POLITYKA ENERGETYCZNA – ENERGY POLICY JOURNAL

2025 ✦ Volume 28 ✦ Issue 3 ✦ 79–98

DOI: 10.33223/epj/205948

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Simulation of a hybrid solar-hydro-biomass energy system with hydrogen storage for optimal energy demand fulfillment

Abstract: The intermittency of natural renewable energy sources poses a significant challenge to supplying electricity in rural areas that rely on standalone renewable energy systems. Although battery storage is often used to address this issue, it has several limitations, especially in hot climate regions where performance and longevity are compromised. Ensuring reliable and accessible electricity in these areas is essential for promoting economic development and improving quality of life. This study aims to develop a novel hybrid power system to provide a sustainable and dependable energy solution, that integrates solar photovoltaic (PV), micro-hydro, biomass, and hydrogen storage in one hybrid system, where this specific combination has not been explored in previous literature. After conducting a comprehensive field survey to evaluate the available natural resources and design the system, the proposed model was subsequently simulated in HOMER Pro software. The testing results indicated a high degree of compatibility between the tested energy sources, with each one contributing well to an ongoing year-round energy supply. The largest shares were solar PV 64.8% and micro-hydro 24.3%. Biomass and hydrogen storage both accounted for 6% and 5%, respectively, particularly in periods when other sources were not available. The lessons learned from these findings offer valuable input for shaping future energy

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policy and represent a consultable kit to be used in similar areas, as well as a direction for the next stages of the hybridization process on advanced energy systems for further research.

Keywords: hybrid, HOMER Pro, hydro, biomass, hydrogen storage

1. Introduction

1.1 Problem background

The research addresses the issue of limited access to reliable electricity in rural and remote areas, particularly in developing countries, where traditional energy sources are either inaccessible due to geographical constraints or are not financially viable to extend. Conventional fossil fuel energy sources are rapidly depleting and contribute to climate change, while renewable power sources, like solar, wind, and hydropower, face challenges due to their intermittency. This leads to an unreliable power supply in rural villages. The study seeks to overcome these limitations by proposing a hybrid energy system that integrates solar, biomass, and micro-hydro power generation, along with hydrogen energy storage, to provide a sustainable and reliable electricity solution for rural areas.

1.2. Motivation

Overcoming constraints and poor or no power access to rural areas are essential to the development of such regions, life quality, and sustainability. Uneven power supply at various locations obstructs vital services such as education, health, and communication necessary for development of society. Designing of a hybrid energy system aims to minimize reliance on fossil energy sources; minimizing the environmental impact with the provision of a sustainable and renewable energy generation method so as to ensure sustainable energy accessibility. Additionally, it offers a pathway to energy security, supporting rural economies, and potentially alleviating energy poverty, while contributing to global climate change mitigation efforts.

1.3. Literature reviews

Numerous studies have explored hybrid energy systems, each addressing various configurations and optimization strategies. However, this review will focus specifically on studies that closely align with the hybrid system investigated in this research, ensuring relevance and direct applicability to the study's objectives.

