operation as far as entrees are concerned ought to lower the above grading in the following years.

Chapter 5 - : Effective measures for market reform and liberalization

There are certain shortcomings and structural inconsistencies for the electricity grid in order to maintain its inland generation at an efficient level. Since 1996-2007, the average index of dependency for EU-27 was 48.4% while Greece displays a significant higher 68.8%. Noteworthy is the 83.8% of solid fuel in gross inland consumption.

Another issue of the Greek electricity market manifests in the form of an expensive generated Kwh.

IEA claims the industrial sector pays a relatively medium price among O.O.S.A members (IEA, 2011) On the contrary, residential customers pay the 4th lowest Kwh despite the 25% increase at retail prices since 2013 after deregulation. Prices remain inconsistent and non-cost reflective. Accounting factors such as fuel price fluctuations, variations of demand and the evolution of generating electricity (Siani, 2011) , there are still issues at the structure and operation of the power grid. Clearly, there is inefficiency at production attributed to non-fuel operating costs opposed to net power (Iliadou, 2009). In specific, examining labor costs per MW , maintenance, operation and network costs , all combined surpass the European average. Despite using lignite as a prime fuel for electricity, since 2013 there is an annual tax added because of exceeding CO_2 emissions and the increased operational costs of aging lignite burning generators.

A constant point of concern tends to form in last few years in inability of state controlled agencies to collect unpaid debts from households and heavy industries [EUSTAT, 2014].

In power market, there are debts consisting of Low Voltage (L.V), Medium Voltage (M.V) and few especially costly large debt consolidations from High Voltage (H.V) customers. Economic crisis has already stranded households from their ability to meet their finance obligations and even heavy industries are operating under disproportionate cost.

As a counter measure, from 2013, Greek Parliament voted for Social Tariff, which excludes penalties and restrictive financial measures for economically challenged households. Despite the small reform in pricing elasticity, PPC cannot collect open settlements. In 2013 alone, these unpaid transactions did account for Euro 1.2 Billion (*eKathimerini,Chrysa Liaggou,article151160, 20/06/2015*).

CO_2 emissions costs retain a difficult challenge for Greek power market. EU-ETS and the 3rd Energy Plan aim at binding goals for each member state by reducing greenhouse emissions from power plants. Promoting renewable power solutions instead of fossil fuel comes with a specific system of allowances. Every year, the cap is reduced by 1.74% since its original target in 2009. Main driving force is the 21% decrease of harmful gases by 2020. Greece uses lignite and despite the decrease each previous year before 2009, in recent years and due to severe economic turndown, coal fired plants were used more often. As a result, and due to price penalty if a market exceeds emissions, electricity production from coal is fined by 100 Euro per tonne of greenhouse emissions. In a perspective, coal generators in 2013 produced of 40-42 million (*IEA report, 2011)*.

Mandatory pool is the type of market that its currently implemented in electricity sector of Greek power grid. It is a broad and well-known model with extensive applications, with regional variations, in many power markets like Britain, Irelan, California and France. As far as the Greek market is concerned though, an imminent problem inhibits future development and unbundled potential: a market participant with many assets gathered unequally combined with a potential market abuse. As a dominant player in electricity generation, P.P.C operates coal fired-generators, large-hydro plants and P.V systems. However, the largest generating capacity is being managed by a single entity, a situation that could lead to market manipulation by changing the merit order in favor. Possible entrants to the market are skeptical to participate in a national grid with economic uncertainty, political negligence and monopoly tactics.

On the other hand, P.P.C also suffers from a non-cost reflective retail prices in generated electricity and aging power plants while being responsible for maintaining properly the transmission network and assess all operating costs as the sole transmitter.

5.1 Liberalization

As a EU and especially EU-ETS member, Greek power market needs to adopt certain policies and directives of the 3rd Energy Market Scheme. Main goal of directives is the full liberalization of electricity and gas market (IEA report, 2011).

Suggested actions in the initiative started at 2009 are:

1. *ownership unbundling*, which stipulates the separation of companies' generation and sale operations from their transmission networks
2. *establishment* of a National regulatory authority (NRA) for each Member State
3. *establishment* of Agency for the Cooperation of Energy Regulators which provides a forum for NRAs to work together

Primary targets have already set action including:

- *Effective unbundling* of energy production and supply interests
- *Transparency* of retail markets
- Effective *regulatory oversight* in selected segments
- Strengthen the *cross-border collaboration*

The legislative package suggests various structural models, such as the ownership unbundling or the existence of an Independent System Operator or an Independent Transmission Operator named also legal unbundling

Analyzing actions already taken in power market, RAE is the N.R.A and must be able to carry out its regulatory activities independently from government and from any other public or private entity. Greek power market selected the 3rd option, naturally as it suggested along with other EU members in 2008.

By 2012, RAE selected ADMIE as the I.P.T.S.O. Legislation offered full separation in case of ADMIE from PPC.

