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Forecasting the Jordanian Commercial Sector's Electrical Power Demands for the next ten years with and without implementing the Minimum Energy Efficiency Standard

Hana Zedan[1], Prof. Dr. Ali Ali[2], Dr. Ahmed Al-Ghandoor[3]
[1]Dept. of Civil Engineering, ISRA University, Amman, Jordan
[2]Dept. of Electrical Engineering, ISRA University, Amman, Jordan
[3]Dept. of Industrial Engineering, Hashemite University, Amman, Jordan

Abstract: Jordan witnessed a significant expansion in the commercial sector in recent years, leading to increased consumption of electricity, with the ratio of electricity consumption 17% of the total consumption of Jordan in 2012, an increase of 11.7 % from 2011. The expectations for the next year that the needs will reach an amount of 2900 GWh and if the same consumption estimated up by the year 2023, it will be 8600 GWh. It is concluded that the three services most major energy-consuming are the air conditioning, refrigeration systems as well as lighting. The Power consumed in these devices rates 39.5 %, 27.7 % and 18.4% of the total supplied power respectively. Four scenarios were adopted for maximizing the power saving, of which the forth scenario found to be the best, which gives a save of 15704 GWh in electricity consumption and the amount of the bills save will be 1.9938 billion JD.

Keywords: Energy Management, Electrical Energy Consumption, Electrical Power Demand Forecasting, Jordanian Commercial Sector, MEES.

INTRODUCTION

Energy management is the discipline and measures executed to achieve the minimum possible energy usage and cost while meeting the actual needs for the activities occurring within a facility. Actions intended to achieve this energy efficiency focus on reducing necessary end-usage, increasing efficiency, reducing wasted energy and finding superior energy alternatives. The fundamental goal of energy management is to produce goods and provide services with the least cost and least environmental pollution effects. According to the National Electricity Company (NEPCO, 2012) [1], Jordan imports more than 97% of oil derivatives. Also the decline quantities of natural gas imported from Egypt led to the low amounts of electrical power generation using gas from 90% in 2009 to 20% in 2012 which in turn led to the reliance of power plant operation on heavy fuel oil and diesel to meet the electrical power demands. It is also reported, (NEPCO,2012), that the amount of electricity consumption in 2012 increased by 14274 GWh, which was 13534 GWh in 2011 or an annual increase by 5.5 %, with an average per capita of 2227 KWh in 2012, while in 2011 it was 2167 kWh at a growth rate of 2.8%. The percentage growth of electrical power consumption in the commercial sector between 2011 and 2012 is 11.7%, while it was 0.6% between 2010 and 2011.The following figure presents the electrical power consumed by the different Jordanian sectors for the year 2012.

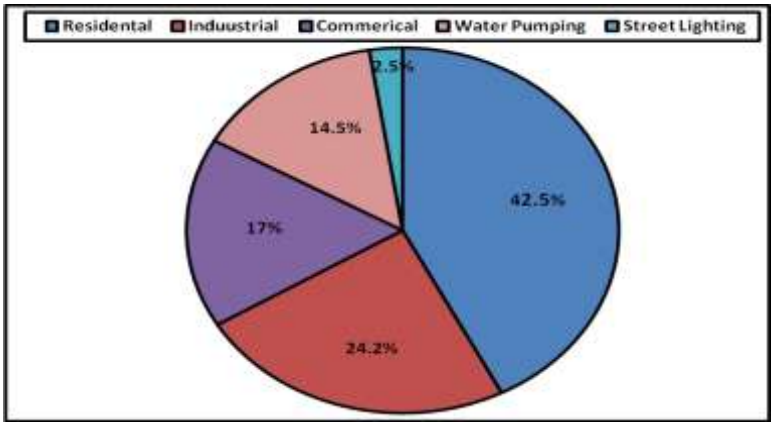

Figure (1): The distribution of energy consumption in Jordan by sectors for the year 2012

So the problem can be formulated as to find areas of potential energy saving in the Jordanian commercial sector through a systematic approach that includes: Data collection, Analysis, and Modeling.

