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Energy Management and Cost Reduction: A Predictive Approach to Monthly Electricity Billing in Mosul Residential Settings

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ABSTRACT

Efficient electrical power management is crucial for both suppliers and consumers, significantly affecting consumer budgets and national economies. In Iraq, residential electricity consumption constitutes 56% of the national demand, leaving households with unpredictable monthly bills due to the absence of real-time usage monitoring. This financial uncertainty worsens grid instability and hinders efficient energy management. This paper proposes a methodology for energy management by estimating monthly electricity bills. We propose a predictive billing system that estimates monthly costs by analyzing kWh meter readings at 6-hour intervals, aligned with Iraq's tiered pricing structure (10–120 IQD/kWh). The readings were collected over 30 days from a household in Mosul (House-1). To simulate high-consumption households (House-2 and House-3), the dataset was subsequently expanded by generating statistically and mathematically modeled synthetic data based on House-1 readings. Five management strategies were tested, including dynamic reductions (2–10 kWh) triggered by tiered thresholds. This methodology not only provides an estimate but also offers suggestions to help reduce the total bill, ensuring it stays within a reasonable range. The implementation of the proposed methodology led to a decrease in electricity consumption between 6% and 23%, resulting in cost savings of 14% to 49% across three different household profiles. The tiered feedback approach (Scenario 4) achieved the highest monthly cost savings, with a 49% reduction for households consuming more than 4000 kWh per month. This approach empowers consumers to align usage with budgetary goals while alleviating grid stress. Future work will integrate IoT-based outage detection and mobile app deployment.

Keywords:

Electrical Energy Consumption; Energy Meter Readings; Power Management; Electricity Grid Stability; Residential Energy Management.

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1. INTRODUCTION

The continuous and increasing growth in public life in the country has been greatly and clearly reflected in the continuous increase in electrical energy. The increase in current energy production does not equal this continuous growth, especially in the developed countries. In 2022, the majority of Iraq's electricity consumption was attributed to the residential sector, which used 56% [1]. It has become necessary to focus on reducing the consumption of this energy to increase its availability. The amount that an individual saves, no matter how small it is, will reflect positively on the provision of energy in general in the country. This will be done by increasing society's awareness and culture of the importance of this energy and the necessity of maintaining its use in an appropriate and balanced manner. This study aims to address this issue by promoting energy-saving behaviors for the residential sector through daily monitoring and final bill estimation. By increasing consumer awareness, the research seeks to reduce consumption, lower costs, and improve grid stability.

This research includes a literature review, a problem statement, and residential billing calculations in the introduction, followed by the methodology in Section 2. Sections 3 and 4 present the proposed methodology and the results and discussion, respectively. Section 5 covers the conclusions and future work.

1.1. Literature Review

The management of electrical energy consumption has garnered significant research interest, and in this context, we present a review of related works.

S. Mischos et al. [2] highlighted the need to address rising energy consumption, particularly electricity, to mitigate global climate change. It suggested that monitoring and modifying energy use in homes and buildings, along with implementing automation, are effective strategies for reducing energy consumption. A new hybrid hardware and software technology for energy savings is proposed. Various methods, including wireless technologies like Wi-Fi, Bluetooth, and transmission line communications, have been analyzed and implemented to enhance home energy management [3]. Another study highlighted the need for regulating consumer usage standards to improve energy efficiency through IoT in smart networks, which is essential for resource and energy management. It was conducted at four sites of an energy production company in Pakistan [4]. The home energy management systems (HEMS) monitor real-time consumption and optimize appliance usage to lower costs or meet specific goals. A study [5] reviews the literature on HEMS, covering managed appliances, scheduling objectives, operational limits, and security issues. It recommended increasing focus on clean, renewable energy sources like solar and wind. I. Paraskevas et al. [6] presented a method for accessing data directly from local smart meters using an external device, as well as a technique for identifying popular household appliances through energy consumption signals at a sampling rate comparable to that of the smart metering system. The authors demonstrated how this method could enhance energy management in households by allowing real-time monitoring of energy usage patterns. By analyzing the data retrieved from the smart meters, users could gain insights into their consumption habits, identify energy-hungry appliances, and make informed decisions on how to optimize their energy usage. The research [7] identifies several challenges that the government and public must tackle to ensure effective energy conservation and electricity supply. Success hinges on strategic planning, program organization, and expert committee oversight. Key actions include controlling imports, regulating appliance marketing, enforcing construction protocols, and funding awareness initiatives. Implementing energy-saving measures, such as inverter air conditioners, home insulation, and energy management techniques, is crucial to meet peak electricity demand. Public cooperation is essential for electricity rationing, as improper usage can lead to increased consumption. M.Dell'Isola et al. highlight that human behavior often has a greater impact on energy use than building inefficiencies. To enhance awareness of actual energy consumption, European Directives 2012/27/EU and 2018/844/EU emphasize metering systems, real-time data, and smart readiness indicators. The project utilizes Internet of Things (IoT) technology to collect and analyze data on indoor temperature and energy use, aiming to educate residents about their energy habits. The effectiveness of this approach is demonstrated through two case studies that explore optimal methods for sharing energy data and promoting better consumption practices [8]. Since health service buildings use the most energy in the administrative sector, energy prediction, supervision, and improvement must be given top priority. The use of sophisticated simulations, which are constrained by modelling assumptions, is common in traditional research. In a study conducted by M. de Simón-Martín et al., the yearly changes in consumption are analyzed to generate reference profiles, and an improved method for building clustering based on electrical energy usage is presented. Using statistical clustering and data mining techniques, the area consumption index is used to evaluate the transient variation across time. Applying the methodology, over 250 buildings (hospitals, health centers, and administrative buildings) in Castilla y León, Spain, provided monthly consumption data over three years. The research found five unique consumption characteristics associated with five reference buildings that greatly improve demand estimates when compared to traditional indicators [9]. Another work [10] focuses on Information and Communication Technologies (ICTs) to enhance smart buildings' energy efficiency, especially concerning electrical energy. It emphasizes important ICT methods and technologies, both current and emerging, such as energy harvesting techniques, renewable energies, sensors, communication technologies, and intelligence algorithms. High-performance intelligent systems that minimize energy use and raise occupant comfort are made possible by these technologies. To attain improved energy efficiency, the study highlights the most appropriate technologies, their key features, and their applications in smart buildings. The necessity to examine how much electricity is used in university buildings has increased due to growing global electricity prices.