However, despite separate management of ADMIE and independent actions, the I.P.T.O is still solely (100%) owned by PPC. Even power market adopts another model from the proposed European energy agenda, considering P.P.C dominant position, there are possibilities of crossed interests and challenges arise for competitors to attain the market on equal terms.

Unbundling of DEDDIE, the distribution operator fully owned by PPC could improve market transparency with the provision of a well-maintained operative network sharing cost among competitors.

Since July 1st of 2013, L.V prices have been liberalized which was introduced with a 5.2% increase in kwh retail price (*eKathimerini, article, 20/10/2013*). Full liberalization is expected in the whole segment (M.V and H.V). Another parameter under review is that the incumbent electricity company retains monopoly of power supply. In 2012, there were 4 companies considering entering the market but all did abandon their initiatives due to dominant energy capacity. However, competition can drive prices lower while acquiring cost reflective pricing of produced energy.

There are also reforms that could take place in current Greek power market. Examples of Great Britain and France pool markets could transfer valuable information on avoiding certain limitations and exploit the full benefit of this economic structure. They fall into category of liberalized markets with pool structure improving bilateral agreements. A short-term market coordinated by a system operator and tradeable transmission rights (*Hogan,1998*) depicts a strong framework that a new reformed power market can rely on.

The chosen legislative and structural framework requires certain incentives to function, preserve and gradually improves Greek Power market:

- **Political Stability**: An absolute and utmost ultimatum for the efficient planning and execution of the pool reform. Government should decide about which of the proposed legislative and structural reforms are more appropriate for national grid. After selection, the plan needs to be implemented with determination and assess challenges that will arise, in residential and industrial segments. Furthermore, it is a strong indication for a foreign investor of a multinational fund to enter with strong vision, in a healthy competitive market creating more work opportunities. Another positive consequence could be the rationalization of the costs by keeping steady operation and avoid market distortions.
- **Political Awareness:** Transparency in market functionality and informing consumers about the nature of bilateral agreements with companies involved could help mitigate an advanced attitude towards energy savings.
- **Non-Interconnected grid:** Another cost effective measure gravitate towards Greek islands and the currently non – interconnected system. Currently, mainland residential consumers pay an extra tax attributed to electricity generation in islands such as Crete. Consumption increases dramatically in summer months, costing 3 times above previous average price. Diesel fire generators are the prime choice in non-interconnected grid and small wind generation plants contribute much less to a hefty kWh retail price. Renewables can enhance lower cost production while help achieve the national grid efficiency goals towards 2020. Pollution and heavy noise production present a challenge for critical place in tourist attraction and should considered in the final solution.

5.2 Legislative and structural reforms

Critical for a struggling energy market among a very competitive European Union is the simplicity and an accelerated licensing procedure for new entrants. Political promises usually start with addressing the issues of bureaucracy but despite minor improvements, a problematic situation persists.

Greek Parliament has voted the 3851/2010 Law related to R.E.S and licensing. Before legislative reformation, a license could acquire lengthy timetables that could resort into years , in some cases. Licensing currently has become easier and more direct. In specific, there is no necessity for a certification directly related to R.A.E of a generation license for power plants up to 1 MW installed capacity. As a result, wind, solar and biomass generators among other can now produce electricity and connect to mainland transmission system.

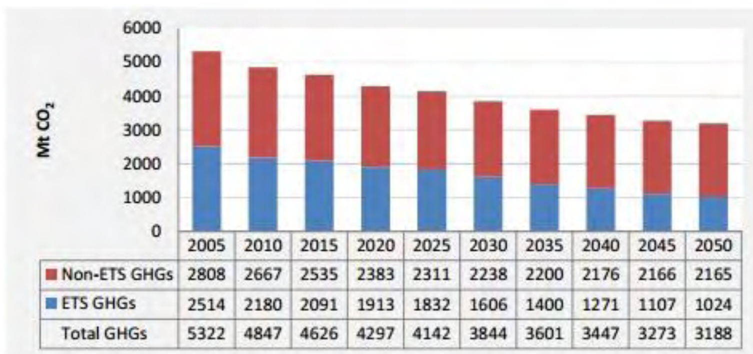
RES and CHD plants are pursuant to licensing code of 2011 by Law 4001. A generation license does not release its holder from the obligation to acquire other licenses or permits stipulated in other pieces of legislation such as construction permits, installation and operation licenses, environmental permits and land planning permissions. Small-scale plants are exempted from some permits. There are also financial incentives for feed-in tariffs excluding thought P.V energy.

However, the whole framework should become solid and rationalized. There are civil courts that recorded violations this law amended such an allowance to install RES plant in an area that was under reforestation program. Similar cases have been recorder that violated certain protected areas by global NGO like Natura and resulting in environmental disturbance.

Another licensing procedure under review consists of an improved framework for larger than MW entrees and a market stability. Large scale invests in RES are especially critical due to de-carbonization road the government has paved. Strict CO2 emissions and RES at a 40% power generation until 2020 need better support. Economic incentives and fast-track kind of operations might assist in the difficult but admirable task. Transparency must be attained to improve stability in the long term.