Ceglia et al. (2023) evaluated the feasibility of a Renewable Energy Community in Northern Italy by analyzing real energy consumption data. They designed a hybrid system that integrates biomass cogeneration, hydropower, and photovoltaics, optimizing system layouts. Their results indicate a 20.3% increase in renewable electricity usage, a 68.1% fulfillment of thermo-electric demand via biomass, reduced grid dependency, and an 18.5% decrease in CO_2 emissions. Assouo et al. (2025) proposed a hybrid renewable energy system model integrating photovoltaics, biomass generation, and battery storage to power remote regions in equatorial climates. Using HOMER software, they conducted a techno-economic analysis to reduce the net present cost while ensuring reliability. Their findings indicate that the solar with biomass and battery storage system is the better cost-effective, with a power deficiency probability of 5.08% for domestic demand and 3.07% for commercial demand. Additionally, cycle charging proved more economical than load-following, and sensitivity analysis highlighted solar irradiation as a key cost factor. Osalade et al. (2022) conducted a feasibility and techno-economic analysis of an off-grid hybrid system integrating solar PV, biomass, diesel, and battery storage for rural electrification in Kajola, Nigeria. Using HOMER software and real-world data, they identified the PV-BG-BB combination as the optimal configuration, achieving a 100% renewable energy fraction with a Levelized Cost of Energy of \$0.178/kWh. The system supplies an average power of 52.7 kW and meets a daily demand of 483.71 kWh. Their findings provide a reference for stakeholders and investors in designing sustainable rural electrification systems. Palej et al. (2019) conducted a comprehensive analysis and optimization of a grid-connected photovoltaic PV-wind hybrid system. The system was modelled using real-world components and evaluated using annual experimental data. The research employed multi-objective optimization with two main criteria: economic (minimizing the cost of energy, COE) and environmental (minimizing CO_2 emissions). The findings demonstrate the importance of trade-off analysis in designing hybrid systems. The economically optimized configuration resulted in lower energy costs but relatively higher carbon dioxide emissions, while the environmentally optimized configuration achieved lower emissions but with higher system costs. Dewi et al. (2025) developed a Smart Integrated Aquaponics technique that integrates a hybrid solar-hydroplane station with AI-driven forecasting and IoT-based observing to enhance aquaponics efficiency. Using PV and micro-hydro energy for energy forecasting and for monitoring fish and plant growth, the system ensures resource optimization and scalability. Experimental results demonstrated stable power generation, improved water quality, and high classification accuracy for fish and plant monitoring. Al-Hafidh and Ibrahem (2013) examined the viability of using a hybrid clean energy system combining wind-turbine and solar PV power to supply residential loads in Mosul, Iraq, a region geographically close to the current study's focus area. The study utilized HOMER software to optimize the system for three scenarios, considering off-grid, on-grid, and a system integrating solar water heaters. The results highlighted the inefficiency of wind energy in this region due to low average wind speeds, rendering the use of small wind turbines uneconomical. The study emphasized that, in similar areas, solar power remains the more viable option, with wind energy showing no substantial economic benefit. Allouhi (2024) designs and optimizes a hybrid renewable energy system (HRES) for Ouenskra, Morocco, combining a photovoltaic array, a wind power station, a battery storage bank, and a micro-hydropower plant. The system aims to provide clean electricity and green transportation using fuel cell bikes. The optimized system shows high economic feasibility, with a Net Present Cost (NPC) of $473.6k and a Cost of Electricity (COE) of $0.147/kWh, with solar energy contributes 60% and the hydroelectric power plant contributes 40%. The system also satisfies hydrogen needs for fuel cell bikes. Sensitivity analysis showed reduced costs with higher solar potential, while wind variability had a minimal impact. Jagtap et al. (2019) investigated a multi sources renewable energy system integrating PV, biomass, hydro, and battery storage to meet electricity demand in rural areas. Using HOMER software, they simulated different configurations and optimized the system size for maximum efficiency. Meteorological data from Panahalghar village was utilized for solar radiation input. The results demonstrated that the proposed hybrid system effectively meets energy demand while minimizing costs, highlighting its potential as a sustainable and cost-efficient solution for rural electrification. Ibrahim et al. (2024) demonstrates that hydrogen storage is more suitable than batteries for off-grid and hot regions, particularly for nighttime irrigation systems. The solar-hydrogen closed--loop fuel cell system showed higher efficiency related to diesel generators and batteries, offering a 9% cost reduction and zero carbon emissions. The findings suggest that hydrogen storage is a more reliable and efficient solution for remote, energy-scarce areas.

1.4. State of the art and limitations

A review of previous studies indicates that most research on hybrid energy systems has been conducted in environments that differ significantly from the study area in terms of climate and geography. Furthermore, no study has been identified that examines a hybrid system integrating solar, hydro, and biomass energy with hydrogen storage. While similar systems were studied in (Allouhi 2024) and (Jagtap et al. 2019), they relied on battery storage. However, according to (Ibrahim et al. 2024), battery storage is deemed an unreliable solution in developing countries with hot climates, and hydrogen storage is recommended as a more suitable alternative. Since the performance of hybrid energy systems is highly influenced by geographical location, climatic conditions, and the specific mixture of renewable power sources used in the system, the direct applicability of findings from previous studies to the current study area cannot be assumed. Therefore, an independent evaluation of a different hybrid system is essential to ensure its feasibility and effectiveness. The following research addresses this important gap by proposing a novel hybrid system suitable for such situations and assessing its performance. The findings aim to provide valuable guidance for the research community involved in developing hybrid renewable energy systems and to support energy policymakers in formulating effective energy solutions for remote areas.

1.5. The research contribution

This research presents a novel hybrid renewable power system that integrates a photovoltaic array, a micro-hydroturbine, and a biomass generator with a hydrogen storage unit, as illustrated in Figure 1. Unlike conventional systems in the literature that rely on traditional battery storage – often demonstrating suboptimal performance in hot climates – this proposed configuration leverages hydrogen storage to enhance efficiency and reliability. Using HOMER Pro, the study identifies the optimal energy mix to maximize efficiency while minimizing system size. This approach ensures a continuous power supply to the load and effectively mitigates the power fluctuation issues commonly associated with standalone renewable sources.

