FUTURE HYBRID ENERGY SYSTEM OF PHOTOVOLTAIC AND FUEL CELL FOR KANIFING IN THE GAMBIA

Thesis presented in consideration of partial fulfillment for the requirements of the degree of
BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONICS ENGINEERING/TECHNICAL EDUCATION

Ousman Sanyang
210032204

Akram Ali
210032205

Lamin J Ceesay
210032206

Sarjo Bayo

210032209

Department of Electrical and Electronic Engineering
Islamic University of Technology (IUT)
Gazipur, Bangladesh

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Approved by:

Mr. Muhammad

Supervisor and Assistant Professor,
Department of Electrical and Electronic Engineering,
Islamic University of Technology (IUT),
Board bazar, Gazipur-1704.

Date: ……………..

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Above all, we sincerely thank Almighty allah for his divine mercies that have made it possible for us to successfully accomplish this thesis. We also want to express our profound appreciation to our parents for their steadfast guidance, confidence, and support. We are deeply grateful to our supervisor, Mr. Muhammad, an assistant professor in the Electrical and Electronic Engineering department of the Islamic University of Technology (IUT), Dhaka, Bangladesh. His guidance, support, and inspiration made it possible for us to succeed. He imparted knowledge to us through our frequent encounters and in-depth discussions. He guided us with recommendations and astute critiques. It was helpful to learn from his suggested theoretical framework and other research endeavors. We shall be eternally appreciative to him. We express our gratitude to The National Water and Electricity Company (NAWEC) for their invaluable assistance in shaping the concept for this study by giving insightful information on load requirements and power-related issues faced in the Kanifing Industrial Estate zone. Finally, but no less, we would like to thank and congratulate our classmates for the wonderful and unforgettable times we shared.

Abstract

The present research shows the outcomes of an optimal grid-connected with photovoltaic and fuel cell system design for Kanifing in the Gambia west Africa. The most efficient hybrid renewable power system is chosen by testing its performance and utilizing integrated modeling, simulation, optimization, and control methodologies. The key objective is to design a grid-connected with photovoltaic and fuel cell energy system with high utilization of clean energy, low greenhouse gas emissions, and a low cost of energy to meet the Kanifing's electric load. The performance and cost of the hybrid power system configurations using load executing and phase charging control techniques were assessed using hourly simulations, modeling, and optimization.

Getting electricity is a significant difficulty in Africa. Although there is a lot of potential for using solar energy, there is little investment in renewable energy projects. Thus, a lot of people continue to rely on personal diesel generators, which emit large amounts of pollutants and harm both the environment and people. Situated in the Sunbelt, Gambia is one of the countries in Africa endowed with an extremely high solar irradiation potential. HOMER simulation software was used to determine the optimal configurations and sizes. A comparison is made between several hybrid combinations and a regular system. The studies showed that the suggested system had nearly lowered costs and CO_2 emissions by 39% and 79%, respectively. The annual carbon footprint with avoided CO_2 emissions is approximately 151,751 kg. The outcomes demonstrated that implementing a hybrid power system might be a reliable and profitable way to achieve social and environmental advantages in isolated rural and urban electrification.

CONTENTS

List of Tables

List of Figures

List of Acronyms

AC: Alternating Current

BESS: Battery Energy Storage System

BIPV: Building-Integrated Photovoltaic

CSP: Concentrated Solar Power

DC: Direct Current

DOE: Department of Energy

FC: Fuel Cell

GHG: Greenhouse Gas

PVGIS: Photovoltaic Geographical Information System

PV: Photovoltaic

PEM: Proton Exchange Membrane

SOC: State of Charge

SOFC: Solid Oxide Fuel Cell

TRNSYS: Transient Systems Simulation Software

LCOE: Levelized Cost of Electricity

MPPT: Maximum Power Point Tracking

NPC: Net Present Cost

COE: Cost of Energy

PEMFC: Polymer Electrolyte Membrane Fuel Cell

SC: Super capacitor

H_2: Hydrogen

USD: United States Dollar

kW: Kilowatt

kg: Kilogram

Chapter 1

Introduction

Kanifing is the largest and most populated regions with diversity of industries in the Gambia. Considering an area land surface of nearly 75.5 km^2 and population density of persons per square kilometer the most densely populated in the Gambia increased by 15 percent, these make up the Kanifing the duty-free status to protect against industrial production and to increase sustainability. However, it is difficult for government to provide the Kanifing with sufficient energy. The Ministry of Energy ignored a feasibility study for the development of an environmentally friendly model for Kanifing in the Gambia.

For now, everything all of the Power is generated by The National Grid, which is connected through a high-voltage substation in Kotu power generation to the substation in Kanifing via an undersea cable with two voltages of about 100 and 150 kV, respectively and total energy consumption in Kanifing is 10MW, PEAK is 8MW and OFF PEAK is 6MW. The diversity of industries utilizes all of the grid's energy resources.

1.1 Basic Functionalities of Future Hybrid Energy System of Photovoltaic and fuel cell for Kanifing in The Gambia

The project's goal is to create and put into place a hybrid fuel cell and PV array system in the Gambian city of Kanifing.

The project involves the following steps:

Energy Generation: Creating power with fuel cells and solar panels Batteries are used in energy storage to store excess energy and maintain supply and demand.
Smart algorithms are used in control and monitoring systems to optimize energy flow and utilization. Grid Integration: Enabling two-way energy exchange by linking the hybrid system to the current grid.