5.3 Efficient de-carbonization

From 2013, during the 3rd phase of EU-ETS there are no free allocations on fossil fuel production. As a result, all emissions allowances must be bought. It is a general framework, proposed by EU in order to sustain a low level of CO2 emissions in state members by 2020



	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Non-ETS GHGs	2808	2667	2535	2383	2311	2238	2200	2176	2166	2165
ETS GHGs	2514	2180	2091	1913	1832	1606	1400	1271	1107	1024
Total GHGs	5322	4847	4626	4297	4142	3844	3601	3447	3273	3188

Figure 25: Evolution of GHG emissions (*Energy Trends to 2050,2013*)

Greece shows commitment and efficiency measures to achieve greenhouse and RES goals. Average efficiency of the efforts achieve above average EU-28 score.

However since 2013, excessive usage of coal fired plans, economic recession and the above average gas price per metric ton indicate an increase in fossil fuel consumption. A trend intensified by political actions during 2015 insisting on greater use of lignite during 2015 [source: media]

Reforms can sustain a balanced and mild transition to decrease the use of coal – fired generators, accompanied by an increase in R.E.S. A proposed framework solution could be:

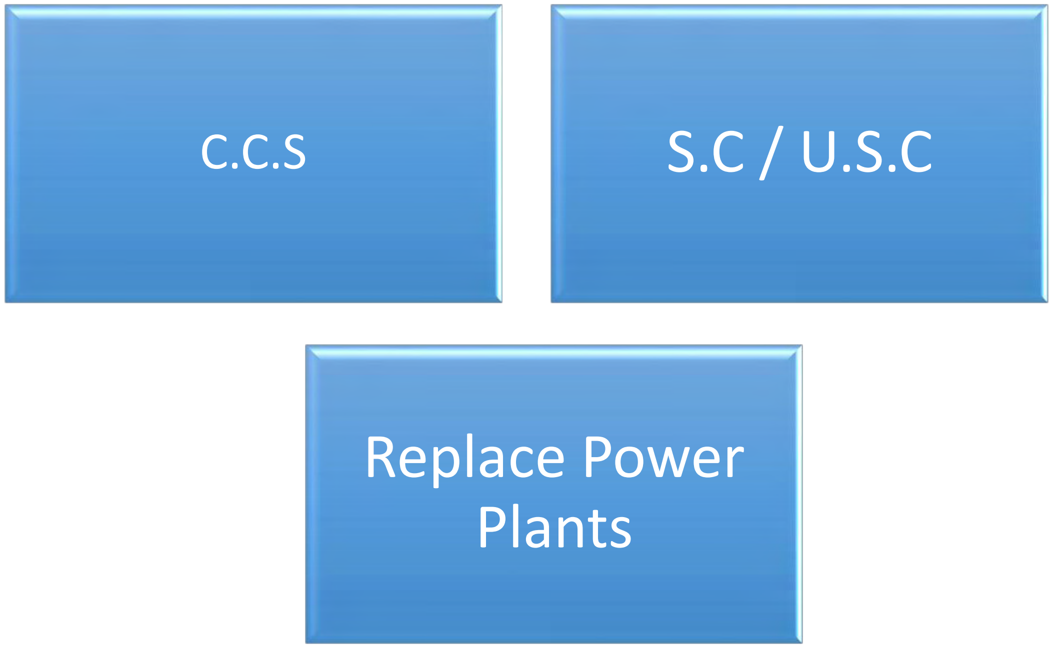
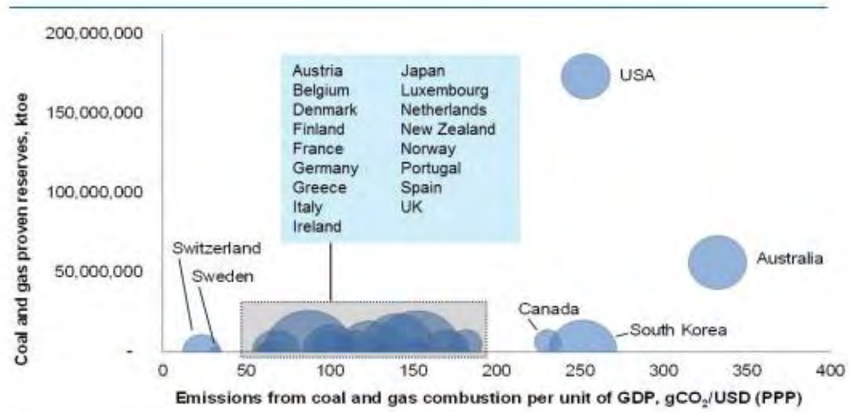


Figure 26: Technologies that can help reduce CO2 emissions by coal-fired plants

- **<u>Carbon Capture and Storage:</u>** A new promising technology for power plants that according to estimates by Intergovernmental Panel on Climate Change are responsible for up to 60% of world's total fossil fuel CO_2 emissions (*Exxon, 2013)*.
  Its core technology is already in use by large oil and gas companies. The basic principle is compression of the emitted gas, transfer through pipeline and then a beneficial use or injection through a geological formation.
  According to IEA 2012 report, the technology is characterized as immature and beneficial in the long term. Main reason is lack of private funding and a turnaround to RES.
  However, large power markets using lignite, such as China could invest to decrease the still high capital costs. In the long term, CCS offers the means to reduce greatly CHG emissions, right now projected to 19% (*IEA, 2012*).