The three primary objectives of this analysis are to develop solar PV installations, increase energy efficiency, and decrease consumption. It has been rare for prior studies on educational buildings to look at comprehensive, real-time data on electricity use, particularly hourly data, which is essential for the development of solar PV. This study fills this gap by offering a thorough approach to employing electricity indicators to analyze hourly consumption patterns and electrical energy in university facilities. The study, which was carried out at the University of Castilla-La Mancha in Spain, provides insightful information about how to maximize energy use in comparable learning environments [11]. A study on energy use in Iraqi homes, particularly in the area of lighting, emphasizes the consequences of poor lighting systems. DIALUX Evo 8 was used to analyze the energy usage of 48 residential samples. The results indicate that outdated, energy-intensive luminaires and poorly positioned lighting fixtures are significant contributors to excessive consumption. The study found that energy efficiency can rise by up to 60% when modern LED systems are used. Furthermore, the careful placement of fixtures, guided by advanced lighting algorithms, improves both lighting quality and visual comfort [12]. Iraq's human meter-reading-based power billing system has several drawbacks, including missing data, logistical problems, and large theft losses, particularly in remote areas. A study suggested a prepaid power billing system built as a web application with C# and ASPNet to overcome these problems. Through an interactive interface, this system allows users to recharge accounts, manage balances, keep an eye on electricity consumption, and deal with disconnections. The electricity distribution company's administrators oversee the system, guaranteeing openness and safeguarding the interests of the business and its clients. In addition, the system assigns penalties during blackouts and classifies users into usage categories [13]. Iraq's domestic energy efficiency laws and regulations were explored in another study [14], which highlights the need for a comprehensive strategy that considers consumer protection, resource efficiency, environmental preservation, emission reduction, and energy security. Since 2003, Iraq has had severe power outages, with technical and commercial losses exceeding 50% of electricity output, primarily in the residential sector, which is the nation's largest energy consumer. As efforts have focused on increasing supply, demand-side energy efficiency has largely been neglected. Additionally, highlighted are the institutional, financial, and technical difficulties. G. de Oliveira et al. [15] explore the potential of IoT for improving building power management, identifying critical aspects influencing energy use and management, and addressing theoretical and practical integration gaps through a thorough literature analysis. The study's main topics are energy monitoring, consumption analysis, and planning. It ends with the creation of a conceptual framework that integrates real-time energy data with the Internet of Things to bring diverse facets of energy management together. A thorough grasp of IoT-based energy efficiency is advanced by this framework. Due to a shortage of accurate statistics on end-user electricity consumption in Jordanian homes. To solve this, final-year engineering students from the German Jordanian University gathered data for a thorough analysis of about 350 buildings in central Jordan. With the use of this special dataset, policymakers can better understand how power is used in residential structures, develop large-scale energy efficiency projects, and support pertinent technology for the next energy-saving initiatives [16].

Affum et al. [17] introduced "Homergy," an IoT-based system that integrates smart and non-smart appliances, achieving weekly energy savings of up to 13 kWh through real-time monitoring. Advances in IoT and machine learning have further refined residential energy management systems, as demonstrated by Sureshkumar et al. [18], who developed a smart home system utilizing multi-sensor data fusion to minimize energy waste, and Kiruba et al. [19], who applied ANN-based backpropagation for demand prediction. These innovations align with our proposed methodology, which leverages manual meter readings to estimate bills and promote conservation, underscoring the significance of IoT and data-driven strategies in energy management.

Unlike previous studies that concentrated on fixed automation systems or IoT-based smart homes, this research investigates a cost-effective, human-driven alternative suitable for non-IoT residential settings, while still allowing for future automation possibilities. Our approach focuses on manual meter readings and incremental billing, aiming to achieve energy savings. This differs from IoT-based solutions such as those by Affum et al. [17] and Sureshkumar et al. [18], which rely on smart sensors for real-time monitoring and automated adjustments. While our method prioritizes financial feedback to influence user behavior, IoT systems like Kiruba et al. [19] employ machine learning for predictive optimization, offering greater precision. Despite these differences, both approaches share the common goal of reducing energy consumption by enhancing user awareness. IoT systems enable proactive automation through advanced

