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User Habits Impact on Winter Energy Consumption in Iraqi Houses

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Abstract

In this research, heating systems in Iraqi houses were discussed and analyzed to study their effect on energy consumption during winter. The study area was regionalized into three regions depending on prevailing climates: north, central, and south. An online survey was conducted to collect usage patterns and observe occupancy behavior related to heating systems in Iraq. Heating systems were classified into three major categories: electrical, fuel, and augmented. Detailed questions were included in the survey to collect as much data as possible for crosschecking and future research.

Consequently, the heating systems usage collected from the survey was classified into three main categories according to the type of energy utilized. Subsequently, a descriptive statistical analysis was carried out and followed by a Chi-square analysis to investigate the mutual relationships among different variables involved in the study. Results show that electrical systems dominate others due to the safety and cleanness characteristics compared to other fuel systems such as kerosene or natural gas. Education level and culture play essential roles since intellectual people pay more attention to safety and environmental health.

Keywords: Occupant behavior; Heating systems; Energy efficiency; Chi-square analysis.

1. Introduction

The residential sector, in general, uses a high percentage of energy around the world. Around 25% of the total energy in Sweden goes to the residential sector [1]. In 2018, the residential sector in Iraq consumed 48.3% of total electricity consumption in the country [2] [3] [4]. The International Energy Agency (IEA) provided a study about the electricity supply and demand in Iraq from 2018 to 2030, which showed a dramatic increase in the power demand compared to the actual power supply in 2018. The IEA also illustrated the possible improved network during the next ten years, as shown in Fig. 1 [5]. Focusing on increasing the generation capacity of electricity is not enough to solve the power crisis in Iraq. Energy efficiency and management strategies and relying on a greener energy source are essential to be adopted by the government to reduce the energy consumption of households.

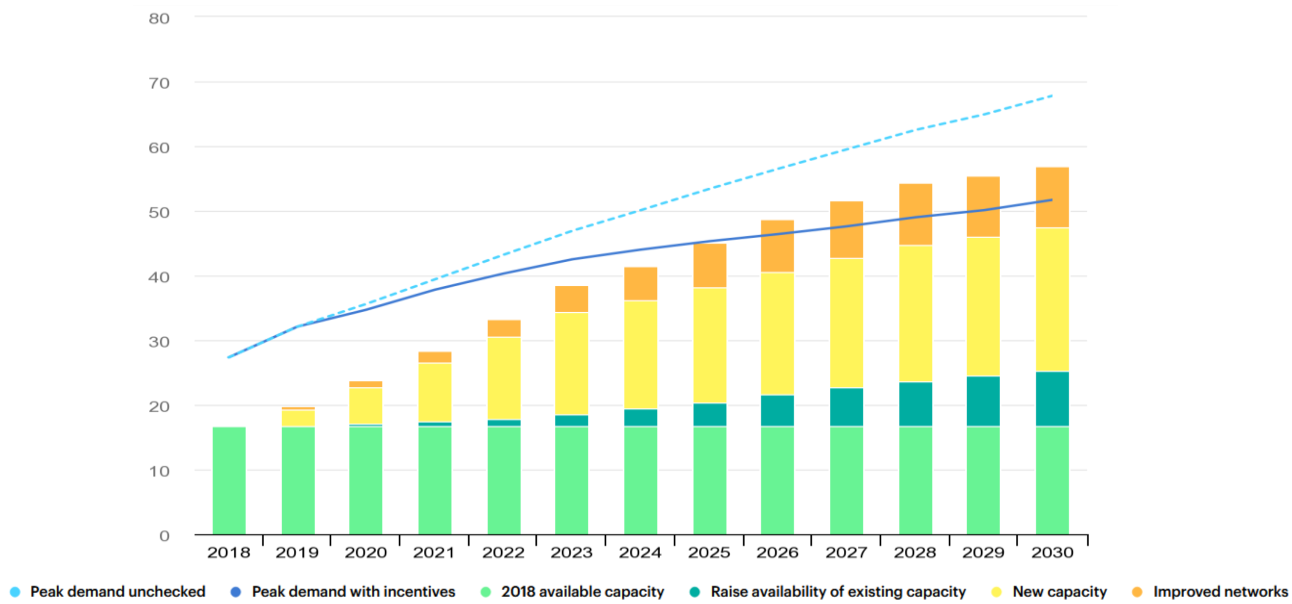

Figure 1 Iraq's Electricity Supply and Demand, 2018-2030 [5]