Notes: Focuses on Annex II countries with obligations under the Kyoto Protocol to support developing countries. Size of bubble proportional to potential climate damages.
Sources: Wheeler, 2011 (climate vulnerability); IEA, 2010a and 2010b, and Penn World Tables (emissions from coal and gas combustion per unit of GDP), BP Statistical Review of World Energy, 2010 (coal and gas proven reserves).

Figure 27: Possibility of CCS adoption (*Policy Strategy for CCS, IEA, 2012*)

According to projections by IEA and the resources that Greece uses for electricity generation, Greece is likely to adopt C.C.S technology by 2050 to achieve a -19% increase in emissions.

An adoption in combination with a balanced legislative framework proposal can further increase efficiency and transparency.

The UK Department for Energy and Climate Change (DECC) has recently proposed a combination of instruments to achieve decarbonisation and headroom in power generation capacity. In addition to GBP 1 billion provided to the first CCS demonstration project, and further funding for another one to three CCS projects, the proposals include the following:

(a) an emission performance standard (EPS), set so that no new coal-fired power stations are built without CCS (DECC, 2011a);

(b) a carbon price floor (CPF), intended to reduce investment uncertainty and strengthen the incentive for low carbon electricity generation;

(c) a system of feed-in tariffs (FITs) combined with contract-for-differences (CfD). This in effect guarantees the price received by the generators if the wholesale power price is below an agreed level;

(d) a capacity mechanism, to ensure headroom in generation capacity.

As a set of multiple instruments aimed at multiple objectives, these proposals reflect many elements of the framework described in this report. We have yet to see the impact of the proposed policy, but it is nevertheless worth noting that the UK proposals constitute the first more comprehensive approach globally to set CCS policy beyond the first demonstration facilities.

Figure 28 : UK proposal for CCS (IEA, 2012)

UK power market initiatives simplify:

- Build coal fire plants with CCS
- An CHG limit
- An economic usage incentive
- Failsafe mechanism

All the above are amidst the general policy that IEA and could help Greek power market to succeed.

- **<u>Super-critical and Ultra-Super-Critical steam conditions:</u>** Usually, efficiency levels at power plants are ranging from 30-39% at constant 540 degrees Celsius. Increasing pressure can lead to higher levels of efficiency. Technical specifications indicate an much higher pressure than 22.1 MegaPascal , that can lead to 600o Celsius and even further to Ultra Super Critical levels , enhancing efficiency of operation. Reports indicate a 42% efficiency for SC and 45% respectively for USC technologies comprising coal fired plants. Inevitably, new alloys and harder metals are being already tested to endure such high pressures and the possibility of rising 700o Celsius for a claimed 50% efficiency, Long-term solution as the commercial implementation is expected at 2020s.

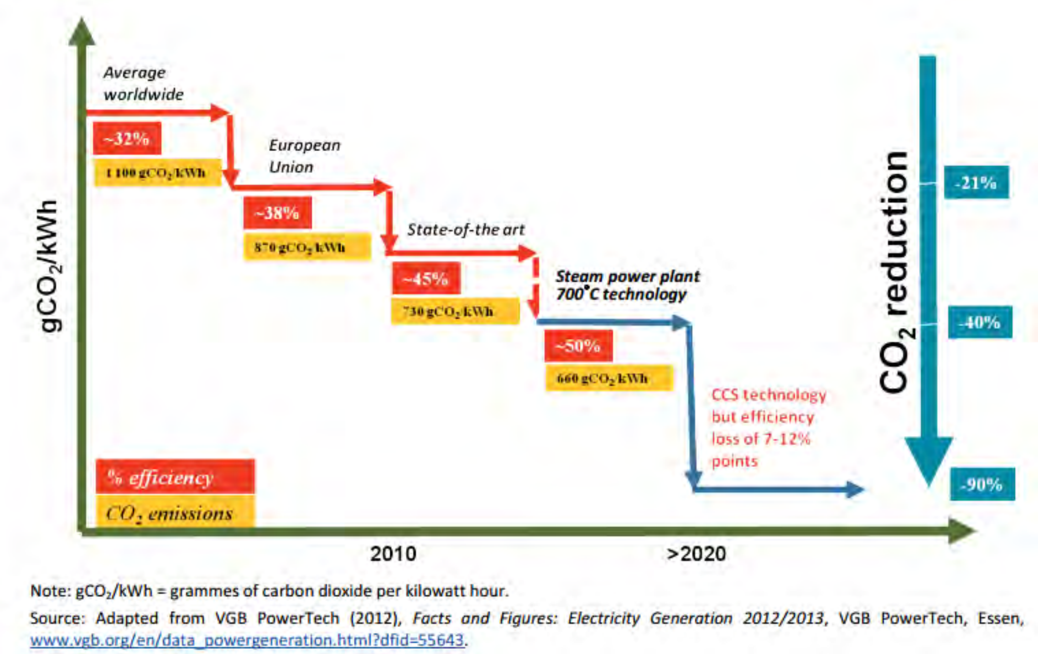


Figure 29: CO2 reduction in context with country and technology (*VGB,2012*)

