Evaluate consumption of electric energy of residential sector and its environmental and economic effects

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Article Info

Article history:

Received Jan 15, 2022
Revised Jul 19, 2022
Accepted Jul 26, 2022

Keywords:

Control electricity consumption
Energy efficiency class
Minimum energy efficiency standard
Predicted residential sector's
Residential sector

ABSTRACT

The demand for electric power in Iraq increased significantly after 2003, The residential sector is the most consumption according to the statistics of the iraqi ministry of electricity (ICME) and the data published by the international energy agency (IEA). In this paper, a survey was applied for a sample of the population; whereby questionnaire models were used for some of the most energy consuming devices to determine the estimates of supply and demand for energy, and some data from the Iraqi Ministry of Electricity available until 2020 was relied on to predict the consumption of electrical energy for next ten years. Five Scenarios have been implemented for energy saving, CO_2 gas emission and electricity production cost that reduce the accumulative energy consumed for the coming years.

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1. INTRODUCTION

There are many reasons caused for increasing the demand for electrical energy in Iraq, as: population growth, increasing the family income, and import of various electrical appliances of various origins. The residential sector remains the sector that consumes the largest amount of electrical energy, which contributes to impact on Iraqi economy also to the environment by gases emission containing toxic substances such as CO_2. The residential sector consumption of the total energy produced in Iraq is about 47%, including imported energy [1]. The data published by the international energy agency (IEA) also indicate that 45% of the total electric energy produced and imported was consumed by the residential sector in 2015 as shown in Figure 1 [2].

The adoption of minimum energy efficiency standard (MEES) has economic benefits that contribute to increase investment in industry and other services sectors, in addition to its impact on environment improvement through reducing gas emissions resulting from electrical energy production; In China, the application of MEES on refrigerators and freezers is expected to reduce energy consumption by 588 and 1,180 GWh respectively for the period from 2003 to 2023. This, in turn, has reduced gas emissions as follows: 629 to 1,260 million tons respectively of CO_2, 4.0 to 8.04 million tons respectively of SOx, and 2.37 to 4.76 million tons of NOx through the supply of efficient electrical appliances [3]–[8].The rationalization of energy consumption in the residential sector can achieve all the goals relating to electricity production in Iraq and get the best environmental conditions and good public health by reducing environmental pollution, as well as boosting the national economy. Since the Sun shines on Iraq all over the year, Iraq is must be encouraged to use solar energy after providing all the facilities necessary for such type of renewable energy which will be economical and clean energy on the long run. In this paper the main objectives are: estimate the amount of carbon dioxide emitted from energy consumption in the residential sector, save the conservation fund from the reduction of production cost and retrieve management system to control electricity consumption. Research methodology is divided into two parts: practical part, data collection, such as the total amount of consumed energy, the number of appliances and their energy rating capacity through drafting a questionnaire and conducting statistical data analysis. Propositional part, data collection and result analysis will be used to suggest a model for the best energy consumption with lower cost and minimum pollution.

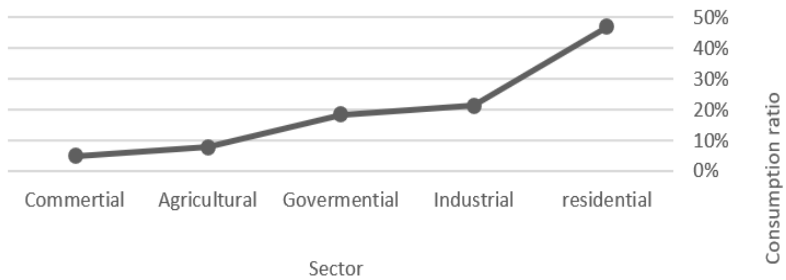

Figure 1. Sectorial percentage of electrical consumption in Iraq during 2000-2020

2. PREDICTION OF ELECTRICAL ENERGY CONSUMPTION

Convenience sample (110) has been taken to conduct the survey. The method used to estimate the electrical energy consumption by the residential sector is time Series by trend components with a view to selecting the best trend component predicting the energy consumption. The method was used to describe the relationship between variable Y_t as the function of variable $_t$, where Y_t is the energy consumption and t is the increment.