1.1. Energy efficiency and energy prediction

The energy consumption of buildings depends on several internal and external factors. External factors are climate condition and location, while internal factors are building design and envelope, building materials, type of heating and cooling system, the efficiency of ventilation, lighting system, strategy of controlling household equipment, and occupancy behavior [6]. During the design phase of buildings, energy efficiency strategies must be taken into consideration. Estimating energy consumption is essential to be concluded using various energy simulation methods [7]. However, the performance of buildings may differ from what was predicted, which is called the performance gap or rebound effect [8]. There is evidence showing that buildings' energy performance is not as efficient as predicted during the design phase [8]. Studies showed that building operation system and occupancy performance had the most significant impact on the performance gap of various types of buildings. Research aimed to study the performance gap of schools in the United Kingdom showed that occupancy behavior and operation system of the buildings are the main factors affecting the efficiency of building energy consumption [9]. The inconsistency of the actual energy consumption of buildings with what was predicted during the design phase relies on several factors relating to the simulation process and the building and its occupants [9] [10].

In order to create an assumption about building energy consumption, it must be transferred into a computer model. During the modeling process, designers and engineers simplify the model due to the lack of information during the design phase, relying on design standards and rules of thumb. Also due to the client's request, the building's elements may be changed from what was designed during the construction phase for instant different kinds of insulation material or cheaper kind of windows may be adopted during the construction phase. The simplified model of the designed building results in an inconsistent energy performance compared to the real complex building after construction [9] [10] [11]. Energy consumption of buildings can be increased from what was predicted due to the neglect of natural lighting, artificial lighting during the day, inefficient HVAC operating systems, and unexpected additional power loads [11] [12]. The factor that has an important influence on the energy performance of buildings is the occupants.

Occupants can control the building lighting, ventilation system, and hot water and are considered an important factor affecting building indoor temperature. Since occupants' behavior is impulsive, it leads to inconsistency in energy consumption [9] [10] [13]. People responsible for operating, controlling, managing, and maintaining the building also have a significant influence on energy consumption. Thermal comfort of buildings can be increased through efficient control of the building ventilation system, HVAC system, lighting, etc., which reduces energy consumption. On the other hand, occupants and facility managers' poor handling of the building and poor maintenance can increase the energy consumption of buildings up to three times what was predicted [9] [14]. A medium-size office building was analyzed using a computer simulation method to investigate the inconsistency of energy consumption due to weather and building operation and management. Poor operation and management of the building resulted in a 49-79% increase in energy use across four different climate zones, whereas the excellent operation of the building reduced energy use by 15-29% [10].

1.2. Factors affecting energy consumption in residential buildings

Offices, schools, and nonresidential buildings' energy consumption can be predicted and analyzed more accurately due to the limited hours of operation, unlike residential buildings that are occupied all day [6] [15]. It is more complicated to predict residential building energy consumption due to many factors such as building condition, occupant's education level, gender, age, employment, family size, cultural background, and energy cost. [16] [17]. A study carried out in Sweden aimed to study the relationship between gender and energy consumption showed that changing the behavior towards decreasing energy consumption was greater in women than in men. Women's attempts to decrease energy consumption led to increased workload. For instance, they avoided clothes dryers and worked during the night and on weekends as power rates were cheaper [1].

