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Determine the Electrical Energy Saving in Residential Sector of Iraq

Farook A. Sultan*

Lecturer at Al-Hikma college University, Baghdad – Iraq
Email: farookalshadood@yahoo.com

Abstract

The electricity consumption in residential complexes has severe impact on electricity production in Iraq because it currently constitutes more than 47% of the national energy consumption. Calculations have been made on the basis of predicted growth of residential energy consumption for the next 10 years which shows an increase from 64783 GWh in 2013 to 121606 GWh in 2023. This study analysis the data with a view to exploring the most suitable management systems for the residential electricity consumption in order to reduce the impact on the national energy production and promote the other sectors by saving energy consumption. It is worth mentioning that the household appliances and lighting devices which consume 34.95%, 13.55% and 13.20% of the total electrical energy consumptions in the residential sector respectively. Five scenarios have been adopted for maximizing the energy saving. It has been found that the fifth scenario is the best one.

Keywords: Electrical energy saving **(ES)**; minimum energy efficiency standard (MEES); energy efficiency class (EEC).

1. Introduction

Energy management is the discipline that measures and executed to achieve the minimum possible energy consumption and production cost while meeting the actual needs of the activities of a facility. Actions intended to achieve this energy efficiency focus on reducing necessary end-usage, efficiency increasing, reducing wasted energy and finding superior energy alternatives. The main goal of energy management is to produce goods and provide services with the least environmental pollution effects. Electrical energy consumption in residential sector increases due to the increase in the use of electrical appliances and population growth.

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* Corresponding author.

The extensive use of electrical appliances, including air-conditioners, lightings and heaters consumed large proportion of electricity production in Iraq during the last ten years. During the past years, the order for electrical energy has dramatically increased due to family income increase after 2003, the opening of Iraq's doors for importation and the relatively cheap prices of electricity (KW/h). Thus, the Iraqis have rushed to buy and use more and more electrical appliances with no due consideration for rationalization, especially that the electricity governmental authority does not force the consumers to pay the electricity consumption bills. The residential sector has consumed 47% of Iraq's production of electrical energy, including both the production of the national grid and commercial sources[1]. However, the data published by the International Energy Agency indicates that the residential sector will consume 45% of Iraq's production of electrical energy after 2015.[2] This sector consumes more and more electrical energy. This makes it imperative to explore the proper ways and methods to rationalize electrical energy consumption by this sector. According to the estimates published by the Iraqi Ministry of Electricity, electrical energy production was 15576 MW in 2013 of which the residential sector consumed 47% as shown in Figure 1.

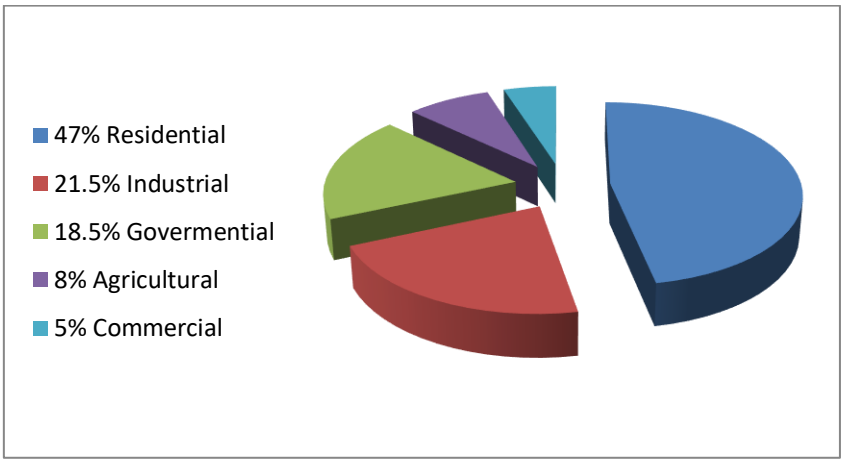

Figure 1: Sectorial percentage of electrical consumption in Iraq during 1990-2018

2. Electrical energy saving (ES)

To evaluate energy saving and the environmental impact resulting from implementing MEES, five scenarios were adopted and analyzed.

Scenario 1: The market share of the efficient models of class A, B and C will take a year constant of 20% and 80% of ordinary models.

Scenario 2: The market share of the efficient models of class A, B and C will take a year constant of 40% and 60% of ordinary models.

Scenario 3: The market share of the efficient models of class A, B and C will take a year constant of 60% and 40% of ordinary models.