2.1. Trend component methods [4]

Linear trend method: the linear trend equation is an expression of the from:

$$Yt = B0 + B1.t \quad (1)$$

quadratic Trend method: the quadratic trend equation is an expression of the form:

$$Yt = B0 + B1.t + B2.t2 \quad (2)$$

exponential trend method: the exponential trend equation is an expression of the form:

$$Yt = B0.B1t \quad (3)$$

where: $\mathbf{B_0, B_1}$ are constant.

2.1.1. Mean absolute percentage error (MAPE)

This criterion is used to select which method of trend that should be used to predict the energy consumption as per the following formula [9]:

$$\boldsymbol{MAPE = \frac{1}{n}\sum_{t=1}^{n}|PE_t|} \quad (4)$$

where PE_t calculated as:

$$PE_t = \left(\frac{Y_t - e_t}{Y_t}\right) * 100 \quad (5)$$

where: PE_t is Error percentage in increment t, n is most value of t and e_t error in Y_t. Minitab 19 has been used to find the solution's equations of the three trend methods and their *MAPE* to obtain the best trend which identifies the graphical and numerical fit results.

2.1.2. Predicted residential electrical energy consumption

Table 1, it is clear that the exponential trend equation is the best way to forecast the electric energy consumption for the next ten years. We notice in Table 1 a clear and significant difference in the value of MAPE compared to the other two methods, which prompts its adoption as a method for forecasting the consumption of electrical energy for the next ten years. This result shows the lowest average exponential Trendequal to (0.000001). So, this is considered the best trend methods.

Table 1. MAPE value for the different trend methods

Trend method	MAPE value
Linear trend	8.22898
Quadratic trend	1.04495
Exponential trend	0.000001

2.2. Contribution percentage of household appliances (CP)

Checking the costs of operating the different appliances is the best way to measure how much energy they consume (W). The energy consumption of electrical household appliances will be reflected on the electricity utility bill and the funds to be spent on other local sources of energy. The use of electrical energy inside homes depends on lifestyle, the family size and number of each appliance. Moreover, the amount of consumption varies according to the seasons of the year. Data collection for sample shows the electrical appliances contribution percentage to Iraqi energy consumption (Baghdad household) as resulted from the survey data. For each of the key end-uses, technical specifications of particular products were considered, as shown in Table 2 and Figure 2. The following formula has been used to estimate the annual energy consumption (AEC) by specific appliances [3], [10]–[13]:

$$AEC = (appliance\ watt\ rating) * (hour/day) * (day/year) \quad (6)$$

Table 2. End-use and product considered for efficiency standard

Product considered	End use
Room air conditioning	Air conditioning
Refrigerator, freezer & water cooler	Cooling appliances
All lighting devices	Lighting
Electrical water heater	Water heating

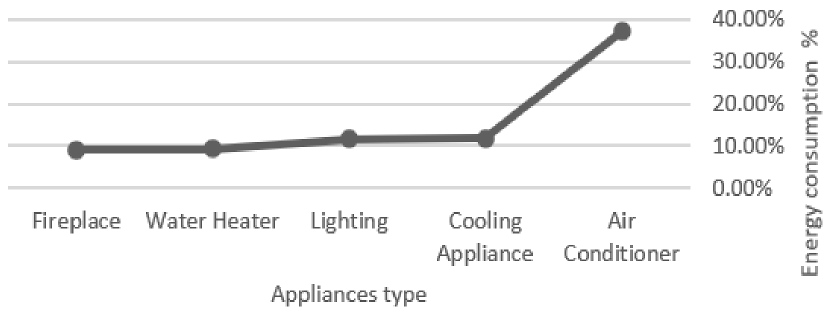

Figure 2. The percentage of appliances energy consumption from total residential energy consumption

3. REDUCTION OF TOTAL CO_2 EMISSION (TCOE)

Implementing the minimum energy efficiency will not only affect electricity consumption but also the environmental impact resulting from energy production too. In this paper, only greenhouse gas emission, represented by carbon dioxide is considered because it forms about 95% of greenhouse gas emissions [6]. The projected reduction in CO_2 emission can be calculated according to the direct relationship between electricity generation and CO_2 emission. Higher rate of energy consumption means more CO_2 gas release into the atmosphere. According to Euro-electrical estimation, the coefficient of CO_2 emission in 2015 year was 451.4 gm/KWh [14]–[19]. It is assumed that this amount will be constant in the next predicted years. Thus, TCOE can be expressed as follows:

$$TCOE = COE * ES \quad (7)$$

where COE is CO_2 emission, and ES is electrical energy saving.