Data about age, number of occupants, and occupancy behavior simulated an energy-efficient house in Lithuania. The researchers recommended collecting as much information about occupants as possible because it significantly influences the energy consumption of houses [6]. Surveys about Danish dwellings found that the main factors affecting occupancy control of heating were outdoor temperature and the availability of wood stoves (an alternative heating system) [18]. House's internal temperature can be affected by several factors such as; the number of children, age of occupants, condition of the building, insulation thickness in walls and roofs, and building age. Increasing or decreasing indoor temperature will impact the energy consumed for heating and cooling [19].

In Belgium, researchers investigated the effect of three factors associated with occupants' behavior on the heating loads of houses (family size, controlling the heating system, and controlling heated area). They tested them with seven levels of insulation. It was found that human behavior showed the best results when the level of insulation was highest [20]. In Kuwait, 30 houses were studied to understand the reasons behind the high electrical consumption of houses. The results showed that occupancy behavior has the most significant impact on the energy consumed for lighting and cooling the house. They tended to leave the lights and air-conditioning on even when nobody occupied the room. The simulation showed that annual energy consumption was dropped by 39% when using lights only when required and setting the AC thermostat to 24 ℃ instead of 22 ℃. [21].

1.3. Residential buildings in Iraq

The residential sector in Iraq is the major energy consumer, representing 48.3% of total electricity consumption in 2018, as illustrated in Fig. 2 [2] [4].

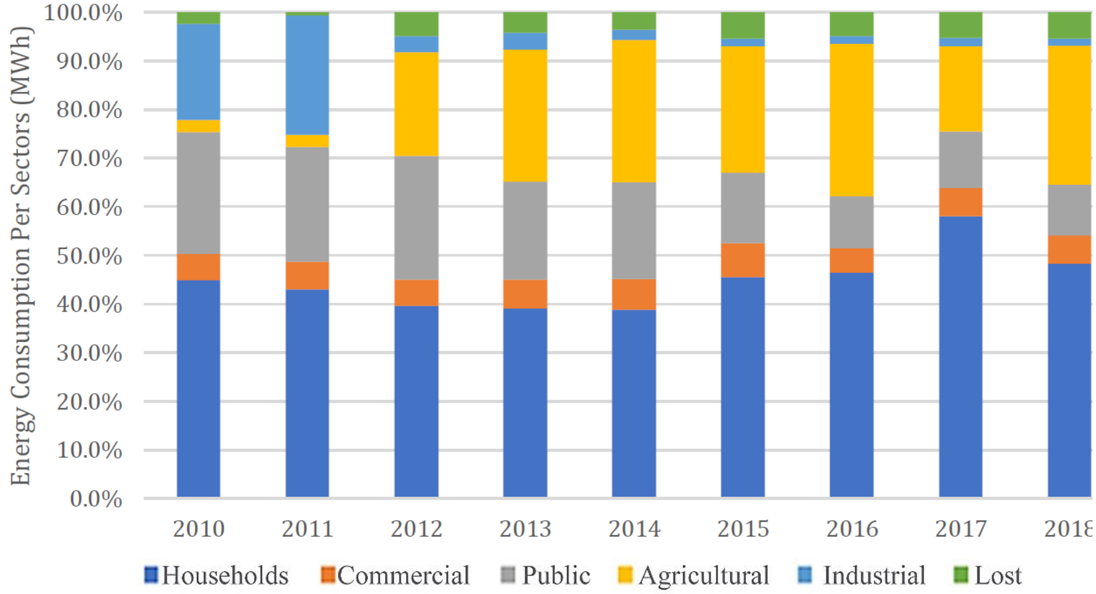

Figure 2 Electricity Consumption per Sectors 2010-2018 [2].

Expanding energy consumption is due to an increase in the usage of electrical appliances after 2003 due to the rise in family's income and the population growth. The main factors affecting the energy consumption of the residential sector in Iraq are construction materials, geographic location, building orientation, climate condition, and occupancy behavior [3]. Iraq is located between the arid Arabian Desert and the humid Arab Gulf. This location resulted in a harsh climate during summer in the middle and southern parts of Iraq [22].