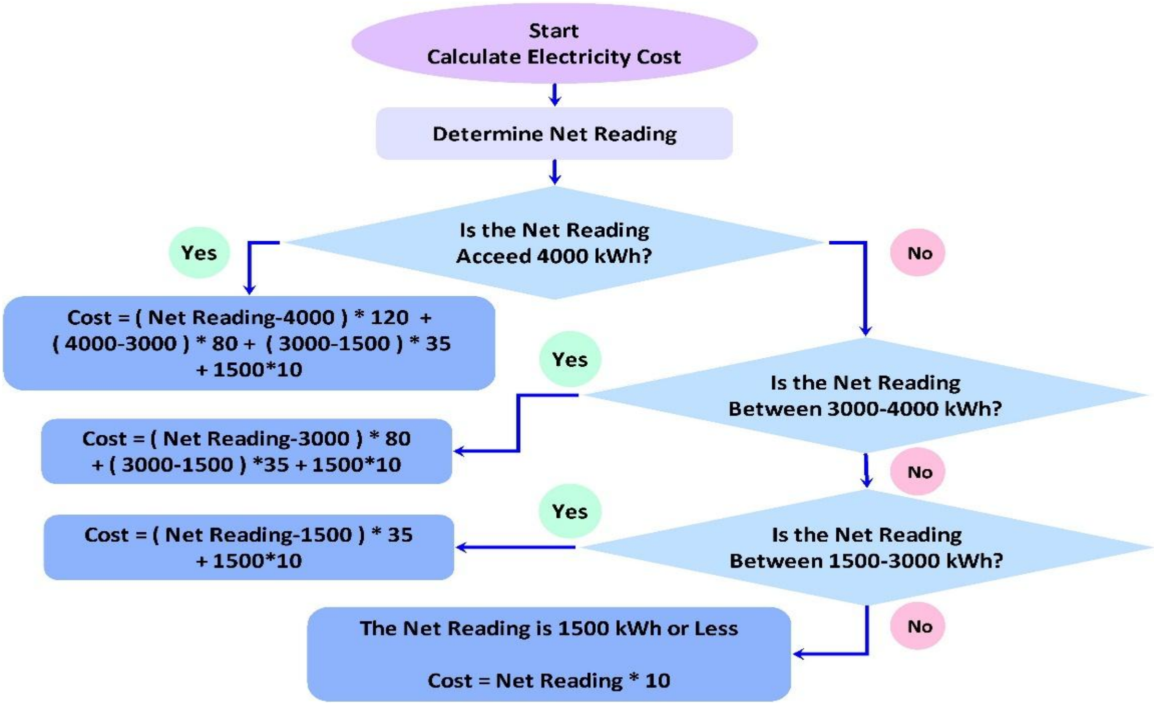

Fig. 1. Iraqi Ministry of Electricity calculations of electrical energy consumption cost.

technologies, whereas our method, relying on manual tracking, offers a more accessible solution for low-infrastructure regions such as Iraq.

1.2. Problem Statement

This study addresses the issue of Iraqi households being unaware of their electricity consumption patterns until they receive unexpectedly high monthly bills, which hampers effective energy management. It proposes a solution that allows consumers to monitor their usage and estimate bills in advance, promoting more efficient energy use.

1.3. Residential Electricity Billing Calculation in Iraq

Electromechanical electric energy meters are primarily used in Iraq. Trained staff conduct regular meter readings, either monthly or bi-monthly, through manual inspections, ensuring accurate usage tracking and reliable records. The Iraqi Ministry of Electricity [20] calculates energy consumption costs based on four categories per month from the net reading, which is the difference between the current reading and the previous reading as shown in Fig. 1.

1.4. Energy Management and Bill Estimation Process

Fig. 2 outlines the steps for managing energy consumption and estimating the bill. First, record daily meter readings multiple times, then calculate the estimated monthly electricity bill based on the differences between current and previous readings. Next, provide savings suggestions by estimating the new bill according to the user's consumption patterns, which encourages the user to reduce consumption by emphasizing the financial benefits.

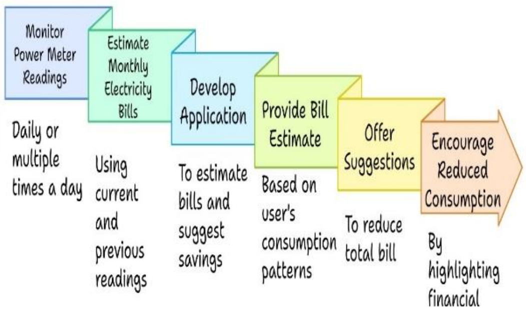

Fig. 2. Energy management and bill estimation process.

2. THE PROPOSED METHODOLOGY

This study estimates the monthly cost for a particular residence and proposes an energy management system based on daily or sub-daily energy usage. Reducing his electrical energy costs puts the householder at the center of energy management. Dataset acquisition, estimation criterion formulation, applying multiple scenarios for total cost estimation, and energy reduction rate calculation are the four subtopics that comprise the suggested methodology.

2.1. Dataset Acquisition

We had produced the dataset by manually recording the kWh meter readings for a specific Mosul City home four times a day, every six hours, for thirty days. This produced 120 readings; each reading was recorded alongside its recording times and date, and was saved in an Excel sheet to be used in the study as House-1. The difference between every two consecutive readings was calculated and added to the dataset as a separate column. The electricity grid is subject to the service provider's programmable cutoff criteria because of the lack of electrical supplies, which has been an issue in Iraq for decades. While Iraq experiences frequent outages, our method targets active consumption periods. Electricity outages caused by grid issues (zero readings) do not trigger alerts, as no reduction is feasible.

As a result, the electricity supply was not constant throughout the day. Consequently, the target house's electricity consumption was lower than anticipated. Fig. 3 shows a line graph of the net kWh meter readings taken every six hours over 30, with three threshold lines indicated. Most readings were between thresholds one and three, with only a few exceeding the third threshold.
To address the challenge of gathering data from households with higher energy consumption, the simulation increased energy usage. Two synthetic subsets of kWh meter readings were generated by applying two different formulas to scale up energy consumption, representing two additional households (House-2 and House-3), as illustrated in Fig. 4.

The criteria for data generation are detailed in equations 1 and 2. Many of the generated readings exceeded the second and the third thresholds, while a few were between the first and second thresholds. These generated subsets were used to illustrate the findings.