Scenario 4: The market share of the efficient models of class A, B and C will take a year constant of 80% and

20% of ordinary models.

Scenario 5: The market share of the efficient models of class A, B and C will take full share.

The market share of the efficient models for class A, B and C is divided as 40%, 30% and 30% respectively according to prices of appliances classes . Table 1 represents the considered market share percentage for all classes for each scenario. Each scenario will be applied for the most electricity appliances in Iraq.

Table 1: Market share percentage for all classes for each scenario

Scenario	Efficient Model			Ordinary Model
	Class A	Class B	Class C	
Scenario 1	8%	6%	6%	80%
Scenario 2	16%	12%	12%	60%
Scenario 3	24%	18%	18%	40%
Scenario 4	32%	24%	24%	20%
Scenario 5	40%	30%	30%	0%

To determine which household appliances consume the highest rates of electrical energy, Pareto Chart has been outlined as shown in Figure 2 . It has been found that the following five electrical appliances consume about 80% of total electrical energy consumption at the level of households: air-conditioners (room air conditioner), cooling appliances (refrigerator, freezer & water cooler), lighting (all lighting devices), water heating (electrical water heater) and space heating (electrical heater) as shown in Table 2 The minimum energy efficiency standard (MEES) has been applied in this study to the following three appliances: air conditioning, cooling appliances and lighting devices.

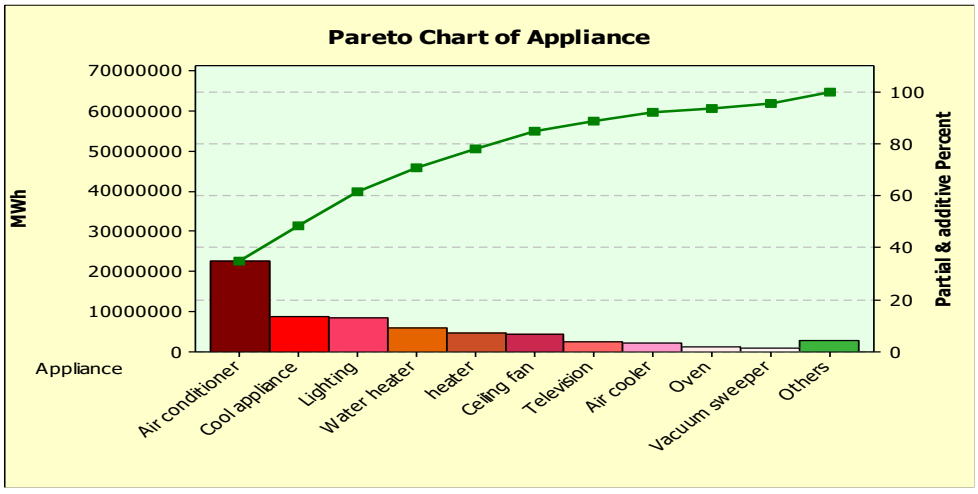

Figure 2: Pareto chart of electricity consumption (MWh) of appliances

Table 2: The highest electrical energy consuming household appliances

No	Appliance	MWh/year	CP%
1	Air conditioner	22653742	34.95
2	Cooling appliance	8792624	13.55
3	Lighting	8593530	13.20
4	Water heater	5857389	9.05
5	Fireplace	4763098	7.35
6	Ceiling fan	4286574	6.65
7	Television	2551048	3.95
8	Air cooler	2047780	3.20
9	Oven	1139848	1.80
10	Vacuum sweeper	1096880	1.70
11	other	2909594	4.6

The energy efficiency class (EEC) reflects the minimum energy efficiency standard concept. The energy efficiency class on the energy label makes it possible to compare the annual energy consumption of the given model with other appliances in the market. The energy efficiency is divided into five or more classes depending on the appliances type. Each energy efficiency class is offset by energy efficiency index or ratio range varying as per the appliance type. The class has indicated that individual model falls, so the average annual energy consumption will be clear, as shown in Table 3.