Hybrid System Optimization: Employing sophisticated algorithms to enhance the hybrid system's efficacy, dependability, and affordability; Backup Power Supply will offer backup power in the event of system or grid failures.

The safety standards and regulations for renewable energy systems, together with community engagement and education, are as follows: increasing the local community's knowledge of and participation in the advantages of renewable energy.

1.2 Different Aspects of Future Hybrid Energy Systems

The study explores the creation of a hybrid energy system that integrates fuel cell and photovoltaic (PV) technologies for Kanifing, The Gambia. It takes into account multiple factors to guarantee sustainability, dependability, and efficiency. A thorough and well-thought-out hybrid energy system for Kanifing can support environmental preservation, energy security, and sustainable development by taking these factors into consideration. These are several factors to take into account, according to studies.
The project's goal is to create and put into place a hybrid fuel cell and PV array system in Kanifing, Gambia.

The project involves the following steps:
Evaluating the region's solar and fuel cell resources; optimizing system integration and design for optimal dependability and efficiency; and putting in place an energy storage system to store extra energy and balance supply and demand.
Creating management and control systems to synchronize fuel cell and photovoltaic operations and guarantee efficient energy use and looking into ways to produce and store hydrogen for use as a fuel source in fuel cells.
Examining the possibilities for microgrid integration, the influence of the hybrid system on the current energy infrastructure, and analyzing the economy and environment to determine the feasibility and impact of the hybrid system.
Involving and teaching the local population about the advantages of renewable energy and the hybrid system; coordinating the hybrid system with national energy policies and regulations; and promoting laws that encourage the development of renewable energy.

1.3 Background and Motivation

The research presented in this dissertation aims at:

For Literature Reviewand Engagement with various stakeholders, including community members, local authorities, health professionals, and cultural experts to gather diverse perspectives on safety expectations. Currently, there has not been any specific study conducted regarding the renewable energy project on Kanifing.

The extensive study being done on renewable energy technology gives Kanifing hope. Research by [NIGER, LANGKAWISKYCAB and Dawood] shows that hybrid systems that combine fuel cell and solar technology can be successful. The basis of our creative strategy is this research. In light of these difficulties, it is evident that a sustainable energy solution resilient energy in the future**.**

This combination fuel cell/photovoltaic system is assessed for Kanifing system utilizing the real load profile.

Several configurations of hybrid using the actual load profile in the system. Using the HOMER software, multiple hybrid system configurations were simulated in order to compare economic and emission factors (mitigate climate change and air pollution).

These Grid-connected PV/fuel cell, PV/battery, and PV/fuel/battery were the configurations.The results were used as a reference to determine an efficient, dependable and cost-effective system for Kanifing. This will not only enhance the resident's quality of life but also promotes economic development by reducing energy-related constraints. The project aims to display technological innovation by integrating two renewable energy technologies that is photovoltaic (PV) and fuel cells. This combination represents a forward-thinking approach that could set a precedent for similar initiatives in the region.

Background: Kanifing is a growing population of about 800,000 inhabitants and Companies covering an area of 75.5km square with so many factories and industries, Hospitals, universities, schools, commercial outlets etc. According to resent studies it has shown that the consumption rate of Kanifing is 10 megawatts (10MW) with a population increment of 0.5 % annually amounting to 400,000 inhabitants. These demands are making things difficulty for the government to continue providing enough energy for the people of Kanifing Estate. The area of Kanifing is expose to sufficient sunshine even during the raining season. It is expected that by 2050 the population of Kanifing will be approximately 1.2 million required. By incorporating state-of-the-art renewable technology, the Future Hybrid project seeks to close the gap and guarantee both immediate relief and a cleaner more reliable energy source.

.Chapter 2

Introduction

The table below lists the technical components of the sun-panel employed within this framework.

.

PV panels are connected to the DC side and use the photovoltaic effect to generate energy to power the system. The hourly energy production of PV panels is calculated with the temperature and solar radiation readings taken into account. The important parameter for sizing and optimizing a PV power plant is the power output. In this case Mono crystalline Silicon panel will be use because of its high efficiency.

Temperature has an impact on PV module performance since higher temperatures cause them to lose effectiveness. These modules have a temperature coefficient of 0.5%/°C, meaning that a 1°C increase in temperature will result in a 0.5% decrease in power.

2.1 Photovoltaic panel characteristics.

1	**Parameters**	**values**	**unit**
2	Type of Cell	Mono crystalline Silicon	
3	No of Cell	72 in series (6*12)	
4	Maximum Power	300	W
5	Voltage at Pmax- Vmp (V)	32.2	V
6	Open Circuit Voltage -voc(v)	42.4 8	V
7	Current Short Circuit - Isc A)	8.97	A
8	Maximum power current- Imp(A)	9.32	A
8	Module conversion Efficiency	18.44	%
9	NOCT	45 ˚C+-2˚C	
10	Warranties	25	yrs.

Table 1. PV panel characteristics. STC: Irradiance 1000W/m², Cell Temperature25ºC, Air Mass 1.5 https://www.sunketsolar.com/standard-mono-solar-panel/58625260.html

2.2 Alkaline Electrolyser

Table 2. Signify the component parts of the Alkaline Electrolyser. There is an integration of the component to achieved the internal operation.

.No	Names of the components is nel Alkaline electolyser
1	Eletrolyser cell stack
2	Hydrogen Separator Tank
3	Oxygen Separator Tank
4	Hydrogen flange
5	Oxygen flange
6	Lye circulation pump
7	Gas cooler
8	Lye cooler

Table 2 component part of the Nel Alkaline Electrolyser.