Most houses in Iraq are built of mud-brick and concrete blocks for walls, reinforced concrete for ceilings, and steel, aluminum, or PVC doors and windows for openings. The use of insulation materials is not required by law in Iraq [2]. Research in Adana, Turkey, showed that using insulation materials for a building in a hot-humid climate reduced the initial and operational cost of the air-conditioning system [23]. A study in Iraq showed that adding a layer of expanded polystyrene (EPS) insulation with a thickness of 60mm decreases the thermal transmittance of a concrete block wall from 2.39 (W/m2.℃) to 0.43 (W/m2.℃), which meet the insulation specification requirements in countries with a sweltering climate [24]. The geographic location of the house has a significant impact on the internal temperature and subsequently on the energy consumed for cooling or heating. In Iraq, houses that are located in the south, such as Basrah and Thi-Qar, require more energy for cooling during summer. On the other hand, houses located in the north, such as Mosul, require more energy for heating during winter. Cities in the middle require cooling and heating due to the tremendous annual temperature range, such as Baghdad [2].

The household appliances that consume the highest rates of energy in Iraq are space cooling devices (35%), refrigerators and freezers (13.5%), and lighting devices (13.2%), followed by water heaters and space heating devices [3]. Survey statistical data for 2000 residential units in Baghdad in 2006 showed that 69% of the annual energy consumption of a house goes for space cooling and heating appliances (42.43% for cooling and 26.56% for heating). It also showed that 76.9% of the energy consumed during summer was for air-conditioning, and 76.3% of the energy consumed in winter was for space heating devices [25] [26]. Lighting also contributes to the increase in energy consumption in the residential sector [27].

1.4. Heating loads

Heating energy consumption in Iraq may vary according to geographical location. Other factors that might influence the heating energy consumption of houses are family income, house area, amount of heating equipment, and heating method. A study in China established a theoretical model to study the effect of family income on Building Heating Energy Consumption (BHEC) [28]. In order to examine the relationship between income and (BHEC), 662 houses in China were used to collect the data. Results showed that the (BHEC) was directly affected by the income factor by 84%. The amount of heating equipment affected the energy consumption by 18.8%, and the residential space area had an effect of 15.8%, while the heating method impact was 1% only [28].

To understand occupants' behavior and the barriers to using environmental-friendly heating appliances that consume less energy or cause fewer emissions, Joana and Tiago collected responses from 1136 houses. Results showed that cost, energy label, operation and maintenance of the new appliances, and consumer awareness about the environment are the main factors that influence their intention to use heating appliances that are more energy-efficient [29]. Yigzaw surveyed domestic energy use, which was similar to the previous study [30]. Other factors that might influence heating energy consumption related to human behavior are people dressing habits and window opening. Field investigation in Inner Mongolia, a city in China located to the north with cold winter, studied people's behavior during the cold season. It was found that people tended to open windows during winter to bring fresh air into the house, and 62% used to wear light clothes inside the house and were dissatisfied with the indoor temperature addressed by the national standards. The investigation results showed that the indoor temperature measured in the study was higher than 22℃. Therefore, they tend to consume more energy on heating to reach their thermal comfort [31].

2. Research methodology

This research aims to analyze the types of heating systems in Iraqi houses and how they affect energy consumption during winter. The study area for this research includes the whole country of Iraq. As shown in Fig. 3, the study area was classified into three major regions according to the three dominant climates in Iraq. The northern region includes provinces: Erbil, Sulaymaniyah, Duhuk, Ninewa, and Kirkuk. The central region includes provinces: Anbar, Diyala, Najaf, Babylon, Baghdad, and Karbala. The southern region includes provinces: Basrah, Qadissiya, Muthanna, Thi-Qar, Missan, and Wassit. The main assumption of this research is that the heating system type can be related to the climate region, the zone of the residential area, whether it is urban or suburban, and the level of education.

