Ministry of Higher Education and Scientific Research

National Higher School of Management (ENSM)

Research Master in industrial economics of networks and infrastructure

Final thesis

TITLE

Modeling peak load electricity in an Algerian liberalized market

Presented By:

CHABOUNI Naima

Supervised by:

Dr. BENHASSINE Wassim

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2nd academic promotion

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Abstract

Peak electricity demand is a major issue in power supply system, it occurs when demand exceeds the available capacity. Continuous growth in peak demand increases the risk of power failures. Peak demand is affected by several parameters such as: the day of the week, seasonal variations, holiday periods, bank holidays and the weather. This study, estimates an equation of daily peak electricity load. The model incorporates deterministic influences such as holidays, and exogenous influences such as the weather (cooling and heating degree). The influence of the weather and seasonality is provided, and is significant even when the autoregressive effects and dynamic specification of the temperature are taken into account. Moreover, Holidays will make peak demand lower. The estimated general model shows a high predictive power.
Keywords: peak demand, temperature, seasonality, autoregressive effects, dynamic effects
Résumé

La demande de pointe en électricité est un problème majeur dans le système électrique, elle se produit lorsque la demande dépasse la capacité disponible. La croissance continue de la demande de pointe augmente le risque de pannes de courant. La demande de pointe est affectée par plusieurs paramètres tels que: le jour de la semaine, les variations saisonnières, les périodes de vacances, les jours de fête et les conditions météorologiques. Cette étude, estime une équation de charge quotidienne de pointe d'électricité. Le modèle intègre des influences déterministes telles que les vacances, et les influences exogènes telles que les conditions météorologiques (refroidissement et de chauffage). L'influence de la température et de la saison est prouvée et est significative, même lorsque les effets autorégressifs et la spécification dynamique de la température sont pris en compte. En outre, les vacances réduisent la demande de pointe. Le modèle général estimé montre un pouvoir prédictif élevé.
Mot-clé : La demande de pointe, la température, effets autorégressifs, spécification dynamique
ملخص

تشكل ذروة الطلب على الكهرباء إحدى أكبر تحديات نظام إمدادات الطاقة ، لكونها تحدث عندما يتجاوز الطلب القدرة المتاحة. استمرار نمو ذروة الطلب يزيد من خطر انقطاع الطاقة . تتأثر ذروة الطلب بالعديد من المتغيرات مثل أيام الأسبوع، التغيرات الموسمية، فترات العطل والعطل الرسمية. وتقدر هذه الأطروحة معادلة العبء اليوم الكهربائي. يتضمن النموذج تأثيرات حتمية مثل الأعياد، وتأثيرات خارجية، مثل أحوال الطقس (درجة التبريد والتدفئة). ولقد تم التأكد من مفاده و أهمية تأثير الطقس والموسم حتى عندما تؤخذ آثار الانحدار الذاتي والمعادلة الديناميكية درجة الحرارة في الحسبان .
علاوة على ذلك، فان العطلات تخفض من ذروة الطلب.كما يظهر النموذج العام المقدر قوة التنبؤية العالية.
الكلمات الرئيسية :ذروة الطلب، أحوال الطقس، التغيرات الموسمية، الانحدار الذاتي، المعادلة الديناميكية.

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ABBREVIATION LIST :

Abbreviation	*Meaning*
AIC	Akaike Information Criterion
AEC	Algerian Energy Company
BETTA	British Electricity Trading And Transmission Arrangements
CREG	Commission De Regulation De L'éléctricité Et Du Gaz
CDD	Cooling Degree-Day
DLC	Daily Load Curve
DPD	Daily Peak Demand
DOE	Department Of Energy
DW	Durbin-Watsom Statistic
EC	European Commission
ENTSO-E	European Network Of Transmission System Operators For Electricity
ETSO	European Transmission Operator
EU	European Union
EP	Evening Peak
FERC	Federal Energy Regulatory Commission
Gwh	Gigawatt-Heure
GDP	Gross Domestic Product
HDD	Heating Degree-Day
Hv	Hight Voltage
ISO	Independent System Operators
IEM	Internal Electricity Market
IGMC	Iran Grid Management Company
Kv	Kilovolts
Kw	Kilowatt
LM test	Lagrange Multiplier Test
GRTE	Le Gestionnaire Du Réseau De Transport De L'electricité
MV	Medium Voltages
MW	Megawatt
NEM	National Electricity Market
NEMMCO	National Electricity Market Management Company
NGC	National Grid Company
NETA	New Electricity Trading Arrangements

NAERC	North American Electric Reliability Council
OEFFR	Office Of Energy Regulation
OASIS	Open Access Same-Time Information System
OTC	Over-The-Counter
PURPA	Public Utility Regulatory Policy Act
RTO	Regional Transmission Organizations
SC	Shwarz Criterion
SO	System Operator
TI	Temperature Index
TEN-E	Trans-European Energy Networks Program
TSO	Transmission System Operators
UK	United Kingdom
USA	United State of America

INTRODUCTION

In the late of 19th century the electric industry was predominated by small competitive markets with an existing technology limiting distribution to short distances. Shortly afterwards these small utilities were transformed (due to inefficiencies that lead to high cost) to monopolized and regulated markets in the course of the 20th century, based on the natural monopoly character of electricity transmission and distribution as well as economies of scale in generation. In the late 1990s a growing interest in new liberalized models emerged in the UK, Australia, Chile and Europe and disrupted the monopoly status.

The changeover and the boost in economic activities allowed the emergence of new industries leading to a surge in electricity supply aligned with a growing demand. Increased electricity demand lead to the occurrence of the problem of peak demand which become one of the most serious problems faced by many countries. Peak load is defined as "*the maximum requirements of the network at a given time, when the electricity need is the greatest.*" *(CAISO, 2007).* In developed countries including Australia, increased peak demand has resulted in increased electricity cost due to the need for the installation of peaking power plants which serve for very short periods annually. Australia is one of the Peakiest regions in the world (Fan, S. Hyndman, J. 2011). For this reasons, the liberalized industries turned the issue of high peak demand into a major problem and implemented several programs designed to manage the peak load.

Algeria's economy remains dominated by the state, a legacy of the country's socialist post-independence development model. Gradual liberalization since the late 1980s has opened up more of the economy. The first glimpse of the reforms appeared in the 90s, The Algerian government was dragged to the implementation of new reforms especially after the crisis of 1986, the oil crisis had left a serious impact, and the lack of a strong financial system able to boost the economy plus its weak companies make matters worse. This situation, forced the Algerian authorities to monitor trends that arose in the international market, through privatization and globalization.

The main forms of energy available in Algeria are electricity, natural gas, petroleum products, and liquefied propane gas (LPG). The electricity market is held almost entirely by national company SONELGAZ. Coverage of the country by the power grid is at 98% with a capacity of 13614 MW through 2013. This network has over 6.5 million customers.

Recently, Algeria's electricity demand has been increasing fast, mainly due to the expansion of economic activities and population growth. Algeria's electricity consumption is projected to rise sharply; it is expected to reach 75-80 TWh in 2020. Electricity consumption occurs in three primary sectors. Electricity consumed in private homes is included in the residential sector. Electricity consumed in manufacturing business activities is included in the industrial sector. The commercial sector includes electricity consumed in non-manufacturing business activities and includes electricity consumed in office buildings, hospitals, retail stores, restaurants, warehouses etc

The growth in electricity demand generates peak load problems and in these last years it occurred more and more in Algeria. In order to resolve this problem the OS appeals to load shedding especially in 2012 and 2009. This will cost the economy greatly.

There are several factors directly contributing to the changes of peak load electricity demand over time.

Taking in consideration the previous statements, we chose to examine the impact of temperature parameters and holidays on the peak demand. For that, our concern in this study is:

To identify the main drives of the peak load demand in Algeria; as well as getting good results from the regression model used.

We would also address the following problems:

- *Which of the chosen variables influence more the peak load electricity demand?*
- *Is there an evident seasonality in the behavior of the peak load demand?*
- *Is it necessary for the Algerian government to implement new programs aiming to reduce the growing problem of peak demand?*

The following assumptions are contracted to answer the previous questions:

- *Temperature has the strongest effect on peak load electricity.*
- *Previous studies confirm the existence of strong seasonality in the behavior of the peak load demand.*
- *Peak load demand has become a major issue in Algeria.*

Methodology:

There are several studies on peak modeling which are using statistical techniques. These are considered as essential elements of efficient planning and operation of power system. Univariate and bivariate models are among the statistical techniques used in load studies. In our case we will use a similar framework to (Engels et al, 1992) (Henley, A. Peirson, J. 1994), where they analyzed the impact of exogenous variables such as the cooling and heating degree days, and also of seasonal dummy variables that capture the 'day of the week', 'holiday' and 'month of the year' effects. Additionally, the significance of the different autoregressive and dynamic patterns has been checked.

Organization of the study:

The remainder of this thesis is structured as follows. *Chapter 1* reviews the restructuring processes in electricity markets around the world in the last decades, followed by a presentation of the Algerian electric industry, with a descriptive analysis of the main parameters of the system. Afterward, a definition of the problem of peak load and the factors that triggers it, along with the different means used to manage it in the world. *Chapter 2* an empirically investigation is conducted using an econometric study, to determine the main drives of the peak demand in Algeria.

Chaptre I:

Peak Load Management in a Liberalized Electricity Market.

CHAPTER I: PEAK LOAD MANAGEMENT IN A LIBERALIZED ELECTRICITY MARKET

Introduction:

The electricity power industry in many developing countries is moving from a centralized operational approach to a competitive one. The understanding of electric power supply as a public service is being replaced by the notion that a competitive market is a more appropriate mechanism to supply energy to consumers with high reliability and low cost. This wave of deregulation turned the issue of high peak demand into a major problem. For this reasons, several programs designed to manage the peak load were implemented in many countries Algeria among those countries that is facing an increasing rate of electricity peak demand especially in the resent years. Significant efforts have been implemented in order to control the peak demand.

This chapter discusses Peak Load Management in a Liberalized Electricity Market in **section1** reviews the liberalization of the electricity market in some developing and developed countries. **Section 2** addresses in particularly the liberalization on the electricity market in Algeria and the specification of it industry. **Section 3** discusses the problem of peak demand and its drives. We conclude with a brief conclusion.

I. HISTORY OF ELECTRIC POWER SYSTEMS RESTRUCTURING

Electricity markets around the world were for a long time either vertically integrate, state-owned, or private firms subject to governmental regulation that were often monopolies.

Electricity differs from most products in several aspects: electricity supply and demand are subject to great seasonal and random variations in both short and long term. Electricity cannot be stored which amplify the volatility in the electric market. Electricity transmission is highly constrained[1]. In addition, electricity supply industry may exhibit economies of scale, which suggest that is inefficient to have many companies in the sector. Furthermore, distribution and transmission are commonly known to be natural monopolies[2].

Since electricity is considered to be the backbone of any economy, supply of electricity must be continuous, reliable and supplied with sustained frequency and voltage.

[1] Due to the high cost resulting from the implementation of new lines, plus it is time consuming

[2] Faye Steiner (2001), "**Regulation, industry structure and performance in the electricity supply industry**", OECD *Economic studies* No.32,2001/1

These characteristics have motivated the regulation and the liberalization of the electric industry.

A move toward restructuring and liberalization of electricity market has been taken by many countries, who agreed that the success of liberalization in other industries can be duplicated in the power sector, and motivated by the idea that electricity liberalization will promote efficiency gains, to stimulate technical innovation and lead to efficient investment.

The restructuring typically is based on functional splitting or *unbundling* of the vertically integrated monopoly structures (that traditionally have managed generation, transport and distribution) leading to the potential for competition. Therefore, different governance structures and market design models emerged to reflect regional needs and preferences. The reform may also include the creation of electricity spot markets in charge to set of electricity price and trade, and freedom in supplier choice. It can also include a shift from (cost-based) rate of return regulation of transmission pricing to price cap[3].

1. Movement toward power industry restructuring:

Power market liberalization first took place in Chile in the late 1970s. The reform was based on the idea to split generation and distribution companies.

Later on different continents of the world embrace the idea of introducing competition in the wholesale supply and purchase of electricity with an open access regime for the use of electricity network.

We will here discuss some example of the leading movement of restructuring of the electric industry.

1.1 Nordic Countries:

Electricity market reform in the Nordic countries preceded the EU electricity market directive of 1998 and has been more far-reaching.

The electricity industry of the Nordic Countries (Norway, Sweden, Finland, and Denmark) used to be protected from foreign competition, tightly regulated and dominated by vertically integrated publically-owned power companies, except for Denmark, the power companies have been and still are owned primarily by municipalities and consumer cooperatives[4]. The

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[3] Rafal Weron,(2006) "**Modeling and Forecasting Electricity Loads and Prices -A Statistical Approach**", Published by John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester.

[4] **The Nordic electricity market—continued success or emerging problems?** Lars Bergman

industry went through a major reform during the 1990s. The first Nordic country that have introduced competition in its electricity market was Norway through the Energy Act of 1990. Afterwards; the restructuring of the Swedish industry occurred in 1995. By the end of the century, the four national markets have been transformed into a (close to) fully integrated electricity market with competition in generation and supply within a common power exchange (Nord pool)[5]. Presently the Nordic Countries electricity market is the only truly international electricity market[6].

1.2 Great Britain:

The United Kingdom was one of the first nations to embark upon widespread privatization of it electric utilities. This privatization reform was considered as a beacon for several nations following the UK experience as a policy guide in their own electricity restructuring, privatization and regulatory reform efforts.

Restructuring of the electricity industry got off to a relatively late start in Great Britain has its origins in the passage of the UK's electricity Act of 1989. The idea that electricity generation and marketing could be introduced to competition stimulates the restructuring of the industry by the government. Meanwhile, transmission and distribution needed to be treated as Natural Monopolies; regulation was postponed in these segments for an indefinite future, and a regulation based on *Price-cap* was introduced in these segments, a long with a new regulatory authority, the *Office of Energy Regulation* (OFFER). In April 1, 1990 a newly-created electricity industry emerged.[7]

Restructuring the electric industry in the UK did not occur all at once; it started with the signed up of the Electricity Act of 1989 as law, which was one of the most important elements of privatization involved the restructuring of the industry prior to its sale.

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[5] Denmark was lagging behind and the Danish electricity market was not fully integrated in the Nord Pool system until the end of 2000

[6] Kwok W.Cheung et al. « restructed electric power systems and electricity markets » History of electric power systems restructuring

[7] **Electricity Reform Abroad and U.S. Investment " Electricity Restructuring and Privatization in the United Kingdom", Energy Information Administrating ,** Page: 13-31, September 1997 http://actrav.itcilo.org/actrav-english/telearn/global/ilo/frame/elect2.htm

Initially, the former General Electricity Generating Board was restricted into three main generators, two privatized National Power [8]and PowerGen and one state nuclear company Nuclear Electric, and a transmission company (The National Grid Company). The distribution network consisting of twelve regional companies (RECs).

In order to balance electricity supply and demand the UK government instituted a *power pool* to act as a clearinghouse between suppliers of electricity (generators) and wholesale consumers of electricity (mainly the regional electricity distribution companies).

The pool was managed and operated by the National Grid Company (NGC). The generators bid to supply electricity to the pool on a daily basis, the bids being used to generate a spot price for electricity every half hour and also determining which generating sets are called on to supply[9].

In February of 1994, in response to a sharp run up in pool prices in April of 1993, OFFER issued its first report on pool pricing activity, which called for two-year price cap and required national power and PowerGen to sell off 6000 megawatts of generation capacity.

Following this review, the pool was replaced by an entirely new trading structure known as the New Electricity Trading Arrangements (NETA) in 2001. NETA established a framework for bilateral trading and new power exchanges had been developed. The third wave of reform was called the British Electricity Trading and Transmission Arrangements (BETTA) it started in 2005 and was the extension of NETA to the regions of Scotland so that one single wholesale electricity market is for the whole of Great Britain[10].

1.3 Australia:

Before the introduction of market reform in Australia, the electricity industry had never operated on a national basis, and the supply of electricity was provided by vertically integrated, publicly-owned state utilities meeting the needs of individual states and territories[11]. The electric grid was weak and the trade had been restricted between the

[8] National Power was the larger generation company and account for 46% of electricity supplied in England and Wales in 1990/1991, compared with 28% generation output from PowerGen.

[9] Andrew Powell "**On Restructuring, Regulation and Competition in Utility Industries: the Experience in the United Kingdom and the Implications for Latin America**", Dept. Economics University of Warwick, April 1995.

[10] Kwok W.Cheung et al. "**Restructured electric power systems and electricity Markets**". Edited by Xiao-Ping Zhang. 2010 Institute of Electrical and Electronics Engineers.

[11] Australia is divided to six states**: Victoria, New South Wales, Queensland, South Australia, Western Australia, Tasmania**, and two mainland territories: **Australian Capital Territory and Northern Territory**.

interconnected states. In all that the government was the responsible for planning and tariff structures.

In 1995, Australia's population counted for 18 million and with total landmass nearly three million square miles. However, the eastern part of the country (New South Wales, Victoria, and Queensland) contains the majority of the population and count for almost 70% of domestic electricity consumption.

Electricity reform and privatization in Australia have occurred at both the state and national levels unlike other countries, this approach allowed each state to pursue different reforms.

The electricity reform effort has been underway since 1991; with main objective of delivering more efficient and sustainable use of capital infrastructure and energy resources and to improve Australia's domestic and international economic performance.[12] The government was well aware that competition is the right tool in achieving its goal.

The major reform in the Australian electricity industry involved the establishment in southern and eastern Australia of the National Electricity Market (NEM). NEM include the states of Victoria, New South Wales, South Australia, Queensland, and the Australian Capital Territory. Western Australia and the Northern Territory will not participate in the market due to geographical and cost factors.

In 1997, a National Electricity Generation Pool was introduced with main goal to integrate the wholesale power markets of New South Wales and Victoria into one market in order to ease the eventual full transition to the national electricity market. A National Electricity Code was implemented to establish the regulatory and operational framework of the new Australian national electricity market and it applies to all participants in the wholesale power generation market.[13]

A new national regulatory body, the National Electricity Market Management Company (NEMMCO) was established by the participants of the national electricity market to be responsible for the operation of the power pool and the short-term forward trading market.