2.3 Financial Summary of system

Table 3. compare the cost of different components of cost summary capital cost, replacement cost, fuel cost and total cost.

Cost Summary by Component

Component	**Capital Cost ($)**	**Replacement (10-yr) O&M ($)**	**Fuel Cost ($/kWh)**	**Total Cost ($)**
Generic 100kWh Li-ion	$621,623.65	$77,405	$(1793.83)	$2,621,077.73
Generic 100kWh Lead-acid	$(18)	$0	$0	$(18)
Generic flat plate PV (1)	-$5026.26	-$72.87	$0	-$5292.86
System inverter	-$3186.62	$0	$0	-$3186.62
System	$5,307,122.52	$673,849.90	$(5634.38)	$6,738,065.13

Table 3. Cost Summary by Component

2.4 Results from HOMER software

Figure 1. Photovoltaic power potential in the Gambia

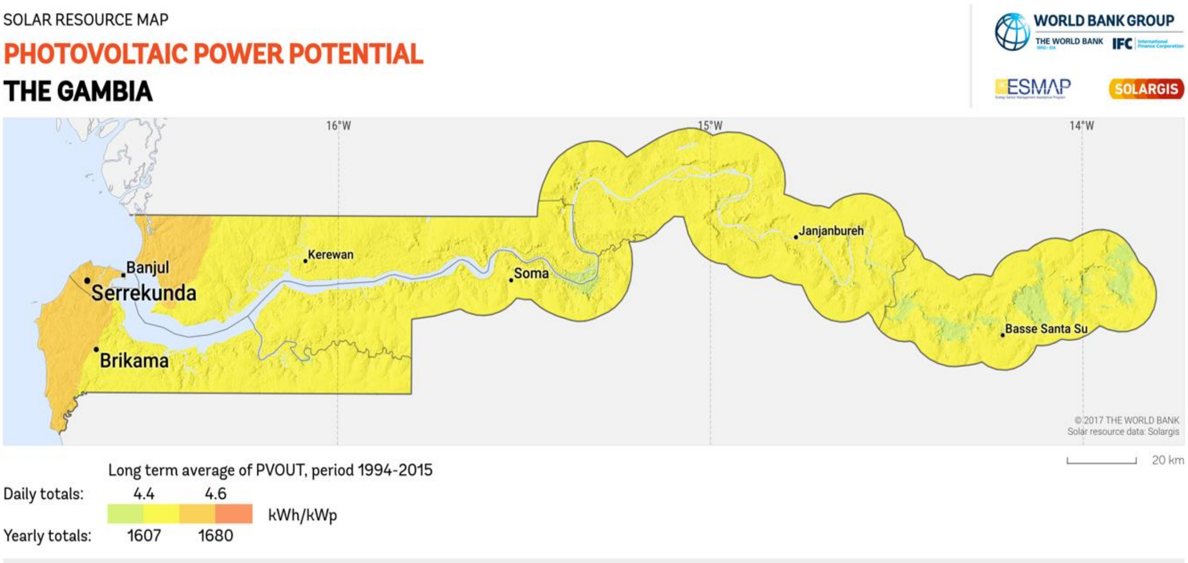


Figure 2. Schematic of the proposed PV/Fuel cell hybrid system with hybrid PV–battery–hydrogen model, imported from HOMER

Modern Engineering Tools use (HOMER software) for system design schematic integrates the components (diesel generator, converter, load, electrolyzer, fuel cell, solarPV hydrogen tank, and battery) in figure 2.

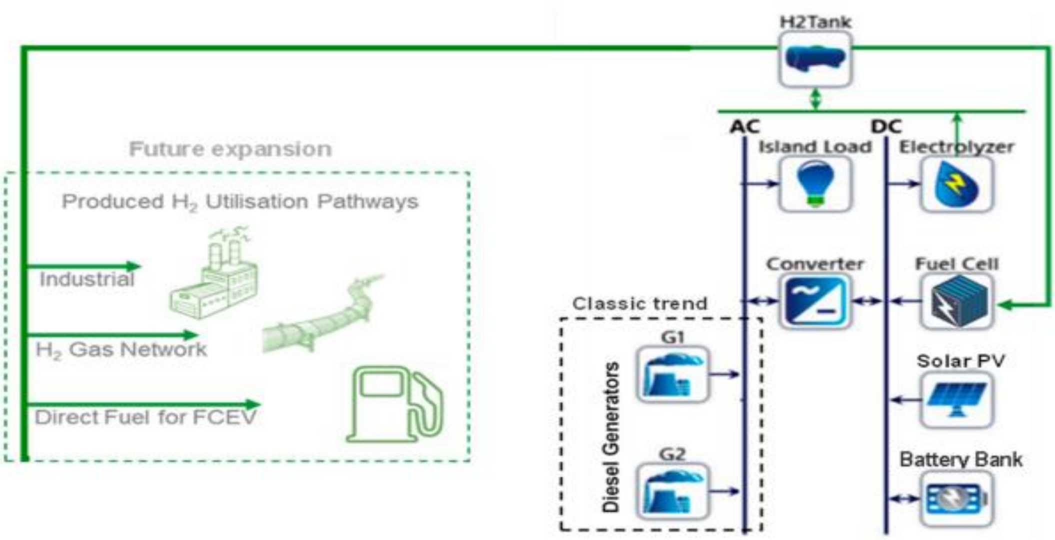
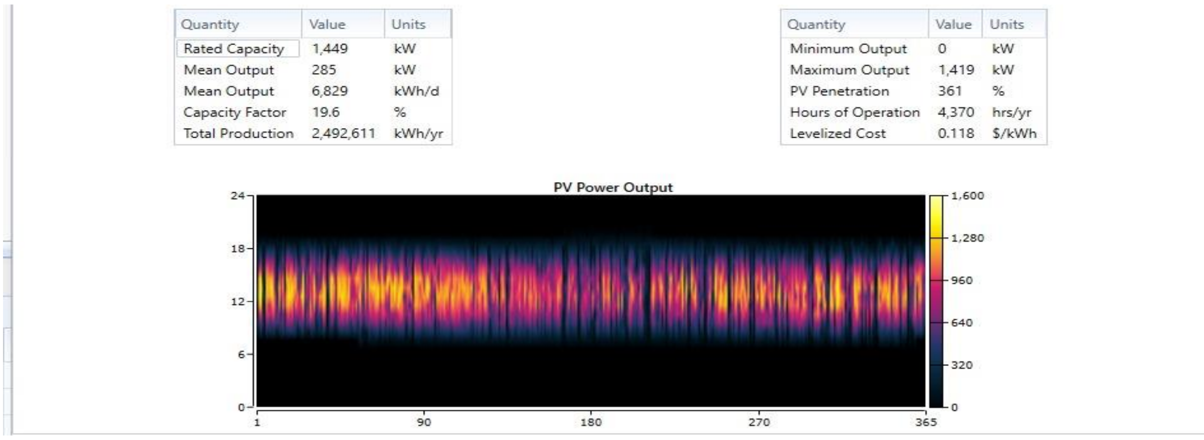