Table 3: Proposed EEC & energy efficiency (index/ ratio) of selected appliances

Appliance class	Energy Efficiency Rate (EER) for Air conditioner	Energy Efficiency Index% (EEI) for cooling appliances	Energy Efficiency Rate %(EER) for Lighting
A	3.2 < EER	EEI < 55	20 < EER < 60
B	3.2 > EER > 3.0	55 <EEI < 75	60 < EER <80
C	3.O > EER > 2.8	75 < EEI < 95	80< EER <95
D	2.8> EER >2.6	95< EEI < 110	95< EER <110
E	2.6 > EER > 2.4	110 < EEI < 125	110< EER <130

For energy saving, the different appliances can be calculated using appliances the following equation [3].

$$ES = \{(E_t - E_0) + (E_0 * R)\}\ CP * MS * S \quad (1)$$

Where:

ES, Energy Saving

$E_{t,}$ Predicted Energy Consumption at (t) year

$E_{0,}$ Energy Consumption at base year (2018)

R, Replacement Factor

CP, Contribution Percentage

MS, Market Share

SF, Saving Factor

The first part of equation ($E_t - E_0$) represents the increase in the electricity consumption from base year (2013) due to the increase in electrical appliances numbers. The second part ($E_0 * R$) represents the consumed energy by the replaced appliances due to damaging, depreciation and increasing MEES effect on electrical utility bill. The replacement factor is assumed to be increased by 10% every year to reach 100% at the end of 2023. This means that all old appliances will be replaced by new ones of the three selected energy efficiency class A, B, or C.

3. Saving Factor (SF)

The probable saving amount is indicated by using saving factor. The saving factor value changes according to appliance efficiency class and appliance type, and can be calculated by the following equation formula [4].

$$SF = (AEC_c - AEC_a) / AEC_a \quad (2)$$

where:

AEC_c is the annual energy consumption for specific energy class

AEC_a is the annual energy consumption average in Iraq

3.1 Air-conditioner

For room conditioners, the used energy ratio is the Energy Efficiency Ratio (EER). This rating is posted on the energy guide label attached to all new air-conditioner. [Europe Commission, Directive 2003/31/EC] Some air-conditioner manufactures participate in the voluntary energy labeling program where the Energy Label indicates higher EER. The energy rating has been used from the energy efficiency label of appliances on Iraqi market. To calculate Energy saving (ES), it is necessary to find the saving factor (SF) as per equation (4). Thus, AEC_c &

AEC_a can be expressed as follows [5].

$$AEC_c = TCC / EER \quad (3)$$

$$AEC_a = PR*OP \quad (4)$$

where:

TCC, is the Total Cooling Capacity

PR, is Energy Rating

OP, is Operating Hours

The average cooling capacity for air-conditioners has been taken from market in Iraq, which is equal to 2500 watts and annual operating hours 1200h.

3. 2 Cooling Appliances (Refrigerator, Freezer & Water cooler)

For Refrigerator, Freezer & Water cooler, Energy Efficiency Index (EEI) has been used.

This rating was posted on the energy guide label attached to all new cooling appliances. [Europe Commission, Directive 2003/66/EC]

To calculate Energy Saving (ES), it is necessary to find the Saving Factor (SF) as per equations (5) and (6) , where AEC_c & AEC_a can be expressed as follows [6].

$$AEC_a = (\sum_1^n AEC) /n \quad (5)$$

$$AEC_c = (REE) * (V) \quad (6)$$

Where:

n, is the number of appliances

AEC_S, is the standard annual energy consumption

V is the average volume for cooling appliance which is about 640 L, according the survey.

3.3 Lighting devices

For Lighting devices, the used efficiency ratio is the Energy Efficiency Index (EER). This rating is posted on the energy guide Label attached to lamps. [Europe commission, Directive 98/11/EC] The energy efficiency class of (A) lamp is determined as shown in Table (4).

Table 4: Input energy into Lamps class A

Lighting device	**Power (W)**
Fluorescent	$W < 0.15\sqrt{\emptyset} + 0.0097\emptyset$
Other lamps	$W < 0.24\sqrt{\emptyset} + 0.0103\emptyset$

Where $\emptyset$ is the lumen output of the lamp.

If the lamp is not classified in class A, reference wattage W_R is determined as shown in Table 5.

Table 5: Reference Wattage for other lamp classes

$\emptyset$ **value (lmens)**	**Reference Wattage** W_R
$\emptyset > 34\ lumens$	$0.88\sqrt{\emptyset} + 0.049\emptyset$
$\emptyset \leq 34$ lumens	$0.2\ \emptyset$

Where Energy Efficiency can be expressed as follows [7]

$$EEI = W / W_R \quad (7)$$

The lamp energy reference value depends on the lamp category. The energy reference value was taken from the National Electrical Communication Association [7] for the four lighting devices categories (Fluorescent, CFL, Tungsten lamp) and Spot light).