Gains are considerable as far as GHG are concerned, in such coal dependent economies like Greece. Operating a power generator with USC steam conditions, CO2 emissions can be reduced by approximately 40%.

China is the leading developer in coal-fired plants but Greece can adopt such technologies in the long term and introduce a broad cooperation in the energy sector, benefiting equally both sides. (*Emissions Reduction through Update of Coal Fired Plants, 2014*)

- **Increase efficiency through replacing of power plants:** Usual lifespan of a power plant using coal is 25-35 years. In many markets, power plants are still operating after 40 years and in some rare cases, approximately 50 years. To improve efficiency of those plants, retrofit upgrades is a solution.

Power plant improvements	Potential efficiency increase (percentage points)
Air preheaters (optimise)	0.2 to 1.5
Ash removal system (replace)	0.1
Boiler (increase air heater surface)	2.1
Combustion system (optimise)	0.2 to 0.84
Condenser (optimise)	0.7 to 2.4
Cooling system performance (upgrade)	0.2 to 1.0
Feedwater heaters (optimise)	0.2 to 2.0
Flue gas moisture recovery	0.3 to 0.7
Flue gas heat recovery	0.3 to 1.5
Coal drying (installation)	0.1 to 1.7
Process controls (installation/improvement)	0.2 to 2.0
Reduction of slag and furnace fouling	0.4
Soot blower optimisation	0.1 to 0.7
Steam leaks (reduce)	1.1
Steam turbine (refurbish)	0.8 to 2.6

Source: NETL (2008), *Reducing CO_2 Emissions by Improving the Efficiency of the Existing Coal-Fired Power Plant Fleet*, DOE/NETL-2008/1329, NETL, Pittsburgh, PA, www.netl.doe.gov/energy-analyses/pubs/CFPP%20Efficiency-FINAL.pdf.

Figure 30: power plant upgrades in context with efficiency (*IEA, 2014*)

There many components that can be replaced with newer and more efficient ones. In order to do so, an extensive review of the plant is necessary and must be thorough and cost reflective. Another way to make existing plans scheme more effective is the closing of smaller plants and the design of new power plants that implement modern technologies thus produce more and cheaper.

In China, electricity production efficiency is a priority. An 11-year plant enhances production of electricity by replacing old plants with advanced ones. The advanced coal fired generators and updated energy policies increase efficiency from 280 GCe /Kwh to 325 GCe/Kwh.

PPC announced in 2013 a plan to close four coal-fired plants in order to adjust its installed capacity and reduce overall costs. Reduced timetables, costly production and aging equipment are the main reasons in order to reduce generating capacity from 5288MW to 2433MW in a progressive timeframe.(*eKathimerini,2013*)

Social impact is very important in a devastated economy and careful and smooth operations must be implemented. It is important to allocate personnel if possible and produce an agreeable solution to all involved.

In conclusion, measures exist and can be implemented to improve efficiency of power plants , reduce costs and emissions in a challenging era of Greek power market.

5.4 Net Metering and the IT connection

The smart grid or intelligent grid concept has met many interpretations over the years. It is considered a term with many meanings to many people but the substance is always the same : changing what people think about electricity production, transmission and distribution [IEA, SmartGrids,2011]

Many countries such as UK, USA and France are using smart meters for the last few years successfully. In Germany , Microsoft , Bosch and Yellostrom collaborated in an advanced system , the Sparzahler by providing a smart meter, an enhanced connection to the company gathering results and computer software. Especially software presented capabilities such as real time house consumption and send data to consumer’s personal connected devices.