Figure 3. PV power output imported from the homer simulation

Image show in figure 3, provides detailed data on photovoltaic (PV) power output, which directly aligns with our research on a hybrid energy system. It highlights PV panels' total production (2,492,811 kWh/yr.) represents the annual energy output of PV, emphasizing variability due to changing solar conditions and the potential for hybrid integration with fuel cells.

Integration opportunities include sizing the PV array, assessing energy balance, and minimizing grid dependency. Implementation insights involve energy management and optimal configurations.



Quantity	Value	Units
Rated Capacity	1,449	kW
Mean Output	285	kW
Mean Output	6,829	kWh/d
Capacity Factor	19.6	%
Total Production	2,492,611	kWh/yr

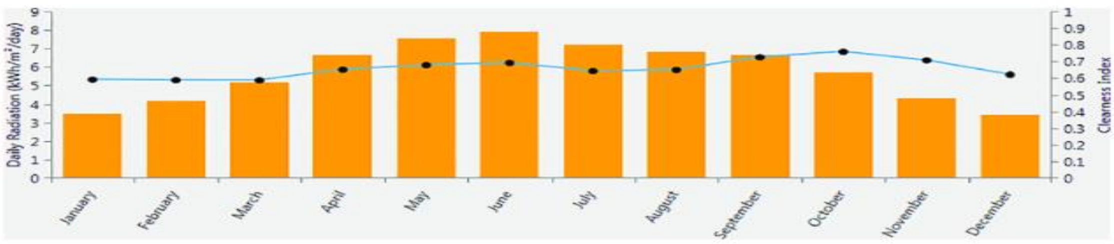
Quantity	Value	Units
Minimum Output	0	kW
Maximum Output	1,419	kW
PV Penetration	361	%
Hours of Operation	4,370	hrs/yr
Levelized Cost	0.118	$/kWh

Figure 4. Mono crystalline Silicon solar fieldhttps://www.energymatters.com.au/monocrystalline-solar-panels/

Figure 5 proposed location of Kanifing community land surface of nearly 75.5 km².

Map of Kanifing

Figure 6 show solar GHI Resource Data and Graphhttps://www.researchgate.net/figure/Solar-GHI-Resource-Data-and-Graph-HOMER-Pro-View



Solar GHI Resource Data and Graph (HOMER Pro View).

Figure 7temperature, solar irradiation, and meteorological information imported from NASA's worldwide data

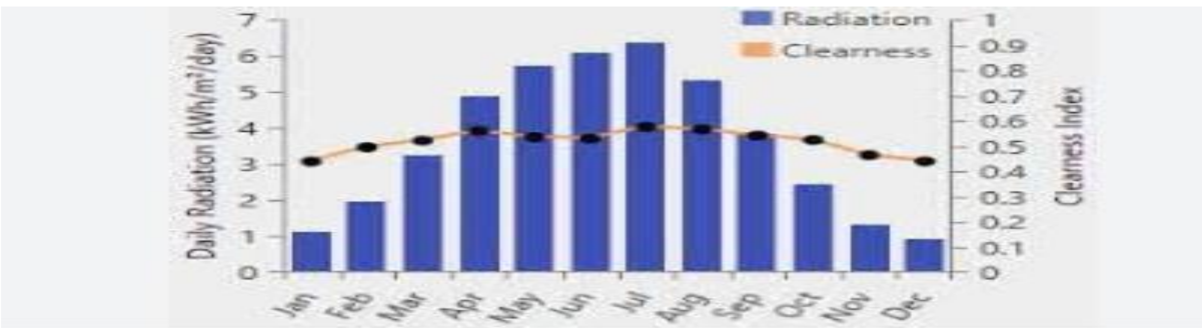


Figure 8. HOMER-Pro software repository have imported inputs modeling (components, parameters load profile, and costs).