4. COST SAVING OF ELECTICITY PRODUCTION (CS)

The reduction amount in electricity bill is linked to the reduction of energy consumption and the energy prices which change according to the global fossil fuel price. The prices are also different according to the energy consumption in households. In this paper, the average energy cost (EC) are assumed to be fixed and constant for the next ten years. The total saving cost due to reduction of electrical production in Iraq can be expressed as follows [20]–[22]:

$$TCS = ES * EC \quad (8)$$

where TCS is the total cost saving of residential energy production and EC is energy cost which is equal to (164.14 IQD / KWh) [23]-[25].

5. RESULTS AND DISCUSSION

5.1. Amount of reduction in CO_2 emission

Further to the evaluation of the impact of implementing MEES on the electrical energy consumption reduction, the environmental impact of energy generation has been evaluated too. Greenhouse gas emissions into the environment have severe impact on life in general. In this paper, have taken CO_2 emission as an example of greenhouse gas emission, because it constitustes 95% of greenhouse gas emissions. CO_2 emission into Iraq's environment will increase significantly due to increase in electricity production as expected, and as mentioned earlier. If the electrical energy consumption in Iraq's residential sector remains at its current levels in the absence of efficient use of energy and public awareness of how to make use of it efficiently, environmental pollution in 2030 will be 1.87 times its level in 2020. By implementing minimum energy efficient standards according to the five scenarios for the three classes (A, B and C). CO_2 emission will grow at lower rate. It is worth mentioning that the European Union gas emission estimates classifications (Eurelectrical) put Iraq at the fraction average of CO_2 emission by 451.4 gm/KWh which is considered at the mid location in comparison with other countries, as shown in Table 3 [10].

Table 3. The fraction average of CO_2 emission for some countries (gm/KWh)

Country	Fraction average	Country	Fraction average
Greece	950	Iraq	451
Poland	879	Spain	390
Denmark	870	Finland	359
Netherlands	538	Austria	219
Germany	494	France	168

5.2. Air-conditioning, Cooling appliance, and Lighting contribution to CO_2 reduction

Efficient air-conditioners will be less harmful to environment in respect of electricity consumption. These appliances contribute to CO_2 emission reduction by 57% of the total reduction for each scenario. The annual CO_2 reduction by 2030 will be about 6.948, 15.695, 28.044, 31.392 and 35.740 (million ton) for scenario 1, 2, 3, 4 and 5 respectively by 2030. Cooling appliances contribute to reducing CO_2 emission by 22% of the total reduction for each scenario. The annual CO_2 reduction by the end of 2023 will be about 0.569, 1.139, 1.608, 2.117 and 2.864 (million Ton) for scenario 1, 2, 3, 4 and 5 respectively. Efficient lighting devices will be less harmful environment in respect of electricity consumption. These devices contribute to reducing CO_2 emission by 21% of the total reduction for each scenario. The annual CO_2 emission reduction will be about 0.632, 1.264, 1.735, 2.647 and 3.059 (million ton) for scenarios 1, 2, 3, 4 and 5 respectively by the end of 2030; Table 4 and Figure 3 shows the annual reduction of CO_2 emission by implementing MEES for air-conditioners, cooling appliances and lighting devices (1,000 ton) as per five scenarios, this high values of CO_2 emission produce high pollution and this press to reducing it. The class of energy efficiency illustrates the notion of a MEES. The yearly energy consumption of a particular model may be compared to that of other products on the market using the EEC.

Table 4. The annual reduction of CO_2 emission by implementing MEES for all appliances (1,000 ton) as per five scenarios

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
2021	2377	4754	7131	9508	11884
2022	2814	5628	8442	11257	14070
2023	3265	6530	9796	13061	16326
2024	3731	7462	11193	14924	18655
2025	4212	8425	12638	16850	21063
2026	4577	8754	12831	16908	21884
2027	4814	8928	13442	17257	22070
2028	5265	9230	13796	17861	22326
2029	5731	9462	14193	17924	22655
2030	6212	9825	14638	18550	23063