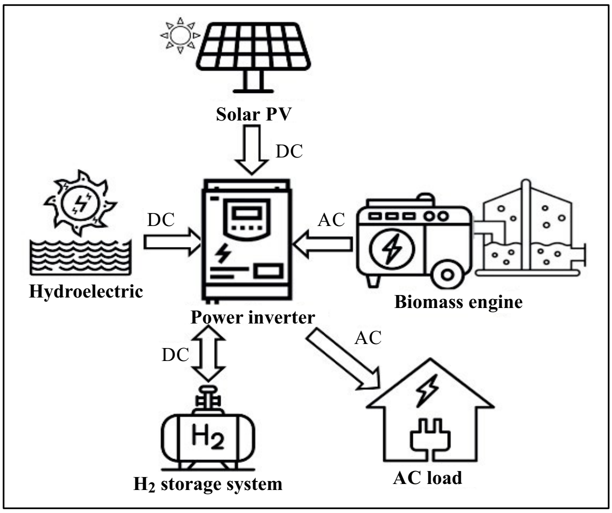

Fig. 1. Illustrative diagram of the proposed hybrid system

Rys. 1. Schemat ilustrujący proponowany system hybrydowy

1.6. Justification

There are indeed several reasons why the proposed solution in this case is a pragmatic and justified approach. Firstly, it is a green energy source, consistent with global energy policies.

Many other countries, like Iraq, are also committed to the Paris Climate Agreement and have adopted the United Nations' Sustainable Development Goals. Second, the system takes advantage of the diversity of renewable energy sources to alleviate the intermittency challenge that is often faced by renewables (Maggu et al. 2024). Solar energy generates energy in the daytime, small hydropower plants work during the snow melting season, and biomass generates energy in the harvest season. Such diversity significantly increases the system's overall reliability (Allouhi 2024). Third, hydrogen can be stored effectively to provide backup that can be scaled to fill in the gaps of renewable services when there are insufficient sources. Hydrogen storage is generally preferred in the long term, especially in hot regions, as it is often more reliable and economical than batteries (Ibrahim et al. 2024). Lastly, the system acts as an independent power system, making it better suited for rural regions without access to conventional infrastructure and centralized power networks (Bhimaraju et al. 2024).

1.7. Thesis statement

This article examines the urgent challenge of unreliable and inaccessible electricity in remote regions with arid climates in developing countries, where conventional energy infrastructure is either not viable or logistically untenable. The proposed hybrid power system is intended to overcome the restrictions imposed by the fluctuaton nature of renewable energy sources. It is a reliable electricity solution for remote regions in hot climates, integrating solar, biomass, micro-hydro generation, and hydrogen-based energy storage. The methodology involves field surveys and computer simulations. In this manner, HOMER Pro software is utilized to best the optimal hybrid system configuration with enough energy to meet the loads without powered interruptions. The anticipated results are a reliable power source that will have little environmental footprint. This has great implications for improving energy access in rural areas, providing a scalable model in similar places, boosting economic development, in addition to also contributing to the research community's work in advancing hybrid energy systems.

2. Methods

2.1. Study methodology

The three main methodological approaches used were field surveys, computer simulations, and quantitative data analysis. Firstly, the field survey was done to find out the various natural energy resources available in the area and gathered all the required data. The results showed that the region has a high availability of solar energy and a moderate availability of biofuel, mostly as seed harvest residues. Forest hydrology reveals that the winter peaks of the nearby river tributary swelled so much from spring to summer due to snowmelt in neighboring northern regions. The field observations played a critical role in defining the elements of the proposed hybrid system. Then the system was evaluated using computer simulations. Last a full analysis was performed on the simulation results to extract some insight into the system's response. Specifics of the simulation design, followed by the results obtained thereafter, are discussed in the upcoming sections for further analysis.

2.2. Simulation tool

The working of the proposed system is analysed using HOMER Pro, an advanced simulation platform introduced by the National Renewable Energy Laboratory (NREL), USA. HOMER Pro – a tool for modeling complex hybrid renewable energy systems (Oladeji et al. 2021). This allows for the integration of a wide array of renewable energy sources, as well as advanced energy storage technologies, to size, simulate, and optimize hybrid power systems (Hassane et al. 2022). However, it enables extensive performance comparisons, despite being based on a large variety of system configurations (Hüner et al. 2025).