Reference Homer Energy, Homer Pro 3.11. Available online: https://www.homerenergy.com/products/pro/docs/3.11/ hydrogen_load.html (accessed on 10 February 2024)

The Methodology isused to Covers load analysis for community's unique requirements, resource analysis (components) and environmental impact of this components (emission of carbon monoxide, load random variability, battery life time, no of tracking system in PV solar etc.)

Figure 9.Fuel cell consumption annually imported from HOMER

Figure 9. Shows below the image consists of two graphs: 1. **Monthly PV Output (Left Box Plot)** and **Fuel Consumption Heat Map**

The left graph shows monthly PV output with vertical blue bars. It reveals seasonal (January to December).

The right graph displays daily and hourly fuel consumption patterns. It's essential for optimizing hybrid system operation.

Help optimize energy systems by balancing solar energy generation and fuel cell usage and grid management strategies for daily and hourly consumption pattern.

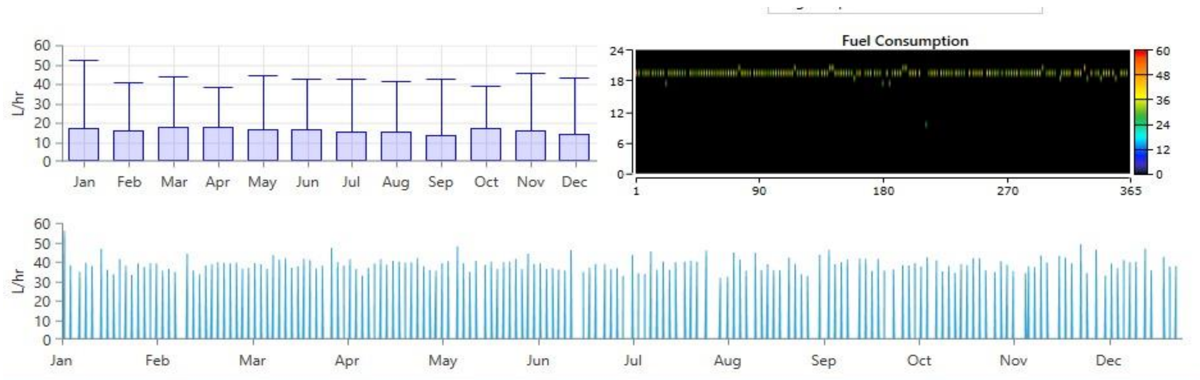


Figure 10. show the clean power hydrogen-power fuel cellhttps://www.energy.gov/eere/success-stories/articles/eere-success-story-fuel-cell-generators-prove-they-can-save-energy

Figure 11. Proposed converter output imported from HOMER

Figure 11 show an image displays two side-by-side bar graphs:

PV inverter output, showing color-coded variations over time. X-axis: days of the year. Y-axis likely indicates power output in kilowatts (785 kW). For understand PV variability for hybrid system design. Rectifier Output is (678,450 kWh/yr.). Shows a similar color pattern. Analyzing both graphs informs PV and fuel cell integration for Optimizing fuel cell integration using rectifier data.

Quantity	Inverter	Rectifier	Units
Capacity	395	395	kW
Mean Output	78.8	0	kW
Minimum Output	0	0	kW
Maximum Output	287	0	kW
Capacity Factor	20.0	0	%

Quantity	Inverter	Rectifier	Units
Hours of Operation	8,748	0	hrs/yr
Energy Out	690,561	0	kWh/yr
Energy In	726,906	0	kWh/yr
Losses	36,345	0	kWh/yr

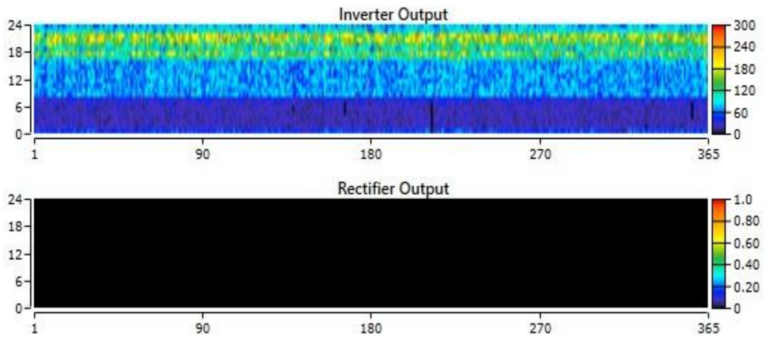


Figure 12. Proposed generator output imported from HOMER

Figure 12. Shows a data has support various aspects related to generator performance and optimization**:**

Total electrical production by the generator is 18,664 kWh.

Data support various aspects are as follows

Economic Analysis: operational (fuel costs, efficiency)

Operational Strategies: (start frequency, operational factor, and capacity load

Integration with Renewable Energy: renewable sources (PV)

Efficiency Optimization: (fuel consumption and efficiency)

Hybrid System Design: (PV and fuel cell integration).