DATA ANALYSIS AND MODEL IMPLEMENTATION

The data necessary for this study is the amount of electrical energy consumed by the so many appliances and devices used in the Jordanian commercial sector. Historical data records, of the electrical power consumption in the Jordanian commercial sector together with the total electrical energy consumption as taken from the Ministry of Energy and Mineral Resources (MEMR, 2012) [2], for the period 1987 to 2012 is as tabulated in table (1) below. This data will be used as a base to predict the electric power required by this sector for the period of the next ten years (2013 to 2022). The Jordanian commercial sector constitutes of different establishments such as supermarkets, restaurants, Clothing showrooms, sweet shops and other types of offices. Some appliances are shared among them such as air-conditioners, cooling devices, televisions and lighting, while some are specific such as electrical furnaces and washing machines. Data about the number, types and power ratings of the different electrical appliances used in the Jordanian commercial sectors is collected using questionnaires. These data are analyzed statistically to calculate the daily and annual consumption taken into account that some services, such as air-conditioning is not running during the whole year.

Table (1) : Electrical energy consumption for the Jordanian Commercial Sector

Years	Energy Consumption (GWh)	
	Total Consumption	Commercial Sector only
1987	2655	292
1992	3674	378
1997	5281	603
2002	6900	971
2007	10553	1757
2012	14274	2427

Ministry of energy and mineral Resources, 2012

A. Electrical Power Demand's Forecast

To estimate the electrical power consumed for the commercial sector through the years, the polynomial curve fitting is used, where the relationship between the amount of consumption (variable y) and the years (variable x) can be represented by the following polynomial equation,[3]:

$$y=c_0 + c_1x + c_2x^2 + ... +c_kx^k \quad (1)$$

Using the annual electricity consumption data of table (1), from the Ministry of Energy and Mineral Resources, and equation (1) infer a set of curves to get best fit for the quantities of electrical energy consumed for the last fifteen years from which it is seen that the 3rd order polynomial curve (equation 2 below) is the best fit with this power consumption, see Figure (2) below, [4].

$$y = 300.51 - 7.03x + 2.8x^2 + 0.03x^3 \quad (2)$$

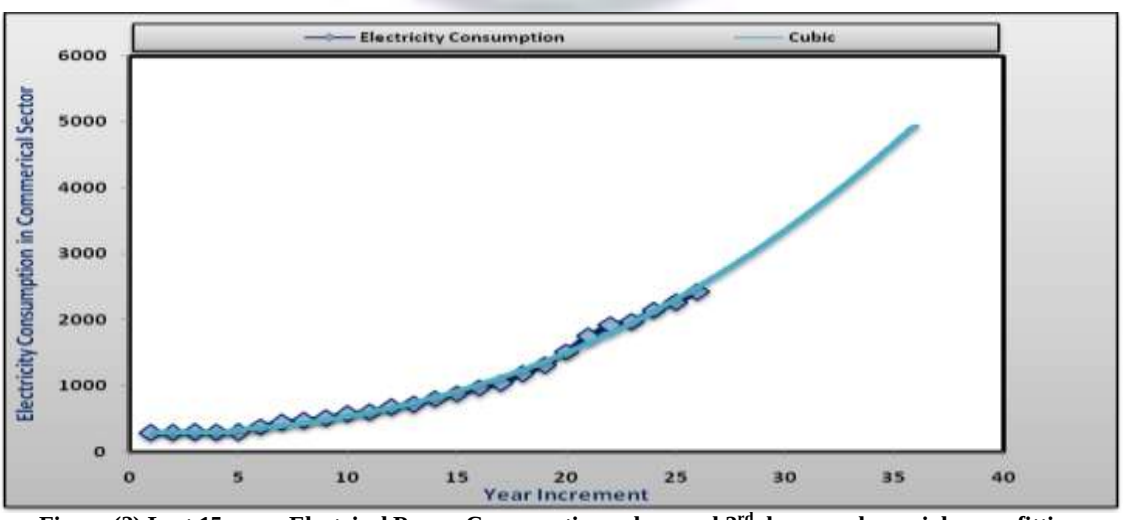

Figure (2) Last 15 years Electrical Power Consumption values and 3rd degree polynomial curve fitting

Using equation (2) above, the electricity consumption forecasting in the Jordanian commercial sector from 2013 to 2022 is calculated and tabulated in the table 2 below.

