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Enhancing Sustainable Energy Integration with a Techno-Economic Evaluation of Hybrid Renewable Energy Systems at the College of Engineering in the University of Baghdad

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ABSTRACT

This paper presents a techno-economic evaluation of a Hybrid Renewable Energy System (HRES) for the University of Baghdad College of Engineering. The objectives include improving reliability and mitigating grid demand. The design of a customized grid-connected HRES for the university, incorporating solar PV and a diesel generator (DG). The optimal hybrid configuration is determined through a complete assessment of economic, technical, and environmental factors using Homer-Pro software. Besides it addresses critical challenges in provides valuable insights into sustainable energy solutions for educational institutions. Additionally, the study extends its scope by presenting a comprehensive analysis of four different proposed hybrid energy systems. The College of Engineering is anticipated to have an estimated daily load of 1110.48 kWh and a peak load of 494.56 kW. The optimal cost for a system comprising PV, DG, and grid is determined to be net present cost (NPC) is 288,348,027IQD and levelized cost of energy (LCOE) is 57.2896IQD/kWh. The analysis emphasizes the integration of both renewable and conventional sources to create a sustainable and efficient energy solution.

Keywords: Renewable energy system, Techno-economic, Microgrid, Homer-Pro.

1. INTRODUCTION

Power is becoming more and more in demand as globalization picks up speed as a result, there is an increasing reliance on different power sources, which has an influence on the environment by reducing carbon dioxide (CO_2) emissions and related expenses, highlighting the microgrid's sustainable nature **(Uyar et al, 2022)**. This has led to investments in alternative energy sources being prioritized in several countries. As a result of the exhaustion of fossil fuel supplies and the ongoing environ-mentals damage caused by fossil fuel consumption **(Kantola and Saari, 2013)**. Renewable energy (RE) is appealing because it

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can reduce the negative consequences of conventional energy sources while producing clean, sustainable electricity to manage the risks related to renewable energy generation (REG) and demand, the load frequency control connected with RE The topics of integration, stochasticity, and robustness were discussed **(Habbi and Alhamadani, 2018)**. A hybrid renewable energy system (HRES) combines Multiple generator types, typically a diesel generator (DG) with a renewable energy source (RES) like photovoltaics (PV), wind turbine, or PV/WT. HRES are frequently the most dependable and affordable power generation option for remote locations. Incorporating solar and wind energy helps mitigate power fluctuations **(Elhadidy and Shaahid, 2004; Abbood and Habbi, 2023)**. Many parts of specialized software, such as PV Case, Solargis, and Homer-Pro, have been created in recent years decades to help the design, Optimization and forecasting of PV electricity generation **(Hamad and Habbi, 2023).** These technologies give us all the data we need to estimate RE potential because they provide information on temperature, clearness index, global sun radiation, and many other variables to maximize PV power plants and other RES **(Sumathi et al., 2015).** Sensitivity analysis and optimization methods are included in the system performance and can be utilized to determine most economical cost and productive system configurations **(AlGarni and Awasthi, 2017)**. In these research paper using Homer-Pro software, the system can be configured and run to maximize the efficiency of PV systems and electricity output forecasting, enhancing the efficiency of HRES that combine multiple RES, such as (DG), power grid and PV system **Fig. 1** show schematics diagram of HRES **(Al-Karaghouli et al., 2010; Sharma et al., 2013)**.

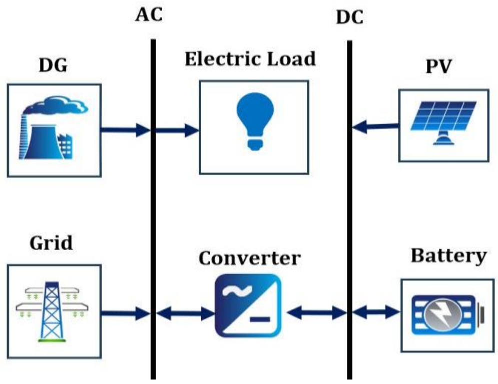

Figure 1. Schematics diagram of HRES.

Multiple technical and economical research studies on the application of hybrid renewable energy resources (HRER) have been conducted in recent years, although many HRES planning and optimization are being developed and created, one of the greatest and most widely used tools worldwide is Homer modeling tools **(Sohail et al., 2022; Bahramara et al., 2016; Sinha and Chandel, 2014)**. They simulated the grid-connected system planning applications to evaluate HOMER Pro's techno-economic analysis by examining the optimal configurations for a hybrid system. The research uses Homer software to enable the design and improvement of micro-grid (MG) hybrid system at Eski¸sehir Osmangazi University in terms of techno-economic analysis, taking into account that practical application of MG system furthermore controlling its operations should be considered at the University of Abdelmalek Essaâdi **(Çetinbas et al., 2019)**. When this research utilizes optimization methods and methodologies to predict the best economic dispatches and coordination of distributed MG capacity sources load demand, RE accessibility, the capacity of energy storage and cost reduction are primary factors discussed in the optimization process

(Belmahdi and Bouardi, 2020). This research determines the optimum size, generation capacity, and technical as well as economic benefits of microgrids based on several case studies along with HOMER insights into optimization analysis **(Murty and Kumar, 2020)**. The topic of MG has received a lot of attention recently as an effective and environmentally friendly approach for tackling the energy demands of distant countries, areas, institutions or communities **(Nurunnabi et al., 2019; Rehman et al., 2020; Ali et al., 2022; Yang et al., 2017)**. A hybrid system that can use solar and wind power to cut costs for the seashore in Baluchistan, the study showed a 64% decrease in pollution gas emissions and made use of minimization NPC **(Nebey, 2021)**. Investigated a hybrid system for a community load in Ethiopia that combined hydropower, wind, and solar PV, the study employed HOMER software for the best combination with low parameters of NPC **(Ghaffari and Askarzadeh, 2020).** In Nigeria the non-centralized grid linked system that blinged biogas, wind, and solar energies. It was found with the aid of the minimized NPC and compromised LCOE, the study also found a significant declining trend of the LCOE by 81% in addition to an incremental increase within the energy supply by 3% **(Khan et al., 2022)**.
The objective of this study is to enhance and examine the potential of (HRES) in contributing to the sustainable provision of power on the University campus. The MG was modeled and simulated using Homer-Pro. The RES and actual load profiles serve as input parameters for the HRES. The chosen campus for the case study is UOB in Iraq. This paper focuses on the primary contributions of the study:

• Design of a grid-connected HRES specifically for the UOB at COE.
•Integration of solar PV and biogas from a diesel generator, addressing electricity challenges.
•Sizing of the HRES components, considering economic costs, technical specifications, and environmental factors using Homer-Pro software.
•Techno-economic analysis to enhance electricity reliability, and decrease grid demand.