Quantity	Value	Units
Hours of Operation	164	hrs/yr
Number of Starts	164	starts/yr
Operational Life	91.5	yr
Capacity Factor	0.627	%
Fixed Generation Cost	21.5	$/hr
Marginal Generation Cost	0	$/kWh

Quantity	Value	Units
Electrical Production	18,664	kWh/yr
Mean Electrical Output	114	kW
Minimum Electrical Output	85.7	kW
Maximum Electrical Output	182	kW

Quantity	Value	Units
Fuel Consumption	5,874	L
Specific Fuel Consumption	0.315	L/kWh
Fuel Energy Input	195,802	kWh/yr
Mean Electrical Efficiency	9.53	%

Figure 13. Two diesel generators

https://medium.com/@Breadarose/how-are-generators-in-a-diesel-electric-power-plant-connected-to-the-grid-18741e0e22c2

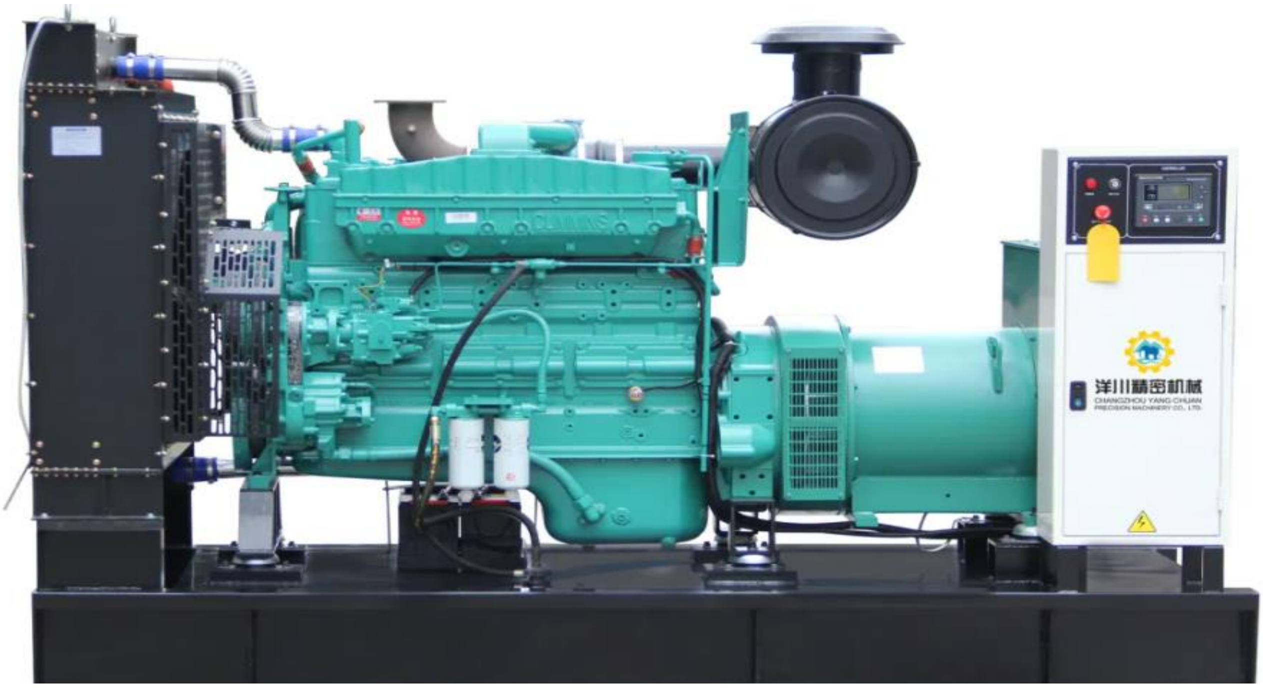


Figure 14. Alkaline electrolyser

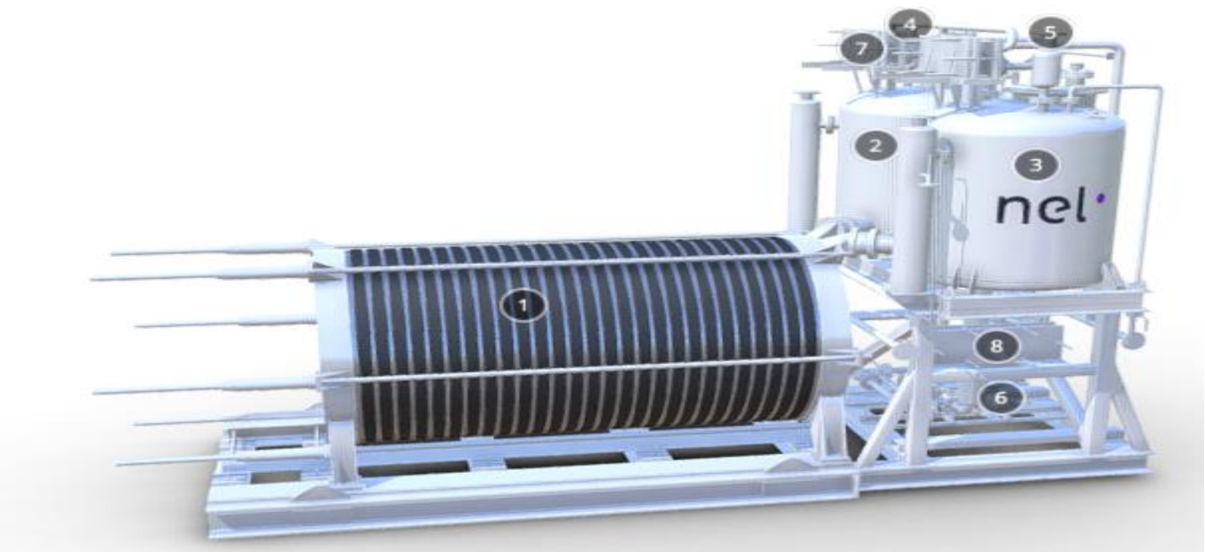


Figure 14. Alkaline electrolyser
https://nelhydrogen.com/product/atmospheric-alkaline-electrolyser-a-series/ (online)

Figure 15. Electrolyzer energy output imparted from the HOMER

Figure 15 shows graph energy production by the electrolyzer throughout the year. Each month's green bar indicates the energy output (13.173MJ) in kilowatts (3.659 kW).
Support discussions on the stability and reliability of electrolyzer performance. Consider how external factors (climate, maintenance) might influence this steady output.

