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Energy Efficiency Enhancement for Residential Sector: Case Study of Lighting in Iraq

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ABSTRACT

The electrical energy crisis is a global problem that all developing countries face in general and Iraq in particular. A lot of body in the literature holds that lifestyle and consumption choices strongly affect residential energy consumption. Hitherto releasing energy savings in households is not simple. Previous studies indicate that the lighting requirements for the residential sector consume a significant amount of Iraq's energy resources. In this study, the authors analyzed the energy consumption of 48 samples of residential loads at different dwellings in the country. In addition, the simulation study based on the DIALUX Evo 8 lighting software has been conducted, which shows the energy consumption savings for various types of luminaires. The results clearly show that a relatively large portion of lighting system consumption is because of the poor distribution of lighting fixtures and the use of relatively high-consuming traditional lighting luminaires. The study deduces that the energy efficiency of the lighting system may be improved by about 60% by simply replacing the traditional lighting systems with modern LED-technology-based systems. It is also necessary to redistribute lighting fixtures using state-of-the-art lighting software for achieving adequate levels of lighting and visual comfort for humans.

Keywords:

Residential load; Electrical system in Iraqi; LEDs; energy-saving; lighting efficiency.

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1. INTRODUCTION

Residential lighting load is an essential part of energy consumption in most countries. In Malaysia, lighting accounts for approximately 17% of national electricity usage [1]. In the United States, in 2015, lighting accounted for 10% of electricity consumption [2] . In Indonesia, lighting in the residential sector consumes 21.02% of the total electricity[3] . In India, 28% of energy is used for lighting [4]. In the EU, around 10% of the total electricity consumption is used for lighting, ranging from 5% in Belgium and Luxemburg to 15% in Denmark and the Netherlands. Globally, the residential sector represents 28% of the electric lighting energy use. Much of the research attention has been focused on energy efficiency with the common target of reducing greenhouse gas emissions [1]. One of the easiest ways to save energy is to make users cut the lighting bill [5]. Reducing the energy consumption in the residential sector will have a large impact on the economic, social, and environmental sectors.

In summer, the LED lighting illuminance increased by about 40 percent and the lighting con tribution was 7.8 percent for indoor heat gain. The synergistic effect of the light-emitting diode (LED) was examined and the performance of lighting and building energy savings in heating and cooling was studied [6]. Different studies [3][7], focusing on the current problems of the built (surrounding conditions), especially related to energy use. Also, natural design concepts examined in houses. In this work, summarizes the environmental and economic benefits of improving energy efficiency for both retrofitted and new buildings in Kuwait City[8]. During October and November 2015, survey data collected from 600 households were used to test hypotheses on demographic and socioeconomic, information and participatory determinants of willingness to purchase LEDs [9]. Residential lighting has been studied in different countries such as India [5], [10], the United States [11], Indonesia[3], Jordan [12], Finland [13], Egypt [14], Surabaya [15], Japan [16], Poland [17], Brazil [18] and Nigeria [19]. Other studies have covered rural areas, including those of India [20] and Nepal [21]. In other research, lighting was studied for educational buildings in Malaysia [1], [22], India [23], Thailand [24], and Sri Lanka [25]. In further research, street lighting was studied, including that in Italy [26], Sri Lanka[25], Spain [27]and Libya [28]. Improving the energy efficiency in buildings will result in (a) less energy consumption while maintaining the comfort levels, (b) savings in terms of energy and money, and (c) reduction of harmful emissions[29].

This study aims to investigate the possibility of energy saving of lighting components in Iraq's residential sector. A questionnaire form was created and distributed to a large number of consumers, from which the data of 48 participants were used in the study. The questionnaire forms were distributed to all districts and sectors of the city of Mosul. Appendix A shows the questionnaire form used. As indicated in the questionnaire, the household loads are distributed among the components such as lighting, home appliances, air conditioning (cooling and heating), and water heating. Furthermore, analyzed the electrical loads on lighting load and devices. Besides, authors conducted a simulation study based on DIALUX to demonstrate the influence of the selection of lighting unit types and their distribution on the power consumption. The results of using various lighting devices were also analyzed.

The Authors chose the cases of three consumers, with different consumption patterns. The consumption of the first consumer is less than 1000 kilowatt-hours per month, which means low consumption. The consumption of the second consumer is between 1000-1500 kilowatt-hours per month, which is a medium consumption. The consumption of the third is more than 1500 kilowatt-hours per month, which is a high consumption. The Authors want to study the energy savings, electrical bill, annual frugality, and payback period, when LED devices are used to replace the tungsten and fluorescent lamps.