[12] **Electricity Reform Abroad and U.S. Investment: "Electricity Restructuring and Privatization in Australia"** Energy Information Administrating. Page: 39-57, September 1997
This report is online: http://www.eia.doe.gov/emeu/pgem/electric/ch3.html

[13] Kwok W.Cheung et al. idem

Pricing in the transmission and distribution sectors of the Australian electricity industry are set by a spot price[14]. Marginal spot prices can be separated between the regions, due to the constraints on interconnectors and the six geographical regions that NEM comprise.

1.4 Continental Europe:

In most continental European countries restructuring of the electricity market started in the late 1990s, before that almost every electricity industry was vertically integrated monopolies with captive franchise market; either state owned (the majority of cases) or under price-regulated mixed private/public ownership (as in Belgium, Germany, and Switzerland).

Spurred by the liberalization in the UK, the European commission (EC) undertook a reorganization of its electricity policy that resulted in the proposal of liberalization. The liberalization process started in 1996 by the Directive 96/92/EC, "Directive for common electricity market", and had to be adopted by each country by February 1999. This action was trigged due to the EC conviction that liberalization, price deregulation and privatization would directly lead to competition in generation[15] and supply[16] which would then result in lower prices for all Europe.[17]

In June 1996, the European council of Energy Ministers agreed with the European parliament on a market liberalization directive which lay down the general principal and conditions of a common competitive European electricity market "*Internal Electricity Market*" (IEM), thus, leading to competitive electricity prices. IEM is divided into submarkets according to the control zones of the various transmission system operators (TSOs).

Although member states of the EU have similar electricity market architectures, these markets are weakly integrated among national borders. The association of ETSO (European Transmission Operator) was founded in 1999 in response to the Emergence of IEM. ETSO has been integrated to a larger association called European Network of Transmission System Operators for Electricity (ENTSO-E) in 2009. ENTSO-E pursue the co-operation of the

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[14] A form of price cap regulation had been applied on both sectors.

[15] **Generation** is the production of electrical energy from mechanical energy (take place at central stations normally far away from consumers necessitating the other two processes of transmission and distribution.

[16] **Supply of electricity** is the sale of electricity to end-users. This includes metering, billing, and marketing, and maybe wholesale or retail.

[17] **REINHARD .H, GLACHANT .J, KESERIC .N, PEREZ .Y**. "Chapter 9: competition in the continental European Electricity Market: Despair or work in Progress", pages 265-315

European TSOs and has an active and important role in the European rule setting process in compliance with EU legislation.[18]

The outcome of Electricity Directive 96/92/EC was unsatisfactory and a second directive was proposed at the European Council in Stockholm in 2001, which was later formalized as Directive 2003/54/EC. It reduced freedom of choice and shortened the deadlines to encourage convergence among the member states:

The second directive, only partially fulfilled in 2007, remains incomplete in 2009. A particular concern of the IEM development is the insufficient cross border capacity and the partly inefficient allocation mechanism. Starting with the liberalization process the Trans-European Energy Networks Program (TEN-E) was initiated. Since the first directive did not address the issue of cross border trade, to provide a framework and to establish more consistent trading, Regulation 1228/2003 was issued together with Directive 2003/54/EC. The regulation included a compensation mechanism for cross border electricity flows and harmonized cross border transmission charges and capacity allocation. TEN-E together with Regulation 1228/2003 builds a framework for the cross border development.[19]

The directives make no recommendation or requirement regarding the actual wholesale market design. Thus either the national governments set up market architecture (e.g. the mandatory pool in Spain) or left it to the industry to develop proper markets. As a result, most of the trade transactions in the EU take place bilaterally and in over-the-counter (OTC) markets[20].

Each year the EC issues a Benchmark reports on the status of liberalization. Their 2007 report concluded that despite encouraging improvements, particularly in cross-border coordination, major barriers to achieving a single IEM still existed.

1.5 United state:

Prior to the 1970s, the US electric power industry successfully developed in the form of regulated vertically integrated companies, where electricity was exchanged among them. To promote national liberalization, the US relied largely on state initiatives supported by the

[18] Kwok W.Cheung et al. idem

[19] **Hannes Weigt,** "Modeling Competition and Investment in Liberalized Electricity Markets" –Dissertation- July 2009, submitted to the Faculty of Economics of the Technical University of Dresden,
Available on line: http://d-nb.info/1007754532/34

[20] **Hannes Weigt,** Idem

Federal Energy Regulatory Commission (FERC) and the Department of Energy (DOE). In essence restructuring consisted of a transmission policy defined by FERC and DOE that opened networks to competition and state-level restructuring of wholesale and retail markets.

The U.S. sector combined with portions of Canada and northern Mexico was composed of three bulk interconnected power systems[21]. Following the northeast blackout in 1965 the reliability organizations and the North American Electric Reliability Council (NERC) were created to develop voluntary operating reliability criteria and coordination of long-term planning. NERC lacked the authority to set investment incentives.

Nevertheless, the role of NERC and the reliability rules have not been adopted within the liberalization process which amplifies the transmission congestion in the US. It was until the blackout of 2003, the federal government was forced to prioritize grid planning.

Before the implementation of the reforms, transmission pricing was state-regulated and most utilities provided "voluntary" transmission service for neighboring utilities which were regulated by FERC but the commission had no authority to require utilities to allow grid access to third parties.

The Energy Policy Act of 1992 and state programs requiring utilities to meet additional generation needs through competitive bidding further expanded opportunities for independent power producers to sell electricity to utilities for resale[22], and expanded The Federal Energy Regulatory Commission FERC's authority to demand that utilities provide transmission service. With the state restructuring initiative in California, FERC realized that transmission access needed to adapt to a completely new market setting and thus took the lead in two major rules in 1996:

- ✓ Order 888 requires transmission owners to provide third parties grid access at cost-based prices. This Triggered the formation of independent system operators (ISO), including California ISO (CalISO), New York ISO (NYISO), ISO New England (ISO - NE), PJM (Pennsylvania-New Jersey-Maryland) Midwest ISO (MISO), Southwest Power Pool (SPP) and Electric Reliability Council of Texas (ERCOT). The ISOs have the Responsibility of ensuring the reliability of one or more than one control areas.

[21] The Eastern Interconnection, the Western Interconnection and the Texas Interconnection.
[22] Paul L. Joskow (1997). "**Restructuring, Competition and Regulatory Reform in the U.S. Electricity Sector**," *Journal of Economic Perspectives*, 11 (3),123-127.

- ✓ Order 889 required utilities that are involved in interstate transactions to participate in an Open Access Same-time Information System (OASIS) which provides necessary information for transmission customers. Furthermore, it requires utilities to functionally separate transmission and unregulated wholesale functions.

The second aspect of liberalization in the US is the restructuring of wholesale and retail markets, mostly upon state initiative. It was initiated in 1978 with the Public Utility Regulatory Policy Act (PURPA) which required utilities to buy power from co-generators and small power producers using renewable resources, significantly spurred long-term contracts between vertically integrated utilities and certain types of independent generating companies.

In 1998, New Hampshire, Massachusetts, Rhode Island and California states initiated the restructuring of their market which foster wholesale and retail competition which enabled new generators to enter the market.

Retail competition was introduced in some states, mostly those with the highest regulated retail prices in 1996. The monthly utility bill shows a regulated component (network services) and a competitive component (generation and supply). Incumbents were generally required to continue to offer a regulated “default service”. Overall the switching numbers of household consumers have been low, only large industrial consumers have really exploited to the opportunities to switch suppliers. Some market critics fault state regulators for complicated rules that the average consumer finds difficult to understand, and failing to penalize marketers who neglect to inform consumers of the costs of switching[23].

Later on FERC Order 2000 encouraged the formation of Regional Transmission Organizations (RTO), which had larger authorities and responsibilities than the ISOs to oversee a region to ensure proper market operations and system reliability. The same year of 2000 California had its electricity crisis. California adopted a pool-based system, divested incumbent generation, and introduced an ISO. However, the market design was so flawed that it finally broke down in 2000-2001[24].

Following the California crisis and the eastern blackout in 2003, restructuring efforts in many states were suspended or cancelled even as the northeast and Texas continued to move

[23] **Hannes Weigt,** Idem
[24] For more detail see: James L. Sweeney “**The California Electricity Crisis: Lessons for the Future**”,(2002)

forward. In summary, today the US is a mixture of liberalized states, states under traditional regulation, and states in delayed transition.

All the cases that have been dealt in prior occurred in developed countries. So to see the introduction of market liberalization in a developing country, I've chosen Iran as a study case due to the similarities between it electric industry and the one implemented in Algeria (the case of Algeria will be discussed furthermore).

1.6 Iran:

Following the successful experience of some developed counties in Power market restructuring and reforms, many developing countries have followed suit.

For the last thirty years, and since its Islamic revolution of 1979, Iran had an economy predominated by the state, but has been thinking to take some legal steps towards private participation in the electricity sector so as to meet the rapidly rising electricity demand.

Since 1986, the electric and water industries in Iran were managed by TAVANIR a vertically integrated state power company holding a monopoly right over generation, transmission and distribution, furthermore, it worked under the jurisdiction of the Power Ministry, and stayed likewise for many years.

TAVANIR Company had public service obligations (PSO) and sets the prices based on expansion of production. This situation remained until the launch of market reforms.

At last the early months of 2001, recorded the official steps for restructuring the electric sector. This decision was taken due to the need for investment in capacity expansion to meet the increasing demand rate[25].

Initially, they started with unbundling the electricity sector into Generation, Transmission, distribution and supply. Followed by the creation of a competitive atmosphere through corporatization of the regional electricity companies was given premium over privatization.

Like many developed countries, Iran introduced competition only in generation and supply while transmission and distribution, being natural monopolies, remained in public ownership functioning as regulated monopolies.

[25]Nima Nasrollahi Shahri, "**Power market reforms and privatization of the electricity industry in the Iranian energy sector; an uphill struggle?"**. University of Dundee (CEPMLP). 7. January 2011, MPRA Paper No. 28047, posted 10. January 2011 21:07 UTC

A new state-owned company was founded called the IGMC. Besides, Regional electricity companies remained responsible for both generation and supply.

IGMC was responsible for creating and running the wholesale market. Iran Power Pool operates on a daily basis taking the lowest bids based on the assumptions received from buyers. And by the end of the discussions between buyers and sellers, winners are announced to the dispatching centre which interacts with the market for any necessary modifications in the amounts; electricity is bought from generators at a uniform price called the *Pool Price*.

In 2003; based on a Ministerial directive a regulatory committee consisting of five members was created. Their responsibilities rely in supervising over the pool and providing regulation required for running the pool in any unforeseen circumstances.

The Article 44 of the Iranian constitution acknowledge the role that plays the state in all major part of the economy[26], leaving the private sector restricted in some small industries such as Agriculture and animal husbandry…ect. This article was considered as a set back and an obstacle in the path of privatization.

In 2005, the exigency Council issued and eight-article Act allowing the privatization of many major industries, it called for minimum 20% of privatization on an annual basis. Nevertheless, this privatization reforms will not affect the oil and gas upstream activities as they remain state owned even though 90% of electricity in Iran is generated using these two sources. This will oblige generators to buy from the government at the same price which in itself limits the room for competition.

Power Ministry privatization committee was formed to facilitate privatization in electricity and water.

Restructuring and privatization of the electric industry in Iran is nascent reform so any impartial qualitative judgment will be inexorably immature.

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[26] Paragraph 2, Article 44, Islamic Republic of Iran Constitution: "The state sector is to include all large-scale and mother industries, foreign trade, major minerals, banking, insurance, power generation, dams, and large-scale irrigation networks, radio and television, post, telegraph and telephone services, aviation, shipping, roads, railroads and the like; all these will be publicly owned and administered by the State" http://www.en.ipo.ir/index.aspx?siteid=83&pageid=822

II. THE ALGERIAN POWER SECTOR

1. THE NEW REGULATORY FRAMEWORK IN ALGERIA:

1.1 Background:

The Algerian electricity industry has traditionally been publicly owned by the state. This centralized organizational structure was maintained until the promulgation of the law 02-01 issued in 5 February 2002.

The first glimpse of the reforms appeared in the 90s, The Algerian government was dragged to the implementation of new reforms especially after the crisis of 1986, the oil crisis had left a serious impact, and the lack of a strong financial system able to boost the economy plus its weak companies make matters worse. This situation, forced the Algerian authorities to monitor trends that arose in the international market, through privatization and globalization. The Algerian government has invested quickly in this field by undertaking structural reforms leading to the opening of the market, as well as the establishment of a competitive legislative framework with a view to deregulation mainly in the field of electricity and gas.

In May 2001 the Algerian Energy Company (AEC) was created, combining Sonatrach and Sonelgaz, the two most important public companies in the energy sector. This affiliated company manages energy production and seawater desalination projects, using private foreign investment. Three companies have been created:

1. Kahrama – the American firm Black & Veatch, initially holding 80% of its shares, now retains 5% after a huge investment drive by the AEC, which now has 95%. The company is planning the creation of an electricity production and seawater desalination installation at Arzew;

2. SNC Lavalin (Canada) and Mubadala (Emirats Arabes Unis), grouped in mixed company named “Algerian Utilities International Limited” (AUIL), which holds 51% of SKH.

3. HWD: this company is 70% owned by the American company Ionics and is managing the construction of a desalination plant in Algiers.

1.2 The New Electricity Law:

Law 02-01 was issued in 5 February 2002, changing the previous law 85-07 (6 August 1985) establishing the new regulatory framework. The main objectives of the law were:

- ✓ Elimination of the existent monopoly;
- ✓ Promote competition in generation;
- ✓ Establishment of a free market for electricity to eligible customers and protect their rights;
- ✓ distribution of licensing concessions;

- ✓ The creation of The commission de regulation de l'éléctricité et du Gaz (GREC) ;
- ✓ Restructuring SONELGAZ [27];
- ✓ Stable and incentive regulatory framework to attract private funding;
- ✓ Electricity generation: freedom of installation in the field of electricity production; (operating permit issued by CREG);
- ✓ Transmission and distribution (networks): natural monopolies → regulated;
- ✓ Introduction of third Party Access to Networks (ATR).

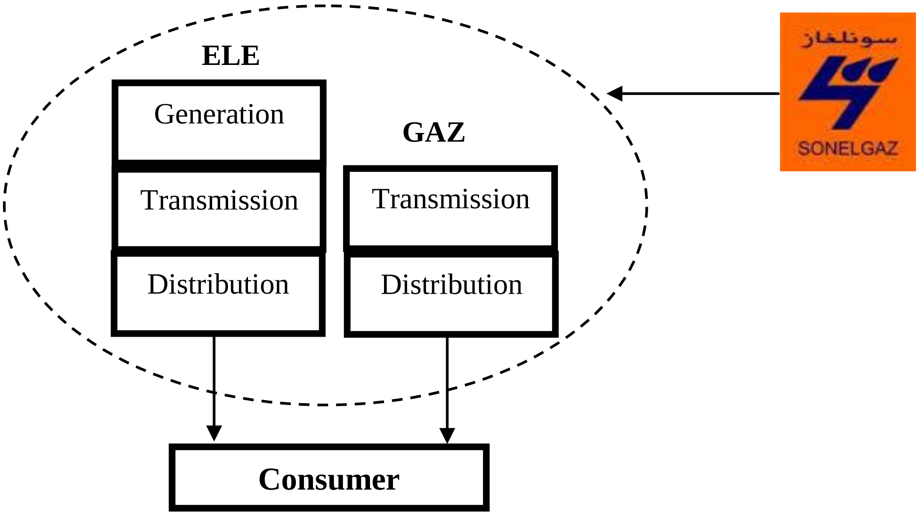
The law should have prepared the way for liberalization by 2005 through these actions.

However, more than a decade has passed since the promulgation of the law 02-01 called for the electricity and pipeline gas sectors, a series of obstacles stand in the way of liberalization of the market. The functional efficiency of the sector is not improving, in fact the State (through Sonelgaz) is omnipresent and remains the biggest investor.

The graph below shows the structure of the electric sector before and after the reform:

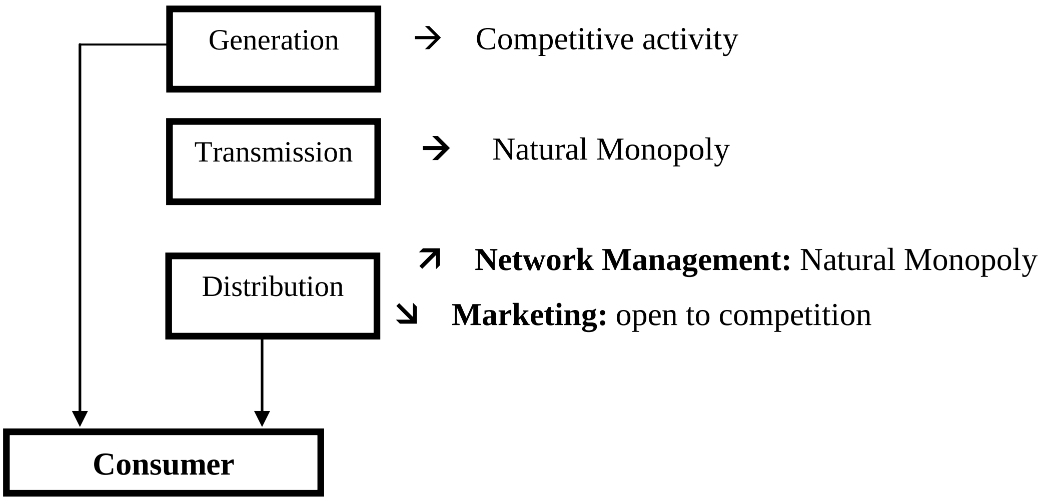
Before the reform

Vertically integrated system



[27] Decomposition of its value chain, known as "unbundling".