❖ ***Formula 1*** using statistical criteria (equation 1):

$$New\ reading = Max\ \left(0.1, NORM.INV\ (RAND(\,), \mu new, \sigma)\right) \quad (1)$$

Where: $\mu new = \mu \times 1.5$, μ is the mean of the acquired data for each six-hour period, and σ is the standard deviation for it, where the $1.5 \times \mu$ multiplier aligns with Iraq's tiered pricing thresholds. The Iraqi Ministry of Electricity establishes the following billing tiers:
- Base Tier ($1 \times \mu$): 0–1500 kWh/month at a rate of 10 IQD/kWh.
- Mid Tier ($1.5 \times \mu$): 1501–3000 kWh/month at a rate of 35 IQD/kWh.
- High Tier ($2 \times \mu$): Over 3000 kWh/month at a rate of 80–120 IQD/kWh.

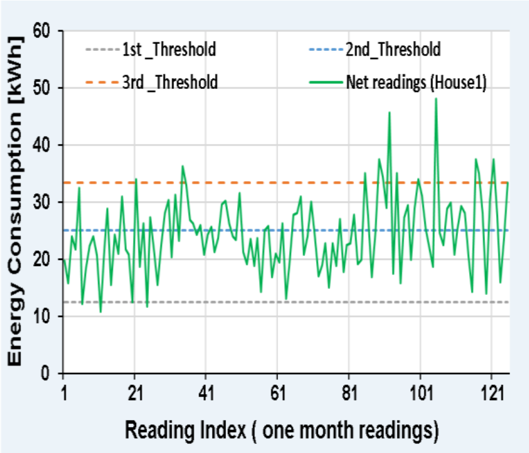

Fig. 3. The net kWh meter readings acquired every six hours for a month.

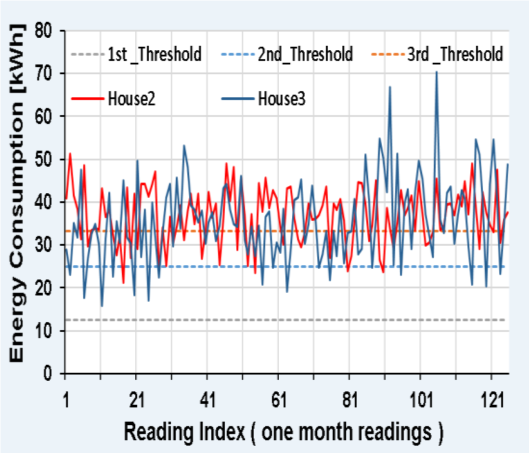

Fig. 4. The kWh meter readings of the synthetic datasets (House-2 & House-3).

The $1.5 \times \mu$ threshold aligns with the 1500 kWh pricing breakpoint, ensuring that our synthetic datasets (House-2) accurately reflect high-usage households under Iraq's regulatory framework. To validate the use of $NORM.INV$ function, the acquired was plotted using s Quantile-Quantile (Q-Q) plot, which is a graphical tool used to assess whether a dataset follows a theoretical probability distribution (typically the normal distribution). It compares the quantiles of the observed 6-hour readings (Y-axis) against the quantiles of the expected distribution (X-axis) as shown in Fig. 5.

The process for calculating the readings of House-2 based on the readings of House-1 for each six-hour interval using ***Formula 1*** involves the following steps:

1. Compute the mean (μ) and standard deviation (σ) for the 30 days of readings from House-1.

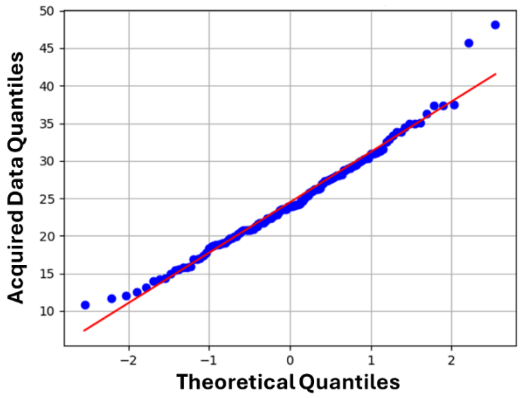

Fig. 5. Q-Q Plot of 6-Hour kWh consumption.

2. Determine the new mean (μnew) for the desired 30 days of readings for House-2.
3. Generate a new value using the inverse of the normal cumulative distribution function (*NORM.INV*). This function takes a randomly generated probability using RAND() between (0 and 1), the new mean (μnew), and the standard deviation (σ) as inputs.
4. Ensure the generated value is not less than 0.1 by applying the MAX function.

❖ ***Formula 2*** using Max. criteria (equation 2):

$$New\ reading = acquired\ reading \times \frac{Wanted_{Max}}{Acquired_{Max}} \tag{2}$$

Where: $Wanted_{Max}$ represents the desired peak reading for House-3, $acquired_{Max}$ is the highest recorded reading from the data collected for House-1, $acquired\ reading$ represents the six-hour readings for House-1, and finally, the $New\ reading$ was generated using ***Formula 2*** and used to simulate the six-hour readings for House-3.

2.2. Formulation of The Estimation Criterion

The monthly cost calculation categories were divided into daily and six-hour segments, as shown in Table 1, and can be further segmented for continuous estimation. The proposed methodology encourages householders to optimize energy consumption through cost monitoring, which is more comprehensible and more effective than tracking kWh consumption.

The process involves the following steps:

1. Comparing the net reading from the last six hours with the established thresholds to identify the consumption zone.
2. Provide a useful recommendation based on this reading:

Table 1. Cost tires (Thresholds).

kWh	Monthly Tire Levels	Daily Tire Levels	Six-Hour Tire Levels	Cost (IQD)
1st Tire	1500	50	12.5	10
2nd Tire	3000	100	25	35
3rd Tire	4000	133.3	33.25	80
More than	4000	133.3	33.25	120

a. Maintain the current consumption pattern if the reading is below the first threshold.

b. Reduce power consumption if the reading is between the first and second thresholds.

c. Immediately decrease power consumption if the reading exceeds the last threshold.

d. Calculating the cost for the last six-hour segment and informing the householder of any out-of-limit costs based on the thresholds.