In addition to this introduction, this paper contains four other sections. Section 2 presents significance of study for this work. The analysis of the current situation is fully explained in section 3. While in section 4, the method and tools are presented respectively. The obtained results and their corresponding discussions are included in section 5. Finally, section 5 concludes this paper.

2. SIGNIFICANCE OF THIS STUDY

The power system in Iraqi suffers from an increase in the electrical load. This issue leads to interrupting and cutting power supplies for large sectors of consumers. As well as, this also leads to multiple economic problems. To address this problem, consumption must be rationalized to match the available generation. The residential load components are the largest (up to 50% of consumption) in Iraq. It was found that residential load components consist of multiple elements, lighting, household appliances, air conditioning, and water heating. In the current research, a rationalization of consumption of the lighting components studied. The study deduces that the energy efficiency of the lighting system may be improved by about 60% by simply replacing the traditional lighting systems with modern LED-technology-based systems.

3. ANALYSIS OF THE CURRENT SITUATION

The Iraqi electricity system suffers from a higher demand for load than the available generation. One way to reduce consumption is to gradually mount electricity tariff. Table 1 shows the pattern of gradually mounting electricity tariff for the residential sector. A previous study analyzed the electricity distribution system in the Iraqi city of Mosul [30] and classified the components of the residential load into five categories: Lighting component, household appliances, heating equipment, cooling equipment, and the water-heating component. The study found that the load on lighting component is within 7% (6.94%), as shown in Table 2.

Table 1: Electrical tariff of residential sector

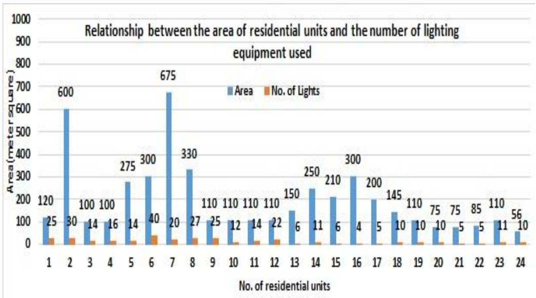
Load range (kWh)	Tariff (I. D.)
0-1500	10
1501-3000	35
3001-4000	80
More than 4000	120

A field survey was carried out using the questionnaire shown in Appendix A [31], [32]. The questionnaire was prepared based on the lighting information of consumers available in previous research [30]–[32]. From the responses received from various consumers distributed throughout Mosul, northern Iraq, answers of 48 consumers were approved.

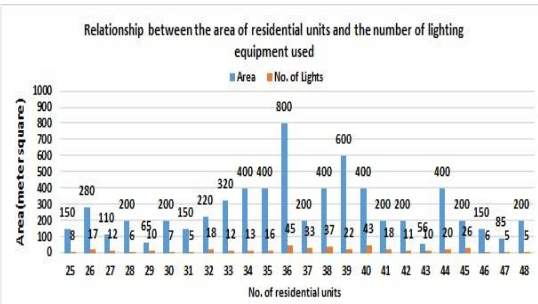
Table 2: Percentage of residential load components

Component	Percent (%)
Lighting	6.94
Home Appliances	20.83
Cooling Equipment's	15.73
Heating Equipment's	24.21
Water Heating	32.29

Figure 1. Shows the relationship between the area of residential units and the number of lighting equipment used. The minimum area is 56 m2, while the largest area is 800 m2. This is because of the widespread sample distribution across the city's various neighborhoods having different levels of living. The rest of the housing units are classified between the minimum and maximum areas. The majority of the housing units have areas between 200 and 300 m2. There are a few residences with areas less than 100 m2 and a few having areas more than 600 m2.