2.3. Model description

The planned model has been simulated using HOMER Pro, as shown in Figure 2. The system consists of multiple renewable energy sources: a PV solar array, a micro-hydropower plant, a biomass generator, a power converter, and a hydrogen storage system (which consists of a fuel cell, an electrolyzer, and a hydrogen tank). Solar power generates electricity during the day, while micro-hydro contributes during snowmelt periods. Biomass provides a stable energy supply during the harvest season. Additionally, hydrogen storage serves as an efficient long-life backup, ensuring a continuous electricity supply when renewable sources are not generating power.

The power generated from PV system is expressed by Equation (1) (Katsivelakis et al. 2021; Dong et al. 2025):

$$P_{pv} = Y_{pv} \cdot f_{pv} \left[\frac{\bar{G}_T}{\bar{G}_{T,STC}} \right] \left[1 + \alpha_P \left(T_C - T_{C,STC} \right) \right] \tag{1}$$

where:

Y_{PV} – the rated capacity of the *PV* array, meaning its power output under standard test conditions [kW],

f_{PV} – the *PV* derating factor [%],

G_T – the solar radiation incident on the *PV* array in the current time step [kW/m^2],

$G_{T,STC}$ – the incident radiation at standard test conditions [1 kW/m^2],

α_P – the temperature coefficient of power [%/°C],

T_c – the *PV* cell temperature in the current time step [°C],

$T_{c,STC}$ – the *PV* cell temperature under standard test conditions [25°C].

Additionally, the electrical power output of the hydro turbine calculated using the following (Guimarães et al. 2024; Rodríguez et al. 2025):

$$P_{hyd} = \frac{\eta_{hyd} \cdot \rho_{water} \cdot g \cdot h_{net} \cdot \dot{Q}_{turbine}}{1000\ w / kw} \tag{2}$$

where:

P_{hyd} – power output of the hydro turbine [kW],

η_{hyd} – hydro turbine efficiency [decimal],

ρ_{water} – density of water [1000 kg/m^3],

g – acceleration due to gravity [9.81 m/s^2],

h_{net} – effective head [m],

$\dot{Q}_{turbine}$ – hydro turbine flow rate [m^3/s].

Moreover, the power output of the biomass generator is calculated using the following formula (Tulu et al. 2022):

$$P_{gen} = \frac{\eta_{gen} \cdot m_{fuel} \cdot LHV_{fuel}}{3.6} \tag{3}$$

where:

η_{gen} – generator efficiency,

m_{fuel} – the mass flow rate of the fuel [kg/hr],

LHV_{fuel} – the lower heating value (a measure of energy content) of the fuel [MJ/kg] (Arifin et al. 2023).

The factor of 3.6 arises because 1 kWh = 3.6 MJ (Rahimi et al. 2019).

The previous formulations, shown in Equations (1), (2), and (3), are based on the methodology provided by the official HOMER Pro documentation (HOMER Pro 2025).

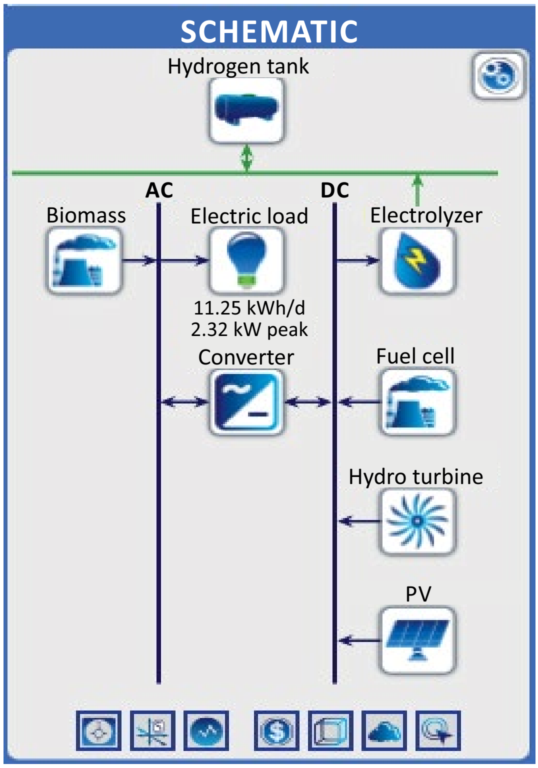

Fig. 2. The simulation model of the hybrid system as shown in HOMER Pro

Rys. 2. Model symulacyjny systemu hybrydowego przedstawiony w programie HOMER Pro

2.4. Input Parameters

The simulation model incorporates multiple input parameters, which are outlined in Table 1 below. The primary source of input data is the field survey, supplemented by data obtained from the HOMER software website, which serves as a key reference for acquiring relevant input parameters.