2. SIMULATION PARAMETER

2.1 Study Location

The study was carried out at the University of Baghdad (UOB), which is on the eastern side of the Tigris River, in the city of Baghdad, at a latitude of 33.3152° N and a longitude of 44.3661° E. **Fig. 2** depicts the chosen site's location. In this paper, the UOB was chosen as a case study. UOB campus includes nine colleges, four graduate institutes, five research centers, and three service centers. The hybrid system was chosen to be applied in the College of Engineering (COE).

2.2 Renewable Energy Resource Assessment

For twenty-two years, the UOB College of Engineering collected meteorological data information from NASA's surface weather data and solar power database **Fig. 3** shows meteorological data for the UOB College of Eng. The yearly average daily temperatures and levels of radiation are 5.02 kWh/m^2/day and 23.54 ^{o}C respectively**.** It is possible to compute the amount of electrical energy generated on a daily, monthly, or yearly basis. The simulation model necessitates the precise whereabouts of the electrical station. **Fig. 4** shows the solar irradiance.

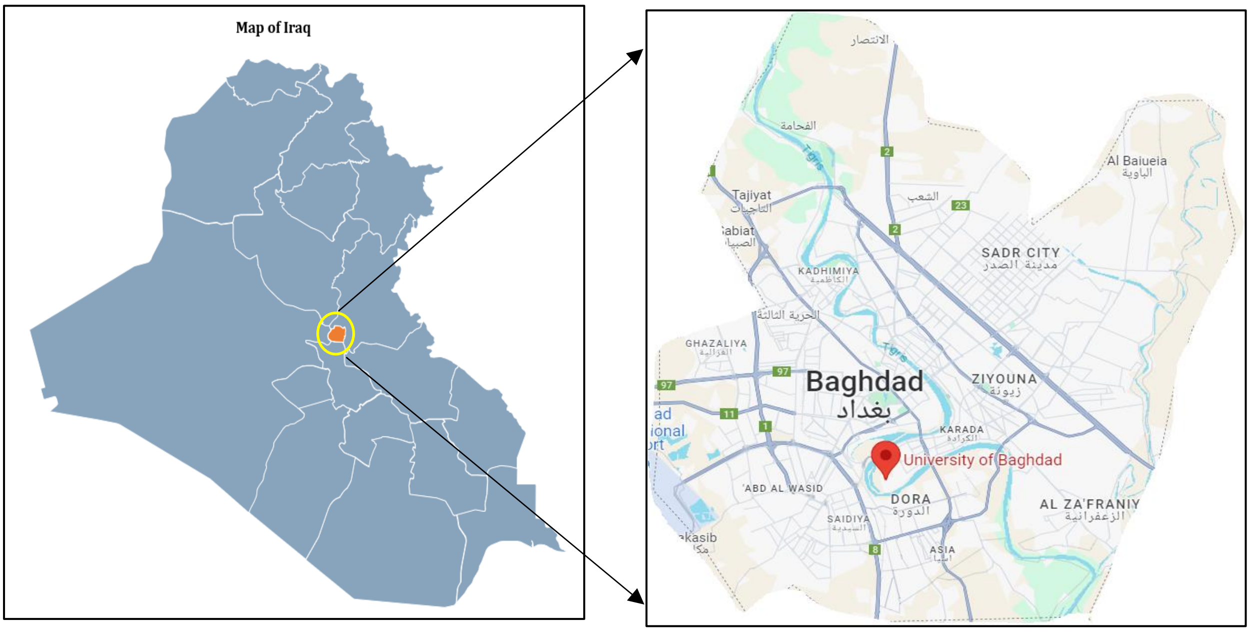

Figure 2. Location University of Baghdad.

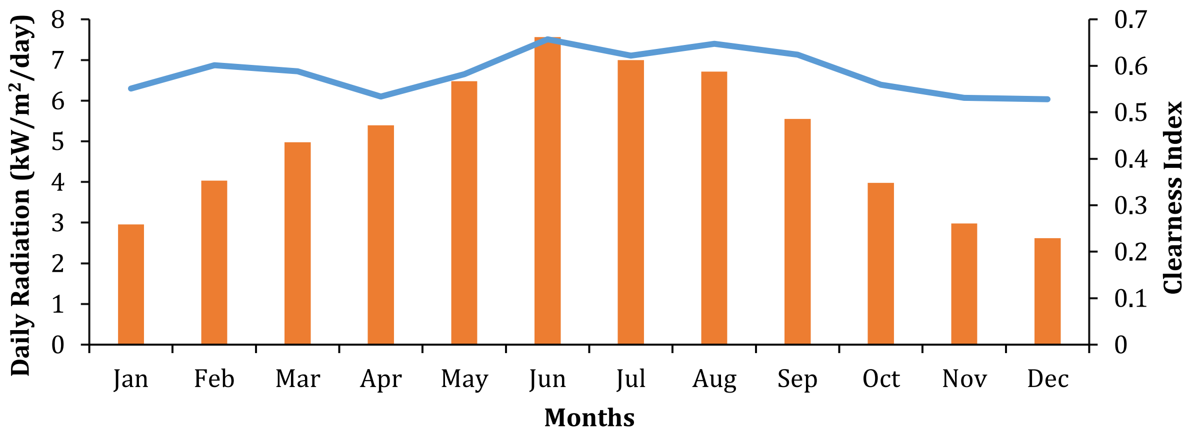

Figure 3. Monthly global horizontal irradiance.