(a)Residential units (1-24)

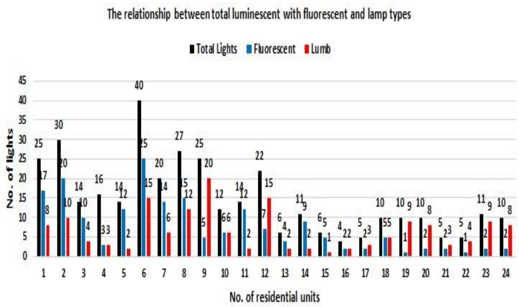


(b)Residential units (25-48)

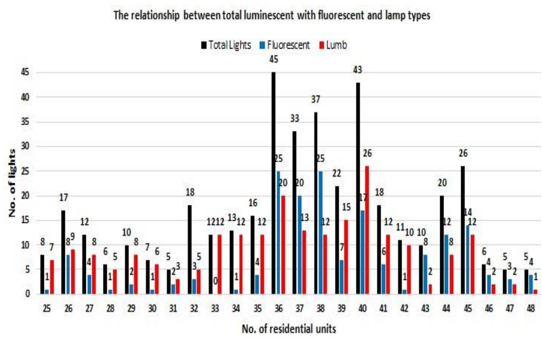
Fig 1. Relationship between housing area and the number of lighting equipment

The number of lighting equipment also varies across households greatly. The minimum number of lighting equipment is 5 and the maximum number is 45. The reason for this large difference is the absence of a base or a documented programmer for the distribution of lighting equipment in residential units. There were no standard specifications for residential unit lighting either. Fig 2. Shows the relationship between the number and types of lighting equipment in residential units. Two types of lamps, tungsten and fluorescent, are generally used. The total number of lighting equipment is 757, with 395 (52.2%) being tungsten and 362 (47.8%) being fluorescent.

Tungsten lamps have a number of disadvantages, mainly low energy conversion efficiency. It converts only 5% of the energy into light and the rest into heat. It also consumes large quantities of power, around 15 lumens/watt. In addition, the operational life of tungsten lamps is short (less than 1000 hours).



(a)Residential units (1-24)



(b)Residential units (25-48)

Fig 2. Relationship between the number and types of lighting equipment

Fluorescent lights do not differ much, but have slightly better specifications. The efficiency of converting energy into light is about 20%, and power consumption is within 50–100 lumens/watt [1], [33], [34]. From the Fig 2, illustrated two important trends:

1- Random use of lighting equipment, mainly because of the lack of use of lighting equipment distribution software in residential units.

2- Use of low-lighting, high-consumption, and short-life lighting equipment, which results in a number of disadvantages, high-energy consumption, low lighting, and lack of access to the standard lighting intensity adopted in residential units. The current situation demands studying the use of modern alternatives to address the existing flaws.

4. METHOD AND TOOLS

The Iraqi electrical power system suffers from many problems. One of these problems is the lack of sufficient capacity to supply the loads. This shortage of generation causes the source to be cut for long periods (programmed cut). Despite the relentless pursuit to increase generation capacity, the growth of loads leads to the continuation of programmed cuts. Therefore, the appropriate solution is to rationalize loads.

In cooperation with the Nineveh Electricity Distribution - State Company of the Electricity Distribution for North – Ministry of Electricity, the electrical load for the residential sector was studied. Studies began to find the Diversity Factor of the distribution system[30]. Then to study the maximum load of residential units [27]. Previous studies led to the conclusion that rationalizing consumption and using appropriate alternatives, especially renewable energies, is the solution. To take appropriate rationalization steps, you must first know the electric load components. The components of the residential load in the Iraqi system were studied. The residential load was classified into five components. Lighting, home appliances, heating, cooling, and water heating. The amount of each component was determined over months of the year. These components were drawn with months for a whole year [28].

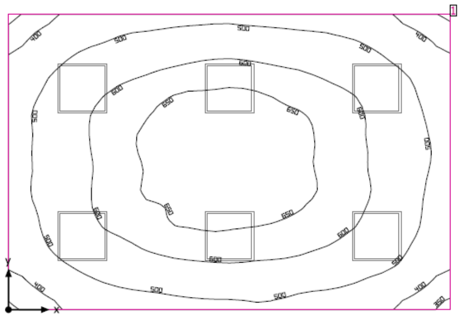
Two methods are used in this research. First, the effectiveness of modern lighting technology is analyzed and presented using DIALUX, a lighting computer simulation programmer. Second, the lighting situation of the samples of Iraqi residential buildings is investigated as a case study.

4.1. Case Study

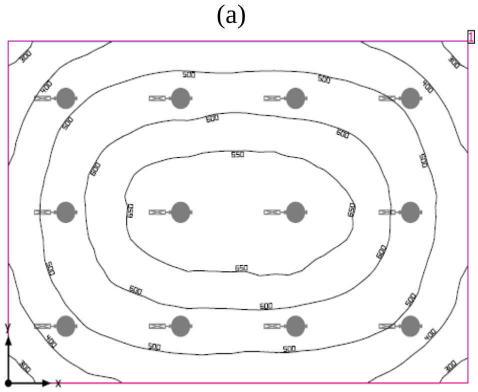
The case of electrical consumption in the residential sector in the city of Mosul, Iraq, was studied to estimate the energy savings, electrical bill reduction, and frugality when replacing existing lighting devices with LEDs.