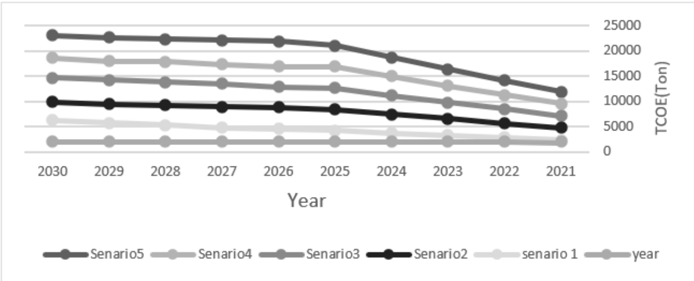

Figure 3. The annual reduction of CO_2 emission by implementing MEES for all appliances (1,000) as per five scenario

5.3. Reducing the cost of energy production

In addition to the positive environmental effects achieved by implementing the minimum energy efficient standards, it has positive effects on the economy by reducing the cost of energy production through reducing the expenses of electricity generation and the steadily increasing cost of fossil fuel production. However, this study considered this aspect as constant during the ten years (2021-2030) at a value of 164140 IQD to generate one MWh. On the long run, the consumer will benefit when receives the lower cost energy bills due to using more efficient appliances. The total saved cost of energy production will be 3576, 7155, 10730, 14310 and 3401 (billion IQD) according to scenarios 1, 2, 3, 4 and 5 by the end of 17886 respectively.

5.3.1. Contribution of Air-conditioning in cost reduction

Air-conditioners are expected to be the first to contribute to electricity production reduction by about 57% of the total cost of energy production for appliances mentioned in this study. Figure 4 shows the reduction amount achieved by efficient models for five implemented scenarios. The annual reduction of energy production cost by implementing minimum energy efficiency standard where the total saving at the end of 2023 as per scenarios 1, 2, 3, 4 and 5 are about 5.088, 10.167, 15.265, 20.353 and 25.442(Billion IQD) respectively.

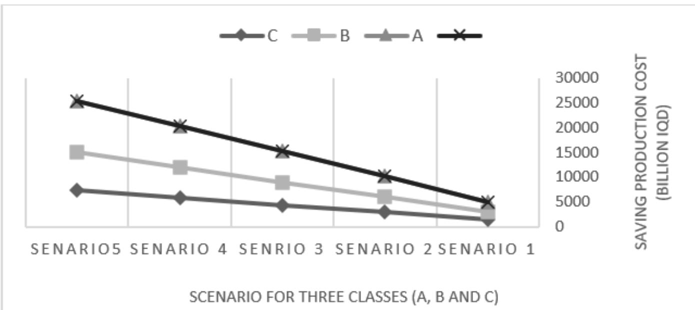

Figure 4. Saving production cost (billion IQD) by implementing MEES for air conditioning as per the five scenario for three classes (A, B and C)

5.3.2. Contribution of cooling appliances in cost reduction

Cooling appliances are expected to contribute to energy production cost reduction by 22% of total residential energy production due to the use of efficient models as shown in Figure 5. The annual reduction of energy production cost by implementing minimum energy efficiency standard where the total saving at the end of 2023 as per scenarios 1, 2, 3, 4 and 5 are about 1.583, 3.166, 4.75, 6.334 and 7.917 (billion IQD) respectively.

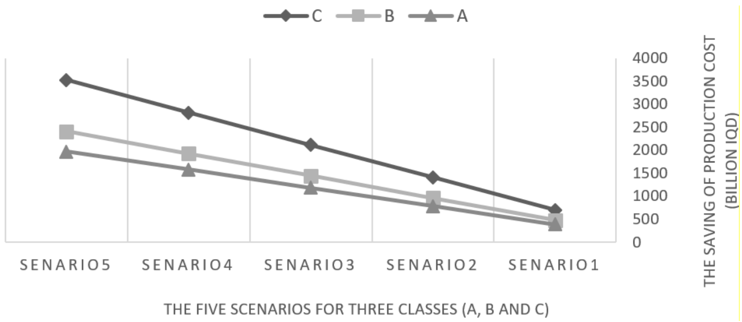

Figure 5. The saving of production cost (billion IQD) by implementing MEES for cooling appliance as per the five scenarios for three classes (A, B and C)

5.3.3. Contribution of Lighting in cost reduction

Lighting contributes to the reduction of energy production cost by about 21% of the total amount of energy production for residential sector. Figure 6 shows the reduction amount achieved by efficient models of lighting by implementing the MEES for the different scenarios. five scenarios for three classes (A, B and C). The annual reduction of energy production cost by implementing the minimum energy efficiency standards where the total saving at the end of 2023 for scenarios 1, 2, 3, 4 and 5 are about 1.93, 2.781, 4.172, 5.563 and 6.953 (billion IQD) respectively. Figure 7 shows the saving in production cost (billion IQD) by implementing MEES for all appliances as per the five scenarios, it is clear that scenario 5 is the best as compared with worst scenario but any scenario save money.