UNBUNDLING



1.3 Regulatory Authority:

The commission de regulation de l'éléctricité et du Gaz (GREC), who works with the jurisdiction of the Ministry of Energy and Mines, has overall responsibility and regulator power over the electricity industry.

CREG was created by the electricity Law with the functions of regulatory commission. CREG is an independent body with legal personality and financial autonomy, it is financed by revenues from tariffs and its budget is approved by the energy minister. CREG reports to the Ministry of Energy and Mines. It is governed by a board of directors comprising a president and three directors proposed by the energy minister and appointed by presidential decree.

The article 115 of the law 02-01 classified the main duties of CREG which can be summed up thus[28]:

- ✓ The CREG sets the payment to the operators for transport and distribution, the tariffs for use of the network and tariffs for the clients. It also sees to the management of electricity and gas funds and ensures the compatibility of the companies.
- ✓ It protects consumers' interests by ensuring that public services obligations are carried out; it prepares complaints and appeals of the operators; sets administrative sanctions for the violation of rules or standards; it publishes information that may be useful for the defense of consumers' interests.
- ✓ It acts as a conciliation and arbitration body. The CREG **conciliation service** handles disputes between operators, relating to the application of regulations. There is also an

[28] "Regulatory Activities In The Energy Sector of Analysed Countries of The Mediterranean", Dipartimento Della Funzione Pubblica, Pubblica Amministrazionz, May 2006 , Http://Www.Caimed.Org

arbitration chamber that delivers judgments in controversies, when called on by one of the parties[29].

- ✓ The CREG may hold consultations before making decisions, which may be motivated and public, or open to appeal. It may give judgments; it organizes public hearings, it presents the energy minister with an annual report on the execution of its duties and on the evolution of the market.

2. GENERAL DESCRIPTION OF THE POWER SYSTEM

The economy of Algeria is heavily dependent on energy. Electricity is used for a number of purposes that include industrial, commercial and household purposes; it is supplied to consumer by monopolized public utility known as Sonelgaz which used to be the sole, state owned generation, transmission and distribution utility. The recent legislation (2002) has, however, opened the door for independent producer to enter the market. Sonelgaz embarked a National electrification program in 1977. Between 1977 and 1986 1.2 million households were connected to the national grid. It is estimated that by 2025 about 10099835 households will be connected to the grid.

2.1 GENERATION:

Generation is the production of electricity. It involves the transformation of another form of energy into electrical energy. Electricity production may use oil, natural gas, coal, nuclear power, hydro power (falling water), renewable fuels, wind turbines, and photovoltaic technologies.

Production must be able at any moment to meet the demand (consumption + losses); it must provide the means of production to cover the extreme peak demand.

Within Algeria electricity is generated by more than 13614 MW installed power capacity in 2013.

Until the late 1970s, a quiet revolution occurred within the electric utility industry, this revolution took place when the Algerian government committed in a national electrification plan, with a main objective to promote life conditions of it population.

[29] Article 133-136 of "**Collection of Laws and Regulations".**

A significant fraction of the total generation serving Algeria comes from *Sonelgaz*, where the government carried out a vertically integrated electricity company and a natural monopoly since 1969.

It was until February 2002, the law on electricity and gas distribution was promulgated, which led to the introduction of the first independent generators with an estimated contribution of 26% in 2013, and by that the opening to competition and private investments in electricity generation.

Currently, more than 99 percent of Algeria's electricity generation comes from fossil-fuel sources. The Algerian government recently adopted a renewable energy program that aims to produce 40 percent of its domestically consumed electricity from renewable energy sources by 2030.

The following table presents the resource composition of the electric generation serving Algeria.

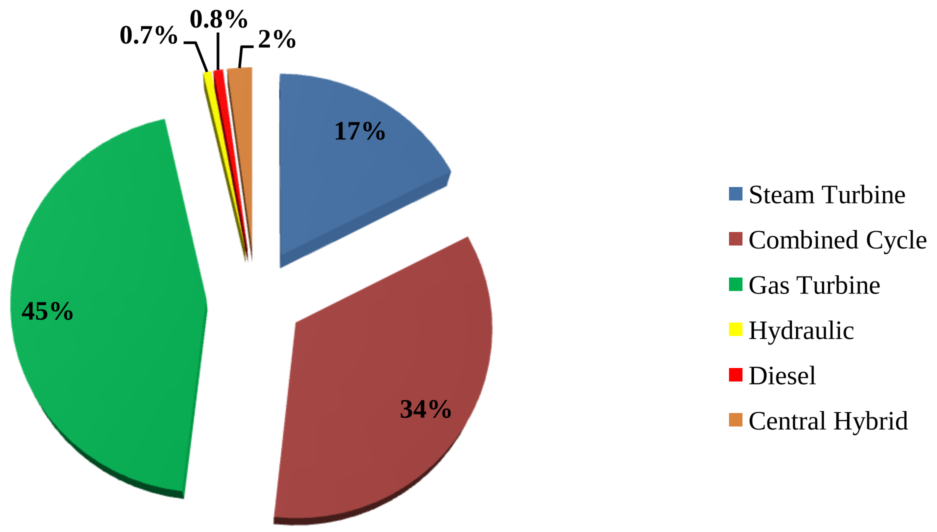
Table 01. Resource composition of the electric generation in 2012.

Sources	Generation (GWh)	Energy
Steam Turbine	9422	17.4%
Combined Cycle	1862.5	34.3%
Gas Turbine	24074.6	44.5%
Hydraulic	389.4	0.7%
Diesel	415.9	0.8%
Central Hybrid	1159.4	2.1%

Source: BULLETIN STATISTIQUES 2012[30]

[30] Société algérienne de l'électricité et du gaz, Direction Générale de la Stratégie et de la Prospective, Direction analyse et prévision, BULLETIN STATISTIQUES 2012 ; N° 721/DGSP.13

Figure 01: Sector representing the resource composition of the electric generation



2.2 TRANSMISSION AND INTERCONNECTIONS:

Transmission is the high-voltage transport of electricity. However, transmission is not exactly transportation, but it also involves the management of dispersed generators in a grid to maintain suitable voltage and frequency and to prevent system breakdown. Transmission is a natural monopoly because competition in transmission would result in duplication of the existing network (duplicating High voltage AC networks and competing grid co-ordinators would increase transmission costs)[31].

The electric utilities in Algeria are linked through an extensive network of transmission lines, it over 140,000 miles of power lines, serving almost the entire population.

In Algeria; the main transmission grid consists of 60Kv-220Kv high-voltage transmission some sectors of heavy industry receive service at these high voltage levels such as: Water and Energy - Oil - Mining and Quarrying. Furthermore medium voltage is between 5.5Kv- 30Kv which assemble the sectors of light industry mainly: Agriculture - Building Materials - Batim.Trav.public - Industries Textiles - Agro-food - Industries Leather - Transport and PTT - Commerce - Hotels. Restaurants ect. For smaller customers, the voltage is stepped down to lower voltages 110v-380volts for residential customers.

[31] Faye Steiner (2001), idem

The electricity law considered Sonelgaz as the system operator (SO) and transmission owner and this according to the Art29 of the **Collection of Laws and Regulations**[32] published by the Regulatory Commission for Electricity and Gas (CREG), where it qualifies it as a natural monopoly. The management of the transmission grid is entrusted to GRTE.

Algeria consists of two transmissions network:

- ✓ An interconnected network that covers the northern and few southern parts of the country, and includes:
  - An interconnected transmission system which are connected to the central of production and major industrial customers.
  - And the distribution system serving the rest of the customers (households, services and SMI/SME).
- ✓ Twenty-five (25) isolated systems, powered by gas turbines (Adrar, Illizi, in Saleh and Tamanrasset) or by diesel generators serving the cities of the south, through distribution networks.

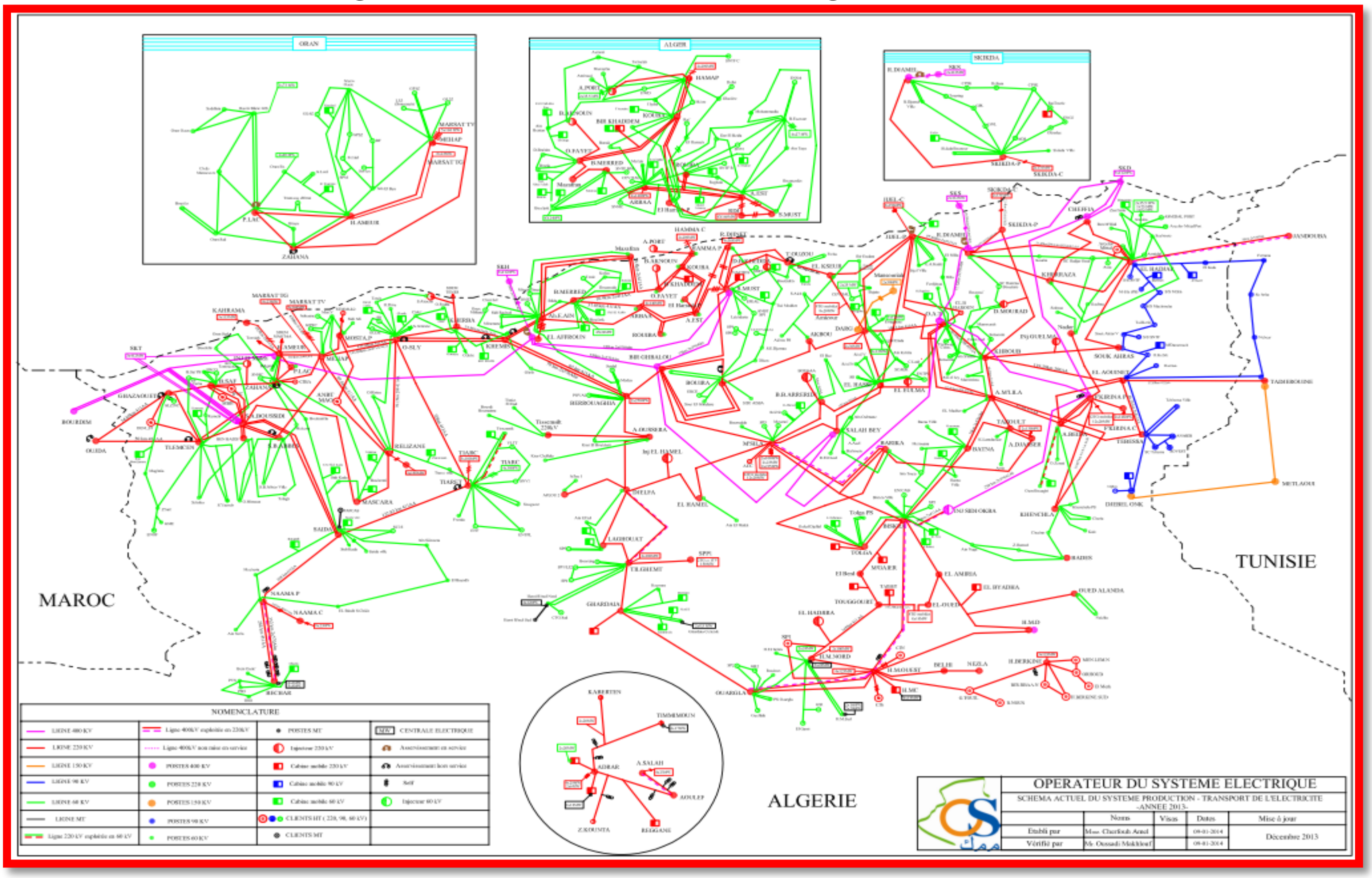
Algeria has transmission interconnections with adjacent countries, these transfers are mainly with Morocco and Tunisia with 600 to 1200MW[33] of interconnection capacity for each.

The transmission grid is display in the following map:

[32] **DU TRANSPORT DE L'ELECTRICITE, DE LA CONDUITE DU SYSTEME PRODUCTION-TRANSPORT DE L'ELECTRICITE ET DE L'ORGANISATION DU MARCHE DE L'ELECTRICITE**
Art. 29 — Le réseau de transport de l'électricité est un monopole naturel. Sa gestion sera assurée par un gestionnaire unique. Le gestionnaire du réseau de transport de l'électricité bénéficie d'une autorisation d'exploiter délivrée par le ministre chargé de l 'Energie, après avis de la commission de régulation. Cette autorisation est incessible.

[33] Global transmission report : http://www.globaltransmission.info/archive.php?id=1433

Figure 02: The Transmission Grid in Algeria



Source: CREG

2.3 DISTRIBUTION:

Distribution is the low-voltage transport of electricity. Like transmission, it is generally considered to be a natural monopoly; competition would similarly entail duplication of the existing set of "wires".[34]

Sonelgaz retain a monopoly on distribution and provides Algeria with electricity.
The electricity distribution is organized by four companies:

- **La société de distribution de l'ouest (SDO)**,
- **la société de distribution du centre (SDC),**
- **la société de distribution d'Alger (SDA)**"
- **la société de l'est (SDE)**".

[34] **Faye Steiner** idm

Distribution power lines include lines of medium and low voltages, the total length of all network voltages reached in 2012 a combined 269 460.5km.

Table 02: The Main Distribution Companies in Algeria

Company	Activity
Sonelgaz	National electricity production, commercialization and distribution of natural gas
Algerian Energy Company (AEC)	Electricity production, commercialization, energy transport and distribution, desalination of sea water and telecommunications
KAHRAKIB	Studies on and realisation of high tension electricity infrastructure
KAHRIF	Works on electrification
KANAGHAZ	Studies on and realisation of canalisation and gas transportation

2.4 CONSUPMPTION:

For the past few years, Algeria's electricity demand has been increasing fast, mainly due to expansion of economic activities and population growth.

According to the national energy balance of 2012, consumption is divided into three main strands: the Industry Construction & Public Works (I.CPW) or -intensive industry consumes 19% of total consumption in Algeria; Residential and others including agriculture (R) in the other hand use another 54%; Transport (Tr) consumed the remainder of a total annual consumption of 43149GWh in 2012, the following table shows the total consumption for the period 1971-2013

Table 03. Annual Consumption in Algeria during 1971-2013[35]

years	Consumption in GWh	years	Consumption in GWh
1971	1 655,0	**1992**	14 476,2
1972	1 804,0	**1993**	14 611,4
1973	2 063,0	**1994**	15 107,8
1974	2 312,0	**1995**	15 698,5
1975	2 756,0	**1996**	16 210,7
1976	3 251,0	**1997**	16 560,4
1977	3 603,0	**1998**	18 165,1
1978	4 364,0	**1999**	19 611,0
1979	4 918,0	**2000**	20 761,0
1980	5 392,0	**2001**	21 901,2
1981	6 285,0	**2002**	22 977,4
1982	7 052,0	**2003**	24 935,6
1983	7 696,0	**2004**	25 909,8
1984	8 433,0	**2005**	27 314,0
1985	9 408,0	**2006**	28 612,0
1986	10 223,0	**2007**	30 318,0
1987	10 385,0	**2008**	32 587,0
1988	11 876,0	**2009**	33 817,0
1989	11 773,0	**2010**	35 802,6
1990	13 013,3	**2011**	38 899,9
1991	13 423,1	**2012**	43 148,6
		2013	45 055,0

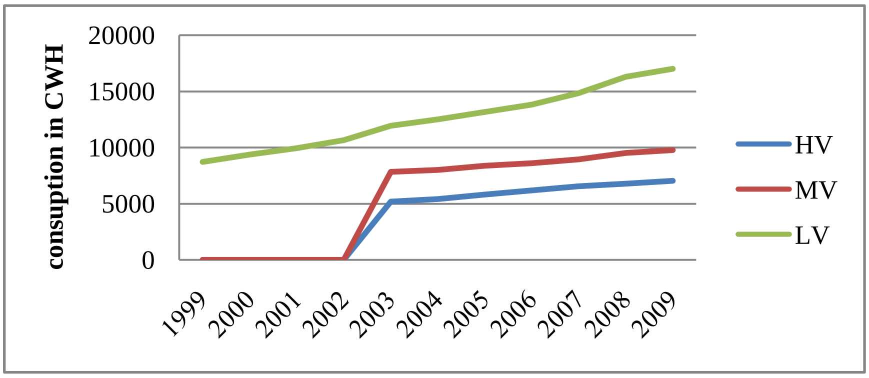


Fig.03: Evolution of consumption by voltage level

35 CREG, "Commission De Régulation De L'Electrice et du Gaz," 2013.

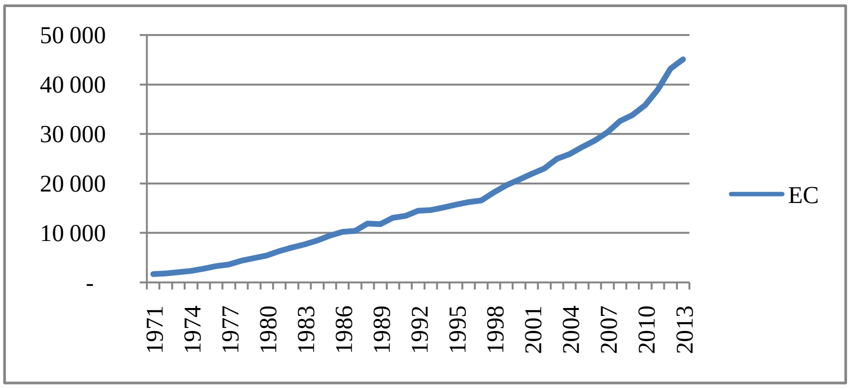


Fig.04: Algerian's electricity power consumption from 1971 to 2010.

Analysis:

Electricity consumption is fast increasing for the three sectors during the period 1999-2009.

Residential sector*:* electricity consumption is increasing too fast, from 8716.4Gwh in 1999 to 16283 Gwh in 2008, with an increase of 7.19%. In 2009 this growth has experienced a slight decline of 0.27% mainly due to climatic variations.

High voltages (HV): the record shows an increase less than that of the residential sector, from 4746.8 Gwh in 1999 to 7035 in 2009, this represent a rate of 4.01%.