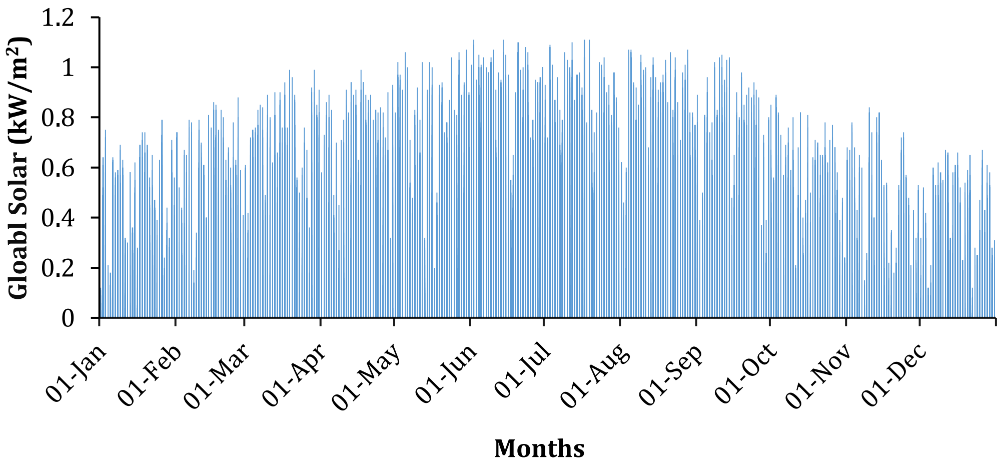

Figure 4. Solar irradiance.

2.3 Load Estimation

The load demand for the engineering college campus depicts in **Fig. 5**, revealing essential insights into the energy consumption patterns. The graph illustrates that the estimated daily load for the COE is approximately 1110.48 kWh. The peak load, representing the maximum power demand during a specific period, is also recorded at 494.56 kW. This visualization provides a clear understanding of the fluctuating energy requirements throughout the day, offering significant information for designing and optimizing the HRES. Analyzing load profiles is crucial for appropriately sizing the energy generation and storage components, ensuring that the system meets the demand variations effectively.

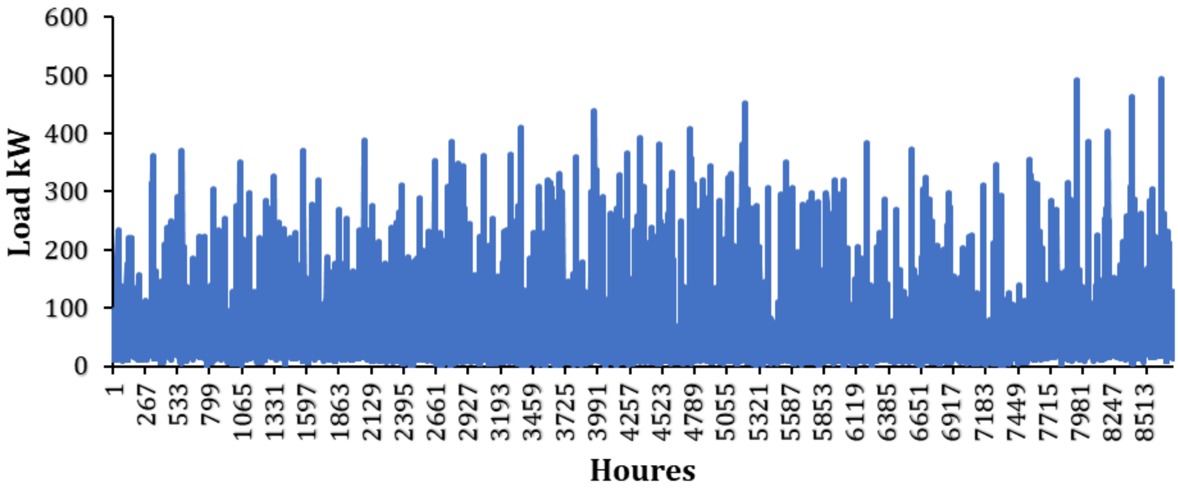

Figure 5. Load demand.

2.4 Grid Electricity

The UOB operates with grid energy. However, grid energy in Baghdad is now unreliable. According to available information, there were 7.4 hr/d power outages every month, with an average duration of 3.6 hr. To compute random grid outages in a year, HOMER used a mean power outage frequency of 88.8 each year and average repair time of 3.6 hr.

2.5 Solar PV

In China, a flat plate PV solar panel costs 0.26$ per watt (260$ per kw). However, since solar PV technology is still in its early stages, 2 kW costs around 1,250,000IQD in Iraq. The cost of operation and maintenance has been estimated. Solar modules have been estimated to have a lifetime of 15 years with an 80 percent derating factor. Solar PV power generation is calculated as:

$$PV_{power\ output} = P_{pv,STC}\ f_{PV}\ \frac{G_T}{G_{T,STC}}\left[1 + K_p\left(T_{pv} - T_a\right)\right] \tag{1}$$

2.6 Diesel Generators

relationship between the electrical output power and fuel consumption of a diesel engine unit is represented in Eq. (2). The minimum operational ratio of diesel is estimated to be

25% of the power output of the event generator. the average growth of the intercept coefficient of the fuel production curve is zero. The electric power rating is 0.0480 L/hr/KW, and the expected slope of the fuel engine curve is 0.2860 L/hr/KW. Thus, **Fig. 6** illustrates the fuel consumption and efficiency curves of a diesel system.

$$F_{(t)} = F_0 \, . P_{rated} \, + \, F_1 \, . P_{G(t)} \tag{2}$$

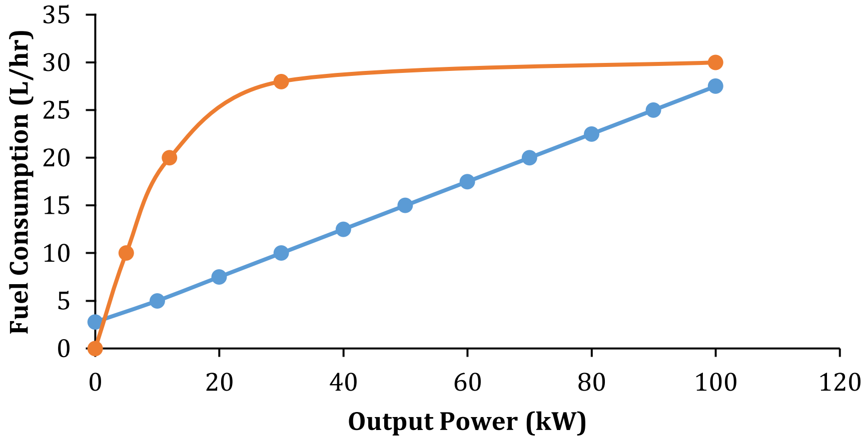

Figure 6. Generator fuel curve intercept coefficient.