The Saving Factor for the energy efficiency class for each lighting category is calculated on the basis of the following equation (8) below.

$$SF = (W_a - W_C) / W_a \quad (8)$$

where:

W_a is average energy input for specific light type in Iraq,

W_C is the energy input of specific light type and energy efficiency class.

4. Simulation Analysis and Results

4.1 Electrical Energy Saving

These appliances consume about 61.7% of the total household electrical energy consumption In Iraq. It has been found that implementing MEES according to scenario 1, 2, 3, 4 and 5 at the year 2023 will save about 9340462, 18680924, 28021386, 37361848 and 46702310 MWh, respectively.

Table 5 and Figure 3 shows the Annual energy consumption with and without implementing MEES for each scenario.

Table 5: Annual Energy saving in residential sector with and without implementing MEES in (GWh)

Year	Without Energy Saving	Energy Saving With Scenario				
		1	2	3	4	5
2014	42569	821	1642	2463	3284	4105
2015	45336	1663	3326	4989	6652	8315
2016	48282	2527	5055	7852	10110	12637
2017	51421	3415	6831	10247	13663	17078
2018	54763	4329	8658	12988	17317	21647
2019	58323	5270	10540	15810	21080	26350
2020	62114	6239	12479	18719	24958	31198
2021	66151	7239	14479	21719	28959	36199
2022	70451	8272	16545	24818	33091	41363
2023	75030	9340	18680	28021	37361	46702

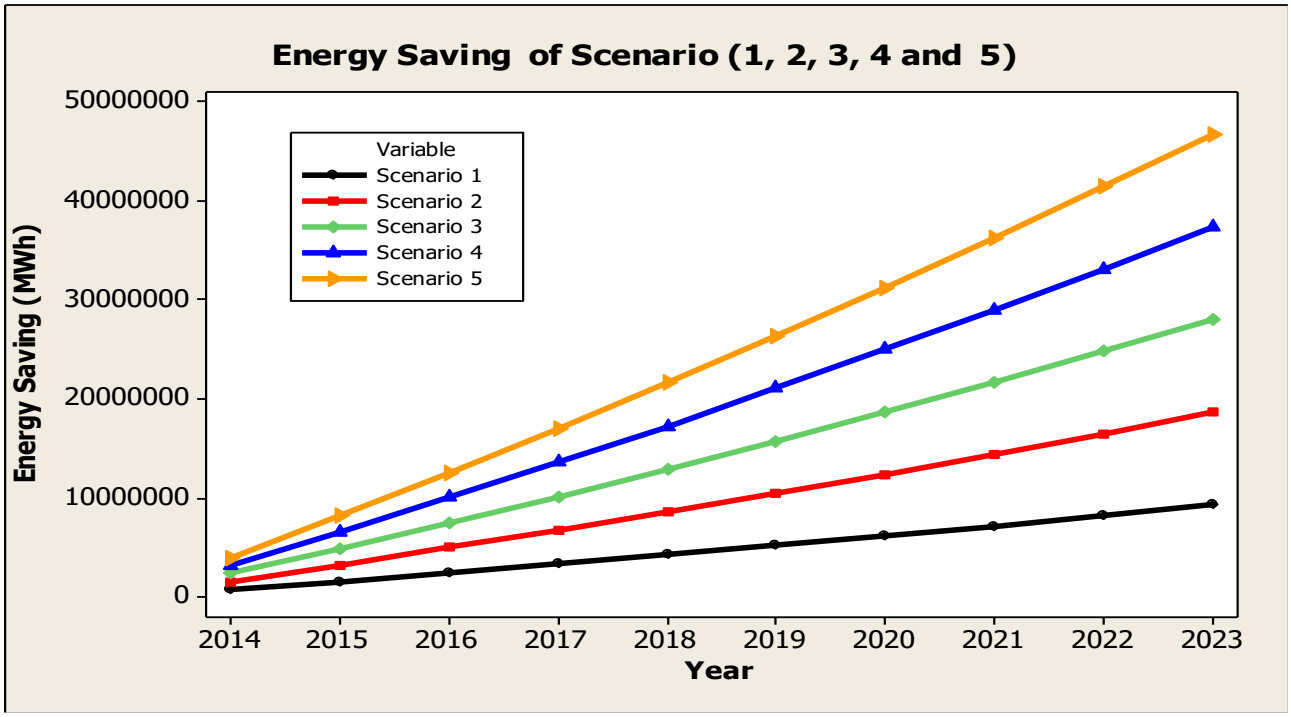

Figure 3: The cumulative energy consumption (MWh) with and without implementing MEES for scenario (1, 2, 3, 4 and 5)

Table 6 and Figure 4 shows with and without accumulative energy saving for each scenario by implementing MEES.