3. Estimating and informing the consumer of the total monthly bill if consumption continues at this rate. With this information, consumers can lower their total bill by managing power consumption for the remainder of the month.

This process can be repeated with each new energy meter reading. The formulation of the energy management criterion was illustrated in Fig. 6.

2.3. Total Cost Estimation Scenarios

We propose 5 scenarios for estimating the total monthly cost based on current meter readings, utilizing either the average of four consecutive readings (Daily-Avg.) or the moving average of five consecutive readings (Moving AVG.). Average values were used to prevent decisions based on anomalies in meter readings. These scenarios aim to simulate potential power consumption reductions that house owners can implement to keep their monthly bills affordable. The total cost can be estimated using equation 3. Where: d represents the count of days and n represents the count of 6 hours readings. The proposed scenarios were applied to the data from the three houses, which are listed below in order:

$$Monthly\ Cost = \sum_{d=1}^{30} \sum_{\substack{n=1 \\ (Each\ 6Hour)}}^{4} Cost\ of\ Readings \tag{3}$$

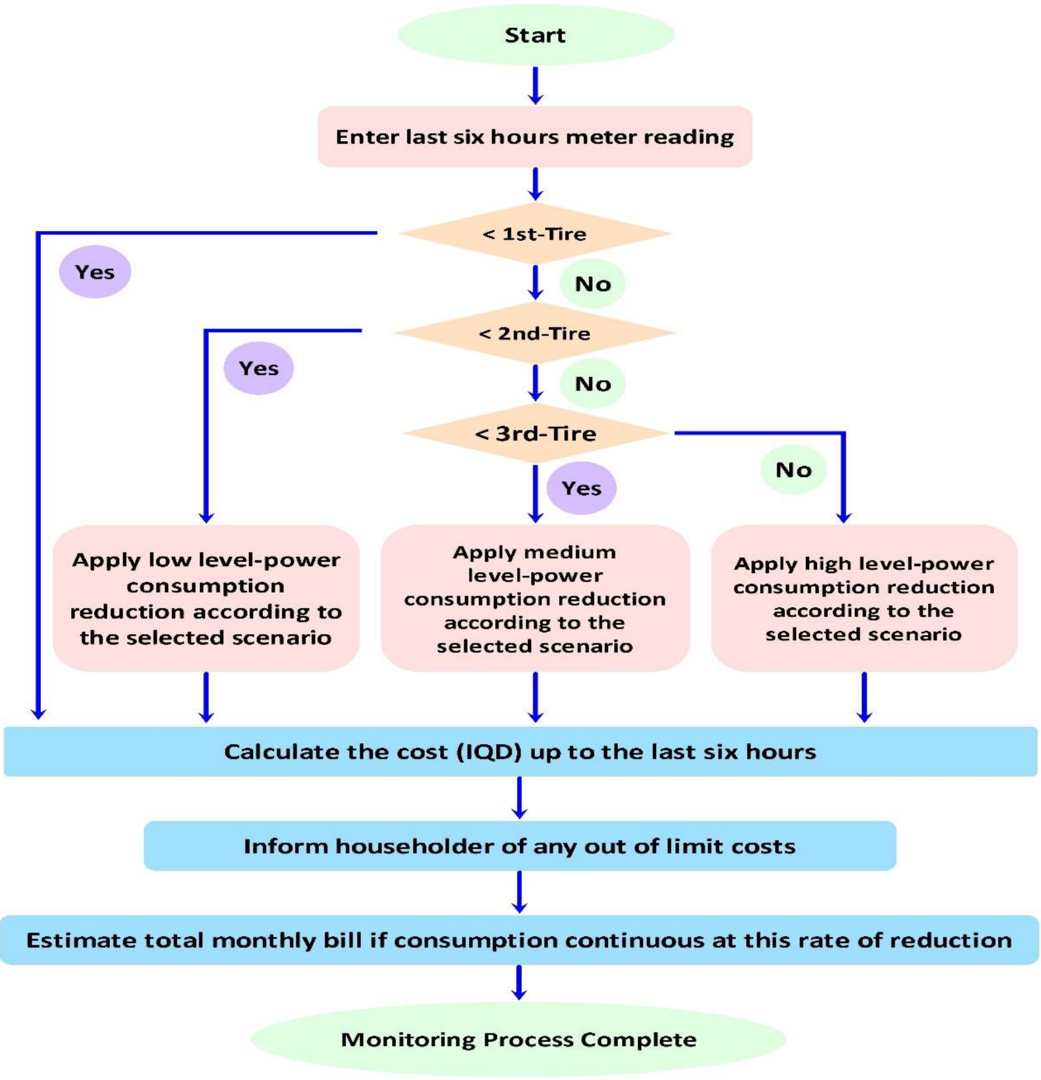

Fig. 6. The proposed energy consumption monitoring and mangement.

1. The acquired and the generated meter readings are kept as it is for comparison.

2. Reduce energy consumption by 5 kWh for the next 6 hours if the moving average of every four consecutive difference readings exceeds 25 kWh. The moving average was calculated for the readings before applying this scenario, as shown for House-1 in Fig. 7.

3. Reduce energy consumption by 2 kWh over the next 6 hours if the cumulative total of the last four readings exceeds 50 kWh. The moving average for each reading was computed before the implementation of this scenario, as illustrated in Fig. 8 for House-2 as an example.