Medium voltages (MV): the evolution of consumption in this area is similar to the one in HV where it goes from 6151.2Gwh in 1999 to 9772GWh in 2009 with a rate of 4.7%,

We can also notice a remarkable leap in the period 2002/2003 in both high and medium voltages this can only be explain by the creation of new firms and due to the population dynamics.

Like the developing countries where energy demand in the residential sector is the highest of all other sectors. In Algeria, the residential sector is the greatest consumer of electricity, 50% of total electricity in Algeria is consumed by the residential sector in 2009; and this despite the technical progress in equipment with low energy consumption. This rise can be explained by the households changing lifestyles where they look for more comfort. Therefore, Algeria has made the reduction of energy consumption a major goal.

2.5 Electricity price:

Currently, the retail electricity price is set by the government and the electricity price at all levels of consumption is below its production cost. Almost all of Algeria's electricity generation comes from natural gas (98 percent of power). Like natural gas prices[36], electricity prices have been frozen since 2005[37] and are much lower than in most other emerging and advanced economies. Low tariffs, however, mask other costs.

Obtaining an electricity connection is time-consuming and expensive, involving five procedures that take 180 days and cost the equivalent of 1,563 percent of per capita GDP. Taking these factors together, Doing Business ranked Algeria 148th in terms of the ease of getting electricity[38].

In Algeria, the price of a kilowatt-hour of electricity is sold to individuals between 2 and 3.20 DA / kWh. Equivalent to 2 to 3.2 € cents)!!

Moreover, Sonelgaz, the public utility company, has seen its debt rescheduled on multiple occasions by the government as a consequence of supplying services at below-market prices.

Meanwhile, no revision of the prices of electricity and gas are included in the agenda of the Government in the short term that is what was stated by the Minister of Energy and Mines Youcef Yousfi.

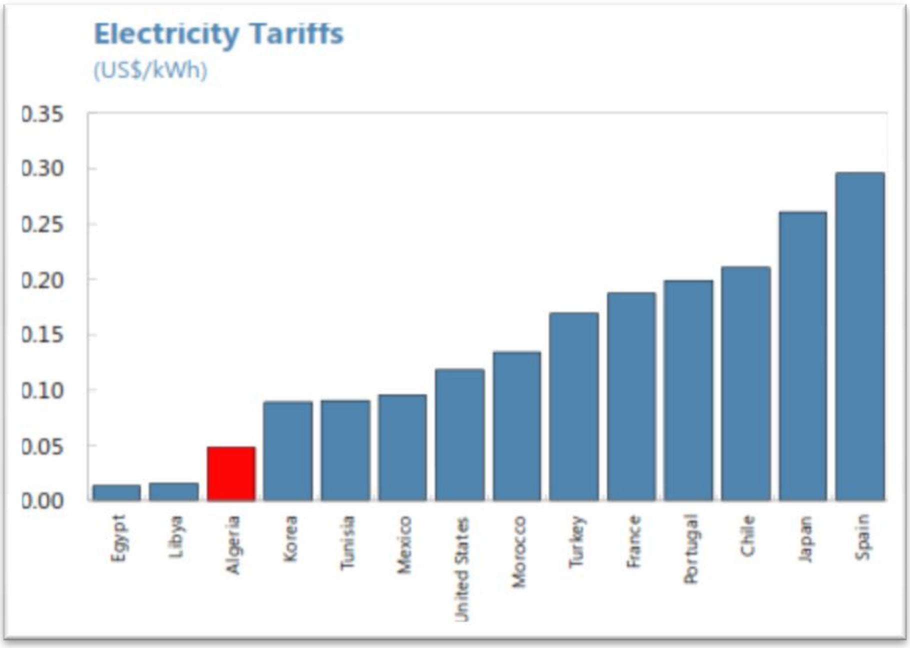
In an interview with the daily "Echorouk" published Tuesday 3 December 2013 the minister said "the increase in fuel prices, all types included does not occur in the agenda of the Government, either this year or next year. However a draft revision of the pricing in the medium term is possible"

The following chart shows that the electricity tariff in Algeria is the cheapest in the region after Libya and Egypt.

[36] The Retail prices of natural gas have been frozen since 2005 and are now below operational costs.

[37] As contemplated by a law dated 30 May 2005 as an outcome of the reforms of Chakib Khelli.

[38] **IMF Country Report No. 14/34** February 2014



Source: **IMF Country Report**

III. PEAK LOAD MANAGEMENT:

In Algeria, Peak demand problem has been growing on the average at about the same rate as the annual consumption growth. There are sometimes strong annual variations in the general variation trend. This section gives a clear comprehensive of the concept of peak electricity that sometimes occurs on the network of utilities.

The factors contributing in the occurrence of the peak load are discussed in what follows.

1. The Problem of Peak Demand:

1.1 Definition of the daily peak:

For the purpose of this study a number definitions of peak load have been compiled from various sources and presented here.

When referring to energy use, peak demand describes a period of strong consumer demand. Peak demand fluctuations can occur on daily, monthly, seasonal and yearly cycles. For an electric utility, the actual point of peak demand is measured by means of single half hour or hourly period which represents the highest point of customer consumption of electricity.

Units of measurement are megawatt (MW) or kilowatt (kW) and denotes the maximum power requirement of a system at a given time, or the amount of power required to supply customers at times when need is greatest.

Various definitions of peak load cited in many articles contain two important keywords: *maximum or greatest demand* and *specific period of time*. In other words, the peak demand is the maximum demand at given period of time.

Caston Sigauke, Andréhette Verster, Delson Chikobvu defines in their paper the daily peak as the maximum hourly demand in a 24- hour period see[39]. Also **koomey and brown (2002)[40]** define the peak load as the maximum simultaneous demand for some portion of the electrical system, typically averaged over an hour. It is typically characterized as annual, daily or seasonal.

In their paper **Yusri Syam Akil** and **Hajime Miyauchi** describe the peak period as the maximum values at certain hour[41].

Robert F Engle, Chowdhury Mustafa and John Rice[42] also specifies the peak as the maximum load during a short interval within the basic data sampling.

1.2 The Drives of Peak Demand:

Many factors influence peak demand, including weather, demographics, economic activity, usage behavior, and government policies. **Shuvra et al[43]**. summarized in their paper the factors that directly influence the change of electrical energy demand in many countries. These factors occurred also in **koomey and brown (2002)** article; we will treat each one in turn:

a. ***Weather:***

It is the most important driver of peak demand, it is considered to be the most influential exogenous variables. Energy demand is dependent on weather variation. For example, when winter temperatures are colder than normal, demand is higher and usually causes an increase in electricity prices. Conversely, warmer weather often means lower prices and higher demand. Electrical demand is dependent upon humidity, temperature, etc.

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[39] Sigauke C., Verster A. and Chikobvu D.,"**Tail Quantile Estimation of Heteroskedastic Intraday Increases in Peak Electricity Demand",** *Open Journal of Statistics*, 2012,2,435-442.

[40] Koomey J. and Brown Richard E.,"**The Role Of Building Technologies In Reducing And Controlling Peak Electricity Demand".** Energy Analysis Department University of California Berkeley, September 2002.

[41]Yusri Syam A., Hajime Miyauchi**. "Seasonal Peak Electricity Demand Characteristics: Japan Case Study".** *International Journal of Energy And Power Engineering*. Vol. 2, No. 3, 2013, pp. 136-142

[42] Engle R. Chowdhury M. and Rice J."**modeling peak load electricity demand",** *Journal of Forecasting*, vol. 11, 241-251 (1992).

[43] Ali Mahfuz, Md Mostafijur Shuvra, Arshad Rahman, Shahidul I Ali, Khan, "**Modeling and Forecasting Demand for Electricity in Bangladesh: Econometrics Model",** *International Conference On Economics, Trade And Development.* IPEDR *vol.*7 (2011).

b. ***Time Factors:***

The time factors influencing the system load include the time of the year, the day of the week and the hour of the day. There are differences in load profiles between the seasons and between weekdays and weekends. The load on different weekdays also can behave differently: Sundays and Fridays may have structurally different loads than the days in between. Furthermore, the load profiles during holidays and adjacent days deviate from the typical behavior. The holiday load patterns are also more difficult to forecast because of their relatively infrequent occurrence.

c. Demographics factors:

Population is an important factor that might influence electricity demand; with growing population, the total energy requirement in all sectors is expected to rise.

While modeling the domestic sector, not only the size of the population has a weight, it composition and structure is also considered to apprehend it effect on electricity consumption. Many household characteristics should be taken in account, such as age of the household, his geographical location, as well as the size of the location etc. For example, in his thesis FRÉDÉRIK *AUCOIN* incorporate several independent variables related to the structure of the population and analysis the effect of each one on the electricity demand[44].

d. Economic factors:

Electrical energy demand can be driven by two major economic factors: income and price.

Typically we refer to the income of nation's population as the gross Domestic Product (GDP), it indicates the growth of national economy. From basic economic theory strong economic growth in a particular region will lead to more building construction and migration to that area, thereby higher power purchase and as result an increase in total electricity use and peak demand.

The second economic factor that is an important factor in determining energy demand is price of the energy. Many studies that treat the influence of this factor, shows that the price and demand follow opposite directions. An increase in the price of the commodity leads to reduced consumption. So, it is not logical to expect that increased electricity tariff might influence the consumption.

[44] For more informations on the subject read **"ANALYSE DE LA DEMANDE D'ÉLECTRICITÉ DU SECTEUR RÉSIDENTIEL DU QUEBEC",** *Frédérik Aucoin,* Université Du Québec À Montréal, FÉVRIER 2007, page 58-60

In this regard, many studies have been conducted in the literature. For example, *Emmanuel Ziramba* (2008) model residential demand for electricity in South Africa as a function of real gross domestic product per capita, and the price of electricity during the period 1978-2005.[45]

e. Usage behavior:

The main concern in this factor includes how the end-user behaves while operating buildings and use appliances. *Goldman, Eto, and Barbose* (2002) conducted a study on the contribution of California's consumer on the reduction of the load during the electricity crisis. They presented a simple analysis, which suggests that consumer actions to reduce their electricity consumption were driven force behind the load reductions observed in summer 2001, and this is due mainly to the active role played by various media sources to spread awareness concerning the electricity crisis and helped spur customers to take actions to reduce their electricity usage.[46]

f. Government and utility policies:

Most implementation policies that affect the efficiency of buildings and equipment can also influence peak demand, as can government financial policies, taxation, utility regulation regimes shifting toward renewable and cleaner energy etc. may play a significant role and affect the demand for electricity in the short- and medium term.

g. Technological factors:

Technology is another important factor regarding the variation of energy demand. Introduction of new technologies in the production side, improvement of raw material processing and purification, increase in the efficiency of the machineries may influence energy demand.

1.3 Load Management:

Load management refers to the broad category of mechanisms available to an electric utility to control load on its distribution grid. Some of those mechanisms are entirely owned and dispatched by the utility such as stationary advanced battery storage and smart grid enables

[45] ***Emmanuel Ziramba*** used to estimate residential electricity demand and to examine the issues of stability, income and price sensitivity of both long- and short-run a Bounds testing approach to cointegration analysis. The findings in this study imply that residential electricity demand in South Africa is price and income inelastic. It shows that price increase alone will not discourage residential EC and that the increase in income does not induce a significant increase in residential electricity demand. For further reading see "**the demand for residential electricity in South Africa", 2008**

[46] For more details see **"California Customer Load Reductions during the Electricity Crisis: Did They Help to Keep the Lights On?" ,** *Goldman, Eto, and Barbose* (2002), Section 4 , pages 6-8.

automated substation and distribution system controls[47]. However, the largest and most important load management option is customer demand response. Demand response offers a potential solution to the problem of peak demand by providing incentives for consumers and businesses to reduce consumption at peak time and if possible shift their power use to off-peak periods.

Utilities have used two strategies to reduce residential peak load that lays within demand response resources:

- Direct load control programs;
- Price responsive demand

a. Direct load control programs

This type of control has historically involved residential consumers. Within this program, utilities can ensure that their electrical load is less than what can be generated. Customers agree to allow the utility to control the mode of operation of specific electrical appliances[48] and in return receive discount on their monthly power bill. The end-uses act as a resource to ensure supply-demand balance. The most frequently controlled applications are central air conditioners, water heating cylinders, electric space heaters with storage features, and non-essential lighting. The use of direct load control differs between geographical areas and depends on the load pattern of the location. In Southern Australia and some part of the United States (e.g. California), direct load control is used to control summer air conditioners. Approximately 180 utilities in the USA offer their residential customers direct load control programs. Typical load reductions are in the range of 0.3 to 0.6 kW/house for water heating programs, and 0.4 to 1.6 kW/customer for programs that target only residential air conditions.

Despite the effectiveness of direct load control programs, they have been criticized for the following reason:

- ✓ They offer fixed financial incentives for unmeasured loads For example; the bill credit given by the utility is the same regardless of the amount of load reduction provided by the customer. In Orion’s case, the benefit is linked

b. Price responsive demand:

This approach is based on employing different pricing mechanisms the most common are: time-of-use pricing, critical-peak pricing and real-time pricing. Table (4) provides a list of

[47] PEAK DEMAND & DEMAND MANAGEMENT, “Chapter 9: Peak demand and demand management”, pages 335-375.

[48] Utilities identifies certain appliances as deferrable which means to run later in the day, after the peak.

these methods and describes their ability to give an efficient signal of the real time demand/supply balance[49].

Instead of directly controlling the customer load at peak times, the pricing mechanism aims at influencing customers to shift the usage of electricity from peak to off-peak hours by charging high price per unit of electricity consumed during peak hours. Time varying pricing is employed in New Zealand for large industrial and commercial users with special half-hour interval metering that records customer demand during peak times. This type of pricing is currently not available to the residential customers. The residential sector pays flat rates for electricity consumption. Some residential customers receive split rate: day and night rates. One of the main issues with the pricing mechanisms is its impact on lower socio-economic households. These households use less electricity than the average consumer, and as a result, their ability to conserve is lower. Also, when confronted with an increase in energy costs, lower-income families tend to make "lifestyle cutbacks". Therefore using a pricing mechanism to achieve demand response will not be consistent with all the principles of rate design such as the promotion of social equity and affordability to low income households[50].

Table (**4**): Overview of the peak load pricing structure

	Definition	**Signal of the real time demand/supply balance.**
Real Time Pricing (RTP)	Retail electricity prices that fluctuate with the real time wholesale prices	Accurate, depending on the lag time between the price announcement and the price implementation.
Time of Use Pricing (TOU)	Retail electricity prices varying in preset way within certain block of time	Approximate, since prices don't capture the price variation within a price block. Moreover are based on the average wholesale market variation and adjusted infrequently
Critical peak Pricing (CPP)	System that usually starts with a TOU rate structure, and adds one more rate that applies to critical peak hours, which the system operator can call on short notice	Good , but less accurate than RTP for two reasons: - the level of prices for the peak hours are preset - the number of peak hours that can be called in year is limited

[49] Grazino Abrate, "peak load pricing in the electricity market: theory and practice", University of pavia, Ceris-CNR, HERMES.

[50] "Demand Response Assessment And Modelling Of Peak Electricity Demand In The Residential Sector: Information And Communication Requirements"

Henley and Peirson (1994)[51], they based their study on seemingly unrelated regression SUR to compare mean TOU consumption of the experiment and control groups of consumers facing different prices in the United Kingdom. Their findings show statistically significant changes in the pattern of weekday household consumption resulting from the TOU tariffs. These changes vary across consumers, stratified by total past consumption levels. This suggests that demand system models of consumer behavior in response to TOU tariffs should allow estimated price effects to be conditional on the total consumption level of households. TOU demand models typically do not allow for this. They also show that the experimental tariff did not cause significant changes in total weekday electricity consumption, even though significant changes in consumption may occur during particular periods of the day. TOU pricing may improve allocative efficiency but may not enhance energy conservation.

1.4 Potential benefits of demand management[52]:

- ✓ Avoid an inefficient high rate of peak demand growth;[53]
- ✓ Improve competition and reduce the ability of an individual generator to exercise market power in the wholesale market during congestion at peak periods;
- ✓ Improve the productivity of supply side capacity by shifting the timing of electricity[54] use, also it reduces the gap between average and peak consumption $\Longrightarrow$ achieving allocative efficiency (Henley A, Peirson J, 1994);
- ✓ Reduce generation costs by reducing reliance on higher cost peaking supply;
- ✓ Immediate selective load shedding in an emergency;
- ✓ Reduce volatility in demand (and wholesale prices);
- ✓ In the short term, provide scope for some consumers to receive reduced electricity bills and, and in the future, could slow rate of growth of future electricity bills for all consumers.

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[51] Henley A, Peirson J.: "**Time-of-use electricity pricing Evidence from a British experiment",** Economics Letters 45 (1994) 421-426.

[52] "peak demand and demand management", Idem

[53] This will delay the need for network augmentation.

[54] From peak period to off-peak period

2. Literature Review:

Through the electricity literature there are several studies discussing peak load modeling to identify the factors that drive electricity demand by using different approaches and variables.

The purpose of this literature review is to provide an understanding of the theoretical foundation and modeling approach adopted in this study.

There are several empirical studies that have examined and modeled the determinants of electricity demand in a number of countries (see Table). To our knowledge, this study is the first attempt to examine the determinants of peak electricity demand in Algeria using this approach. Here we review some of the studies on the subject.