Table 6: Accumulative Energy saving in residential sector with and without implementing MEES in (GWh)

Year	Without Energy Saving	Energy Saving with scenario				
		1	2	2	3	5
2014	42569	41748	40927	40106	39285	38464
2015	87905	85421	82937	80453	79632	75848
2016	136187	133660	126164	120883	117804	111130
2017	187608	179182	170754	162057	155562	145473
2018	242371	229616	216859	203832	193008	178589
2019	300694	282669	264154	246345	230251	210562
2020	362808	338544	314277	289740	267407	241478
2021	428959	397456	365949	334172	304599	271430
2022	499410	459635	419855	379805	341959	300518
2023	574440	525325	476205	426814	380079	328846

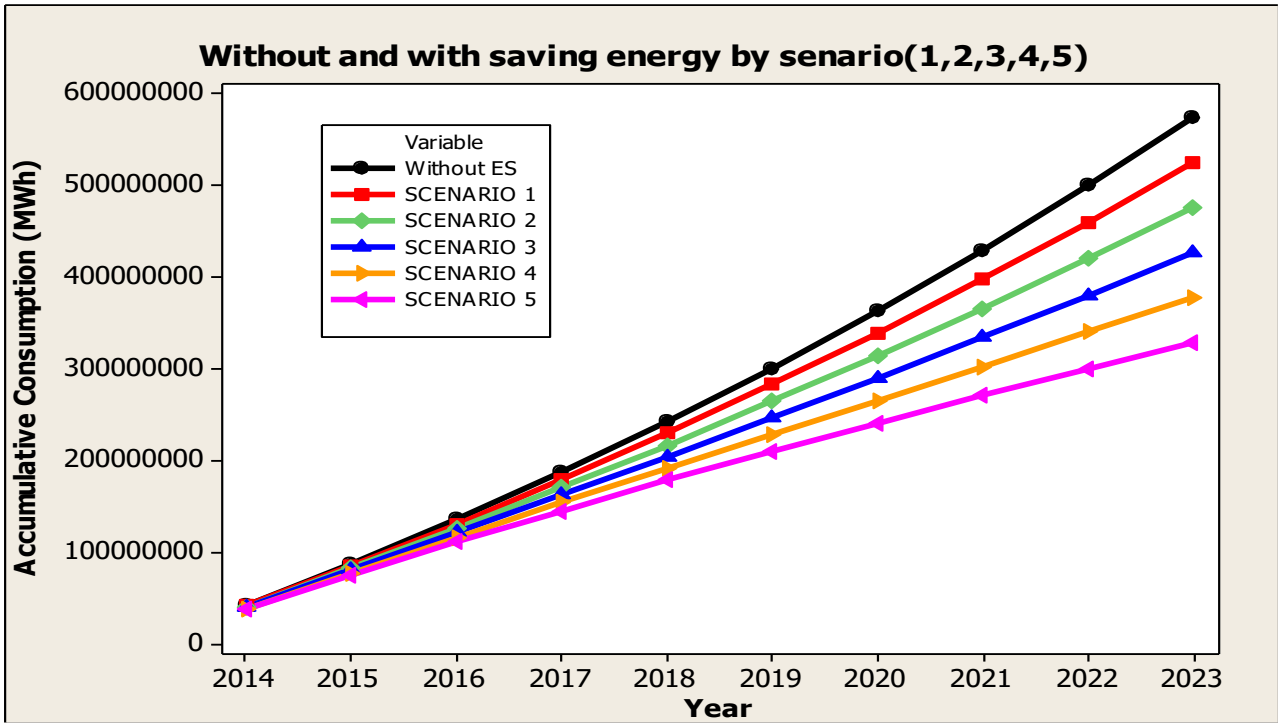

Figure 4: The cumulative energy consumption (MWh) with and without implementing MEES for scenario (1, 2, 3, 4 and 5)

The saved energy is the minimum amount that can be saved by implementing MEES for household appliances. This represents only MEES application to the appliances which consume the highest rate of energy without considering other appliances which are accounted for about 38.3% of residential electrically consumption.