4. This scenario entails the application of three reduction values: 9, 5, and 2 kWh, when the current moving average reading surpasses the thresholds of 33.325, 25, and 12.5 kWh,

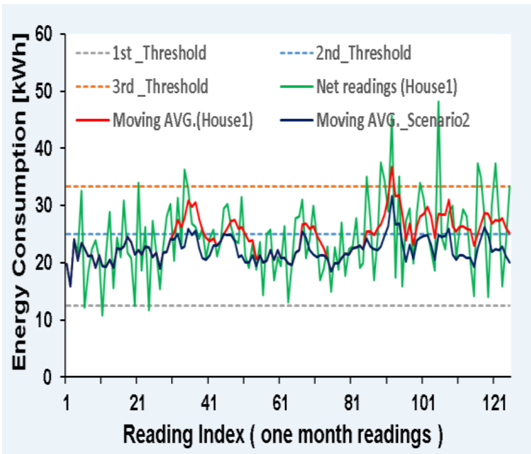

Fig. 7. Readings of House-1 and its moving average and the moving average for the readings after applying scenario 2.

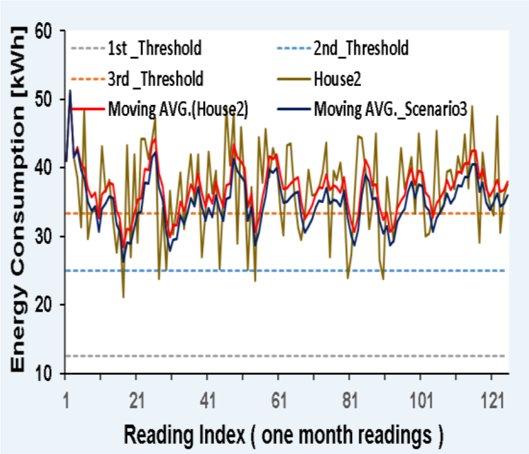

Fig. 8. Readings of House-2 and its moving average and the moving average for the readings after applying scenario 3.

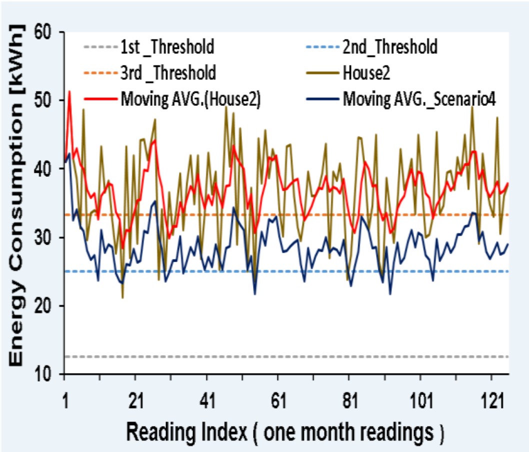

Fig. 9. Readings of House-2 and its moving average and the moving average for the readings after applying scenario 4.

respectively. Fig. 9 depicts the effect of this scenario for House-2.

5. This scenario estimated the monthly bill based on previous readings up to the current one. The estimated values were compared with monthly thresholds, leading to reductions for the next six hours: 10 kWh for readings over 4000 kWh, 7 kWh for those over 3000 kWh, and 2 kWh for readings over 1500 kWh. The effect of this scenario is shown in Fig. 10 when applied to the data of House-3.

2.4 Energy Reduction Rate Calculation

The energy consumed (in kWh) is calculated by multiplying the power of each load by its operating time. Power consumption is determined by voltage and current. With a fixed voltage of 220V, the current, which varies by load type, is the primary factor in electricity consumption, alongside the operating period, as shown in equations 4 and 5. For instance, if a device using 2 Amperes operates for 2 hours, it will consume 880 kWh.

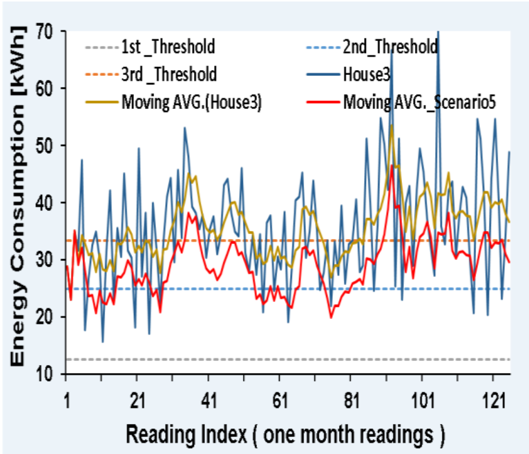

Fig. 10. Readings of House-3 and its moving average and the moving average for the readings after applying scenario 5.

$$E_{dev} = P_{app} \times T \quad (4)$$

$$P_{app} = V_s \times I_{dev} \quad (5)$$

Where: E_{dev} is the device-energy in kWh, P_{app} is the apparent power, and T is the time in hours. In addition, the V_s is the voltage source, which is 220V in Iraq, and I_{dev} represents the device current. The energy consumption can be found using equation 6.

$$Power\ (W) = \frac{Energy\ (kWh) \times 1000}{Time\ (hours)} \quad (6)$$

For example, to reduce energy consumption by 3 kWh, the user can switch off a device that consumes 3 kW for one hour or a device that consumes 1.5 kW for two hours.

2.5 Practical Implementation Considerations

The proposed methodology allows householders to manually record their kWh usage every six hours, input the data into an Excel sheet, and, based on the selected scenario, automatically estimate the monthly bill and costs will be calculated by Excel functions, provided sufficient prior readings are available. According to the chosen scenario, energy management recommendations for the upcoming time interval will also be obtained. While valuable, this approach is not highly practical or easily

implementable on a large scale. Future enhancements could include developing a mobile application as a first suggestion or integrating the system with an Internet of Things (IoT)-based residential energy management system, embedding it into a smart home framework as a second suggestion.
The mobile application allows users to manually capture images of their meter readings at any time, without being restricted to 6-hour intervals. It then employs Optical Character Recognition (OCR) to extract the readings, estimate monthly consumption and costs, and provide energy management advice based on the chosen scenario. Users can interact with the application through a Graphical User Interface (GUI). The second suggestion involves integrating with smart home systems through IoT, enhancing functionality by connecting to a smart kWh-meter for real-time energy consumption monitoring. This integration facilitates automatic calculations and estimations, applying power management strategies to optimize energy usage and minimize costs. Additionally, users can interact with the system to select their preferred scenarios, promoting more efficient energy management. Fig. 11 illustrates these future enhancements.