Table (2): Forecasting of electricity consumption for the next 10 years

T	Year	Forecasted Electricity Consumption (GWh)
1	2013	2690
2	2014	2900
3	2015	3100
4	2016	3375
5	2017	3590
6	2018	3832
7	2019	4100
8	2020	4395
9	2021	4623
10	2022	4980

B. Commercial Sector Power Consumption Analysis

Using the data collected by questioners, the amount of consumption of the different appliances in the Jordanian Commercial Sector, taking into account the average power rating (APR), working hours and the number of devices used in the enterprise, is computed according to equation 3, below. The result is that, as can be seen from table 3, the air conditioners, refrigerators and freezers, as well as the lighting are the most electricity consuming appliances in the commercial sector.

$$AAC = (NoA)\ (APR)\ (H/D)\ (D/Y) \quad (3)$$

Where:

AAC: Appliance Annual Consumption
NoA: Number of Appliances
APR: Average Power Rating
H/d: Hours/Day
D/y: Days/Year

Table (3): Sorting appliances according to their electricity consumption

Appliance	Electricity consumption in the commercial sector (MW)	CP
Air-conditioning	1385	39.5%
Refrigeration/Freezer	972	27.7%
Lighting	520	14.8%
Water Heating	66	1.9%
Electric Grill	55	1.6%
Hair Dryer	54	1.5%
Television	49	1.4%
Other	405	11.6%

The expected annual electricity consumption for the three most power consuming appliances in the Jordanian Commercial Sector (the air conditioners, refrigerators and freezers, as well as the lighting), using data collected by questioner taking into account the average power rating (APR), working hours, the number of devices used in the enterprise and the number of enterprises is computed. The result is as can be seen from table 4 below.

Table (4): Expected Annual Electricity Consumption (GWh) for three most power consuming appliances for next 10 years

Year	Expected Annual Electricity Consumption (GWh)		
	Air Conditioners	Cooling Appliances	Lightning
2013	1062.5	745.1	398.1
2014	1145.5	803.3	429.2
2015	1224.5	858.7	458.8
2016	1333.1	934.9	499.5
2017	1418.0	994.4	531.3
2018	1513.6	1061.5	567.1
2019	1619.5	1135.7	606.8
2020	1736.0	1217.4	650.5
2021	1826.1	1280.6	684.2
2022	1967.1	1379.5	737.0
Total			

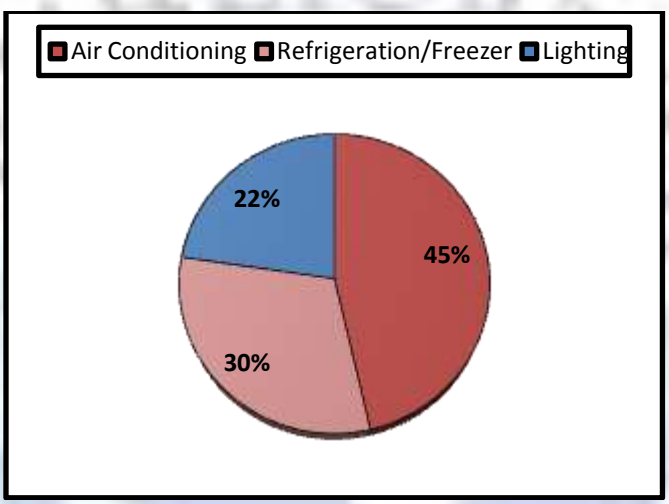

Figure (3): The percentage contributions of different appliances in energy savings