2.7 COST PARAMETERS

2.7.1 Net Present Cost (NPC)

The NPC is calculated as follows

$$NPC = \sum_{i=1}^{t} i_d \left(C_{cap} + C_{rep} + C_{O\&M} + C_{fuel} + C_{sellback} \right) \tag{3}$$

Where i_d is obtained from Eq. (4)

$$i_d = \frac{1}{(1+i)^n} \tag{4}$$

n: Number of years, and i represent:

$$i = \frac{i' - f}{i + f} \tag{5}$$

The annual cost C_{ann} is calculated as:

$$C_{ann} = CRF(i,n) \times NPC \tag{6}$$

where $CRF(i,n)$ is obtained from Eq. (7)

$$CRF(i,n) = \frac{i\,(1+i)^n}{(1+i)^n - 1} \tag{7}$$

2.7.2 Levelized Cost of Energy (LCOE)

The LCOE formula computes the mean expense of producing energy (kWh) throughout the lifespan of the system **(Ishraque et al., 2021)**.

$$LCOE = \frac{C_{inv} + C_{O\&M} + C_{fuel}}{E_{(ren)}(1+r)^{(n-1)}} \quad (8)$$

Where $\boldsymbol{r}$ is rate of discounting measured value of money over time and the price of using capital for other opportunities. The LCOE estimate assumes a consistent production of energy across the whole lifespan of the system.

$$LCOE = \frac{C_{ann}}{E_{(served)}} \quad (9)$$

2.7.3 Operating Cost (OC)

The operational cost investigation establishes the analytical value of the component, eliminating its initial capital and installation expenses **(Mehta and Basak., 2020)**. The mathematical expression for operational cost is provided as:

$$C_{OC} = C_{ann} - C_{cap} \quad (10)$$

In **Fig. 7**, A graphic presenting the energy management is drawn, showing how HOMER Pro software can be used to determine NPC and LCOE of the HERS. This helps outline interactions between different entities of the system and gives an idea about the beauty behind energy management **(Kumar et al., 2017)**.

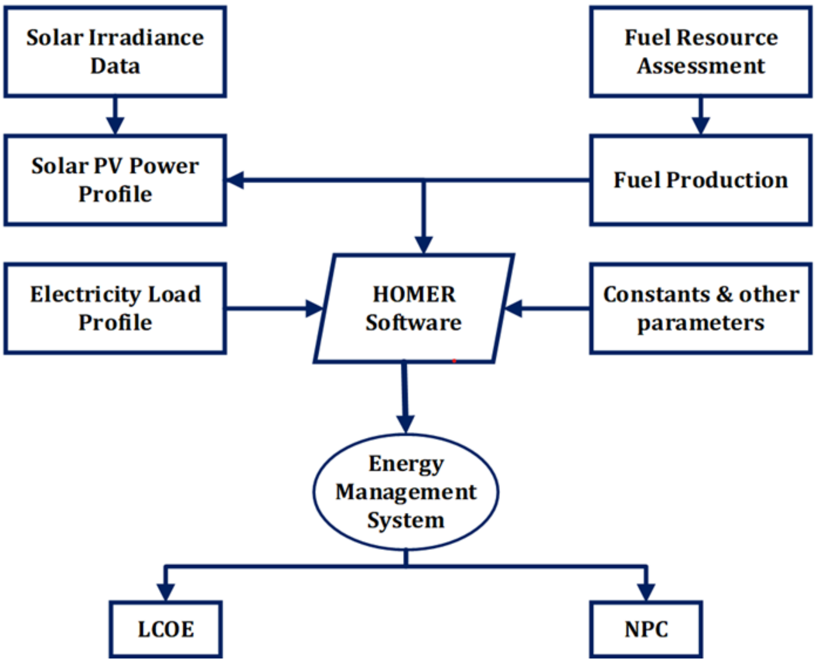

Figure 7. Energy Management Schematic Diagram.

The key performance criteria in terms of the economic viability and efficiency of the HERs are calculated values NPC cost and LCOE. Using the following diagram, one can see that the approach about how you find an optimal solution for a practical and cost-effective hybrid systems **(Nassar et al., 2022)**. It also sugarcoats the dependent on software study. The functional association between NPC and LCOE is covered in the energy these financial parameters are used to select HERs.

3. SIMULATION RESULTS

3.1 Technical Specifications

Table 1 presents the technical specifications of the proposed system design for the university campus.

Table 1. Technical Specification of System Design.

Component	Specifications	Value	Units
Generic Flat Plate PV	Rated Capacity	2	kW
	DF	80	%
	Slope	33.27	Deg.
	GR	20	%
	Operating temperature	47	^{o}C.
	Efficiency	13	%
	Replacement	500	$
Generic 100kWh Li-Ion	Nominal Voltage	600	V
	Nominal Capacity	100	kWh
	Nominal Capacity	167	Ah
	Roundtrip Efficiency	90	%
	MCC	167	A
	MDC	500	A
	Replacement	300	$
Generic System Converter	Rated power	3	kW
	Capital cost	500	$
	Replacement cost	300	$
	O&M	10	$/yr.
	Efficiency	95	%
	Life time	15	yr.
	Ambient temperature range	-25+50	^{o}C.
Generic 10kW Fixed Capacity Genset	Capacity	10	kW
	Fuel curve intercept	0.480	L/hr.
	Fuel curve slope	0.286	L/hr./kW
	CO	19.76	g/L fuel
	UHC	0.72	g/L fuel
	Particulates	1.198	g/L fuel
	Fuel Sulfur to PM	2.21	%
	NOx	22.47	g/L fuel
	LHV	43.2	MJ/kg

	Density	820	kg/m³
	Carbon Content	88	%
	Sulfur Content	0.41	%
	Capital Cost	3,000	$
	Replacement	3,000	$
	O&M	0.125	$/op. hr.
	Fuel Price	0.34	$/L

3.2 Proposed System Studies

MG systems efficiently and effectively meet the increasingly important demands of the modern energy conversion systems because they are extremely flexible, and suitable for different types of civilization and economic programs. Four different systems have been considered in this study harnessing different energy sources such as PV, DG, grid tie interface, and batteries to evaluate the adequacy and viability of the systems by using Homer Pro.