2.5. Boundary conditions

In the computer simulations, it is essential to account for external factors that influence the model's performance but remain beyond the handling of the model designer (Khather et al. 2024). Key factors in the proposed model include solar radiation, geospatial coordinates,

Table 1. Technical parameters of the proposed hybrid system

Tabela 1. Parametry techniczne proponowanego systemu hybrydowego

Technical Parameters		
Equipment	Parameter	Value
Solar panel	Electrical bus	DC
	Derating factor	80%
	Life time	15 years
	Panel slope and azimuth	36.36° and 0° respectively
	Ground reflectance	12%
	Efficiency	17%
	Temperature coefficient	–0.460%/°C
Hydroelectricity	Electrical bus	DC
	Design flow rate	35 L/s
	Available head	4 m
	Efficiency	80%
	Min flow ration	50%
	Max flow ration	150%
	Pipe head loss	15%
Fuel Cell	Electrical bus	DC
	Fuel	H2
	Intercept coefficient	$3 \cdot 10^{-4}$ (kg/hr/kw rated)
	Life time	10,000 hr
	Lower heating value	120 MJ/kg
Electrolyzer	Efficiency	85%
	Life time	15 years
	Electrical bus	DC
Hydrogen tank	Initial tank level	10% relative to tank size
	Life time	20 years
Biomass	Minimum load ratio	50%
	Life time	20,000 hr
	Minimum running time	zero minutes
	Fuel lower heating value (LHV)	5.5 MJ/kg
	Fuel curve slop	2 kg/hr/kW
Hybrid converter	Life time	20 years
	Inverting efficiency	95%
	Rectifying efficiency	90%

streamflow data, ambient temperature, and available biomass fuel. This study focuses on Karse Village, located in northwest Iraq, at a latitude of 36°7.2′ N and longitude of 41°47.7′ E, with an altitude of 1,100 meters above sea level (Google Earth 2025). Due to this geographical positioning, the region experiences an average global solar radiation of 4.85 kWh/m^2/day and an annual average ambient temperature of 18.6°C (Atmospheric Science Data Center 2025). Additionally, the measuring during the field survey reported available biomass is approximately 600 kg/day, while the yearly average stream flow is 32.08 L/s, as illustrated in Figure 3.

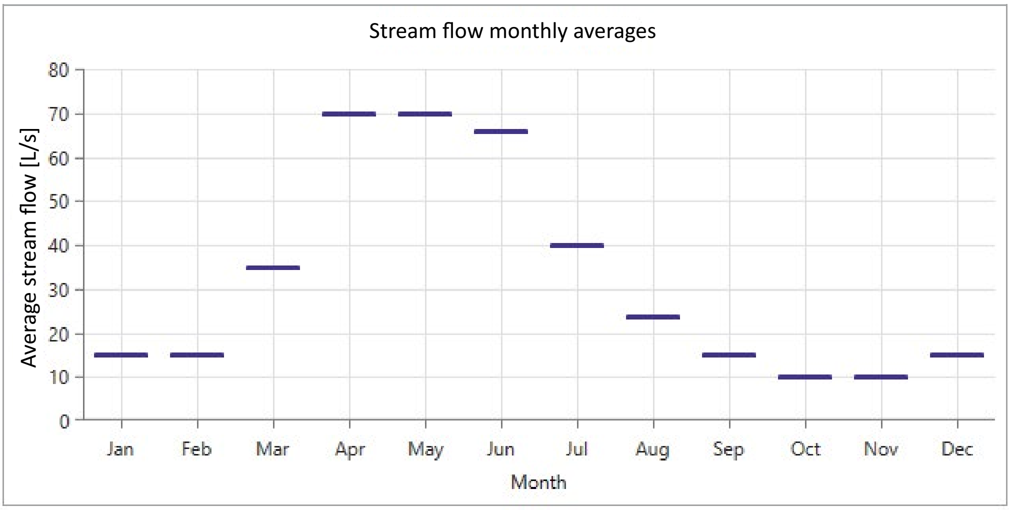

Fig. 3. The annual average stream flow for the hydro turbine model

Rys. 3. Średni roczny przepływ strumienia dla modelu turbiny wodnej

2.6. Simulation settings

It is essential to define the central simulation parameters that dictate the model's performance. These parameters include some configurations and conditions that closely reflect real-world scenarios (Ibrahim et al. 2022). Table 2 provides a summary of the key simulation parameters in HOMER Pro, offering a clear understanding of how the study accurately represents the proposed hybrid system.