An online survey was conducted to collect usage patterns of heating systems in Iraq. Detailed questions were included in the survey in order to collect as much data as possible for cross-checking and future research, as well. To limit the analysis to the research objectives, the heating systems usage collected from the survey was classified into three main categories according to the fuel type. Afterward, a descriptive statistical analysis was carried out followed by a Chi-square analysis to investigate the mutual relationships among different variables involved in the analysis.

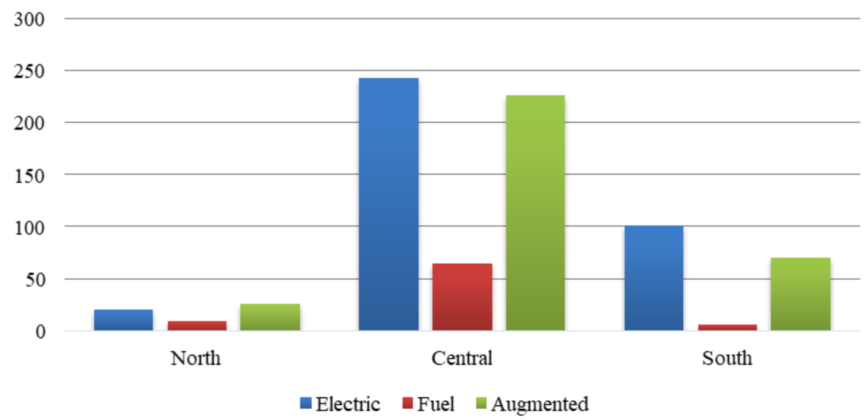

Figure 3 Prevailing Heating Systems in the Study Area

3. Results and discussion

The primary data source for this research was the questionnaire that was conducted online through social media to cover as much as possible of Iraqi cities. Table 1 shows the distribution of survey responses among the three regions of the study area. It is evident from the table that the survey sample is not evenly distributed among different regions. The language barrier was the main reason for fewer responses in the north region. While the fewer number of people reached online could be among many reasons for the less number of responses collected in the southern region compared to the central region.

Table 1 Distribution of Online Survey among the Three Regions of Iraq.

Region	No. of Responses
North	50
Central	454
South	140
Total	644

According to the fuel type, there are three types of household heating systems in Iraq: electric systems, kerosene systems, and natural gas systems. Because of the electrical power shortage in Iraq, people have to augment electrical heating appliances with other fuel systems such as kerosene and natural gas. Consequently, three heating systems are recognized for this research according to the usage patterns; electric, fuel (depends on kerosene or natural gas), and augmented systems, which depend on electric heating appliances during the public electricity supply periods and fuel systems during other times. Research results are outlined in this section according to the two main experiments carried out; the first experiment was designed to investigate the location effect, and the second was designed to investigate the cultural effect.

3.1. Experiment 1: location effect

Fig. 3 depicts the prevailing heating system in the three regions of the study area. It shows that people in all regions prefer electric heating systems followed by the augmented system. The differences in the histogram bar heights reflect the imbalanced sample size among the three regions of the study area. However, indicative results still can be drawn from data as it can be seen that regardless of the number of responses, the usage patterns can be deemed similar. Because of the discrete nature of the data, Chi-square analysis was carried out to investigate the relationship between regions and the heating systems. Table 2 shows the results of the analysis, which prove a strong correlation between regions and the heating systems as the P-value is significant.

Table 2 Chi-Square Analysis for the Regions - Heating System Relationship.

Degrees of Freedom =(R-1)*(C-1)	4
Chi-square Critical Value	9.487729
Chi-square Statistic	17.72399
p-value	*0.001397*

However, one must be careful about this result because of the unevenly distributed survey sample, which can bias the analysis. This can be supported by analyzing the differences between usage patterns of different systems within one region and among regions depicted in Fig. 3. It can be noted that the variations among different systems within each region are similar across the three regions. Thus, it can be concluded that there is no relationship between regions and heating systems, and the varying sample size biased the Chi-square analysis. In order to continue the investigation of the location effect, heating systems were examined in different environments within each region. Figures 4, 5, and 6 show the relationship between the residence environment and heating systems in the three regions of the study area separately, and Fig. 7 shows this relationship for the whole country. It can be clearly noted from the figures that heating systems that depend on fuel are prevailing the usage patterns in suburban and rural environments, while electrical heating systems are superior in urban environments.