Engle, Mustafa and Rice (1992) estimate a model for forecasting the maximal hourly load one day in advance using information on today's peak, average load, and weather. The nonlinear model incorporates among others deterministic influence (holidays), stochastic influences (average loads), and exogenous influences (weather). The simplest model is a univariate forecasting model written as:

$$PEAK = \alpha_0 + \alpha_1 PEAK_{t-1} + \alpha_2 H + \alpha_3 H_{t-1} + \alpha_4 SAT + \alpha_5 SUN + \alpha_6 MON + \varepsilon_t$$

Where H is holiday and other variables self-explained. In order to improve model performance, information on the past daily average load (AVG) was added. The relation is estimated as the following bivariate interdependent forecasting model:

$$PEAK = \alpha_0 + \alpha_1 PEAK_{t-1} + \alpha_2 H + \alpha_3 H_{t-1} + \alpha_4 SAT + \alpha_5 SUN + \alpha_6 MON + \alpha_7 AVG_t + \varepsilon_t$$

$$AVG = \beta_0 + \beta_1 AVG_{t-1} + \beta_2 H + \beta_3 H_{t-1} + \beta_4 SAT + \beta_5 SUN + \beta_6 MON + \beta_7 PEAK_t + \varepsilon_t$$

The above mentioned univariate peak models are further extended with weather, which is very important factor for predicting peak load. Since weather itself is not easily predictable, in some cases one can use past weather as an instrument instead of predicted weather. Here, the weather is proxied by constructed cooling and heating degree variables. The generalized model conditioned on weather is written as:

$$PEAK = \alpha_0 + \alpha_1 PEAK_{t-1} + \alpha_2 H + \alpha_3 H_{t-1} + \alpha_4 SAT + \alpha_5 SUN + \alpha_6 MON + \alpha_7 AVG_t + \alpha_7 CDD_{65} + \alpha_7 HDD_{75} + \varepsilon_t$$

where *CDD65* and *HDD75* are the cooling and heating days measured as the average of the daily high and low temperature minus the base (50 and 65 degrees F°). The diagnosis tests show that the general model is the best overall model, but it performs no better than the reduced form model. The peak forecast error can be decomposed into two sources attributed to average load and other load factors.

Delson Chikobvu and Caston (2013) performed a modeling approach divided in two stages Piecewise linear Regression used to explore the effect of temperature on daily electricity demand, and then they fitted a generalized extreme value theory (GEVD) used to estmate extreme low temperatures and calculating the corresponding marginal increases of electricity demand. They conclude that electricity demand in South Africa is highly sensitive to cold temperature, they detected the existence of non-linear relationship between temperature and electricity demand which is modeled using heating degree days (HDD) and cooling degree days (CDD). Another result spotted while using GEVD to estimate extreme low temperature (6°C) and although it occurred rarely it can cause huge increase in electricity demand.

Le following table summarizes the results from different studies.

Author (s)	Area	Data type	Sample & period	Pricing structure	Dependent variable (s)	Independent variable (s)	Estimation method (s)	Price elasticity	Income elasticity	Other findings
Engle, Mustafa and Rice (1992)	Peak electricity demand	Daily data	Michigan 1983		Peaks	Current weather, past average load, past peak load, holiday and weekend	Univariate forecasting models and Bivariate models	-	-	The models specify the relations between peaks, loads, holidays and weather in a sequential analysis from simple to general models. Specify the best overall model and conditional model. It also suggests that a structural change between the sample period and the forecast period such as an increase in error.
Ismail, et al. (2009)	Peak load electricity demand	Secondary data of daily electricity peak load demand	Malaysia 01/01/2001 to 31/12/2005				Statistical Methods: - Time Series - Regression method Rule-based method for forecasting.	-	-	They conclude that the Rule-based forecasting increase the forecast accuracy when compared to the traditional SARIMA model and that improvement depends on the conditions of the data, knowledge development and validation.
Delson Chikobvu and Caston (2013)	Peak electricity demand	Daily electricity data for industrial, commercial and domestic sectors	South Africa 2000 to 2010		Average Daily Electricity Demand (ADED)	Average Daily Temperature ADT Hot temperature Cold temperature	Piecewise linear Regression Generalized extreme value theory (GEVD)	-	-	The model is used to explain the influence of temperature on electricity demand. Electricity demand in South Africa is highly sensitive to cold temperature, they detected the existence of non-linear relationship between temperature and electricity demand which is modeled using heating degree days (HDD) and cooling degree days (CDD). Another result spotted while using GEVD to estimate extreme low temperature (6°C) and although it occurred rarely it can cause huge increase in electricity demand.

Delson Chikobvu and Caston (2012)	Load forecasting	Aggregated DPD data from all sectors.(time serie)	South Africa January 1996 to December 2009				Regression-SARIMA	-	-	A time series methodology is presented to forecast DPD using SARIMA and regression-SARIMA model. In order to capture the important drives of electricity demand the authors used the regression-SARIMA model. They concentrate their study on short-term forecasting and the inclusion of calendar effects in the model as drive. Their results shows that the SARIMA model produce more accurate short-term forecasts
Holly Suzara (2008)	Load forecasting and understanding the impact of climate change	Historic monthly Peak loads and determinants of Electricity demand.	California January 1993 to December 2003		Peak load	Daily maximum Temperature Population Price of electricity	Regression model			They proposed a hypothesize that the relationship between peak load and temperature is better represented in the form of third-degree polynomial which has been confirmed to be stronger than the quadratic relationship presented by CAISO*. By specifying a third-degree regression the hypothesized model projects a leveling out of peak electricity load as temperatures rise above (≈ 90°F). **CAISO* California Independent System Operator**
Isa S Qamber (2012)	Load modeling		Kingdom of Bahrin 2009-2011		Load	Historical maximum annual loads Maximum ambient temperatures Population		-	-	Simple models are presented to develop an algorithm for the annual peak load.

Srinivasa R Rallapalli and S. Ghosh (2012)	Load forecasting	Monthly peak electricity demand	India April 2005-March 2011				Univariate time-series MSARIMA	-	-	The authors criticize the forecasting method used by CEA* (based on trend method) and propose an alternative one to forecast monthly peak electricity demand using MSARIMA method. They conclude their paper with a comparison between the two methods and observed that MSARIMA model outperforms CEA forecasts. **CEA* Central Electricity Authority**
Yusri S Akil and H Miyauchi (2013)	Demand analysis of the commercial area	Hourly demand data	Japan June 2007-November 2009		CECSM CECA CECW CECS SMDPD ADPD[55] WDPD[56] SDPD	HDD CDD DH dummy for holiday RHD humidity degree	Regression model -All Demand Time ADT -DPD models	-	-	In order to maintain optimal operation of power system and provide the service to consumer at all times it is recommended to knowledge all the characteristics of electricity demand especially during high load hour. First they constructed ADT models for each season were they determined seasonal peak demand hours. Then they composed DPD model for each related hours to identify how far the variables used impact electricity peak load. As result CDD & HDD have the highest effect on peak demand among meteorological variables. The authors also detect peak demand characteristics for each season.

[55] Autumn daily peak demand
[56] Winter daily peak demand

Elham Pourazarm and Coory (2013)	Residential electricity demand	Time series data	Iran 1967-2009		Electricity demand	Price of Electricity Price of Substitute Consumer income[57] Economic progress[58] Weather condition[59]	Unit root tests Cointegration ARDL Error-correction model ECM	**L-r** $E_p = 0$ **S-r**E_p=-0.03	**L-r** E_I= 0.58 **S-r** E_I =0.04	The results show that in the long-run, Households are not responsive to changes in income; also cooling degree days and the indicator of economic progress are the main determinants of electricity demand. Furthermore natural gas is no substitute for electricity in the Iranian residential sector. In the short-run, the consumption of electricity is mainly influenced by income and weather. at the end the residential electricity demand forecast revel the need for authorities to take action in order to cover the increasing rate of electricity demand.
Mark G. Lijesen (2007)	Price elasticity of spot market	Total system load on an hourly basis	Netherlands 2003	Real time price of electricity	Demand of electricity	Price, time of day dummies, day of week dummies Month of the year dummies, weather variables, holiday dummies.	Linear an Log-linear approach	Linear specification -0.0014 Log-linear specification -0.0043	-	Low value for the real-time price elasticity, which may partly be explained from the fact that not all users observe the spot market prices. After correction of this phenomenon, we find the elasticity to be fairly low for consumer currently active in the spot market
Emmanuel Ziramba (2008)	Residential electricity demand	Time series data	South Africa 1978-2005	Price of electricity	Demand of electricity	Real gross domestic product per capita the price of electricity time trend	Bound testing approach to Cointegration within an autoregressive distributed framework OLS	ARDL -0.04 OLS -0.01	ARDL 0.31 OLS 0.87	The result of their empirical study reveals that income is the main determinant of electricity demand, while electricity price is insignificant.

[57] Household income is proxied by final fixed expenditure of household consumption
[58] Number of electrified villages is used as proxy for economic progress
[59] Cooling degree days is used to test for the effects of weather

Chaptre II:

Modeling Peak Load Electricity

CHAPTER II: MODELLING PEAK LOAD ELECTRICITY

Introduction:

Electricity load demand served by power system is volatile during the day and it has maximum values at a certain time of the day known as *peak period*. The peak hour is the main concern of utilities since the demand is the highest, and if this demand is not well managed, a certain system can run in an extreme condition. Furthermore, risks such as load shedding can take place in the system. Thus, it is necessary to keep balance between supply and demand at all times to reduce such risks.

However, electricity demand can be influenced by many factors (see section3 of chapter1) among these factors meteorological parameters. From these considerations, knowing more about peak demand and role of the related driver variables is valuable for utilities. It may help them in managing existing power plants to meet volume of demand more effective.

After assessing the different factors affecting electricity peak demand in the previous chapter a question comes to mind *what are the factors influencing the peak demand in Algeria?,* we will build some assumptions based on a simple analysis of the changes in electricity demand during 1990-2013. These assumptions will be further evaluated.

1. Shifting of Annual Peak:

Table 05: present the annual generation (in GWh) and maximum demand in (Mw) between 1990 and 2013 for Algeria case. As shown in the table, the annual energy and demand increased from 15451GWh and 2742 MW in 1990 to 56163GWh and 10464 MW in 2013 (factor of 5.7%[60]; 5.9% respectively).

[60] Average annual growth =($(\mathbf{final\ value/initial\ value})^{\mathbf{1/number\ years}}$ – 1)*100

Table 05. Annual Electricity Generation in Algeria during 1990-2013.[61]

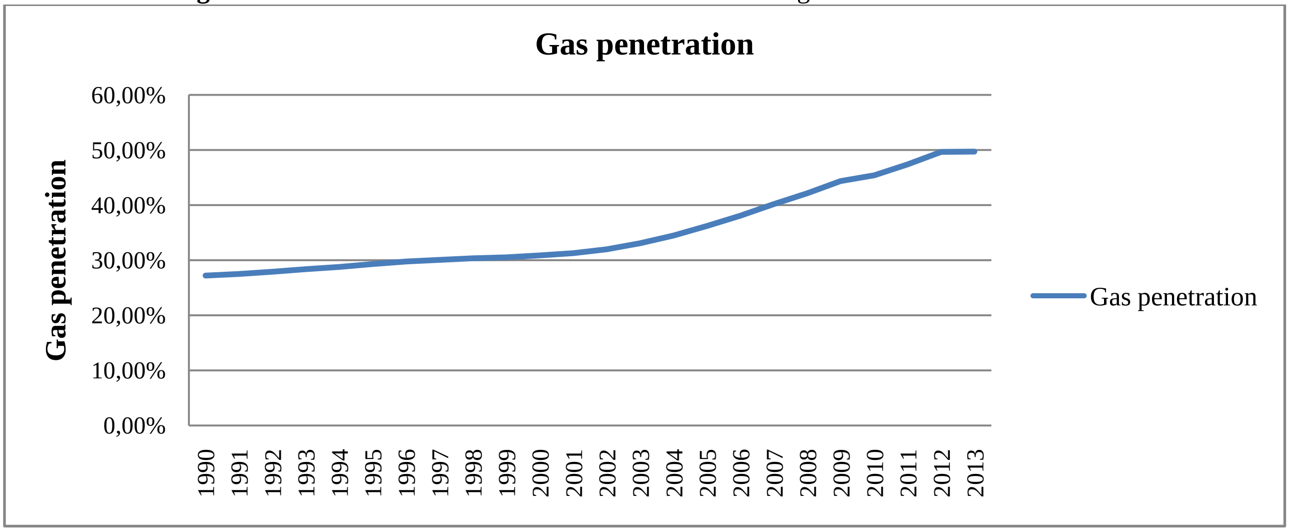
	Generated Energy		peak load (MW)		Peak Load Occurrence date
Years	**(GWh)**	**Gr,%**	**Annuel peak**	**Gr,%**	
1990	15451		2742		
1991	16750	8,4%	2858	4,2%	
1992	17677	5,5%	2911	1,9%	
1993	18938	7,1%	3118	7,1%	
1994	19488	2,9%	3236	3,8%	
1995	19361	-0,7%	3483	7,6%	
1996	20216	4,4%	3790	8,8%	
1997	20982	3,8%	3940	4,0%	
1998	22816	8,7%	4313	9,5%	
1999	24419	7,0%	4489	4,1%	
2000	25008	2,4%	4617	2,9%	18 January
2001	26256	5,0%	4791	3,8%	19 December
2002	27403	4,4%	4965	3,6%	9 December
2003	29192	6,5%	5206	4,9%	16 February
2004	30885	5,8%	5541	6,4%	23 December
2005	33525	8,5%	5921	6,9%	21 November
2006	34922	4,2%	6057	2,3%	08 January
2007	36951	5,8%	6572	8,5%	15 December
2008	39987	8,2%	6995	6,4%	16 December
2009	42770	7,0%	7280	4,1%	23 July
2010	45173	5,6%	7718	6,0%	24 August
2011	48872	8,2%	8746	13,3%	08 August
2012	54086	10,7%	10363	18,5%	02 August
2013	56 163		10464		

Table 5 also shows that starting from year 2009[62], the occurrence of the annual peak load in Algeria shifted from winter (December- January- February) to summer (July- August-September). This shift is mainly due to the increase of gas penetration rate which went from 27.2% in 1990 to 49.7% (see figure) in one hand, and to profuse use of air conditioning and ventilation systems as a result of high temperatures in the other hand.

[61] CREG, "Commission De Régulation De L'Electrice et du Gaz," 2013.

[62] Absence of this information from 1990 till 1999

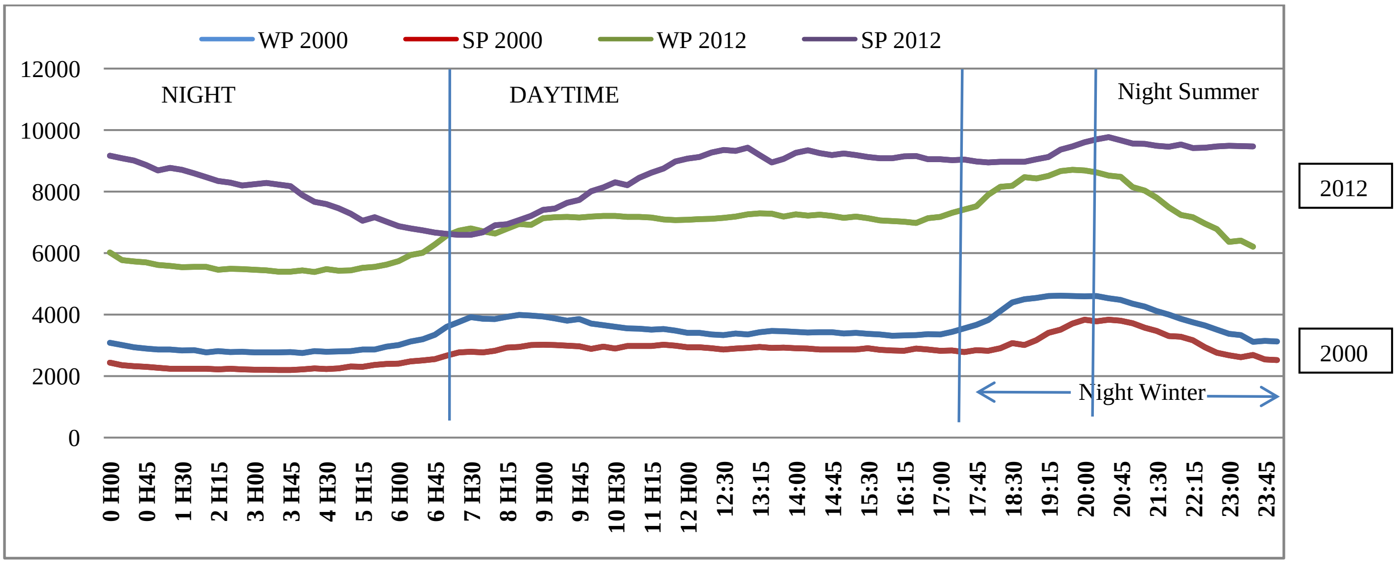
Fig.05. Evolution of Annual Rate of Gas Penetration in Algeria From 1990-2013



2. The Modification in the Annual Daily Load Curve:

The daily Load Curve (DLC) for winter season (December-21, March) and summer season (June – 15, September) of 2000 and 2012 is presented in **Figure 06.** As shown in the figure, the comparison between the daily load curve (DLC) between summer and winter in both years shows obvious changes in behavior. We instantly observe a rise up in the demand for electricity in 2012 relatively to 2000. Moreover, during 2012, the winter evening peak (EP)

Fig.06. The annual maximum DLC for summer and winter of 2000 and 2012**.**



was lower than summer peak with the maximum recorded values were 8712 and 9777 Mw (12% difference). The 8712 Mw occurred at 20:00 pm on 14th February; the 9777 MW occurred at 20:45 pm on 02nd August. A comparison with year 2000, the winter EP was 4617 Mw and recorded two times particularly at 19:30 pm on 18th January and 18:00 pm on 23rd

January 2000, while summer evening peak is 3723 Mw (19% lower than winter peak) occurred at 21:15 pm on 2nd July. This switch is due mainly to the technological factor (extensive use of the air conditioning systems the number of air conditioner has increased from 124315 to 3449953 in 2012)[63], and also the weather factor, where Algeria recorded a rise in the temperature in the late years, it known a hotter summers.

There are several methods that can be used for modeling electricity peak demand. Such as -statistical method that allows modeling the current load value by using a mathematical combination of the previous and current values of exogenous factors, typically weather and time factors.