Table 2. The simulation setting parameters

Tabela 2. Parametry ustawień symulacji

No.	Setting Parameters	Value
1	System design precision	0.01
2	Allowed capacity shortage	0%
3	Load value in certain time step	10%
4	Time step	60
5	Simulation per optimization (maximum)	10,000

2.7. Simulation procedure

HOMER Pro utilizes a comprehensive analytical methodology to model and optimize various components of energy systems, including solar PV arrays, hydrogen storage units, biomass engines, and hydroelectric plants (Babu et al. 2023). The analysis begins with defining the input data, which contains technical specifications, simulation parameters, constraints, load profiles, and the selection of fitness functions (Said et al. 2024; Khalil et al. 2021). During the simulation, system limitations are assessed, and configurations are continuously adjusted to achieve the most optimal system design (Efremov et al. 2025). The entire workflow is visually represented in a structured flowchart, as shown in Figure 4.

2.8. Model validation

The system proposed in this article is a multi-source energy model; these types of systems are inherently complex to validate through analytical methods (Chen et al. 2025). Moreover, no existing model in the literature has been developed and validated in a manner that allows direct comparison. As a result, verifying the accuracy of such a system presents significant challenges.

Considering these aspects, the simulation platform selected for utilization was HOMER Pro, due its high functionality concerning autonomous managing of component coupling processes, energy flow matters, and system optimization (Basnet et al. 2023). By automating this process, you don’t have to intervene as much, reducing errors which can happen in model development. Therefore, the validity of the model is largely related to the validity of the input data given to HOMER Pro. Moreover, a sensitivity analysis has been performed, it is a very common approach for validation such systems. Involves changing the crucial parameters in the model one after the other and monitoring their effects on system performance (Most et al. 2024). This helps in evaluating the behavior of the model and pin-point any abnormal or wrong responses in the

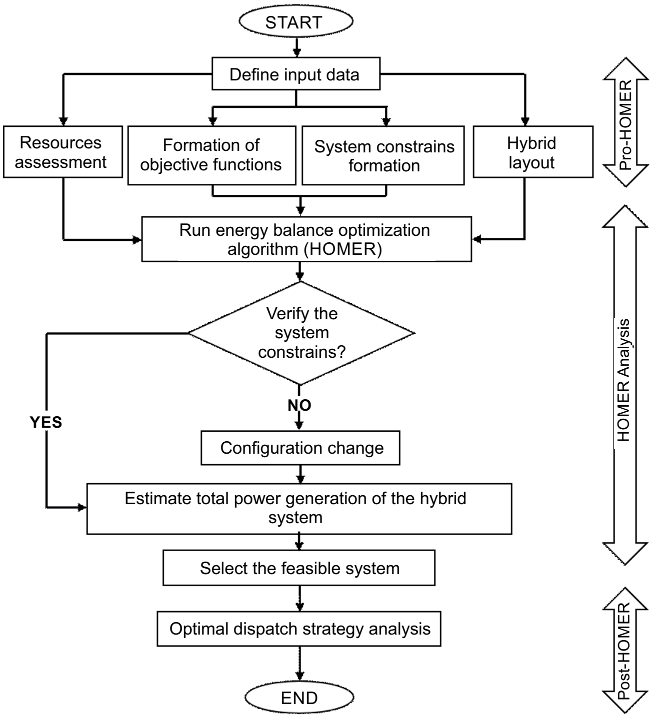

Fig. 4. Illustration flowchart showing the simulation process

Rys. 4. Schemat blokowy ilustrujący proces symulacji

individual component of the system. Exemplar parameters included the solar array temperature coefficient (%/°C), fuel cell crossover coefficient (kg/h/rated kW), hydro turbine available pressure (m^3), and the biomass engine minimum calorific value (MJ/kg).

By evaluating the consistency between these controlled parameter variations and the model's expected performance, it was confirmed that the model behaves as intended. This reinforces the model's validity and reliability.

3. Results and discussion

The annual performance of the presented hybrid system is computed using HOMER Pro simulation software. Since the different seasons can have quite varying environmental attributes, a simulation across an entire year was needed in order to capture all environmental possibilities. The direct impacts of solar radiation, temperature, rainfall, and snowmelt fluctuations on the power output of renewable energy sources, these also define the optimum configuration and mixing of hybrid system components in the HOMER Pro optimization process, and are therefore critical.

HOMER determined the optimum configuration of the hybrid system as shown in Figure 5:

- photovoltaic panels with a capacity of 12 kW,
- a maximum power point tracker (MPPT) with a capacity of 10 kW,
- a fuel cell with a capacity of 2 kW,
- a biomass generator with a capacity of 5 kW,
- a hydro turbine with a capacity of 1.37 kW,
- an electrolyzer with a capacity of 3 kW,
- a hydrogen storage tank with a capacity of 30 kg.