Figure 4 shows the saved energy in the next ten years (2014-2023) through the implementation of the five scenarios. Through the years, the amount of saved energy will increase due to the increase in the houses which use efficient appliances, and the increase of old appliances which will be replaced by efficient models. This calculation will be valid for the next 10 years. Then, new calculation will be applied according to the public awareness of efficient models, its effect on energy production and the economy in general in view of the appliances prices. As shown in figure 5, the percentages of electrical appliances contribution to the total energy saving are 57%, 22% &21% for air conditioning, Cooling appliances and lighting devices respectively.

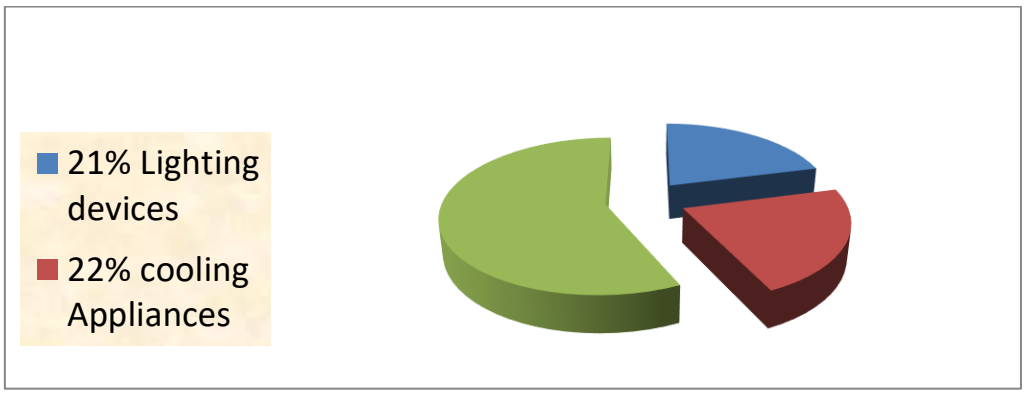

Figure 5: The percentage of electrical appliances contribution to energy saving

Table 7: Energy consumption potential of energy efficiency classes for each scenario/year

Scenario / Class		**Energy Saving(GWh)**										
		2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**Total**
1	**A**	364	739	1121	1516	1921	2338	2769	3212	3671	4144	21794
	B	241	487	741	1002	1270	1546	1830	2124	2101	2740	14083
	C	215	437	665	898	1139	1386	1641	1904	2175	2456	12917
2	**A**	729	1476	2243	3031	3842	4677	5537	6425	7341	8286	43588
	B	481	976	1483	2004	2540	3092	3661	4248	4854	5480	28808
	C	432	875	1330	1796	2277	2772	3282	3808	4351	4912	25834
3	**A**	1092	2214	3364	4547	5763	7015	8355	9637	11017	12429	65382
	B	723	1464	2224	3006	3810	4638	5491	6371	7280	8220	43227
	C	648	1312	1994	2695	3416	4177	4922	5712	6526	7369	38751
4	**A**	1457	2952	4486	6062	7684	9353	11074	12849	14682	16577	87176
	B	963	1951	2996	4008	5080	6184	7322	8495	9707	10960	57636
	C	864	1749	2659	3593	4554	5544	6563	7615	8702	8782	50624
5	**A**	1821	3689	5607	7578	9605	11691	13843	16061	18533	20721	145326
	B	1204	2439	3707	5010	6350	7730	9152	10619	12134	13700	72045
	C	1080	2187	3323	4491	5693	6929	8204	9519	10877	12281	64584

The saved energy resulted from applying different scenarios, has increased through the years based on this calculation. Scenario 5 represents the highest percentage of saving compared with scenario 4. By the end of 2023, the saved energy will be 44.23%. Table 7 indicates the percentage of saved energy by implementing MEES according to the appliances energy efficiency class. The market share of each scenario is divided into energy efficiency classes A, B and C are by 40%, 30% and 30% respectively, in order to boost the number of efficient models in the market.

5. Conclusions

Trend Component Method of Time Series is one of the best fit to predict power consumption in residential sector for the coming years from 2014 – 2023, and MAPE for Exponential is so good which is equal to (0.000001). From analyzing data, it was found that electricity consuming appliances in residential sector are Air- conditioner, Cold appliances and Lighting devices which consume about 34.95%, 13.55% and 13.20% from the total amount of residential power consumption respectively. Because of the three appliances are consuming the most of electricity consumption in residential sector which is about **79%** from the highest energy consuming electric household appliances, different scenarios are adopted .

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