System 1: PV, DG, Grid, and Batters

This case called islanded grid shown in **Fig. 8a** is suggested for this system involves the incorporation of energy in the form of PV panels in conjunction with DG for backup power as well as grid connection and energy storage in batteries. The use of Homer Pro simulations is considered as a way to control and enhance the sizing and the operation of each component to obtain an effective, efficient, and sustainable MG system.

System 2: PV, DG, and Grid

This case shown in **Fig. 8b** considers the PV, DG and grid integrated system, focusing on the renewable electricity generation, backup power and grid ancillary service requirements. With Homer Pro, it is our intention to analyze the interconnection and interaction of various sources of energy, enhance the efficiency of the MG, and evaluate the resilience and feasibility of system.

System 3: DG and Grid

In this case, the system shown in **Fig. 8c**, concern is towards a conventional energy layout where DG underpins energy provision with grid connection as an alternative. During our Homer Pro simulations, our major goals are to determine the actual capacity of the diesel generator, compare the levels of energy utilization, identify further energy-saving possibilities, and assess the feasibility of introducing new renewable power sources to the system.

System 4: PV and Grid

The solar power application scenario shown in **Fig. 8d.** This one involves PV and a grid with which the feasibility of a grid-connected PV system is evaluated. Naturally, using Homer Pro, aimed to analyze the behaviors of the PV system, compare and assess the different possibilities of grid integration, and estimate the economic and environmental profit of this configuration.

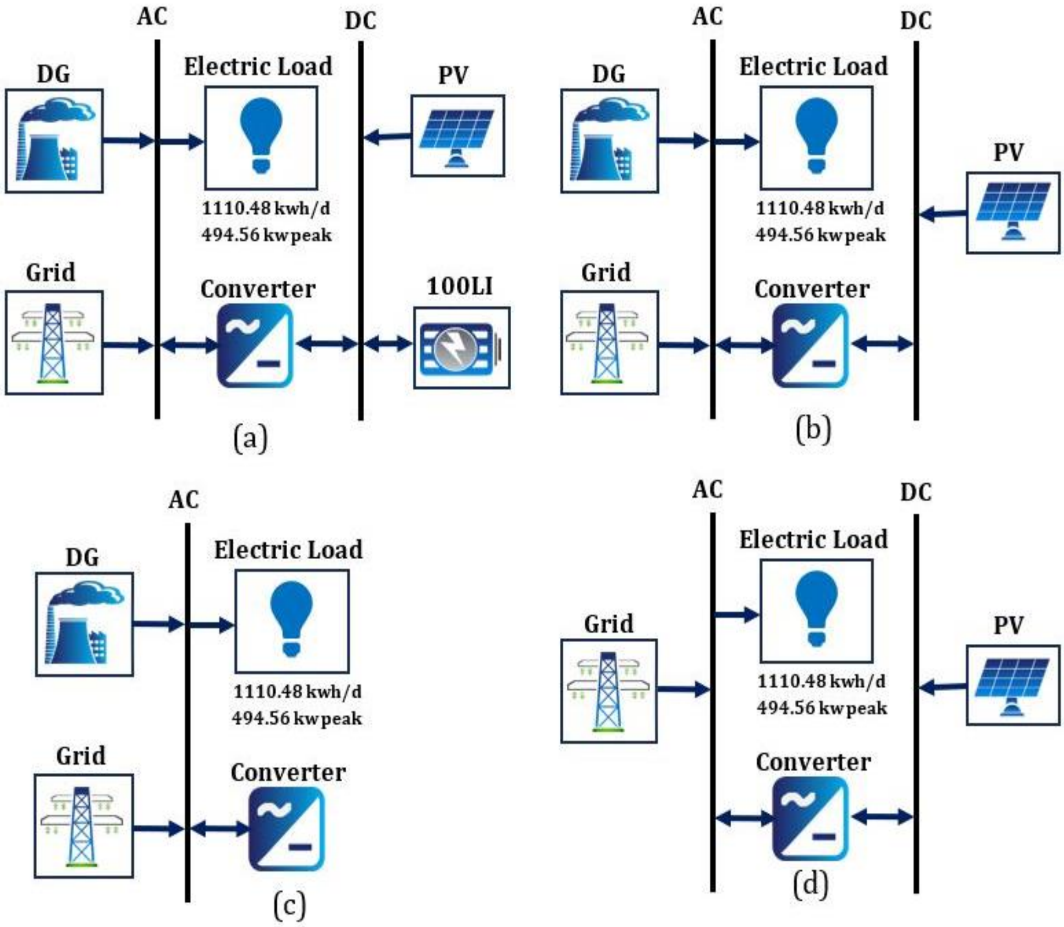

Figure 8. Schematics Designs for **a)** System 1 Islanded grid. **b)** System 2 PV, DG and Grid. **c)** System 3 DG and Grid. **d)** System 4 PV and Grid.

3.3 Economic System Configurations

Four different configurations were simulated through HOMER. Using this software, we found the most optimized configuration of each four systems which is shown in **Fig. 8** on the basis of operating cost (OC), NPC, and COE. **Table 2** shows all system costs of any component design. In context to Homer Pro, electric consumption implies the expenditure of electrical energy by the loads involved in a MG system. This consumption is a great factor to consider during the design as well as the improvement of the system as it is involved in the determination of the sizes of energy sources and storage systems, and the overall performance of the system design shown in **Fig. 9** illustrates the monthly electric production for different systems subfigures (a, b, c and d) represent the system 1, system 2, system 3, and system 4, respectively.