4.2. Simulation Study

There are many computer tools to simulate and analyze the vision of a lighting system in a virtual environment. One of these programmers, and perhaps the most popular among designers, is DIALUX. Furthermore, it allows to construct a room or even a work area as desired. It has access to many lighting units and luminaires of top manufacturers. It is easy to set manual or automatic distribution of the lighting fixtures with the software. Two-dimensional or three-dimensional models can be displayed quickly and easily too. However, the main feature of the software is the option to simulate the lighting system and analyze its power consumption. Clearance height: 2.800 m, reflection factors: ceiling 70.0%, walls 50.0%, floor 20.0%, maintenance factor: 0.80, height of working plane: 0.8 m. Fig 3 (a, b, c, and d) shows the luminous flux distributions for the above cases.



(a)



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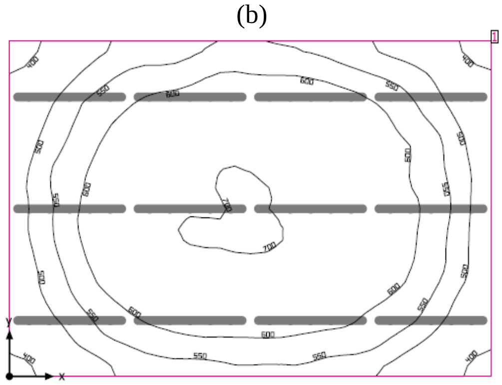

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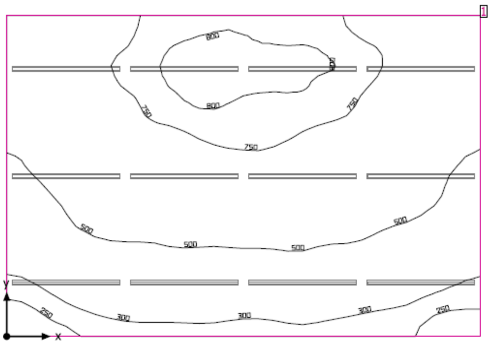

(d)

Fig 3. Luminous flux distributions: (a) incandescent lamp of 100W, (b) fluorescent with a conventional driver, (c) fluorescent with an electronic driver, and (d) LED-type luminaire

It is clear that the LED-type luminaire consumes much less energy compared to other types. For all the presented cases, the design target was to achieve an average luminous flux of 500 lx. It was observed that, apart from considering the first type of incandescent lamp, the LED light consumes approximately 42% of the power consumed by the fluorescent luminaire.

The target of illumination design is to obtain an average of 500 lx, i.e., 500 lumens per square meter. Three types of luminaires are considered: incandescent lamp of 100 W, fluorescent with a conventional driver and an electronic driver, and LED-type luminaire. Appendix B summarizes the number of luminaires used, the power consumed (w) per luminaire, the total power via all luminaires (W), the luminous flux per luminaire (lm), the total luminous flux via all luminaires (lm), the average luminous flux in lm per square meter (i.e., lx), and the design target (lx).

5. RESULTS AND DISCUSSIONS

The monthly electric power consumption in the city is distributed between 900 and 2000 kWh. Consumption is rarely less than 500 kWh and more than 2500 kWh. Three consumers were chosen within the range of common consumption in the city. Table 3 gives the consumers' area of the housing unit and lighting equipment.

Table 3: Housing unit area and lighting devices of the three consumers

Con.No.	Area (m^2)	Lighting Devices	
		Tungsten	Fluorescent
Consumer 4	100	7	7
Consumer 8	330	12	15
Consumer 38	400	12	25

5.1. Electrical Consumption

Figure 4 shows the annual electricity consumption, broken down over the months of the year for the three consumers before changing the lighting equipment. Electricity consumption is affected by weather conditions (weather-sensitive load). Consumption is high in winter and summer, while it is low in spring and autumn. Table 4 shows the annual electrical consumption of the three consumers after replacing the existing lighting equipment with LED lighting equipment and the savings resulting from the change. The annual consumption savings for the three consumers range from 4.51% to 5.19%.