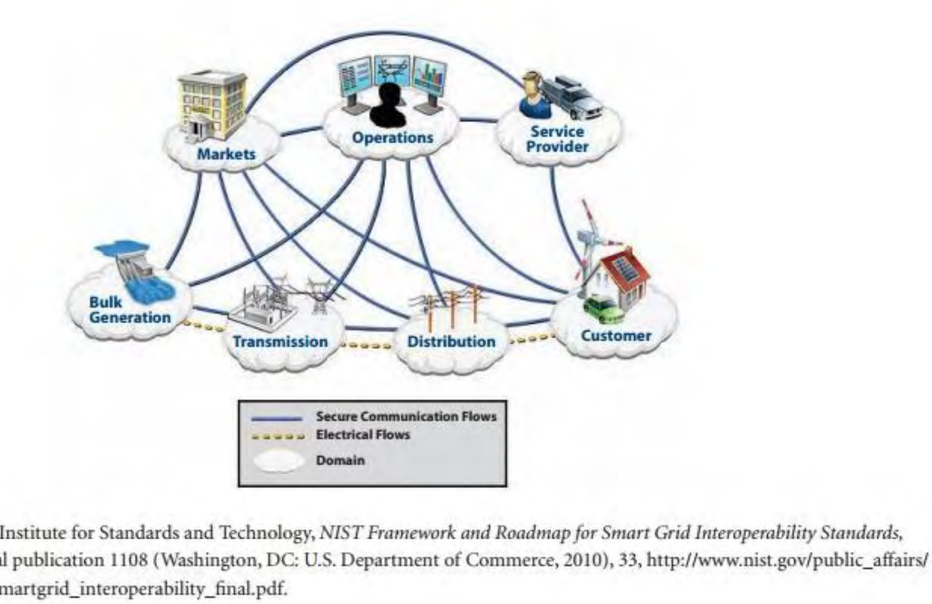


Figure 31: Smart grid overview [*MIT, 2012*]

Companies initiate smart meters, enhanced connections abolishing RS-232 and RF signals in favor of Wi-Fi , Bluetooth , Wi-Max and Ethernet connections. Reasons are more accurate metering, smaller chance of tampering meter and a more demand-response approach to customer needs. Clients can use software to gather more information about their daily energy routine and adapt accordingly to minimize electricity consumption.

Phase	Years	System Characteristics	Network Architecture	Communication Media	Communication Protocols and Standards
Nonstandardized	Up to 1985	• Many proprietary systems • Single vendor per system • Basic data collection	• Hierarchical tree • Single master • Isolated substations	• RS232 and RS485 • Dial up • Trunked radio • Power line carrier • Less than 1,200 bytes per second (bps)	• Modbus • SEL • WISP • Conitel 2020
Standards Development Begins	1985–1995	• Multivendor systems • Protocol conversion	• Hierarchical tree • Multiple masters • Redundant links	• Leased lines • Packet radio • 9,600 to 19,200 bps	• DNP3 Serial • IEC 60870 • TASE 2
Local-area Networks (LANs) and Wide-area Networks (WANs)	1995–2000	• Introduction of LANs in substations • Merging protection and SCADA networks	• Peer-to-peer communication in substation • Joining substations via WAN	• Ethernet • Spread spectrum radio • Frame relay • Megabit data rates	• TCP-IP • FTP • Telnet • HTTP • DNP3 WAN/LAN • UCA 2.0
Integration into Business	2000–present	• Merging automation and business networks • Corporate IT departments • Asset management	• Linking of utility WAN to corporate network • Extension of network to customer premises • Use of Internet	• Digital cellular • IP radios • Wireless ethernet • Gigabit backbones	• TCP-IP • IEC 61850 • XML

Source: V. C. Gungor and F. C. Lambert, "A Survey on Communication Networks for Electric System Automation," *Computer Networks* 50, 7 (2006): 877–97.

Figure 32 : Evolution of Smart Grid systems [*MIT, 2012*]

Being able to gather information about consumer loads at different periods of day and night, assist electric companies to assimilate a pattern of operation for their power plants, minimizing costs and decrease emissions for non-renewable facilities.

After 2009 Eu Directive , all member states should consider acquiring net metering and smart network infrastructure for better interoperability between states. In 2011, PPC issued an international competition for the pilot usage of 160.000 smart meter devices that would be installed in selected areas. There were delays in the implementation of that policy, in 2014, a new competition was re-announced, and finally the pilot installation has begun.

DEDDIE , responsible for the competition, predicts a 15 month period for 200.000 devices and the supporting IT infrastructure. Whole installation costs approximately 86.5 M Euro and offers basic information about the consumption of a residential user and useful information from company such as possible grid irregularities.

Greece has a lot of reformations to do in order to sustain a fully functional smart-grid with devices and infrastructure resembling all the consumer's needs. However, planning and provisioning a safe and efficient net metering system can only help the efforts for a smooth transition in modern grid era for power market.

Security is a major concern for future grid operations. Physical attack to metering infrastructure should be averted by installing anti-tampering mechanisms or optical feedback at any time. Cyber security also presents a serious threat to uninterrupted operation , as a Denial of Service attack or various system exploits might actually power down whole areas and facilities. SCADA type networks with WAMC or SMT present a solution for increased security and continuous operation. Alternative , a network with DSA technology infused with the network can help adjust security parameters in real time. Examples such as ERCOT in Texas sustain high , secure and efficient operation [IEEE, Smart Grid ,Newsletter, July 2014].

Information technologies are crucial in smart grid operation. Networks operate at all stages of electricity and maximum interoperability must be established. Consequently, electric grid is a system of systems and being accustomed to continuous transition into a modern digital era. Data collecting is another need that informatics can provide with extensive data storage with security and efficiency in mind. Data communication and grid modernization in digital era

Chapter 6 - : Epilogue

Summarizing, in this paper we presented a strong case for Greece for adopting a new, liberalized and effective reformation framework for electricity market.