The PV, DG, Battery and Grid configuration has the lowest NPC and LCOE, indicating it is the most cost-effective option among the presented systems. The second system most economical option is "PV, DG, Grid, closely following the first configuration. The configuration with Diesel and Grid has a higher NPC and LCOE than the PV-based configurations, suggesting that introducing RES can contribute to cost savings. The PV and Grid configuration has the highest NPC and LCOE among the presented systems, emphasizing the impact of including DG and batteries in enhancing cost-effectiveness. The economic advantages of integrating RES like PV, with or without DG and batteries, in achieving lower NPC and LCOE, thus promoting more sustainable and cost-efficient energy solutions show in **Table 3.**

Table 2. Costs of system design.

	Component	C_{Cap} ($)	C_{Rep} ($)	$C_{O\&M}$ ($)	Salvage + C_{Fuel} ($)	Total ($)	Total (IQD)
System 1	DG	3,000	0	3,102.60	0	7,902	10,431,432
	Battery	5,000	0	0	1,167.84	3,832	5,058,451
	PV	66,938.31	0	17,306.92	0	84,245	111,203,703
	Grid	0	0	79,771.07	0	79,771	105,297,812
	System Converter	48,024.2	20,375.41	10,347.23	3,834.86	74,912	98,883,826
System 2	DG	3,000	4,345.35	1,899.05	137,727	148,971	196,642,287
	PV	33,272.14	0	8,602.52	0	41,875	55,274,551
	Grid	0	0	227,304.83	0	227,305	300,042,375
	System Converter	19,129.69	8,116.23	4,121.66	1,527.56	29,840	39,388,813
System 3	DG	3,000	6,471.49	3,661.07	179,639	194,771	257,098,314
	Grid	0	0	312,973.81	0	312,973	413,125,429
System 4	PV	34,718.75	0	8,976.54	0	43,695	57,677,782
	Grid	0	0	353,892.59	0	353,892	467,138,218
	System Converter	16,231.25	6,886.49	3,497.16	1,296.11	25,318	33,420,816

Table 3. OC, LCOE, and NPC comparison of four system.

	Component	OC (IQD/yr)	LCOE (IQD/kwh)	Total NPC (IQD)	LCOE ($/kwh)	Total NPC ($)
System 1	DG, Battery, PV, Grid, System Converter	19,855,427	62.3436	330,875,226	0.0472	250,663
System 2	DG, PV, Grid, System Converter	11,882,189	57.2896	288,348,027	0.0435	218,446
System 3	DG, Grid	25,209,320	127.6044	570,223,743	0.0966	431,987
System 4	PV, Grid, System Converter	22,979,673	99.858	458,236,817	0.0757	367,604

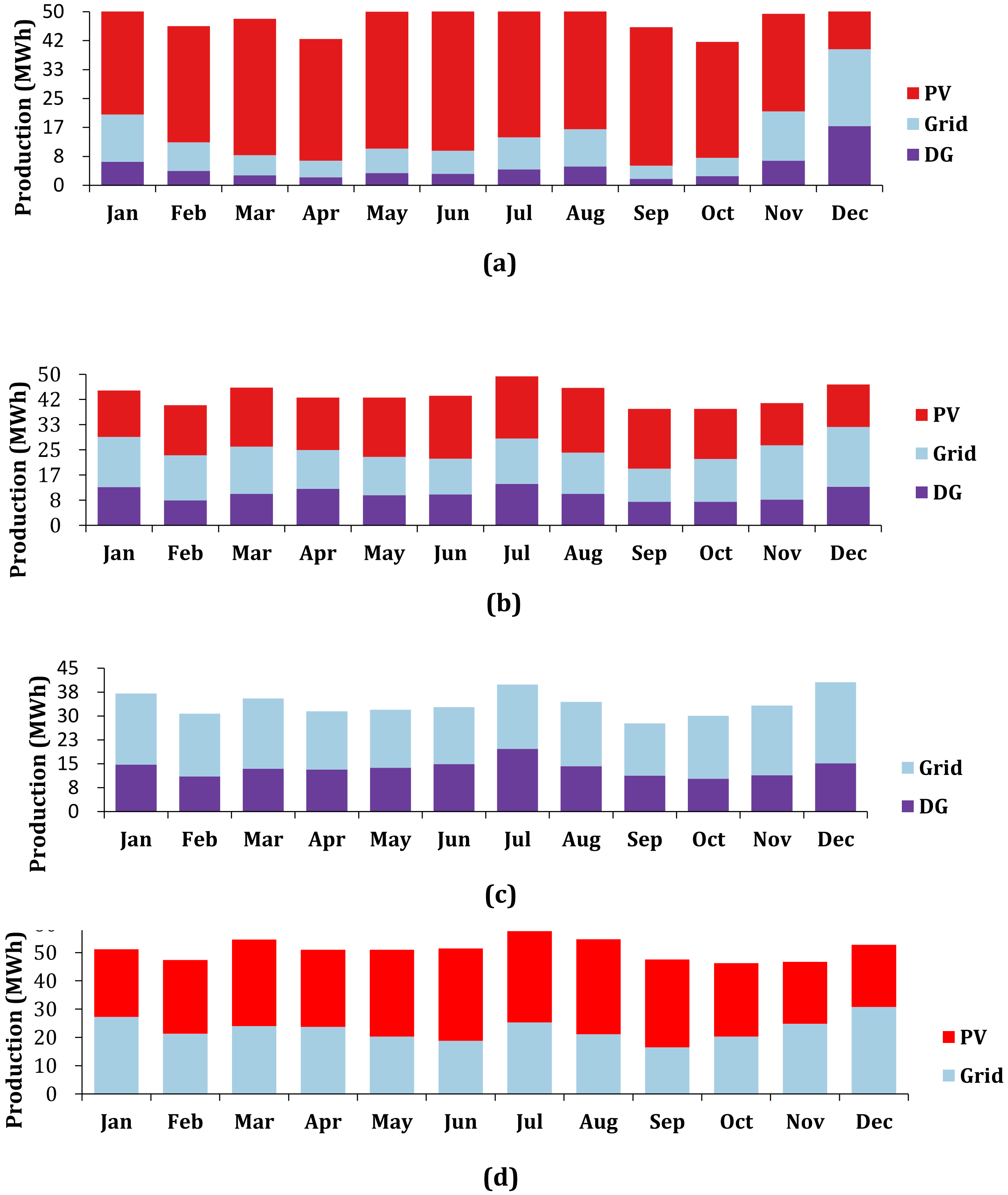

Figure 9. Monthly electric production for **a)** System 1 with battery. **b)** System 2 without Battery. **c)** System 3. **d)** system 4.