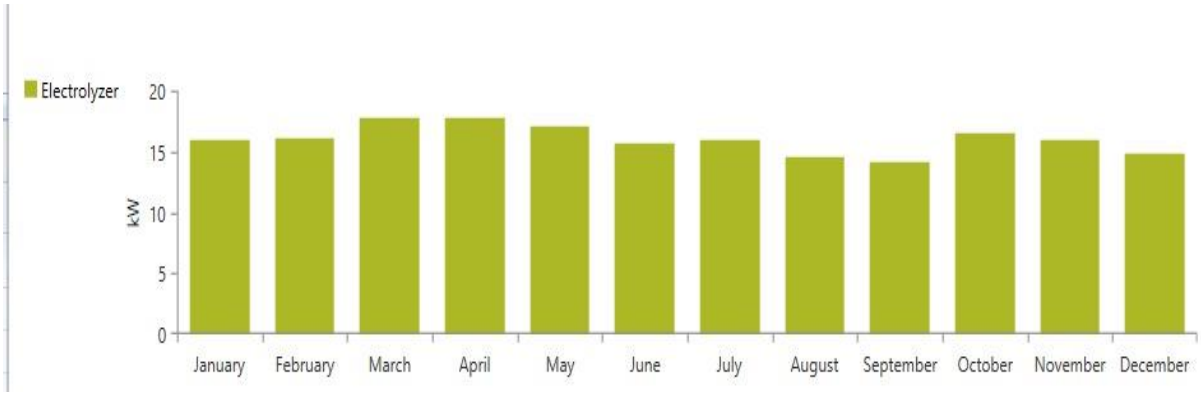


Figure 16. hydrogen storage

https://www.eenews.net/articles/hydrogen-for-heating-is-gaining-steam-is-it-safe/

Figure 17 the proposed hydrogen fuel cell system

Figure 17. show hydrogen output,bar graph in the upper left corner for the frequency of hydrogen storage capacity. Around the lower end (around 100 kg).
Data useful for practical limitations and distribution of hydrogen storage systems.
Energy hydrogen Storage Capacity 3333 kWh and **Tank autonomy:** 42.3 hours Provide quantitative data for evaluating the efficiency and practicality of hydrogen storage.
Monthly Variability box plots (bottom-right) show variations in some measured data across months (January to December).

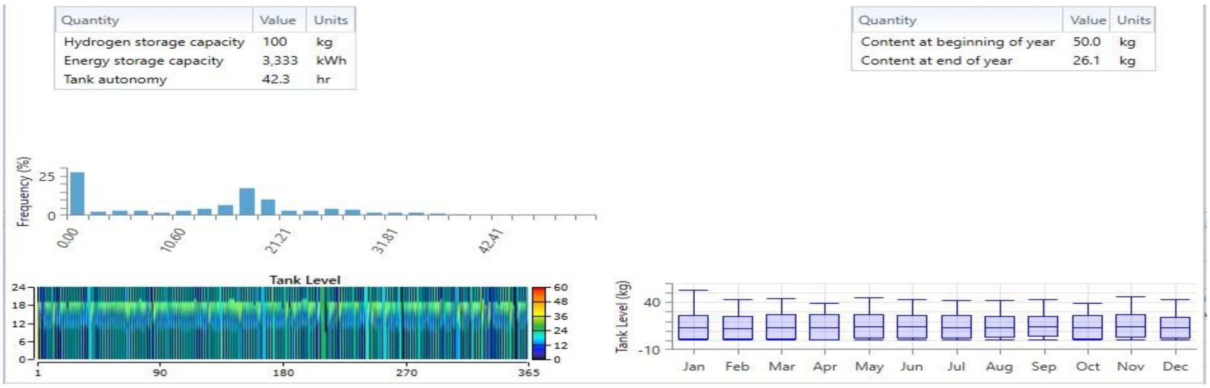


Figure18. The proposed simulation Battery Specifications and Performance

Parameters related to battery performance, quantity, string size, series, parallel, and busvoltage. Like nominal capacity, lifetime throughput, and expected life.
For understanding battery behavior and suitability.
Graph shows the frequency distribution of state of charge percentages at 100% at full charge and Box plot graph displays Monthly Variability for each month December).

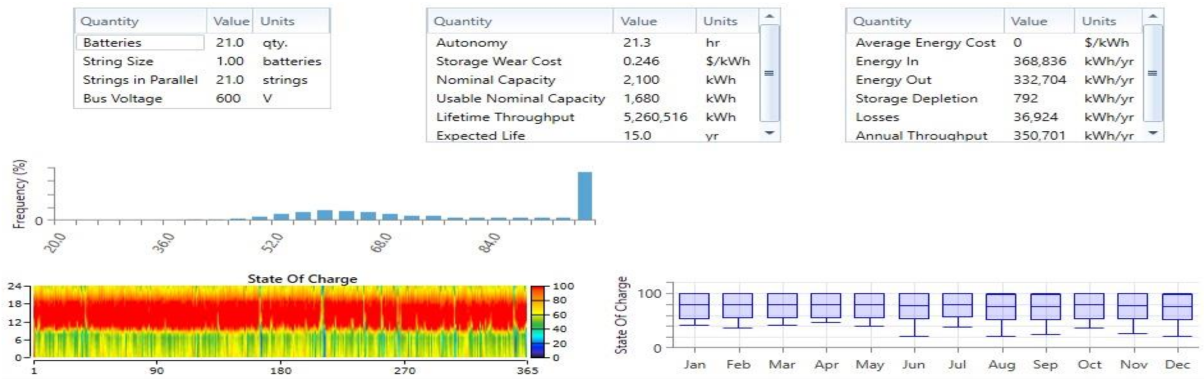


Figure19. Battery

https://www.lithiumion-batteries.com/products/product/group-4d-high-output-12v-150ah-lithium-ion-battery-2