Starting in early 20th century , many countries installed their first electrical grids , a truly amazing human feature . Generation of electricity , transmission and distribution presented a technical challenge but a crucial solution was in demand in order to support booming economies. Following times, regulated prices and monopoly characterized first electricity markets. In the early 1980's airlines had already started to acquire liberal economic tactics in order to improve services and lower costs. United States of America and UK soon after, implemented , as beta-testing , the ability to reform market pools into wholesale competition after retail prices of electricity. Competition improved the market and distributed grid costs among participants making a strong case for a fully liberalized market but with state controlled operator to avoid manipulations and unfair policies.

Cases from United States, France and Great Britain present markets that did work for a long time, pioneered reforms and continue to improve functionality with new technologies and legislative modernization.

Greece has made a commendable effort since 1950's when the first lines of electricity run through the country. In 1981 , the entrance as an equal member to European Union started a new era with many economic promises but also obligations. Reforms were made progressively and in 1998 a new era did start in European Union with the provision for liberalized markets. However, the updated energy policies did implemented with a significant delay.

In 2015, prices in market did liberalize but certain aspects need to haste market transformations and legislative reconstitutions. Political stability remains a prime concern as far as the general energy policy. May the power market stay longer and rely more on aging carbon plants due to envisioned political tendencies to advert on vulgarity , the energy deadlock might be unavoidable. However, more urgent market limitations must be confronted and utterly provided with perspective solutions.

Figure 33 : Simple reformations and constant effort rather than “superheroes” or magic wands. [PV Magazine]

The network framework must be reconstructed towards a market with healthy and fair competition scheme. A true independent regulator with extensive authority is necessary for a reasonable market supervision , providing entrees certainty and unbiased treatment. Competition can decrease prices through offerings and collectively share the high maintenance cost of network. PPC might face a certain challenge in order to reevaluate market strategy and provide cost reflective solutions without probable market non-transparent practices.

Prices that depict a certain value from production to distribution for all consumers represents another issue of Greek power market. Although prices have risen the last few years in order to sustain entrance of other competitors, there are still the lowest across EU-28 without portraying the real cost of generation and transmission. A fair pricing for all consumers ensures that neither Low Voltage consumers nor Medium or High, should be treated unfairly for another’s group benefit, a practice seen at the past many times [IEA,2011].

Renewable sources of electricity, is another initiative that needs to take drastic steps. Photovoltaic are on a rise and wind efficiency among the highest. However, there is a lot of potential to be unlocked and domestic consumption combined with net exports to foreign countries, may turn Hellenic prefecture to a south Europe energy hub. Licencing procedure and nomothetic provisions ought to maintain a more thorough examination of applicants without affecting the time needed.

If Greece stays on coal-fired generators while maintaining efforts on increasing res then it is essential to rethink the approach on lignite power plants. Implementing technologies like CCS or simply updating the aging plants could provide increased efficiency with lower cost of operation, mitigated mainly by PPC. Leading coal markets such as China could lead to successful cooperation about technology sharing which will further drive down costs and develop future potent energy policies.

Finally, the net metering installing, presented with many delays, should urgently complete in order to acquire data from customers and ensure a higher network quality. Accurate measurement provided with online network tools can enhance productivity and decrease losses and potential errors. A smart grid may inform better consumers about their daily energy habits, hence adapt to more green and efficient energy conscious living. As a result, due to lower energy demands, network load can be more rational and presented with lower cost of operation.

Greek power market has still the potential and the chance to improve energy policies in a challenging time for Europe. Acquiring an agile framework while working with technology and ensuring efficient operation, can lead to energy progress and an economic growth.

GEORGE TZAGKAS

References

[1] Report of the Division of Energy Market Oversight of F.E.R.C, "Energy Primer" Department of Energy, USA, July 2012.

[2] Electric Power Supply Association, "Electricity Primer", July 2007.

[3] T. Hughes, "Networks of Power: Electrification in Western Society", John Hopkins Press,1983.

[4] S.M. Kaplan, "Electric Power Transmission: Background and Policy Issues," April 2009, Congressional Research Service.

[5] International Energy Agency, "Energy Policies of IEA Countries: Greece 2011 Review," IEA/OECD Publications, 2011.

[6] International Energy Agency, "Energy Policies of IEA Countries: Greece 2006 Review," IEA/OECD Publications, 2006.

[7] E.R.E.C," Renewable Energy Policy Review: Greece 2004 review", Brussels, 2004.

[8] MJ.D Cock, C. Strauss,"Power Distribution of Industry", vol.1, Newnes Publications, Oxford MA, 2004.

[9] B.Posner," Fundamentals of Electricity Markets", Penn State University, Online, https://www.e-education.psu.edu/ebf200up/node/151, as seen on Dec 2013.

[10] T.A Short,"Electric Power Distribution", CRC Press LLC, London, 2004.