3.4 Determination Most Economic System

The second system most economic design of MG requires consideration of RES availability, load demand profiles, reliability, and cost-effective. The optimal design was chosen based on the comparison of NPC and LCOE for all system design in this study see **Table 3** and **Fig. 8b** Effective contribution of solar energy with DG and electrical Grid. The system consists three components see **Figs. 10 to 13** how to effect output power ofz the intensity color within heatmap would depict the level of output power for system during one year. In general, low power levels are depicted by darker shades such as purple whereas high power levels are described by lighter colors, such as green or yellow.

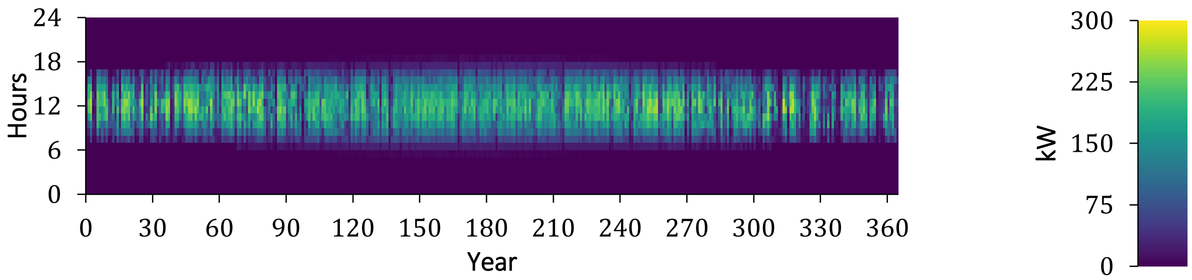

Figure 10. PV output power

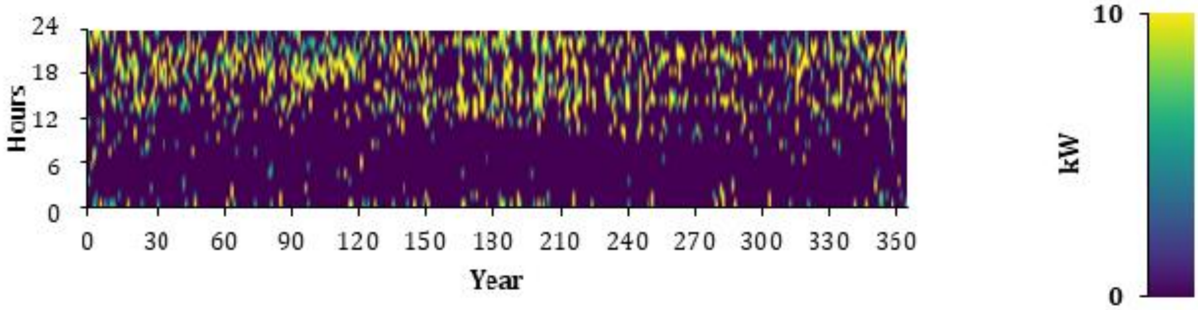

Figure 11. DG output power.

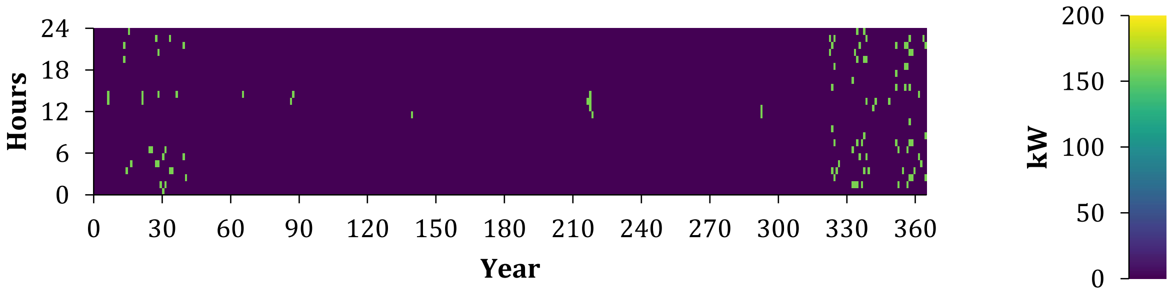

Figure 12. Rectifier output power.

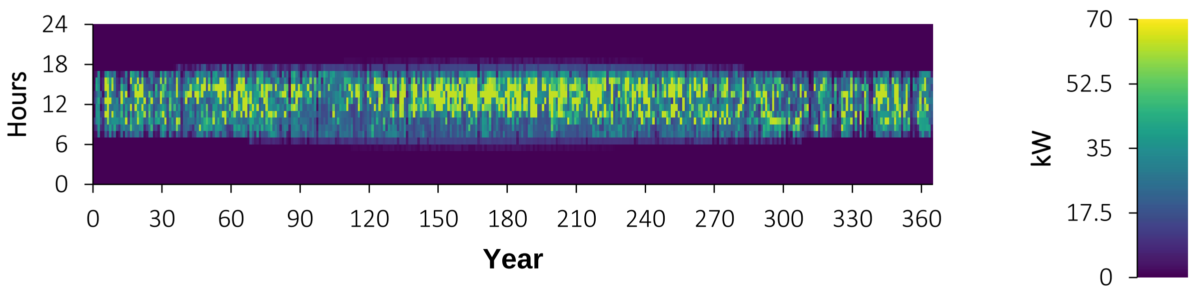

Figure 13. Inverter output power.

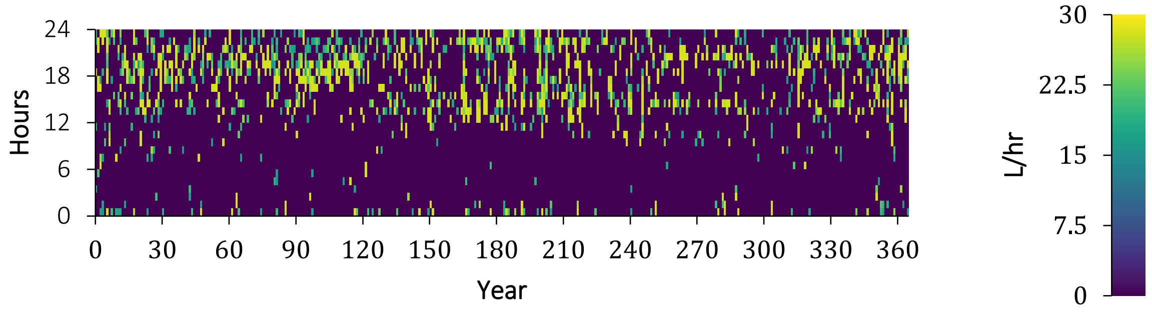

Figure 14. Diesel consumption.