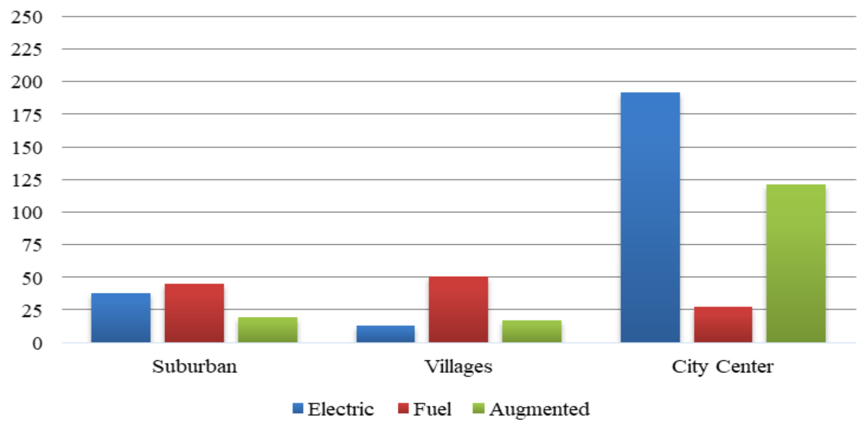

Figure 4 Heating Systems across Different Environments in the Northern Region.

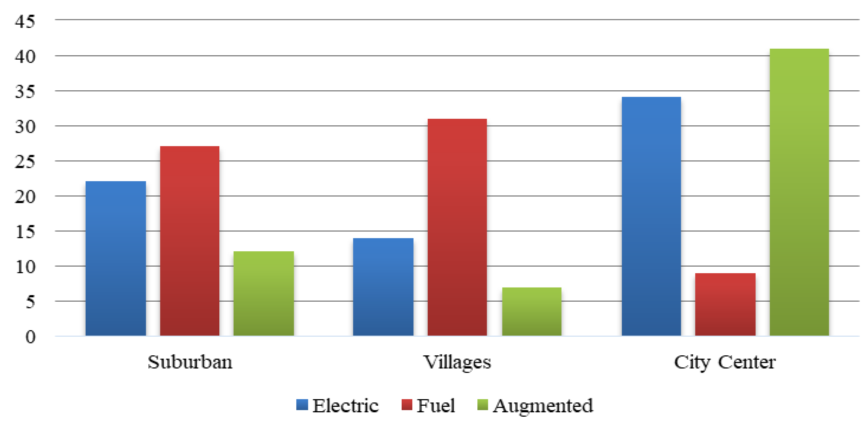

Figure 5 Heating Systems across Different Environments in the Central Region.

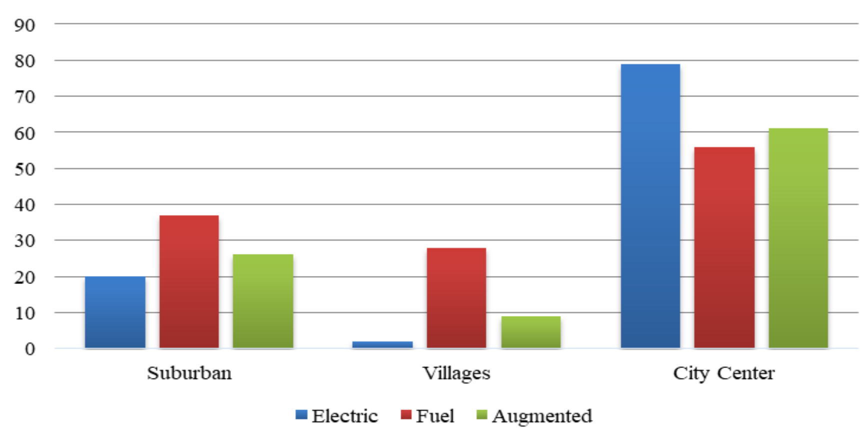

Figure 6 Heating Systems across Different Environments in the Southern Region.