C. Energy Efficiency Classes (EEC)and Model Implementation

Energy efficiency class (EEC) expresses the minimum energy efficiency standard used, as shown in the table (5) below. The category of energy efficiency makes it possible to compare the annual energy consumption for a particular model with the rest of the market models, [5]. This efficiency classes were published in the European Commission, Directive 2003/31/EC, [6], 2003/66/EC, [7] and 98/11/EC, [8] for air-conditioners, cooling devices and lightning respectively. In order to identify the main drivers behind changes in electricity and fuel consumptions in the commercial sector in Jordan, four empirical models are developed based on multivariate linear regression analysis. The amount of expected saving in the electrical power consumption, which in turn will lead to the reductions in electricity bills amount, and in energy prices that are changing according to the global fossil fuel prices, can be achieved through the implementation of Minimum Energy Efficiency Standards (MEES) using a range of scenarios applied for the most power consuming services that consumes about 82% of the total power supplied to the Jordanian Commercial Sector.

Table (5) Energy Efficiency Rate of the most power consuming devices classes

EEC	(EER) for Air Conditioner	(EEI) Index% for Cooling Devices	(EER) Rate% for Lighting
A	3.2 < EER	I < 55	20 < EER < 50
B	3.2 >EER> 3.0	55 < I < 75	50 < EER < 75

C	3.0 >EER> 2.8	75 < I < 90	75 < EER < 90
D	2.8 >EER> 2.6	90 < I< 100	90< EER< 100
E	2.6 >EER> 2.4	100 < I < 110	100<EER<110

European Commission, [6], [7], [8]

Table 6 presents the percentage of market share for all the four scenarios, where all scenarios will be applied to each of the most electricity-consuming appliances.

Table (6): The percentages of market share for each scenario

Scenario	The efficiency of models			Ordinary models
	A	B	C	
Scenario-1	10%	10%	5%	75%
Scenario-2	20%	20%	10%	50%
Scenario-3	30%	30%	15%	25%
Scenario-4	40%	40%	20%	0%

II. Electrical Energy Saving and Bills Reduction

Assessing the annual and cumulative savings in electrical energy consumption and the resultant savings in electricity bills are the main aims of this study through applying minimum energy efficiency standards (MEES) and the implementation of the suggested models (the four scenarios)

A. Electrical Energy Savings

Electrical energy that can be saved for the years to come can be calculated using the following equation [9]:

$$\text{Energy Saving}=\{(Et-E0)+(E0*R)\}CP*MS*SF \quad (4)$$

Where, Et is the expected energy consumed for the t year, E0 is the Energy consumed in the base Year (2012), CP is the device consumption percentage, MS is the market share, SF is the save factor and R is the replacement factor. The results that have emerged from the computations (using the equations illustrated in section two above), to help assessing the best scenario for saving energy and mitigating the consumption of energy as a whole, as well as for devices, are given here after. Also to find the proportion of services that leads to reach the results and illustrations for how to reduce the hard energy consumption in the commercial sector and for further power savings in future. Air conditioners, cool devices and lighting are the most energy consuming appliances in the commercial sector. According to data collected by questioners, the rate of consumption of these devices in the commercial sector is about 82% of the total electrical energy supplied to this sector. After the implementation of MEES it is clear that the possible annual electrical energy saving for the next ten years is huge, see table 7. The cumulative energy savings that can be achieved by the four scenarios are 3926, 7852, 11778 and 15704 GWh, respectively, see table 8. It is clear, from these two tables, that the forth scenario provides the highest energy saving and hence it represents the optimal model.

Table (7): The Annual Energy Saving for all scenarios

Year	Cumulative Energy Save (GWh)			
	1st Senario	2nd Senario	3rd Senario	4th Senario
2013	65.5	131	196.5	262
2014	141.4	282.8	424.2	565.6
2015	206.8	413.6	620.4	827.2
2016	283.2	566.4	849.6	1132.8
2017	350.6	701.2	1051.8	1402.4
2018	422.3	844.6	1266.9	1689.2
2019	497.7	995.4	1493.1	1990.8
2020	577	1154	1731	2308
2021	646.5	1293	1939.5	2586
2022	735	1470	2205	2940