University of Aegean , "The Dynamics of the Electricity Market in Greece", Siani.A.I., Minis.I., Chios, 2011

[11] Iliadou, E. , "Electricity sector reform in Greece", CCP Working Policy, Athens, 2007

[12] International Energy Agency , " Emissions Reduction through Upgrade of Coal Fired Plants ", IEA Publications, 2014

[13] Centre for Renewable Energy Sources & Saving, "Energy Efficiency Policies and Measures in Greece ", Odysee-Mure, Athens, 2012.

[15] MIT study, "The Future of The Electric Grid", Massachusetts Institute of Technology, 2011

[16] PPC , "Annual Report 2014", PPC publications, Athens , 2014

[17] International Energy Agency , "Energy Policy Highlights" , IEA, Paris , 2014

[18] European Commision , "Energy , Transport and GHG : Trends to 2050", IEA Publications, 2013

[19] Andrianesis.P, Mpiskas.P, Liberopoulos.G, “An overview of Greece’s wholesale electricity market with emphasis on ancillary services” , University of Thessaly, 2011

[20] Organisation for Economic Co-operation and Development, “ECONOMIC POLICY REFORMS 2015: GOING FOR GROWTH “, OECD Publications, 2015

[21] Strauss C., Kock D.J, “Power Distribution for Industry”, IDC Technologies , 2004

[22] Hogan W.W , “Competitive Electricity Market Design: A Wholesale Primer”, Harvard University ,Cambridge, Massachusetts, 1998

[23] Huff E.L, “Competitive Electricity Markets:Why They Are Working And How To Improve Them” , Harvard University, 2009

[24] Joskow P., Kahn J, “Lessons Learned From Electricity Market Liberalization”, IAEE, Energy Journal Special Edition, 2008

[25] Borlase S., “Smart Grids : Infrastructure, Technology and Solutions “, CRC Press, 2013

[26] European Investment Bank , “ J.E.S.S.I.C.A Instruments for Energy Efficiency Study in Greece “, Remaco Consulting , 2010

[27] International Renewable Energy Agency , “Evaluating Renewable Energy Policy: A Review of Criteria and Indicators for Assessment”, IRENA Publications , 2014

[28] Regulatory Authority of Energy “2009 National Report to the European Commission”, European Energy Regulators Group for Electricity and Gas, Athens, 2009

[29] Regulatory Authority for Energy “RAE rescipt No. 378/2010 – 2011 Annual Cost and Electricity Distribution Network Use Charges”,http://www.rae.gr/old/elec_charges/RAE_378-2010.pdf [access on 05/06/2015][in Greek]

[30] Regulatory Authority for Energy, “Supplier Charges”, http://www.rae.gr/categories_new/electricity/market/supply/invoice/info.csp [access on 03/07/2015][in Greek]

[31] Papalexopoulos A., “2001 California Energy Crisis: What Happened, Who’s to Blame and Lessons Learned “, Presentation – PPC, Athens , 2008

[32] PV-Magazine , “Greece Turns to Lignite” , http://www.pv-magazine.com/news/details/beitrag/greece-turns-to-lignite-_100019886/#axzz3nJLKu3xn [access on 20/7/2015]

[33] PV-Magazine , “Greek PV market remains idle, defined by paradox”, http://www.pv-magazine.com/news/details/beitrag/greek-pv-market-remains-idle--defined-by-paradox_100016994/#axzz3nJLKu3xn [access on 20/2/2015]

[34] PV-Magazine , “Greece added just 13 MW in 2014”, http://www.pv-magazine.com/news/details/beitrag/greece-added-just-13-mw-in-2014-_100018626/#axzz3nJLKu3xn [access on 15/5/2015]

[35] PV-Magazine , “What next for Greece's energy sector?”, http://www.pv-magazine.com/news/details/beitrag/what-next-for-greeces-energy-sector_100020252/#axzz3nJLKu3xn [access on 3/8/2015]

[36] eKathimerini, “Σχέδιο της ΔΕΗ για το κλείσιμο τεσσάρων λιγνιτικών μονάδων”, http://www.kathimerini.gr/490207/article/oikonomia/epixeirhseis/sxedio-ths-deh-gia-to-kleisimo-tessarwn-lignitikwn-monadwn [access on 15/7/2015]

[37] Institute of Electrical and Electronics Engineer , “Smart Grid Newsletter: Smart Grid Security ”, http://smartgrid.ieee.org/ [access on 10/7/2014]

[38] Exxon , “The promise of Carbon Capture and Storage Technology”, ExxonMobil Publish, 2015

Chapter 7 - Acronyms

ADMIE: ΑΔΜΗΕ or Independent Power Transmission Operator

IEA: International Energy Association

IEM: Internal Electricity Market

EU-ETS: European Union Emission Trading System

FERC: Federal Energy Regulation Commission

H.V: High Voltage

L.V: Low Voltage

M.V: Medium Voltage

OECD: Organisation for Economic Co-operation and Development

P.L.C: Power Line Communication

PPC: Public Power Company or DEI (ΔΕΗ)