3. Data and methodology:

3.1 Electricity consumption data:

The sample used in this study comprises of the daily peak electricity demand (given in Megawatts) in Algeria collected from January 2000 through December 2013 from the Regulatory Commission for Electricity and Gas (CREG). All the sectors (industrial, commercial, and residential) are included The load data are available on the basis of 15-min intervals for each day in every year of the sample, in each day the maximum quarterly demand is recorded, and is referred to as daily peak demand (DPD), this gives us a total of 4749 observation considering the whole period of the study (2000-2012)[64]. Only the data of the interconnected grid was treated. The sample has been transformed by taking natural logarithms of the electricity peak demand data to reduce the impact of the heteroskedasticity that could be present due to the large amount of data and its high temporal frequency.

3.2 The weather variables:

Previous studies have shown that temperature is usually the most significant weather variable influencing peak electricity demand [65](Delson Chikobvu and Caston 2013) (Valor, E. *et al.* 2001). For this reason we have used this variable for the present study, and the possible influence of other variables may be considered as correcting terms for the influence of temperature (Engle et al. 1992)[66].

The selected variable is the mean outdoor temperature (°C).

The mean daily temperature has been calculated as the arithmetic mean of maximum and minimum daily temperature.

[63] CREG, "Commission De Régulation De L'Electrice et du Gaz," 2013.
[64] The year 2013 was not in our simple due to the lack of temperature data proper to this year.
[65] Many articles dealt with this subject some of them were mentioned in the previous literature review
[66] This reference is the one we based our econometric analysis on.

$$T = (T_{max} + T_{min})/2$$

The mean daily temperature was assessed at seven regions each region has a number of weather station distributed across the wilayas which are affiliated to their respective regions, as followed:

- ✓ **Coastland**

- Coastland Est: Annaba, Bejaia, Skikda, Jijel
- Coastland Center: Alger, Chlef, dellys, tizi, medea, miliana, bouira
- Coastland West: Oran Senia, Arzew, Mostaganem, Oran Port, Ghazaouet, Beni Saf, Tlemcen

- ✓ **Interior area**

- Interior area Est: Constantine, Oum El Bouaghi, Setif, B.B.Arreridj, Batna, Khenchla
- Interior area Center: Tiaret, Boussaàda, Djelfa, M'sila
- Interior area West: Saida, El Kheiter, Mechria, El Bayadh, Ain Safra

- ✓ **Southern area**

- Ghardaia, Bechar, Ouergla, H.Messaoud, Biskra

Each region capture different climatic sub-regions, and a population weighted temperature index TI (°C) was calculated from the mean daily temperatures measured at 38 weather stations distributed across Algeria. (Following the methodology used by *Valor et al.2001*).

The reason why population has been selected as weighting factor is that climate influences the electric consumption through the response of people to weather. That is depending on the coldness, or the heat of the weather, people will increase or decrease the use of electric heating appliance or air conditioners. Thus, the higher the populations, the higher the influence of weather conditions in electricity demand.

To follow the impact of climate on the electricity consumption, TI is defined as:

$$TI_t = \sum_{i=1}^{7} \bar{T}_{ti}\, w_{ti}$$

Where $\bar{T}_{ti}$ is the mean daily temperature on day t at weather station i and w_{ti} is a population weight of the area assigned to each station[67], which is calculated as:

$$w_{ti} = \frac{P_{ti}}{\sum_{i=1}^{7} P_{ti}}$$

P_{ti} being the total population assigned to weather station i .

[67] For the period considered the data were extracted from the National Census of Population and Housing of 1998 and 2008. (RGPH)

a. The relationship between peak electricity load and temperature:

Figure7 presents the evolution of both the monthly peak electricity and average TI for each month. The peak electricity load shows a significant trend in the long run this can be due as mentioned in section3 of chapter 1 socioeconomic causes, whereas a much softer trend is detected in the weather index series.

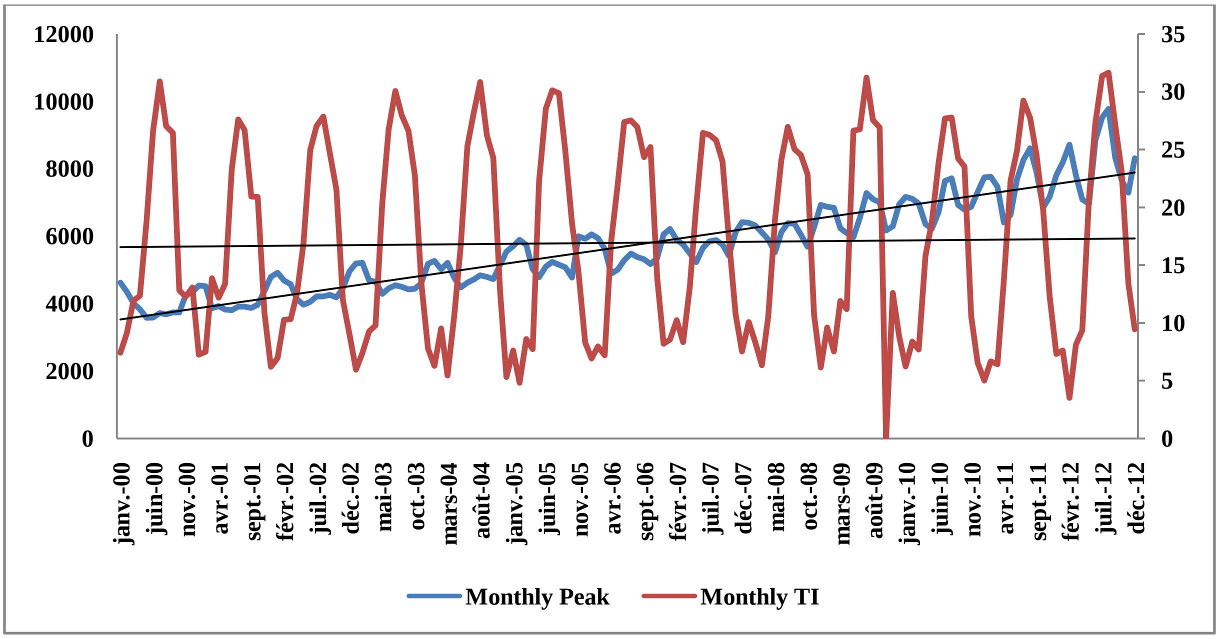


FIG.7 Evolution of monthly peak electricity demand and temperature index TI from January2000 through December2012. The trend line for each series is also shown.

The correlation between both variables is apparent (the peak is observed when both maximum (summer) and minimum (winter) temperatures take place.

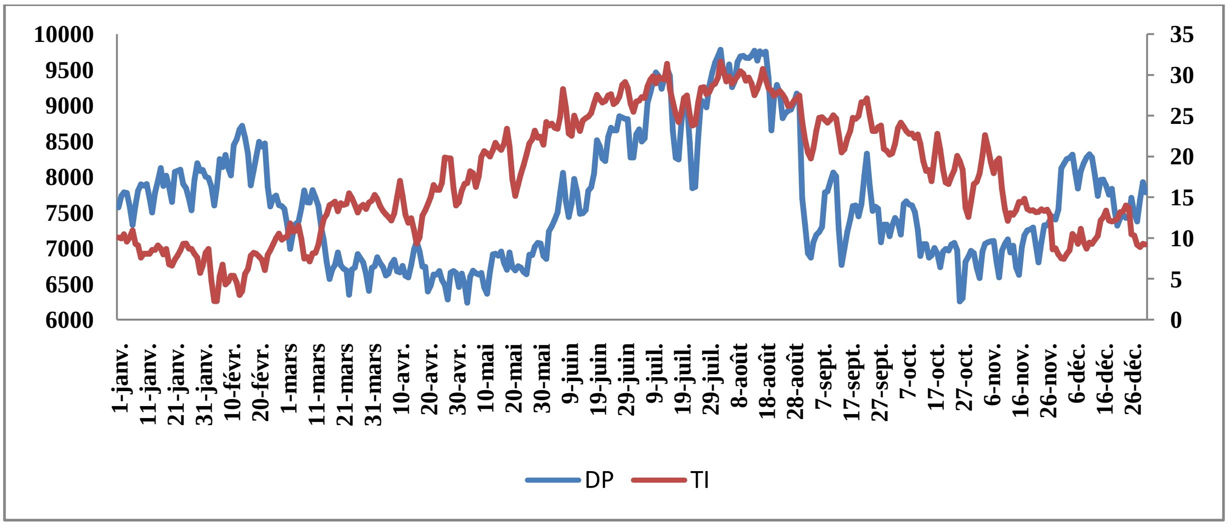


FIG.8 Evolution of daily peak electricity demand and temperature index TI in 2012

Figure 8 displays the evolution in 2012 of the daily peak demand and TI. The peak electricity demand presents a weekly seasonality with minimum values on Friday (the large falls observed in the curve each seven days see FIG 9) and maximum values on the central working days. Nevertheless, this pattern can be disturbed by the existing of single holidays within the week, and also by periods such as the holy month of Ramadan. (See FIG.9)

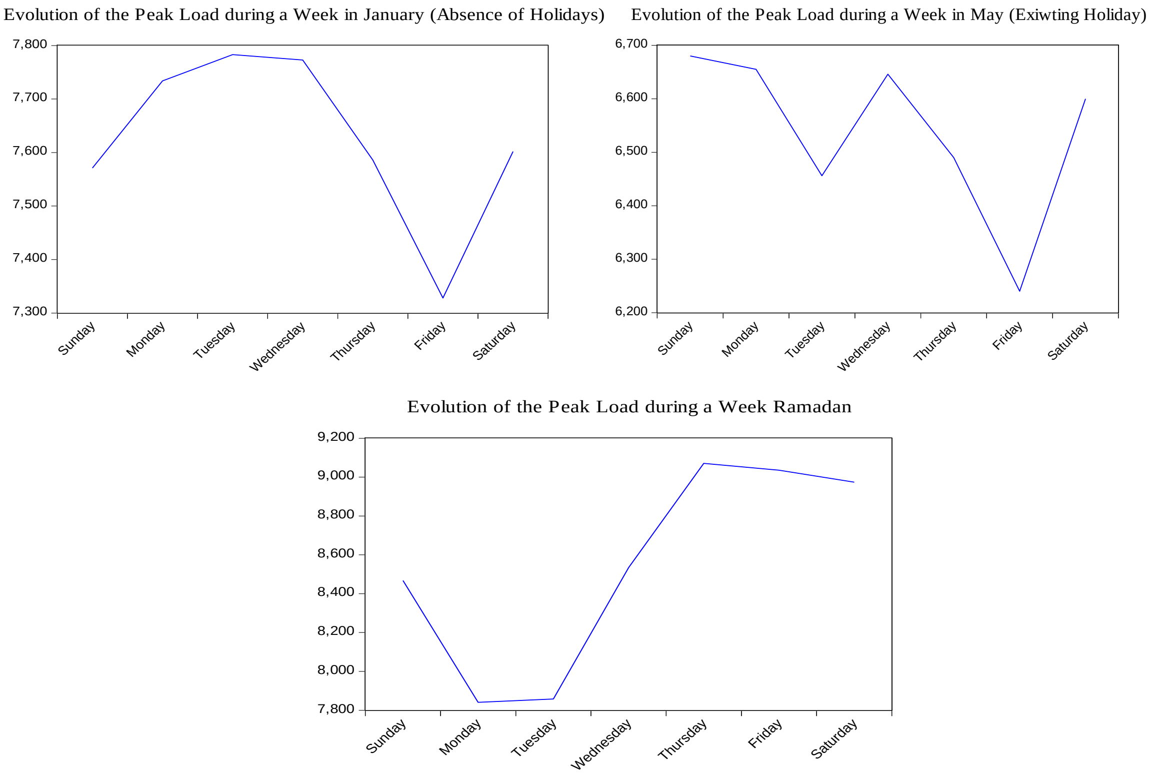


FIG.9 Evolution of daily peak electricity demand during a random week, week with holiday, and a week in Ramadan for the year 2012.

By season, the peak electricity load shows maximum values in winter and summer and minimum values in the transition periods (spring and autumn).

TI also presents a daily random fluctuation around its typical monthly trend which is coupled with the peak load, as it shows maximum values coinciding with the TI extreme values (both maximum and minimum).[68]

In order to better observe the relationship between peak load an TI a scatter-plots was drawn. Figures 10 shows two years selected beginning and the end of the sample respectively.

[68] This relationship was explained earlier.

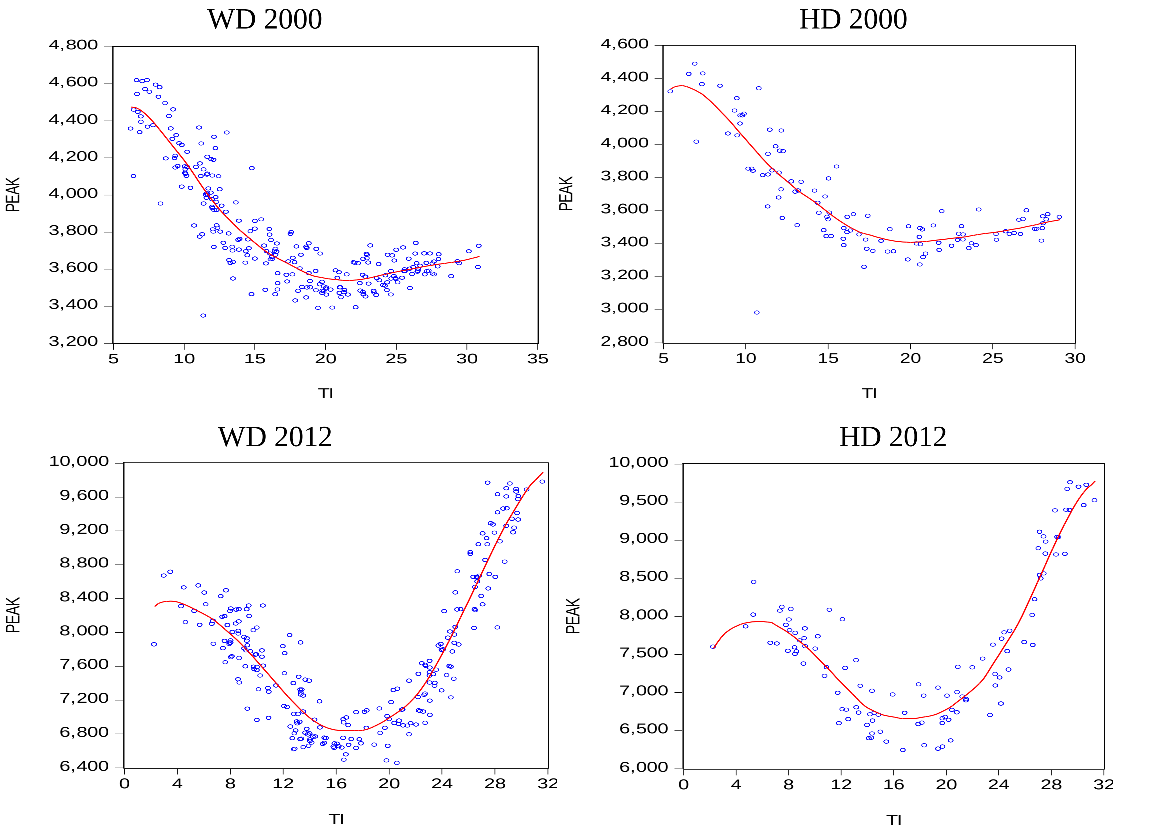


FIG.10 Scatterplots of peak load vs TI, considering separately working days (WD) and holidays (HD+ weekends), for 2000 and 2012.

The data have been grouped in two different subsamples that separate the working days on one side from the holidays and weekends on the other side, because the behavior is clearly different.

The relationship is non-linear, with generally speaking one minimum and two maximums. The minimum value change slightly from year to year and is located near 18C°.

There is an interval centered at this point within which the peak load is insensitive to temperature. The peak load jumps with both decreasing and increasing temperature out of this interval (this is due to the use of heating appliances and air conditioning respectively).

In the winter like in summer there is a threshold temperature beyond which the consumption of electricity no longer increases (saturation points)[69].

[69]Valor et al.2001 In their paper explain the reasons of the existence of a saturation point to limited power of conditioning systems and to the insulating ability of buildings.

b. Heating and cooling demand functions:

Because the relationship between load demand and air temperature in nonlinear, we suggest the use of two temperature-derived functions allowing the separation of the winter and summer data. This will help us to obtain better results in the linear model estimations. This can be achieved by using the degree-day functions defined as:

$$\begin{cases} HDD = \ max(TI_{ref} - TI_t), 0 \ otherwise \\ CDD = max(TI_t - TI_{ref}), 0 \ otherwise \end{cases}$$

TI_{ref} is the base temperature that can be extract from the scatterplots shown in Fig. , a unique base temperature of 18C° could be used. This is the standard reference commonly used to calculate heating and cooling degree-days, especially in the analysis of the impact of weather on peak load demand (ENGLE et al. 1992), (Delson Chikobvu and Caston 2013).

The HDD and CDD samples derived from the temperature index are the exogenous variables that have been used to forecast the peak load electricity. (Appendix)

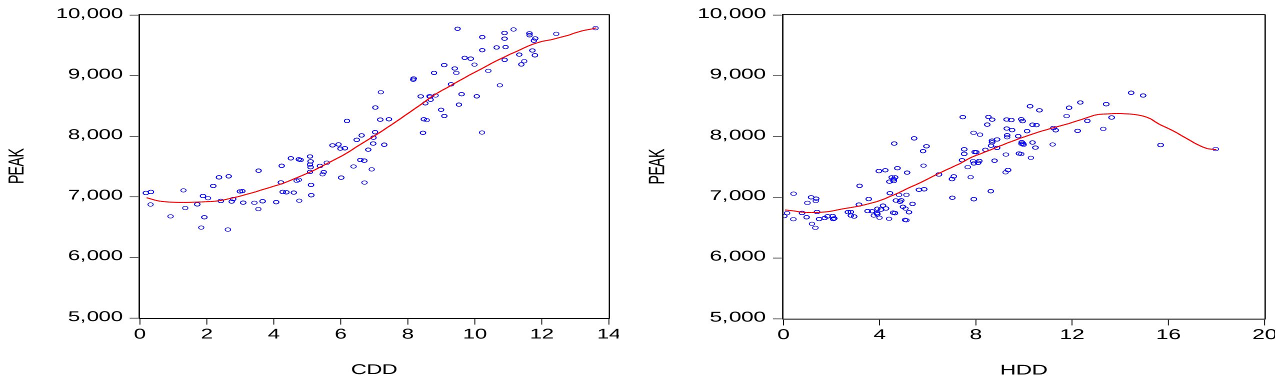


FIG.11 Daily peak in terms of cooling (CDD) and heating (HDD) degree-days in 2012. Only data corresponding to working days are shown

The HDD and CDD values using a base temperature of 18C° have been calculated for the entire sample.