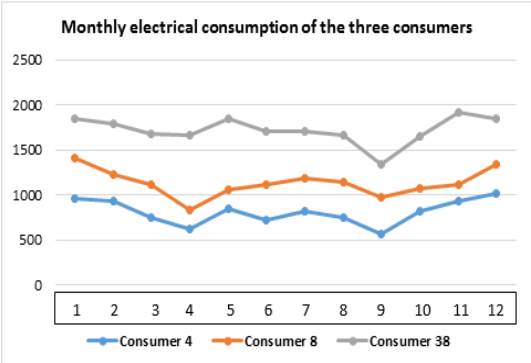

Fig 4. Monthly electrical consumption of the three consumers

Table 4: monthly consumption of the three consumers (without changing lighting equipment)

Con.No.	Annual Lighting consumption (kWh)	Saving (kWh)	Percentage saving (%)
Consumer 4	871	505	5.19
Consumer 8	1058.5	613.5	4.51
Consumer 38	1708	992	4.79

5.2. Lighting Consumption

Figure 5 shows the annual electricity consumption for lighting, broken down over the months of the year, for the three consumers without changing the lighting equipment. Table 5 shows the annual electricity consumption for lighting and its percentage from the total consumption. Luminance consumption ranges from 7.78% to 8.96%.

Table 5 Lighting consumption of the three consumers

Con.No.	Lighting consumption (kWh)	Percent of consumption (%)
Consumer 4	871	8.96
Consumer 8	1058.5	7.78
Consumer 38	1708	8.26

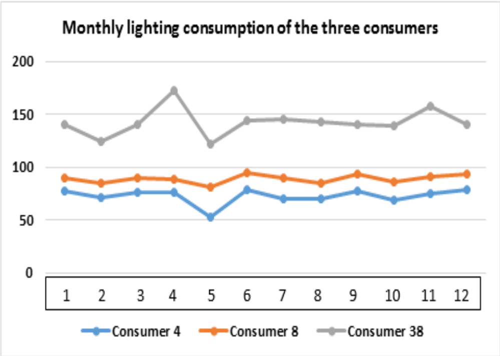

Fig 5. Monthly lighting consumption of the three consumers

5.3. Electrical Bill and Frugality

Figure 6. Shows the monthly electricity bill for the three consumers without changing lighting equipment. Table 6 shows the annual electricity list and the annual frugality percentage for the three consumers. Rationalization ranges from 4.51% to 11.76%.

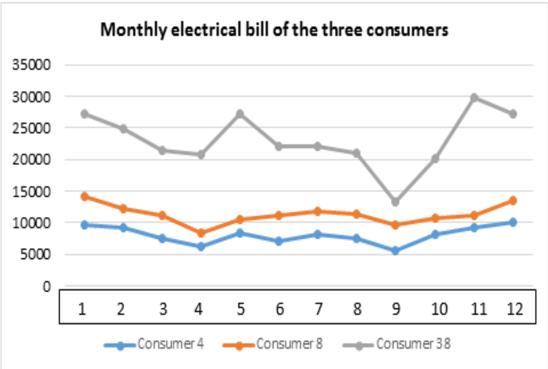

Fig 6. Monthly electrical bill of the three consumers

Table 6 Annual electrical bill of the three consumers

Con.No.	Annual Electrical bill (I. D.)	Annual frugality (I. D)	Frugality Percentage (%)
Consumer 4	79205	5050	6.37
Consumer 8	136010	6135	4.51
Consumer 38	277750	32670	11.76

Conventional lighting equipment (tungsten and florescent lamps) are used in the residential sector in Iraq. The research studies the possibility of replacing the existing equipment with modern LED lighting. The results demonstrate a number of important benefits:

1- Reducing electrical energy consumption: The reduction range is from 4.51% to 5.19%.

2- Reducing the annual electricity bill: The reduction range is from 4.51% to 11.76%. It results in substantial savings, as the price of electricity depends on the amount of consumption.

3- Tackling electricity shortage: Reducing electricity consumption tackles one of the most important problems in the Iraqi electricity system, i.e., shortage of electricity generation.

6. CONCLUSION

In this work, first a field survey to study the lighting in the Iraqi city of Mosul. The study found that the majority of the lighting equipment used are tungsten and fluorescent lamps. The equipment is characterized by high energy consumption and low energy-conversion efficiency. Futhermore, analyzed the modern alternatives using DIALUX, factoring in consumption and lighting intensity.