This heatmap illustrates the typical daily and seasonal consumption density of electricity in terms of the color gradient for a year **Fig. 14** seasonality explains the variation of electric usage, but the following analysis demonstrated that it best explains the peak periods of electricity consumption, which is critical in management, planning and operation of electric grids, low power levels are depicted by darker shades such as purple whereas high power levels are described by lighter colors, such as green or yellow. **Table 4** shows details of DG esmissions in this system.

Table 4. The amount of emitted for the system.

Pollutant	Emission kg/yr.
CO_2	102,457
CO	335
UHC	14.7
PM	1.54
SO_2	511
NOx	186

4. CONCLUSIONS

This study performs a techno-economic evaluation of an HRES at the UOB, focusing on COE enhancing reliability and mitigating grid demand. The custom-designed grid-connected HRES incorporates solar PV and a DG, with the optimal hybrid configuration determined through comprehensive assessments simulation-based analysis that can be provided by charging Homer cycle software. The research investigates four proposed hybrid energy systems. Predicting a daily load of 1110.48 kWh and a peak load of 494.56 kW at the COE analysis identifies the most cost-effective system, comprising PV, a DG, and the grid, with NPC are 288,348,027IQD, OC is 11,882,189 IQD/yr. and LCOE is 57.2896IQD/kWh. The configuration integrating PV, DG, Battery, and the Grid emerges as the most economically viable option with the lowest NPC and LCOE among the presented systems. The proposed system involves a 2kW PV with 146,847 kWh/yr. output, a 100 kWh Li-Ion battery displaying 90% efficiency. A 10kW fixed-capacity DG ensures efficient performance with low emissions, and a 25-year service life, this comprehensive configuration combines renewable and conventional sources harmoniously, offering a sustainable and cost-effective energy solution. The obtained detailed techno-economic summary confirms the efficiency and cost-effectiveness of System 2, incorporating PV, DG, and grid components, with an NPC of 288,348,027IQD and LCOE is 57.2896IQD/kWh.

NOMENCLATURE

Symbol	Description	Symbol	Description
$P_{PV,(STC)}$	Photovoltaic array at standard test conditions peak power (KWp).	F_1	Slope of the fuel curve.
f_{PV}	Derating factor of PV (%).	$P_{G(t)}$	Actual electrical output power of a diesel generator.
G_T	Solar irradiance striking PV array (kW/m^2).	i_d	Discount rate.
$G_{T,STC}$	Solar irradiance under standard test conditions (1 kW/m^2).	C_{Cap}	Capital cost.
K_p	Temperature factor of powers (%/◦ C).	C_{Rep}	Replacement cost.
T_{pv}	Photovoltaic temperatures (◦ C).	$C_{O\&M}$	Operational and maintenance cost.
T_a	Ambient temperatures at 25 (◦ C)	C_{Fuel}	Fuel cost.
$F_{(t)}$	Fuel consumption rate of diesel generator.	$C_{Sellback}$	Sellback cost.
F_0	Intercept coefficient	f	Renewable fraction.
P_{rated}	Rated power generated by a diesel engine generator.	CRF	Capital recovery factor.
i'	Real discount rate.	E_{ren}	Total energy generated by the system over a lifetime.
C_{inv}	Initial investment.	E_{served}	Total electrical load served.
C_{oc}	Operating cost.		

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Credit Authorship Contribution Statement

Ahmed Ameen: Writing, design and modelling methodology, editing.
Hanan Habbi: Reviewing, writing, design and modelling methodology, editing and proofreading.

Declaration of Competing Interest

The authors confirm that they do not possess any recognized conflicting financial interests or personal ties that could have potentially influenced the findings presented in this research.

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تعزيز تكامل الطاقة المستدامة من خلال التقييم التقني والاقتصادي لأنظمة الطاقة المتجددة الهجينة في كلية الهندسة جامعة بغداد

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الخلاصة

تقدم هذه الورقة تقييماً تقنياً واقتصادياً لنظام الطاقة المتجددة الهجين (HRES) في كلية الهندسة بجامعة بغداد. وتشمل الأهداف تحسين الموثوقية وتخفيف الطلب على الشبكة. تصميم نظام HRES مخصص ومتصل بالشبكة للجامعة، يتضمن الطاقة الشمسية الكهروضوئية ومولد الديزل. يتم تحديد التكوين الهجين الأمثل من خلال تقييم كامل للعوامل الاقتصادية والتقنية والبيئية باستخدام برنامج Homer–Pro. إلى جانب أنه يعالج التحديات الحاسمة في توفير رؤى قيمة حول حلول الطاقة المستدامة للمؤسسات التعليمية. بالإضافة إلى ذلك، توسع الدراسة نطاقها من خلال تقديم تحليل شامل لأربعة أنظمة مختلفة مقترحة للطاقة الهجينة. ومن المتوقع أن يكون لكلية الهندسة حمل يومي يقدر بـ 1110.48 كيلوواط في الساعة وحمل ذروة يبلغ 494.56 كيلوواط. تم تحديد التكلفة المثالية لنظام يشتمل على الطاقة الكهروضوئية ومولدات الديزل والشبكة على أنها صافي التكلفة يساوي 288,348,027 دينارعراقي وكان مستوى سعرالطاقة القصوى يساوي 57,2896 دينارعراقي لكل كيلوواط بساعة. ويؤكد التحليل على تكامل المصادر المتجددة والتقليدية لإيجاد حل مستدام وفعال للطاقة.

الكلمات المفتاحية: نظام الطاقة المتجددة، التقنية والاقتصادية،الشبكة الصغيرة ،Homer - Pro.