Fig.11 shows daily electricity consumption versus daily cooling and heating degree-days calculated using a base temperature of 18C° for 2012.

4. Methodology:

The analysis has been structured by following a stepwise scheme, starting with the simplest model and adding each time new terms, this approach was applied in order to assess separately the effect of the different factors that influence the daily electricity demand. This procedure is similar to those used by (Engle et al. 1992) and (Henley, A. Peirson, J. 1994).

The paper describes a transfer function intervention model for analyzing the impact of exogenous variables such as the cooling and heating degree days, and also of seasonal dummy variables that capture the 'day of the week', 'holiday' and 'month of the year' effects. Additionally, the significance of the different autoregressive and dynamic patterns has been checked.

All models have been estimated with daily peak electricity demand data from January 2000 through December 2012.

5. Trend and seasonality:

Initially we have to shed the light on the existence of strong long-term trend in the daily peak load which can be detected in Fig.7 .The common methods for removing the trends in time series are differencing[70].

Former studies have shown significant seasonal daily components in the peak electricity load series (Engle *et al.1992*) (Isa S Q amber 2012) (Yueri S. Akil, H. Miyauchi 2013). In order to capture them, a qualitative variable "day of the week" has been introduced into the model through the specification of six dummy variables (D_{it}) representing all days in the week except the base day of Sunday, *i* represents the day of the week (Monday, Tuesday, Wednesday, Thursday, Friday, Saturday).

$$D_{it} = \begin{cases} 1 \; if \; in \; the \; t \; observation \; day \; is \; found \\ 0 \quad otherwise \end{cases}$$

To improve the performance of the model more dummy variables are constructed to proxy the holidays and days near a holiday. The peak load is partially due to the industrial sector, therefore it decreases during holidays. For that three dummy variables have been introduced to the model. First, a variable H_t has been include (1st January (New Year); Aid el Fitr; Aid el Adha; 5th of July(Independence day), Labor Day, 1st November (revolution day); 1st Mouharam, Achoura) . H_t is defined as:

$$H_t = \begin{cases} 1 \quad if \; t \; is \; a \; Holiday \\ 0 \qquad otherwise \end{cases}$$

Second, a dummy variable H_{t-1} has been introduced to check the impact on peak load produced by the proximity of a holiday, and it's defined as follow:

[70] A Unit Root Test was applied.

$$H_{t-1} = \begin{cases} 1 & if\ t\ observation\ corresponds\ to\ a\ day\ after\ a\ Holiday \\ 0 & otherwise \end{cases}$$

Last, a third variable has been included to analyze the influence of the Holy month of Ramadan[71], this holiday has been treated separately because it is considered as a moving holiday (C. Emre Alper 2001)[72]. Thus, a new variable Ram_t is defined:

$$Ram_t = \begin{cases} 1 & if\ t\ observation\ correspond\ to\ a\ day\ of\ Ramadan \\ 0 & otherwise \end{cases}$$

To account in the model for the monthly seasonality not related to the temperature variable, eleven (11) dummy variables (M_{jt}) were introduced, each representing one of the months in a year and taking January as the base month. Thus, j refers to February, March, April, May, June, July, August, September, October, November and December.

$$M_{jt} = \begin{cases} 1 & if\ in\ te\ t\ observation\ the\ month\ \ j\ is\ found \\ 0 & otherwise \end{cases}$$

In order to capture the effect of load shedding[73] on the peak load electricity a variable LS_t was introduce to measure its effect.

A series of models has been estimated using the methodology mentioned above starting with Univariate models, then moving to bivariate Models as an attempt to improve the performance of the model by adding a weather variables (HDD, CDD) in the model to check whether it has a significant impact on the peak load or not. In each case a series of diagnostic test[74] are applied to check the performance of the models. The objective that lies behind this methodology is to construct the best overall model that contains the true factors that influence the peak load in Algeria. (We choose the final model using AIC, SC, R^2 criteria).

First we examine the daily peak load of our sample (2000-2012) following this procedure[75].

Taking into account all the mentioned effects, the estimated model is finally given by:

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[71] The holy month of Ramadan has a variable time location each year.

[72] **C. Emre Alper, and S. Borgan** The authors emphasize the importance of paying special attention to the phenomena of Moving Holidays

[73] Load shedding is resorted-to mainly because of the demand-supply gap during peak hours. Load shedding can affect a country's economy because it slows down industrialization and affects people's lifestyles. During the daytime it affects commercial and industrial operations and, when load-shedding operations are in the evening hours, it affects more the residential sector.

[74] We used the Lagrange Multiplier tests.

[75]The results of each model estimated are displayed in Appendix a

$$Peak = c_1 + \alpha_t t + \beta_1 HDD_t + \gamma_1 CDD_t + \sum_{i=2}^{7} \delta_{1i} D_{it} + \varpi_1 H_t + \kappa_1 H_{t-1} + \theta_1 Ram_t + \sum_{i=2}^{12} \lambda_{1i} M_{it} + \varepsilon_{1t} \qquad (1)$$

$\boldsymbol{t}$: is the trend

$\boldsymbol{c_1}$, $\boldsymbol{\alpha_t}$, $\boldsymbol{\gamma_1}$, $\boldsymbol{\beta_1}$, $\boldsymbol{\delta_{1i}}$ $(i=\overline{2,7})$, $\boldsymbol{\varpi_1}$, $\boldsymbol{\kappa_1}$, $\boldsymbol{\theta_1}$, $\boldsymbol{\lambda_{1i}}$ $(\boldsymbol{i} = \overline{\mathbf{2,12}})$: are the coefficients to be estimated for the terms considering the different effects.

$\boldsymbol{\varepsilon_{1t}}$: Error term.

Table 6 Equ.1 present the best results for our model. Best model is based on the lowest value of Aikaike Information Criterion *AIC* and Shwarz criterion SC tests (panel B). Additionally, the highest value for adjusted coefficient of determination R^2 of model is also assessed.

The results for the estimation of Eq. (1) are presented in Table 6.

Table 6: Eq. (1) and Eq.(2)

Panel A	**Equation 1**		**Equation 2**	
Variable	**Coefficient**	**t-statistic**	**Coefficient**	**t-statistic**
C	8.156	1762.322	8.156	486.226
T	0.0001	323.849	0.0001	28.504
HDD	0.013	34.772	0.007	23.886
CDD	0.011	26.488	0.006	18.425
D_{2t}	0.027	10.715	0.027	25.472
D_{3t}	0.027	10.604	0.027	21.321
D_{4t}	0.028	11.209	0.029	22.378
D_{5t}	0.029	11.504	0.030	23.075
D_{6t}	0.018	7.382	0.019	15.247
D_{7t}	- 0.011	- 4.386	- 0.009	- 9.084
H_t	- 0.002	- 4.947	- 0.020	- 8.998
H_{t-1}	- 0.015	- 3.331	- 0.014	- 6.500
Ram_t	0.034	13.186	0.013	3.378
M_{2t}	- 0.017	- 5.185	- 0.015	- 2.783
M_{3t}	- 0.069	- 19.684	- 0.028	- 3.877
M_{4t}	- 0.090	- 22.770	- 0.036	- 4.310
M_{5t}	- 0.095	- 21.236	- 0.027	- 3.055
M_{6t}	- 0.084	- 16.557	- 0.032	- 3.447
M_{7t}	- 0.056	- 9.856	- 0.023	- 2.453
M_{8t}	- 0.061	- 10.719	- 0.022	- 2.393
M_{9t}	- 0.082	- 16.393	- 0.041	- 4.557
M_{10t}	- 0.087	- 18.942	- 0.047	- 5.483
M_{11t}	- 0.077	- 20.942	- 0.038	- 5.111
M_{12t}	- 0.034	- 10.413	- 0.023	- 4.177
AR(1)	-	-	0.642	43.720
AR(2)	-	-	0.039	2.298
AR(3)	-	-	0.120	6.992
AR(4)	-	-	0.026	1.543
AR(5)	-	-	0.020	1.159
AR(6)	-	-	0.027	1.575
AR(7)	-	-	0.106	6.179
AR(8)	-	-	- 0.040	- 2.358
AR(9)	-	-	0.012	0.866
Panel B				
Adjusted R^2	0.96		0.989	
DW[76]	0.35		2.001	
AIC[77]	- 3.31		- 4.675	
SC[78]	- 3.27		- 4.630	

[76] DW : Durbin-Watsom statistic
[77] AIC : Akaike information criterion
[78] SC: Shwarz criterion

Eq1 of table 6 present regression coefficients and t-statistic Results:

All the tested variables were significant except for the "load shedding" one (p-value >10%) this mean that LS_t has no effect on the peak load.

The constant and the trend are highly significant. The two temperature-derived variables are also significant, and the coefficient for the HDD (0.013) is slightly larger than that of CDDs (0.011). The results show the importance of the daily seasonality in the peak electricity demand. The days of the week with least influence on the peak demand are, increasingly, Thursday, Saturday and Wednesday. For that, Wednesday is the working day with least peak load. All coefficients for the dummy variables related to holiday effects are significant and negative (- 0.002), indicating a peak demand decreases due to holidays. This is mainly due to the decrease in the economic activity during holidays. All the coefficients for the dummy variables related to the monthly seasonality are negative and significant. These results imply that January, which is included in the constant, is the months when more electricity is consumed. Regarding the dummy relative to the holy month of Ramadan is also significant and contributes in the rise of the peak load. The obtained model presents a high predictive power, with an adjusted R^2 of 96.01% (see panel B of Table 1).

Interpretation of the Results:

These findings indicate an important seasonality in the pattern of the daily and monthly peak load demand this can be the consequences of the variation in consumers behavior (three sectors included). For this reason, it is preferable in the short run to adopt pricing policies to reflect marginal generation costs [79]with a main objective is to induce a behavioral time-shifting response in consumers. This will probably manage the comportment of consumers and by that prevent the problems of peak load demand.

Thus, the results reveals that peak demand is highly sensitive to temperature variations (HDD, CDD) and since we have no power to control its behavior a necessity of long-run planning of capacities expansion to cover the increasing electricity demand and efficient and effective energy policy.

[79] Study showed that the introduction of TOU pricing in Britain may not result in a significant reduction of electricity consumption in the short run.

6. Autoregressive and dynamic effects:

6.1 Serial correlation:

Despite the fact that the proposed model takes into account many seasonal and anomalous effects, the Durbin-Watson statistic and other diagnostic tests indicate a large serial correlation coefficients (see table 6). The effects of serial correlation removal in the static relationship between electricity peak demand and temperature will be examined later on.

One of the common methods to incorporate autoregressive behavior into predictive models is based on the introduction of lagged dependent variables. This procedure can lead to some problems. If variables other than the lagged dependent variable had predictive power, the introduction into the model of the dependent variable lagged by one period would impose a dynamic autoregressive structure on the remaining variables (see Engle *et al. 1992*). In our model, this would be the case for the *HDD* and *CDD* variables. As consequence, the influence of serial correlation in the model has been analyzed by introducing an autoregressive structure in the error term instead of including the lagged dependent variable.

In order to reduce the serial correlation observed in the first lags (see DW in panel B of Table 1), different AR models have been tested using both AIC Akaike Information Criterion and SC Schwarz Criterion as references for the selection.

Finally, the model has been specified by introducing a nine-order autoregressive process in the error term:

$$(1-\varphi_1 L - \varphi_2 L^2 - \ldots - \varphi_9 L^9)\varepsilon_{2t} = \xi_{2t}$$

$$Peak = c_1 + \alpha_t t + \beta_1 HDD_t + \gamma_1 CDD_t + \sum_{i=2}^{7} \delta_{1i} D_{it} + \varpi_1 H_t + \kappa_1 H_{t-1} + \theta_1 Ram_t + \sum_{i=2}^{12} \lambda_{1i} M_{it} + \xi_{2t} \qquad (2)$$

Panel A and B of Table 1 shows the results for model 2.

The significance of the coefficient for the H_{t-1} variable is maintained in spite of incorporating the residual autocorrelation. Nevertheless, there is a decrease both in the size and significance of the coefficients for the *HDD(0.007)* and *CDD(0.006)* variables. This confirm the importance of the AR components. The adjusted R^2 reaches 98.9%, and the Durbin_Watson statistic increases in relation to the previous model[80]. These results indicate the importance of treating the residual serialcorrelation otherwise it will produce biased estimations of peak electricity demand.

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[80] DW= 2.00 => absence of autocorrelation.

6.2 Temperature dynamics:

The estimated models do not include dynamic structures in the temperature-related variables. However, there are factors that suggest the influence of past temperatures in the present peak load. These considerations suggest that the degree-day variables could have, in addition to a contemporary influence on the peak electricity demand, a lagged effect. To check this hypothesis, model 2 has been extended by introducing a five-order lag. Polynomial for both degree-day variables β(*L)* and γ(*L)* for *HDD* and *CDD* , respectively .

Taking in consideration that the lagged effect can be relevant only over short time periods.

The estimated model is given by:

$$Peak= c_1 + \alpha_t t + \beta\,(L) HDD_t + \gamma\,(L) CDD_t + \sum_{i=2}^{7} \delta_{1i}\, D_{it} + \varpi_1 H_t + \kappa_1 H_{t-1} + \theta_1\, Ram_t + \sum_{i=2}^{12} \lambda_{1i}\, M_{it} + \xi_{3t} \qquad (3)$$

$$(1 - \varphi_1 L - \varphi_2 L^2 - \ldots - \varphi_9 L^9)\varepsilon_{3t} = \xi_{3t}$$

From table 7 we can distinguish a slight increase in the adjusted R^2 (99.0%) and the AIC and SC criterions decrease again in relation to the last estimated model.

The main results obtained with the introduction of the dynamic structure are the following:

1. The coefficients of the *HDD* and *CDD* variables are still significant, but their size decrease comparing to the results of Eq. 2.

2. The coefficient for *HDD* is higher than that accompanying the *CDD* variable. Conducting a Wald test to check the equality of both coefficients shows a *P*-value of 0.0091< 5%, and so they are significantly different.

3. Both coefficients for the *HDD* and *CDD* variables are significant until the first lag. This applies that only the temperature lag 1 increases the peak load demand.

4. The size of the coefficients for the *HDD* and *CDD* variables decreases for increasing lags. This mean that the lag temperature affects less and less the peak load demand.

The results of this chapter show that the relationship between peak electricity load and temperature is affected by an autoregressive specification and by a dynamic component of temperature on peak load. Holidays *H* will make peak demand lower during the whole period of the study. The obtained model has high predictive power.

The results of this general model are displayed in Table 2.

Table 7: estimates of Eq. 3:

	Equation 3		
Variable	**Coefficient**	**t-statistic**	**Prob.**
C	8.144	471.662	0.000
T	0.0001	27.948	0.000
HDD_t	0.006	20.020	0.000
HDD_{t-1}	0.001	4.595	0.000
HDD_{t-2}	0.0001	0.283	0.776
HDD_{t-3}	- 0.0004	- 1.160	0.246
HDD_{t-4}	- 0.0002	- 0.578	0.563
HDD_{t-5}	0.0001	0.395	0.692
CDD_t	0.005	16.823	0.000
CDD_{t-1}	0.002	7.942	0.000
CDD_{t-2}	- 0.0005	- 1.471	0.142
CDD_{t-3}	- 0.0002	- 0.687	0.466
CDD_{t-4}	0.0002	0.729	0.447
CDD_{t-5}	0.0002	0.760	0.000
D_{2t}	0.026	25.225	0.000
D_{3t}	0.027	20.942	0.000
D_{4t}	0.028	21.979	0.000
D_{5t}	0.029	22.603	0.000
D_{6t}	0.019	14.816	0.000
D_{7t}	- 0.009	- 9.106	0.000
H_t	- 0.019	- 8.703	0.000
H_{t-1}	- 0.013	- 6.361	0.000
Ram_t	0.013	3.179	0.001
M_{2t}	- 0.014	- 2.651	0.008
M_{3t}	- 0.026	- 3.723	0.000
M_{4t}	- 0.033	- 4.029	0.000
M_{5t}	- 0.026	- 2.896	0.000
M_{6t}	- 0.032	- 3.419	0.000
M_{7t}	- 0.024	- 2.500	0.012
M_{8t}	- 0.023	- 2.481	0.013
M_{9t}	- 0.041	- 4.468	0.000
M_{10t}	- 0.046	- 5.433	0.000
M_{11t}	- 0.037	- 5.097	0.000
M_{12t}	- 0.023	- 4.175	0.000
AR(1)	0.650	44.510	0.000
AR(2)	0.021	1.234	0.217
AR(3)	0.118	6.806	0.000
AR(4)	0.027	1.588	0.112
AR(5)	0.023	1.353	0.175
AR(6)	0.026	1.543	0.122
AR(7)	0.114	6.600	0.000
AR(8)	- 0.046	- 2.647	0.008
AR(9)	0.019	1.349	0.177
R^2	0.990		0.989
DW	2.001		2.001
AIC	- 4.687		- 4.675
SC	- 4.629		- 4.630

CONCLUSION

Modeling daily peak electricity demand is important as it provides short-term forecasts which will assist system operators in dispatching electrical energy. Decision making in this sector involves planning under uncertainty.

In this study, we highlight the modification of the electricity demand in Algeria during the last decade and the shift of the peak load between the winter and summer season, as a result of wide use of the air conditioning systems and the rise of the penetration gas rate since 2008.