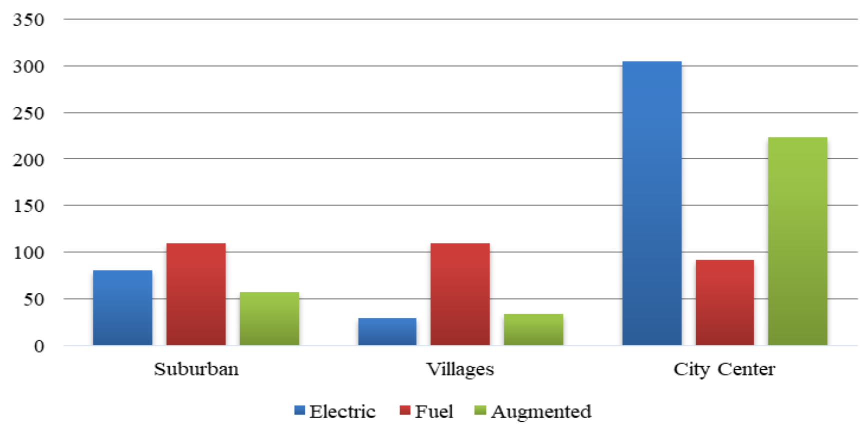

Figure 7 Heating Systems across Different Environments in the Study Area Region.

Chi-square analysis for each region separately and for the whole study area as one part proves a strong relationship between the residence environment and the heating system used in residential units as the P-value is significant at 0.05 level as shown in Tables 3, 4, 5, and 6. Such a relationship can be attributed to the lack of electrical power supply in general and the low quality of service in the suburban and rural areas compared to the urban areas.

Table 3 Chi-Square Analysis for the Northern Region Data.

Degrees of Freedom =(R-1)*(C-1)	4
Chi-square Critical Value	9.4877
Chi-square Statistic	43.5311
p-value	*8.03E-9*

Table 4 Chi-Square Analysis for the Central Region Data.

Degrees of Freedom =(R-1)*(C-1)	4
Chi-square Critical Value	9.4877
Chi-square Statistic	142.5086
p-value	*8.19E-30*

Table 5 Chi-Square Analysis for the Southern Region Data.

Degrees of Freedom =(R-1)*(C-1)	4
Chi-square Critical Value	9.4877
Chi-square Statistic	32.7254
p-value	*1.36E-6*

Table 6. Chi-Square Analysis for the Whole Study Area Region Data.

Degrees of Freedom =(R-1)*(C-1)	4
Chi-square Critical Value	9.4877
Chi-square Statistic	188.0240
p-value	*1.41E-39*

3.2. Experiment 2: cultural effect

This experiment aims to investigate the effect of education level on the choice of heating system. Fig. 8 shows the distribution of heating systems on different education levels collected from the survey.