It is appeared from the resuls; the best alternative is the LED lighting equipment. Changing the lighting equipment brings in significant benefits, including rationalization of electricity consumption and reduction of electricity bill amount. The rationalization of electricity consumption reduces many problems of the Iraqi electricity system, the most important of which is the shortage of electricity generation. For the Future studies

- We propose to study the effect of using sunlight during the day to reduce electricity consumption in residential units. Also, the use of sensors (infrared sensors, motion sensors) to reduce electricity consumption.

- We propose to study the lighting component in other consumer sectors, the government sector, the industrial sector, the commercial sector, and the tourism sector, and to provide alternatives to reduce electrical energy consumption, to solve part of the electricity problem in Iraq.

Therefore, authoers recommend that a government programmer be established to replace the current lighting equipment with LED lighting equipment.

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تعزيز كفاءة الطاقة للقطاع السكني: دراسة حالة الإضاءة في العراق

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الملخص

أزمة الطاقة الكهربائية مشكلة عالمية تواجهها جميع الدول النامية بشكل عام والعراق بشكل خاص. تشير الدراسات السابقة إلى أن متطلبات الإضاءة للقطاع السكني تستهلك قدرًا كبيرًا من موارد الطاقة في العراق. يرى الكثير من الأدبيات أن خيارات نمط الحياة والاستهلاك تؤثر بشدة على استهلاك الطاقة في السكن. حتى الآن ، فإن توفير الطاقة في المنازل ليس بالأمر السهل. في هذه الدراسة ، حلل المؤلفون استهلاك الطاقة لـ 48 عينة من الأحمال السكنية في مساكن مختلفة في الدولة. بالإضافة إلى ذلك ، تم إجراء دراسة المحاكاة على أساس برنامج الإضاءة DIALUX Evo 8 ، والتي توضح توفير استهلاك الطاقة لأنواع مختلفة من المصابيح. توضح النتائج بوضوح أن جزءًا كبيرًا نسبيًا من استهلاك نظام الإضاءة يرجع إلى التوزيع السيئ لتركيبات الإضاءة واستخدام مصابيح الإضاءة التقليدية عالية الاستهلاك نسبيًا. تستنتج الدراسة أن كفاءة الطاقة في نظام الإضاءة يمكن تحسينها بنحو 60٪ عن طريق استبدال أنظمة الإضاءة التقليدية بأنظمة حديثة تعتمد على تقنية LED. من الضروري أيضًا إعادة توزيع تركيبات الإضاءة باستخدام أحدث برامج الإضاءة لتحقيق مستويات مناسبة من الإضاءة والراحة البصرية للبشر.

الكلمات الداله :

الحمل السكني ، النظام الكهربائي في العراق ، LEDs ، موفر للطاقة ، كفاءة الإضاءة

Appendix A

Device current	Rated power	No.				
			house land area			1
			Number of rooms (bedroom, sitting, reception, bathroom, etc.)			2
			Number of individuals			3
			Electrical supply (single-phase, three-phase)			4
			Tungsten lamps	Lighting	A	5
			fluorescent lamps		B	
			Other		C	
			Audiovisual devices (recorder, radio, TV, etc.)	household appliance	A	6
			Kitchen appliances (washing machine, dishwasher, vacuum cleaner, water pump ... etc.)		B	
			Food preservation devices (refrigerator, freezer, water cooler ... etc.)		C	
			Fan (roof, vertical ... etc.)	Cooling devices	A	7
			Air cooler		B	
			Air conditioner /cooling		C	
			Electric heater	Heating devices	A	8
			cooking Heater, oven . . . etc.		B	
			Air conditioner /heating		C	
			Electric bath	Water heating		9

Appendix B Design information using various luminaires

Luminaire Type	Number of Luminaires	Nominal power (w)	Calculated power (w)	Total power via all luminaires (W)	flux per each luminaire (lm)	Total flux via all luminaires (lm)	Average (Target) (lx)	Min (lx)	Max (lx)
incandescent lamp	12	100	111.8	1341.6	1340	16080	533 (500)	264	685
Fluorescent with a conventional driver	12	36	42.5	510	2470	29640	567 (500)	208	815
Fluorescent with Electronic drive	12	36	36	432	2284	27408	582 (500)	374	714
LED-type luminaire	6	36	36	216	3396	20376	558 (500)	345	676