The study has examined the causal relationship between Peak load electricity demand and deterministic variables such as holidays and exogenous variables like weather conditions. In view of this purpose, we mobilized an econometric model based on a stepwise procedure that has made clear importance of the daily and monthly seasonal structures of peak load electricity.

The empirical results show that HDD and CDD have the highest effect on peak demand, and can be seen as the main factors affecting the peak load in Algeria. On the other hand, holidays make peak demand lower in all seasons. These results confirm the set of assumptions previously established.

Other parameters must be introduced in order to maximize the accuracy of the model. In the Algerian case, economic parameters such as: price and GDP, as well as population growth must be taken into account. In the light of our study the use of these parameters would have biased the estimation since our model is based on daily peak data and the prices (tariffs) are of rigid structure since 2005. Moreover the data on GDP and consumers revenues are not available at this range. Nevertheless, these factors are considered to be among the most important determinants of the electricity demand.

In view of the results, Algeria is in urgent need of an adequate energy infrastructure so that it can achieve higher levels of economic development. Moreover, it will have to understand that fossil energy is coming to an end and that is logical to look for substitute energy resources such as renewable energy (solar power and wind speed …). Beside, the Algerian government must undertake new strategies to manage the peak load problem relying on the international experiences where they implemented a broad category of mechanisms to control load on its distribution grid in order to reduce their peak demand following two different strategies: direct load control programs; and price responsive demand.

Based on our findings, and taking in account previous international experiences, we propose a set of recommendations that we believe are necessary in order to reduce the problem of peak load:

- ✓ In the short run, adopting a pricing policies to reflect marginal generation costs, can have positive results on the peak load problems.
- ✓ The state should offer financial incentives such as interest rate and discounted loans to families.
- ✓ Although we cannot control the temperature effects on peak demand there are other means that allow the reduction of the load among them *electricity taxation* which can be used to manage electricity demand, especially the AC and heating appliances.
- ✓ The state and utilities can assist in developing successful exhortations to reduce peak load by making information widely available on energy and peak demand impacts from load reducing technologies.
- ✓ In the long run, depending more on renewal energy to provide diversification in electricity production. Algeria is engaged in a new age of sustainable energy use. The program consists of installing up to 22000MW of power generating capacity from renewable sources between 2011 and 2030[81].

The findings of this study could provide policymakers with a better understanding of the relationship between Climate conditions and deterministic variables (holidays) along with electricity peak demand in Algeria.

[81] EQUILIBRES, « le développement des Energies Renouvelables », la lettre de la commission de régulation de l'électricité et du Gaz, janvier 2014 N°21.

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- **DU TRANSPORT DE L'ELECTRICITE, DE LA CONDUITE DU SYSTEME PRODUCTION-TRANSPORT DE L'ELECTRICITE ET DE L'ORGANISATION DU MARCHE DE L'ELECTRICITE** Art. 29 — Le réseau de transport de l'électricité est un monopole naturel. Sa gestion sera assurée par un gestionnaire unique. Le gestionnaire du réseau de transport de l'électricité bénéficie d'une autorisation d'exploiter délivrée par le ministre chargé de l 'Energie, après avis de la commission de régulation. Cette autorisation est incessible.
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Appendix

Appendix: The Results of Models Testing in Eviews

Model n°1: Testing the eight dummy variables representing the holidays separately + the dummy used for the holy month of Ramadan.

Dependent Variable: LPEAK

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ACHO	0.015544	0.064135	0.242363	0.8085
AA	0.016329	0.064135	0.254605	0.7990
AF	-0.010074	0.064135	-0.157071	0.8752
INDD	0.013998	0.064135	0.218260	0.8272
LABD	-0.102977	0.064135	-1.605627	0.1084
NY	0.038921	0.064135	0.606865	0.5440
RVD	-0.077071	0.064153	-1.201345	0.2297
MOH	0.001003	0.064135	0.015642	0.9875
RAM	0.033479	0.012320	2.717422	0.0066
C	8.558648	0.003535	2421.442	0.0000

R-squared	0.002493	Mean dependent var	8.561062
Adjusted R-squared	0.000598	S.D. dependent var	0.230960
S.E. of regression	0.230891	Akaike info criterion	-0.091637
Sum squared resid	252.6395	Schwarz criterion	-0.078022
Log likelihood	227.5925	Hannan-Quinn criter.	-0.086853
F-statistic	1.315922	Durbin-Watson stat	0.019379
Prob(F-statistic)	0.222640		

ACHO	Achoura
AA	Aid el Adha
AF	Aid el Fitr
INDD	Independence day
LABD	Labor day
NY	New Year
RVD	Revelotion day
MOH	Mouharam
RAM	Ramdan

<u>Model n°2:</u> Testing the effects of each day of the week separately taking Sunday as base.

Dependent Variable: LPEAK

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SAT	-0.000904	0.012517	-0.072233	0.9424
MON	0.001820	0.012522	0.145345	0.8844
TUS	0.002862	0.012522	0.228592	0.8192
WED	-0.007603	0.012522	-0.607195	0.5438
THU	-0.036774	0.012293	-2.991559	0.0028
FRI	-0.026489	0.012779	-2.072809	0.0382
C	8.570761	0.008851	968.3361	0.0000

R-squared	0.004061	Mean dependent var	8.561062
Adjusted R-squared	0.002801	S.D. dependent var	0.230960
S.E. of regression	0.230637	Akaike info criterion	-0.094474
Sum squared resid	252.2422	Schwarz criterion	-0.084944
Log likelihood	231.3295	Hannan-Quinn criter.	-0.091125
F-statistic	3.223029	Durbin-Watson stat	0.013056
Prob(F-statistic)	0.003675		

SAT	Saturday
MON	Monday
TUS	Tuesday
WED	Wednesday
THU	Thursday
FRI	Friday

Model n°3: Testing the seasonality of the days of the week and each month separately.

Dependent Variable: LPEAK

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	8.276530	0.003599	2299.570	0.0000
SUN	0.026739	0.002983	8.964085	0.0000
MON	0.028930	0.002985	9.692790	0.0000
TUS	0.029806	0.002984	9.988287	0.0000
WED	0.019326	0.002984	6.476048	0.0000
SAT	0.025848	0.002984	8.662084	0.0000
THU	-0.010307	0.002932	-3.515259	0.0004
FV	-0.026089	0.003888	-6.710459	0.0000
MR	-0.118400	0.003799	-31.16559	0.0000
AP	-0.165499	0.003837	-43.12888	0.0000
MY	-0.186685	0.003795	-49.19049	0.0000
JN	-0.144191	0.003843	-37.51716	0.0000
JT	-0.079649	0.003797	-20.97730	0.0000
AT	-0.086841	0.003853	-22.53800	0.0000
SP	-0.150422	0.003893	-38.63956	0.0000
OC	-0.180799	0.003859	-46.84556	0.0000
NV	-0.136079	0.003882	-35.05042	0.0000
DC	-0.049701	0.003816	-13.02471	0.0000
RAM	0.033497	0.003057	10.95677	0.0000
@TREND	0.000159	5.72E-07	277.5144	0.0000
H	-0.030279	0.005383	-5.624440	0.0000
H__1_	-0.025015	0.005408	-4.625423	0.0000

R-squared	0.945911	Mean dependent var	8.561062
Adjusted R-squared	0.945671	S.D. dependent var	0.230960
S.E. of regression	0.053834	Akaike info criterion	-3.001212
Sum squared resid	13.69917	Schwarz criterion	-2.971259
Log likelihood	7148.377	Hannan-Quinn criter.	-2.990686
F-statistic	3936.476	Durbin-Watson stat	0.266063
Prob(F-statistic)	0.000000		

Model n°4: Testing the effects of the variables Heating and Cooling degree day on the peak demand

Dependent Variable: LPEAK

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CDD	0.014649	0.000274	53.38091	0.0000
HDD	0.020687	0.000260	79.50045	0.0000
C	8.081991	0.002068	3907.440	0.0000
@TREND	0.000158	5.61E-07	282.0337	0.0000

R-squared	0.947353	Mean dependent var	8.561062
Adjusted R-squared	0.947319	S.D. dependent var	0.230960
S.E. of regression	0.053011	Akaike info criterion	-3.035808
Sum squared resid	13.33403	Schwarz criterion	-3.030362
Log likelihood	7212.527	Hannan-Quinn criter.	-3.033895
F-statistic	28461.02	Durbin-Watson stat	0.441807
Prob(F-statistic)	0.000000		

Model n°5: Testing the effect of weather variables and holidays and a day after holiday + the six days of the week on daily peak load demand

Dependent Variable: LPEAK

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CDD	0.014653	0.000263	55.77492	0.0000
HDD	0.020736	0.000249	83.30441	0.0000
C	8.092423	0.002678	3021.896	0.0000
@TREND	0.000158	5.37E-07	294.9196	0.0000
H	-0.018111	0.005035	-3.596729	0.0003
H__1_	-0.009691	0.005059	-1.915691	0.0555
MON	0.001467	0.002753	0.532766	0.5942
TUS	0.002186	0.002753	0.793996	0.4272
WED	-0.008369	0.002753	-3.040046	0.0024
THU	-0.038418	0.002703	-14.21454	0.0000
FRI	-0.027094	0.002809	-9.644816	0.0000
SAT	0.001001	0.002753	0.363467	0.7163

R-squared	0.951928	Mean dependent var	8.561062
Adjusted R-squared	0.951817	S.D. dependent var	0.230960
S.E. of regression	0.050697	Akaike info criterion	-3.123357
Sum squared resid	12.17520	Schwarz criterion	-3.107019
Log likelihood	7428.411	Hannan-Quinn criter.	-3.117616
F-statistic	8527.542	Durbin-Watson stat	0.371824
Prob(F-statistic)	0.000000		

The Results of Eq 1

Dependent Variable: LPEAK

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	8.156454	0.004628	1762.322	0.0000
@TREND	0.000158	4.89E-07	323.8492	0.0000
HDD	0.013694	0.000394	34.77220	0.0000
CDD	0.011325	0.000428	26.48876	0.0000
SAT	0.027379	0.002555	10.71525	0.0000
SUN	0.027083	0.002554	10.60414	0.0000
MON	0.028647	0.002556	11.20959	0.0000
TUS	0.029395	0.002555	11.50475	0.0000
WED	0.018866	0.002555	7.382942	0.0000
THU	-0.011012	0.002511	-4.386199	0.0000
H	-0.022822	0.004613	-4.947351	0.0000
H__1_	-0.015449	0.004637	-3.331588	0.0009
RAM	0.034545	0.002620	13.18633	0.0000
FV	-0.017309	0.003338	-5.185133	0.0000
MR	-0.069751	0.003543	-19.68475	0.0000
AV	-0.090219	0.003962	-22.77026	0.0000
MI	-0.095631	0.004503	-21.23633	0.0000
JN	-0.084387	0.005096	-16.55791	0.0000
JT	-0.056486	0.005731	-9.856385	0.0000
AT	-0.061108	0.005700	-10.71979	0.0000
SP	-0.082120	0.005009	-16.39348	0.0000
OC	-0.087262	0.004607	-18.94244	0.0000
NV	-0.077996	0.003724	-20.94213	0.0000
DC	-0.034325	0.003296	-10.41328	0.0000

R-squared	0.960366	Mean dependent var	8.561062
Adjusted R-squared	0.960173	S.D. dependent var	0.230960
S.E. of regression	0.046092	Akaike info criterion	-3.311311
Sum squared resid	10.03816	Schwarz criterion	-3.278636
Log likelihood	7886.709	Hannan-Quinn criter.	-3.299829
F-statistic	4977.853	Durbin-Watson stat	0.357526
Prob(F-statistic)	0.000000		

Application of diagnostic test (LM test) to check for serial correlation the results confirm the existence of serial correlation in the model.

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	5183.918	Prob. F(2,4723)	0.0000
Obs*R-squared	3262.699	Prob. Chi-Square(2)	0.0000

The Results of Eq 2

Dependent Variable: LPEAK

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	8.151894	0.016766	486.2263	0.0000
@TREND	0.000159	5.60E-06	28.50473	0.0000
HDD	0.007524	0.000315	23.88695	0.0000
CDD	0.006069	0.000329	18.42570	0.0000
SAT	0.027177	0.001067	25.47289	0.0000
SUN	0.027302	0.001281	21.32147	0.0000
MON	0.029181	0.001304	22.37843	0.0000
TUS	0.030094	0.001304	23.07512	0.0000
WED	0.019533	0.001281	15.24743	0.0000
THU	-0.009673	0.001065	-9.084984	0.0000
H	-0.020450	0.002273	-8.998709	0.0000
H__1_	-0.014081	0.002166	-6.500484	0.0000
RAM	0.013990	0.004140	3.378869	0.0007
FV	-0.015253	0.005480	-2.783241	0.0054
MR	-0.028252	0.007287	-3.877051	0.0001
AV	-0.036253	0.008410	-4.310929	0.0000
MI	-0.027789	0.009094	-3.055740	0.0023
JN	-0.032931	0.009553	-3.447311	0.0006
JT	-0.023634	0.009634	-2.453204	0.0142
AT	-0.022751	0.009504	-2.393784	0.0167
SP	-0.041821	0.009175	-4.557919	0.0000
OC	-0.047221	0.008612	-5.483170	0.0000
NV	-0.038130	0.007459	-5.111825	0.0000
DC	-0.023971	0.005739	-4.177045	0.0000
AR(1)	0.642762	0.014702	43.72068	0.0000
AR(2)	0.039917	0.017367	2.298419	0.0216
AR(3)	0.120698	0.017260	6.992754	0.0000
AR(4)	0.026738	0.017327	1.543149	0.1229
AR(5)	0.020090	0.017333	1.159040	0.2465
AR(6)	0.027284	0.017320	1.575235	0.1153
AR(7)	0.106549	0.017243	6.179170	0.0000
AR(8)	-0.040901	0.017339	-2.358898	0.0184
AR(9)	0.012647	0.014600	0.866226	0.3864

R-squared	0.989913	Mean dependent var	8.561437
Adjusted R-squared	0.989844	S.D. dependent var	0.231016
S.E. of regression	0.023281	Akaike info criterion	-4.675428
Sum squared resid	2.551200	Schwarz criterion	-4.630426
Log likelihood	11113.76	Hannan-Quinn criter.	-4.659613
F-statistic	14435.00	Durbin-Watson stat	2.001165
Prob(F-statistic)	0.000000		

Inverted AR Roots	.98	.45-.51i	.45+.51i	.19+.27i
	.19-.27i	-.18-.69i	-.18+.69i	-.63-.31i
	-.63+.31i			

Check for serial correlation the results confirm none existence of serial correlation in the model.

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	2.450335	Prob. F(2,4705)	0.0864
Obs*R-squared	4.931989	Prob. Chi-Square(2)	0.0849

The Results of Eq3

Dependent Variable: LPEAK

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	8.144174	0.017267	471.6624	0.0000
@TREND	0.000160	5.71E-06	27.94895	0.0000
HDD	0.006833	0.000341	20.02002	0.0000
HDD(1)	0.001687	0.000367	4.595594	0.0000
HDD(2)	0.000104	0.000367	0.283527	0.7768
HDD(3)	-0.000427	0.000368	-1.160387	0.2460
HDD(4)	-0.000212	0.000367	-0.578204	0.5632
HDD(5)	0.000135	0.000341	0.395663	0.6924
CDD	0.005661	0.000337	16.82348	0.0000
CDD(1)	0.002711	0.000341	7.942108	0.0000
CDD(2)	-0.000507	0.000345	-1.471699	0.1412
CDD(3)	-0.000237	0.000344	-0.687043	0.4921
CDD(4)	0.000249	0.000342	0.729131	0.4660
CDD(5)	0.000257	0.000338	0.760224	0.4472
SAT	0.026948	0.001068	25.22523	0.0000
SUN	0.027033	0.001291	20.94259	0.0000
MON	0.028991	0.001319	21.97948	0.0000
TUS	0.029822	0.001319	22.60310	0.0000
WED	0.019139	0.001292	14.81688	0.0000
THU	-0.009777	0.001066	-9.169609	0.0000
H	-0.019732	0.002267	-8.703930	0.0000
H__1_	-0.013737	0.002159	-6.361731	0.0000
RAM	0.013020	0.004095	3.179411	0.0015
FV	-0.014379	0.005423	-2.651380	0.0080
MR	-0.026900	0.007224	-3.723861	0.0002
AV	-0.033648	0.008351	-4.029062	0.0001
MI	-0.026189	0.009043	-2.896007	0.0038
JN	-0.032607	0.009536	-3.419513	0.0006
JT	-0.024182	0.009673	-2.500085	0.0125
AT	-0.023665	0.009538	-2.481193	0.0131
SP	-0.041043	0.009184	-4.468836	0.0000
OC	-0.046738	0.008602	-5.433187	0.0000
NV	-0.037732	0.007402	-5.097681	0.0000
DC	-0.023697	0.005675	-4.175498	0.0000
AR(1)	0.650976	0.014625	44.51046	0.0000
AR(2)	0.021514	0.017427	1.234538	0.2171
AR(3)	0.118074	0.017346	6.806845	0.0000
AR(4)	0.027673	0.017423	1.588267	0.1123
AR(5)	0.023598	0.017433	1.353600	0.1759
AR(6)	0.026892	0.017427	1.543093	0.1229
AR(7)	0.114590	0.017360	6.600664	0.0000
AR(8)	-0.046172	0.017441	-2.647274	0.0081
AR(9)	0.019744	0.014629	1.349690	0.1772

R-squared	0.990062	Mean dependent var	8.561035
Adjusted R-squared	0.989973	S.D. dependent var	0.230805
S.E. of regression	0.023112	Akaike info criterion	-4.687914
Sum squared resid	2.506239	Schwarz criterion	-4.629224
Log likelihood	11141.64	Hannan-Quinn criter.	-4.667287
F-statistic	11129.25	Durbin-Watson stat	2.001595
Prob(F-statistic)	0.000000		

Testing for serial correlation:

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	2.964328	Prob. F(2,4690)	0.0517
Obs*R-squared	5.977983	Prob. Chi-Square(2)	0.0503