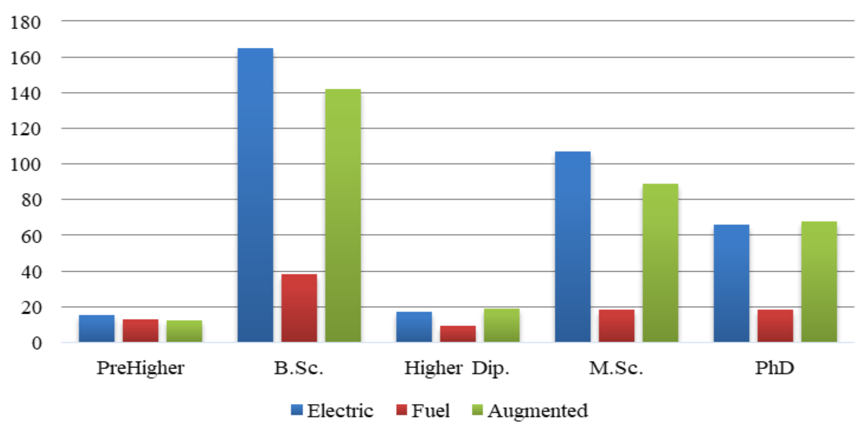

Figure 8 Distribution of Heating Systems with Respect to Education Level.

Fig. 8 shows that most of the people who participated in the survey were from the bachelor category representing the executive class. The lowest response was from the people with a pre-higher education level, which can be since those people have limited access to the internet in Iraq; therefore, they did not receive the survey. However, the Figure still provides meaningful indications. It can be noted that the variations among different education levels in terms of the heating system are very close to each other. Electrical heating systems dominate other systems, and the heating systems that depend on fuel are minor. There is an exception in the pre-higher education level where the fuel heating system is competitive, attributed to the low-income level of this community class in Iraq. Chi-square analysis for the education level and heating systems reveals a minor correlation with P-value equal to 0.003 as shown in Table 7.

Table 7 Chi-Square Analysis for Level of Education and Heating Systems.

Degrees of Freedom =(R-1)*(C-1)	8
Chi-square Critical Value	15.5073
Chi-square Statistic	23.0037
p-value	*0.00336*

6. Conclusion and future work

Household heating systems in Iraq were discussed in this research. The study area was regionalized into three areas depending on prevailing climates: north, central, and south region. Heating systems were classified into three major categories: electrical, fuel, and augmented. Results show that electrical systems dominate others due to the safety and cleanness characteristics compared to other systems that use fuel such as kerosene or natural gas. Education level and culture play essential roles because intellectual people pay more attention to safety and environmental health; therefore, they prefer electrical systems. Low income, in general, in the case of less-educated classes, can encourage them to prefer heating systems that depend on fuel. The language barrier and internet inaccessibility cause the survey sample to be unevenly distributed among different regions and social classes. Therefore, this can be overcome in future research to obtain more accurate results.

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أثر سلوك المستخدم في استهلاك الطاقة شتاءا في المنازل العراقية

الخلاصة: *في هذا البحث تمت مناقشة وتحليل أنظمة التدفئة في المنازل العراقية لدراسة تأثيرها على استهلاك الطاقة خلال فصل الشتاء. تم تقسيم منطقة الدراسة إلى ثلاث مناطق حسب المناخ السائد: الشمال والوسط والجنوب. تم إجراء مسح عبر الإنترنت لجمع أنماط الاستخدام ومراقبة سلوك الشاغلين و المرتبط بأنظمة التدفئة في العراق. تم تصنيف أنظمة التدفئة إلى ثلاث فئات رئيسية: الكهربائية والوقود والمعززة (المختلطة). تم تضمين أسئلة مفصلة في المسح لجمع أكبر قدر ممكن من البيانات للتدقيق المتبادل. تم تصنيف استخدامات أنظمة التدفئة التي تم جمعها من المسح إلى ثلاث فئات رئيسية وفقًا لنوع الطاقة المستخدمة. بعد ذلك ، تم إجراء تحليل إحصائي وصفي وتبعه تحليل مربع كاي للتحقيق في العلاقات المتبادلة بين المتغيرات المختلفة المشاركة في الدراسة. بينت النتائج أن التدفئة المعتمدة على الكهرباء هي المهيمنة على باقي الانظمة بسبب خصائص السلامة والنظافة مقارنة بأنظمة الوقود الأخرى مثل الكيروسين أو الغاز الطبيعي. فضلا عن ان مستوى التعليم والثقافة يلعب دورا أساسي حيث يولي المثقفون مزيدًا من الاهتمام للسلامة والصحة البيئية.*