Fig. 5. Optimization result of the hybrid system configuration

Rys. 5. Wynik optymalizacji konfiguracji systemu hybrydowego

Notably, all proposed components of the hybrid system appeared in the optimized configuration. None were excluded by HOMER Pro's optimization algorithm, which affirms the validity of the proposed design and the accuracy of the field survey at the beginning of the study. These preliminary assessments played a major role in shaping a practical and effective system configuration. Figure 6 presents the monthly contributions of each power generation

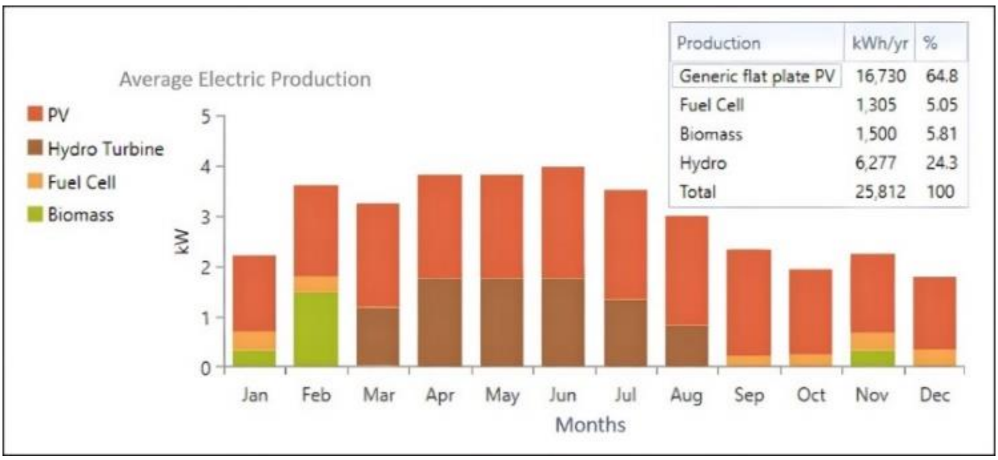

Fig. 6. The average monthly electrical energy production from the hybrid system

Rys. 6. Średnia miesięczna produkcja energii elektrycznej z systemu hybrydowego source within the hybrid system. As expected, the contribution varies month by month due to the impact of changing weather conditions on each renewable source. This fluctuation highlights the complementary nature of the energy sources, ensuring a continuous and reliable power supply to the load throughout the year.

Solar energy had the highest share, contributing 65% of the total power generation. This dominant role is attributed to its year-round availability, supported by the region's strong solar resource, averaging 4.8 kWh/m^2/day, as previously discussed. Hydropower contributed approximately 24%, playing a vital role during the six-month period from March to August, when river flow levels are sufficient to operate the hydro turbine efficiently. During these months, the system was able to meet demand without relying on biomass energy. Biomass energy became a key source during the colder winter months when river flow was limited (due to freezing its sources). It contributed around 6%, working in conjunction with the fuel cell and solar power. Meanwhile, the hydrogen storage system provided about 5% of the total energy, proving essential during periods when the other sources could not fully meet the load. This ensured the hybrid system maintained an uninterrupted energy supply throughout the year under all environmental conditions.

Additionally, the response of the fuel cell on selected days in September, defined as a hot month in the study region, can be seen in Figure 7. The results show that the fuel cell maintains consistent and stable performance even under harsh ambient temperature conditions. Such results stress the potential benefits of using hydrogen storage in the proposed hybrid system as a suitable replacement for conventional batteries, consequently improving the reliability and operational resilience of the hybrid system. It is also worth noting that the renewable energy penetration rate is significantly high, indicating a surplus of energy during certain periods. This surplus could potentially be exported once the electrical grid is extended to reach the region in the future.

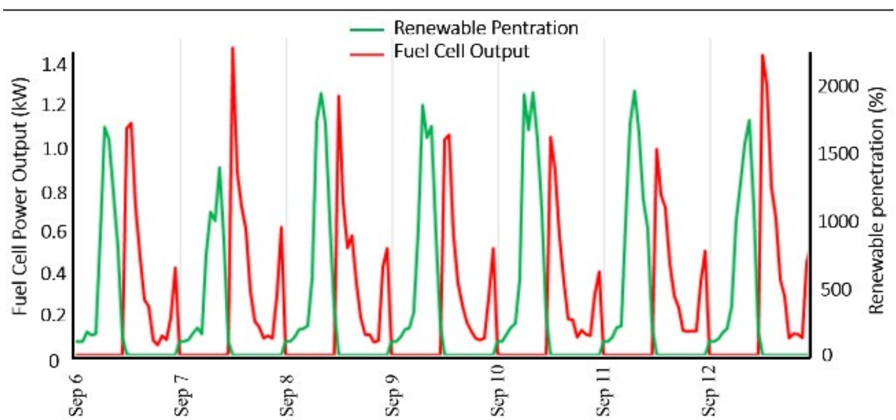

Fig. 7. A sample day in September showing the fuel cell output power and the percentage of renewable penetration