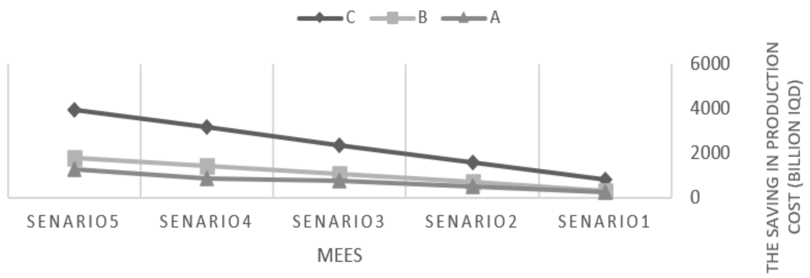

Figure 6. The saving in production cost (billion IQD) by implementing MEES

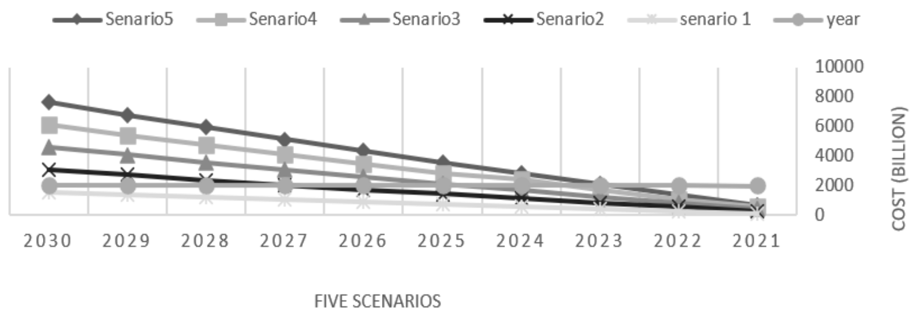

Figure7. Saving in production cost (billion) by implementing for all appliances as per five scenarios

6. CONCLUSION

Reducing electrical energy consumption is one of the ways to contribute to reducing gas emissions. In order to reach the optimal consumption of energy, it is important to study the methods of energy saving in various sectors, identify the most consuming sectors, and determine the reasons and successful solutions to increase energy efficiency to reduce the gases emitted. Among the reasons that cause energy inefficiency in the residential sector, which is considered the most energy consuming sector: consumers hesitate to resort to using alternative energy (environmentally friendly energy), as well as not rationalizing consumption through ineffective use of devices. In this paper, we applied method trend component method of time series to predict power consumption in residential sector for the next ten years where found that the exponential trend model is so good with MAPE which is equal to (0.000001).

Five Scenarios have been implemented for energy saving, CO_2 gas emission and electricity production cost that reduce the accumulative energy consumed for the coming years. As a result of implementing MEES by scenario 5 on year 2020 for the three appliances (air-conditioner, cooling appliances and lighting devices, it was found that ithe Cumulative energy conservation obtained are about 155002.5, 52486.6 and 42362.3 GWh respectively. Through the implementation of the fifth scenario, the amount of energy conservation to reach at the end of year 2030 are 249851.4 GWh, reduction amount in CO_2 gas emission reaches 111. 9 million metric ton and reduction in electricity production cost reaches 40312 billion IQD. Where the worst scenario is the first one since the amount of energy saved was 49119 GWh, reduction amount in CO_2 gas emission 22.17 million metric ton and reduction in electricity production cost reaches 8601 billion IQD. The effective setup scenario as air-conditioner was adapted by the amount of energy saving 155002.5 GWh, CO_2 gas emission reduction 69.9 million metric ton and electricity production cost reduced 22978 billion IQD. Cooling appliances was adapted by the amount of energy saved 52,487 GWh, CO_2 gas emission reduction 23.7 million metric ton and electricity production cost reduced 8,869 billion IQD, where lighting devices adapted by the amount of energy saved 42622 GWh, CO_2 gas emission reduction 19.2 million metric ton and electricity production cost reduced 8,466 billion IQD.

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