Table 2. Some methods to reduce energy consumption.

Device	Power rating (W)	Required time to save 5 kWh
Air Conditioner (Central)	3000–5000 W	1–1.67 hours
Electric Water Heater	3000–4500 W	1.11–1.67 hours
Clothes Dryer	1800–5000 W	1–2.78 hours
Space Heater	1500 W	3.33 hours

kWh values, which represents the decrease in energy use, is shown in the next column. A last indicator of progress is provided by the final column, which represents this decrease as a percentage of the normal usage. After each reading, the homeowner receives advice aimed at enhancing energy management, which they are expected to implement for improvement. This advice indicates the amount of energy to reduce

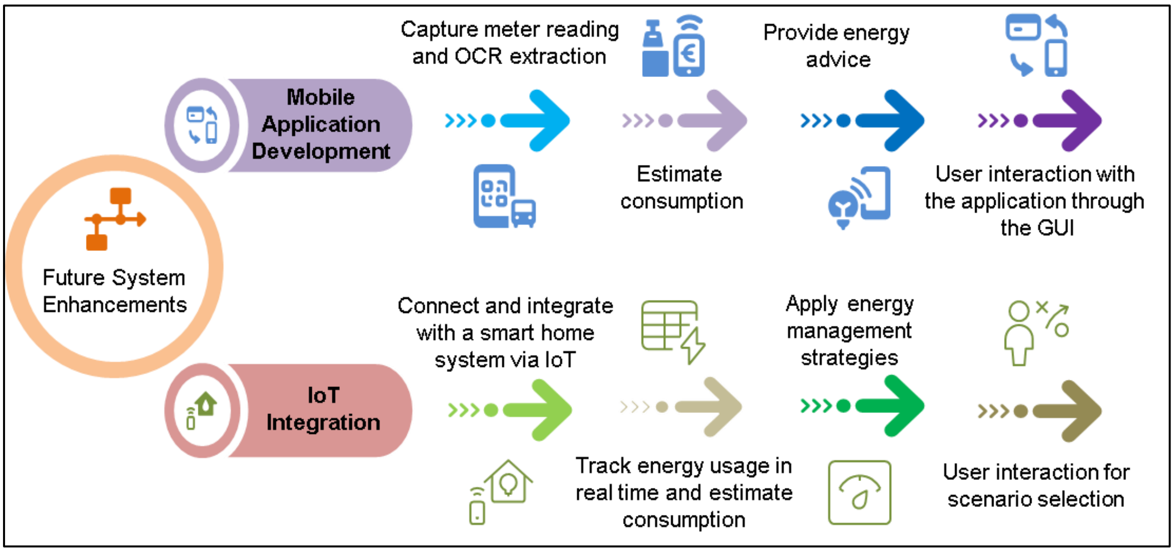

Fig. 11. Exploring Future System Enhancements.

3. RESULTS AND DISCUSSIONS

A summary of the outcomes from using the suggested methodology in five different energy management scenarios is shown in Table 2.
Real energy meter readings from a single home (House-1), as well as two scaled datasets (House-2 and House-3) that represented three distinct homes, were used to evaluate these scenarios. The fourth column of the table displays the new monthly kWh of energy use for each scenario. The difference between the new and normal monthly address the excess energy consumption from the previous time segment, calculated from the energy consumption using equation 6. To reduce energy consumption by 5 kWh, several methods can be employed, as shown in Table 3.
Before any reduction scenarios, the monthly energy consumption was 2944, 4388, and 4289 kWh for Houses 1, 2, and 3, respectively. Fig. 12 displays a bar chart of the percentage improvements from the proposed scenarios for all

three houses, showing that the improvement was more pronounced as consumption increased. House-1 experienced a monthly energy and cost savings shown in Table 3 and Fig. 12. The limited

Table 3. Electrical energy consumption summary for different scenarios.

House	Normal Monthly (kWh)	Scenario	New Monthly (kWh)	Improvement % kWh	Improvement % Cost
1	2944	2	2692	9	14
		3	2777	9	14
		4	2533	14	22
		5	2688	9	14
2	4388	2	3793	14	33
		3	4136	6	16
		4	3395	**23**	**49**
		5	3525	20	44
3	4289	2	3694	14	33
		3	4026	6	17
		4	3358	22	47
		5	3256	19	43

improvement for House-1 was attributed to its lower consumption, which did not exceed the 3000-kWh monthly threshold, unlike the other two

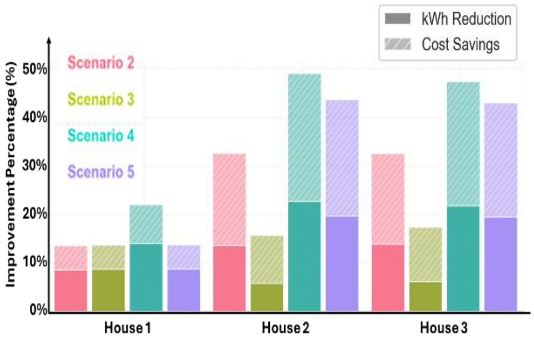

Fig. 12. kWh and cost percentage monthly improvements for three houses over the four proposed scenarios.