Rys. 7. Moc wyjściowa ogniwa paliwowego oraz procentowy udział odnawialnych źródeł energii na przykładzie dnia we wrześniu

Conclusion

The study successfully presents a design of a novel hybrid renewable energy system powered via solar PV, micro-hydro, and biomass, while integrated with hydrogen storage to fulfill the energy demand. It tackles the pressing problem of unreliable access to electricity, especially in developing countries where conventional energy infrastructure is lacking.

This proposed hybrid energy system is designed to eliminate conventional batteries and replace them with hydrogen storage. A stable performance of the fuel cell has been reported even under high ambient temperature conditions, highlighting the compatibility of hydrogen storage in hot climates. By adopting this approach, the overall accessibility and reliability of the system are increased, which supports the system to be consistent with climatic and geographical conditions of multiple remote locations.

The simulation results show that the contribution of solar energy is 64.8%, hydropower is 24.3%, biomass is 6%, and hydrogen-powered fuel cells account for 5%, with these sources providing continual and reliable energy.

This study addresses an important unfilled niche in the literature by examining a hybrid configuration that has not previously been studied. By incorporating multiple renewable sources, the design abates the intermittency problems of each unique resource in order to enhance energy security and realize long-term sustainability. These findings provide a scalable framework for other regions and contributing to the economic development of the region while advancing the research community's ambition in hybrid energy system innovation.

In summary, this combination of power sources of solar, hydro, biomass, and hydrogen storage, together provides an effective, scalable, and environmentally sustainable solution for remote and rural electrification in hot environment, enabling a better quality of life and increasing economic progress across a variety of communities and encouraging the research community to be deeply explored in this type of hybrid system.

The author extends his thanks and gratitude to the University of Mosul, for providing the facilities that enhanced the quality of this research.

This research was funded by University of Mosul.

The Author has no conflicts of interest to declare.

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Symulacja hybrydowego systemu energetycznego wykorzystującego energię słoneczną, wodną i biomasę z magazynowaniem wodoru w celu optymalnego zaspokojenia zapotrzebowania na energię

Streszczenie

Niestabilność naturalnych źródeł energii odnawialnej stanowi poważne wyzwanie dla dostaw energii elektrycznej na obszarach wiejskich, które są uzależnione od samodzielnych systemów energii odnawialnej. Chociaż często stosuje się magazynowanie energii w bateriach, aby rozwiązać ten problem, ma ono kilka ograniczeń, zwłaszcza w regionach o gorącym klimacie, gdzie wydajność i trwałość są ograniczone. Zapewnienie niezawodnej i dostępnej energii elektrycznej na tych obszarach ma kluczowe znaczenie dla promowania rozwoju gospodarczego i poprawy jakości życia. Niniejsze badanie ma na celu opracowanie nowatorskiego hybrydowego systemu energetycznego, który zapewni zrównoważone i niezawodne rozwiązanie energetyczne, integrując fotowoltaikę słoneczną (PV), mikroelektrownie wodne, biomasę i magazynowanie wodoru w jednym systemie hybrydowym. Ta konkretna kombinacja nie była dotychczas badana w literaturze przedmiotu. Po przeprowadzeniu kompleksowych badań terenowych w celu oceny dostępnych zasobów naturalnych i zaprojektowania systemu, proponowany model został następnie zasymulowany w oprogramowaniu HOMER Pro. Wyniki testów wykazały wysoki stopień kompatybilności między badanymi źródłami energii, z których każde w znacznym stopniu przyczyniało się do ciągłego zaopatrzenia w energię przez cały rok. Największy udział miały energia słoneczna PV (64,8%) i mikroelektrownie wodne (24,3%). Biomasa i magazynowanie wodoru stanowiły odpowiednio 6 i 5%, szczególnie w okresach, gdy inne źródła były niedostępne. Wnioski wyciągnięte z tych ustaleń stanowią cenny wkład w kształtowanie przyszłej polityki energetycznej i stanowią zestaw konsultacyjny, który można wykorzystać w podobnych obszarach, a także kierunek dla kolejnych etapów procesu hybrydyzacji zaawansowanych systemów energetycznych do dalszych badań.

Słowa kluczowe: hybryda, HOMER Pro, energia wodna, biomasa, magazynowanie wodoru