Table (8): The Cumulative Energy Saving for all scenarios

Year	Cumulative Energy Save (GWh)			
	1st Senario	2nd Senario	3rd Senario	4th Senario
2013	65.5	131	196.5	262
2014	206.9	413.8	620.7	827.6
2015	413.7	827.4	1241.1	1654.8
2016	696.9	1393.8	2090.7	2787.6
2017	1047.5	2095	3142.5	4190
2018	1469.8	2939.6	4409.4	5879.2
2019	1967.5	3935	5902.5	7870
2020	2544.5	5089	7633.5	10178
2021	3191	6382	9573	12764
2022	3926	7852	11778	15704

B. Electricity Bills Savings

Reducing the electricity consumption bills is important, especially as it helps to save sums of money being sent on oil and gas for a country dramatically dependent on imports.

Reduction in the electricity bills is directly associated with the reduction in electricity consumption, especially that prices of energy used in the production are affected by global prices. In this research, it is assumed that implementation of MEES will lead to reduce consumption and thus affects the provision of electricity in the future to impose a constant rate. According to Jordanian Energy and Petroleum Company report (JEPCO, 2012). [10], the average price of electricity consumption in the commercial sector is 127 fills/kWh.
So:

$$SU=ES * P \quad (5)$$

Where, SU : is the amount of savings in electricity bill
ES : is the total amount of energy savings
P : is the price of electricity (fills/kWh)

Table 9 shows that the reduction in bills values of supplied electricity by the end of the year 2022 are 498.6, 997.7, 1495.7 and 1993.8 million JD for the four scenarios respectively. Again scenario 4 achieves the highest saving amounts and hence it is the best model to be adopted. A total of 1.9938 billion JD to be saved is not a matter of joke, especially for a country, like Jordan, which is completely dependant on imports of energy resources.

Table (9): The total saving amount in utility bills (million JD) by implementing MEES for the four scenarios

Years	Annual saving amount in utility bills (million JD)			
	Different Senarios			
	1st Scenario	2nd Scenario	3rd Scenario	4th Scenario
2013	8.3	16.7	25	33.2
2014	18	36	54	71.8
2015	26.3	52.6	78.8	105
2016	36	72	108	143.8
2017	44.5	89	133.6	178.1
2018	53.5	107.3	160.8	214.5
2019	63.2	126.5	189.5	252.7
2020	73.2	146.7	219.8	293
2021	82.2	164.2	246.2	328.4
2022	93.4	186.7	280	373.3
Total	498.6	997.7	1495.7	1993.8

In addition, it is necessary to encourage the introduction of some efficient measures, such as high efficiency lightings and solar water heating systems, in this sector, to mitigate the future electricity demands especially that the sun rises not less than 300 days through the year on Jordan. The implementation of such measures is very crucial for Jordanian commercial sector to reach desired energy savings and bills reductions. Without employing most effective energy conservation measures, electricity demands are expected to rise by approximately 100% within the next 10 years.

CONCLUSIONS

Some remarks and conclusions that can be retrieved from this research are as follows.

1. Third order polynomial is the best fit to predict the power consumption in the commercial sector for the coming years from 2013 to 2022.
2. It is found that most electricity consuming devices in the Jordanian Commercial sector are the air conditioning, cool appliances and lighting which consume about 39.5%, 27.7% and 14.8% of the total power respectively. They together consume as much as 82% of the total power
3. Four scenarios have been implemented for energy saving. The fourth scenario found to be the best scenario that reduces the amount of cumulative energy consumed for the coming years and achieved the highest bills reduction.
4. After the application of the minimum efficiency for the three services (air conditioners, cool appliances and lighting), it is found that these three appliances have the largest impacts on energy conservation. They consume 45%, 30% and 22% of the total energy supplied to this sector, respectively.
5. Through the implementation of fourth scenario, the amount of energy conservation to reach 15704 GWh, and an amount of 1.9938 billion JD is saved.
6. Most commercial shops, in Jordan, do not employ efficient appliances such as efficient lightings and they abundant solar energy.

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