houses as shown in Fig. 13. The better performance of House-2 compared to House-3 may be due to fewer energy spikes and overshoots cross all scenarios. Notably, scenario 4 yielded the highest improvement for all three houses, likely because it adjusts subsequent energy consumption based on the tire levels at each six-hour reading. Although synthetic kWh data is used for House-2 and House-3, the results remain valid since actual data could exhibit different energy consumption patterns. However, the proposed 6-hour time slot segmentation method effectively tracks

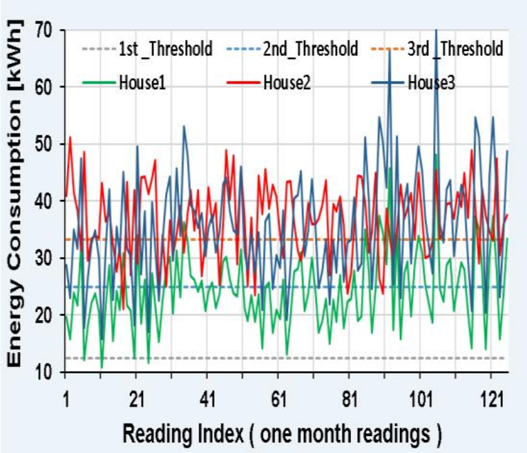

Fig. 13. Energy consumption for the three houses.

subinterval changes and offers recommendations to achieve the desired reductions. Indeed, real data collection enables more realistic analysis and, with sufficient data, can support the application of AI methods for improved performance.

4. CONCLUSION

Rationalizing domestic power use not only serves personal goals but also alleviates pressure on the national electrical system and enhances financial stability for families and society. In Iraq, where household consumption represents approximately 56% of total energy demand, this study highlights the importance of mindful energy management as a key strategy to reduce electricity consumption. It introduces a methodology for monitoring kWh meter readings daily to estimate monthly bills and guide homeowners on how much power to save to avoid high costs. Data was collected from a household over 30 days, at four 6-hour intervals. The results from five proposed consumption management scenarios indicated energy consumption improvements of up to 23% and hence a cost saving of 49%. The proposed method does not provide a standalone tool for householders to use independently but instead outlines a methodology that can be integrated into a mobile application, a spreadsheet, or an IoT-based continuous monitoring system.

Future developments could include creating a mobile application that applies this methodology by allowing users to manually capture images of the kWh meter. The app would process the readings, calculate usage differences from previous measurements, estimate the energy bill, and offer personalized energy-saving tips. Furthermore, a more advanced system could be designed for real-time meter monitoring, either through a fixed camera setup or smart meter integration connected via an IoT application. This could enable efficient consumption management and seamless integration with smart home systems.

Economic benefits, such as monthly savings, are strong incentives for consumers to reduce usage, which in turn enhances the efficiency of the national electrical grid and positively impacts rationalization efforts.

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إدارة الطاقة وخفض التكاليف: نهج تنبؤي لفواتير الكهرباء الشهرية في المناطق السكنية بالموصل

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الملخص

تُعد إدارة الطاقة الكهربائية بكفاءة أمرًا بالغ الأهمية لكل من الموردين والمستهلكين، حيث تؤثر بشكل كبير على ميزانيات المستهلكين والاقتصادات الوطنية. في العراق، يُشكل استهلاك الكهرباء السكني 56% من الطلب الوطني، مما يولد فواتير شهرية غير متوقعة للأسر بسبب غياب مراقبة الاستخدام الآني. يُفاقم هذا الغموض المالي من عدم استقرار الشبكة ويُعيق الإدارة الفعالة للطاقة. تقترح هذه الورقة منهجية لإدارة الطاقة من خلال تقدير فواتير الكهرباء الشهرية. نقترح نظام فوترة تنبؤي يُقدر التكاليف الشهرية من خلال تحليل قراءات عدادات الكيلوواط/ساعة على فترات 6 ساعات، بما يتماشى مع هيكل التسعير المتدرج في العراق (10-120 دينارًا عراقيًا/كيلوواط/ساعة). جُمعت القراءات على مدار 30 يومًا من منزل في الموصل (المنزل-1). لمحاكاة الأسر ذات الاستهلاك العالي (المنزل-2 والمنزل-3)، تم توسيع مجموعة البيانات لاحقًا من خلال توليد بيانات تركيبية مُصممة إحصائيًا ورياضيًا بناءً على قراءات المنزل-1. تم اختبار خمس استراتيجيات إدارة، بما في ذلك التخفيضات الديناميكية (2-10 كيلوواط/ساعة) المُفعّلة من خلال عتبات مُتدرجة. لا تُقدم هذه المنهجية تقديرًا فحسب، بل تُقدم أيضًا اقتراحات للمساعدة في خفض إجمالي الفاتورة، مع ضمان بقائها ضمن نطاق معقول. أدى تطبيق المنهجية المُقترحة إلى انخفاض في استهلاك الكهرباء بنسبة تتراوح بين 6% و23%، مما أدى إلى توفير في التكاليف تراوح بين 14% و49% في ثلاثة أنماط استهلاكية مُختلفة للأسر. حقق نهج التغذية الراجعة المُتدرجة (السيناريو 4) أعلى وفورات شهرية في التكاليف، مع انخفاض بنسبة 49% للأسر التي تستهلك أكثر من 4000 كيلوواط/ساعة شهريًا. يُمكّن هذا النهج المُستهلكين من مواءمة الاستخدام مع الأهداف الميزانية مع تخفيف الضغط على الشبكة. ستُدمج الأعمال المُستقبلية اكتشاف الانقطاعات القائمة على إنترنت الأشياء ونشر تطبيقات الهاتف المحمول.

الكلمات الدالة:

استهلاك الطاقة الكهربائية، قراءات عداد الطاقة، إدارة الطاقة، استقرار شبكة الكهرباء، إدارة الطاقة السكنية.