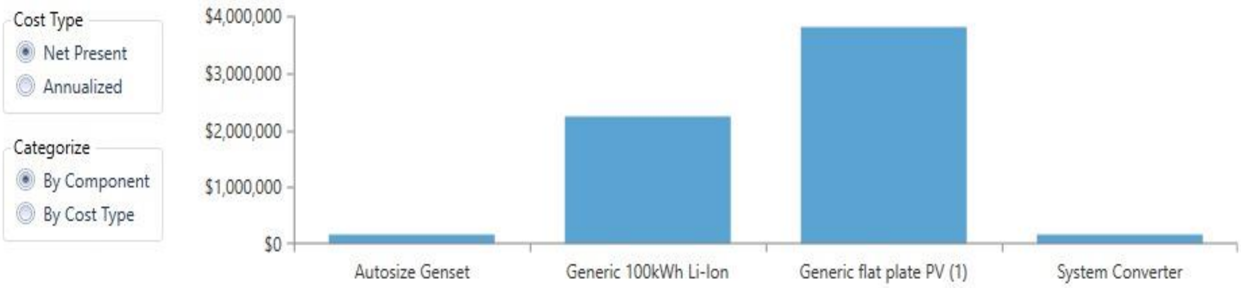
Figure20. The suggested converter output imported from HOMER simulation emission

Quantity	Value	Units
Carbon Dioxide	-152	kg/yr
Carbon Monoxide	96.9	kg/yr
Unburned Hydrocarbons	4.23	kg/yr
Particulate Matter	0.587	kg/yr
Sulfur Dioxide	0	kg/yr
Nitrogen Oxides	91.0	kg/yr

Figure 20shows different types of releases Carbon Dioxide (CO2) A greenhouse gas by burning fossil fuels. **Carbon Monoxide (CO)**fuel produced by incomplete combustion. **Unburned Hydrocarbons:**) emitted during combustion processes. Particulate **Matter and Nitrogen Oxides (NOx)** air particles vehicle or engine exhaust or industrial processes. **Sulfur Dioxide (SO2):** Emitted from burning fossil fuels containing sulfur. Understanding the sources and impacts environmental and health considerations.

Figure 21. the proposed financial summary cost imparted from HOMER

Figure 21.show two Graph bars representing “Net Present Value” and “Annualized.” The y-axis ranges from $0 to $4,000,000 and x-axis shows component specification Table 3. Providing detailed numerical values for each component



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Autosize Genset	$170,000.00	$0.00	$21,625.15	$0.00	($29,593.38)	$162,031.77
Generic 100kWh Li-Ion	$1,470,000.00	$623,682.53	$271,477.85	$0.00	($117,383.35)	$2,247,777.03
Generic flat plate PV (1)	$3,621,696.52	$0.00	$187,278.17	$0.00	$0.00	$3,808,974.69
System Converter	$118,476.00	$50,266.26	$0.00	$0.00	($9,460.62)	$159,281.64
System	$5,380,172.52	$673,948.79	$480,381.16	$0.00	($156,437.34)	$6,378,065.13

Chapter 3

Demonstration of Outcome Based Education (OBE)

Definition: OBE focuses on students demonstrating proficiency in expected knowledge and skills as they progress through their educational journey.

Core Concept: An "outcome" in OBE refers to a culminating demonstration of learning. It's what students should be able to do at the end of a course or degree program. These outcomes are visible and observable demonstrations of knowledge, competence, and orientation.

Approach: Rather than emphasizing what the school provides, OBE prioritizes students' ability to demonstrate what they know and can do. It shifts the focus from content delivery to student performance.

Methodology: OBE Interpersonal skills, life skills, professional and vocational skills, and basic skills.

3.1Course Outcomes (COs) Addressed

The following table shows the COs addressed for Project and Thesis.

COs	CO Statement	POs	Put Tick (√)
			EEE 4700
CO1	Identify a contemporary real-life problem related to electrical and electronic engineering by reviewing and analyzing existing research works.	PO2	√
CO2	Determine functional requirements of the problem considering feasibility and efficiency through analysis and synthesis of information.	PO4	√
CO3	Select a suitable solution and determine its method considering professional ethics, codes and standards.	PO8	√
CO4	Adopt modern engineering resources and tools for the solution of the problem.	PO5	√
CO5	Prepare management plan and budgetary implications for the solution of the problem.	PO11	√
CO6	Examine the suggested solution's effects on society, culture, safety, and health.	PO6	√
CO7	Within ten words, evaluate how the suggested remedy would affect sustainability and the environment.	PO7	√

CO8	Develop a viable solution considering health, safety, cultural, societal and environmental aspects.	PO3	
CO9	Work effectively as an individual and as a team member for the accomplishment of the solution.	PO9	√
CO10	Prepare various technical reports, design documentation, and deliver effective presentations for demonstration of the solution.	PO10	√
CO11	Recognize the need for continuing education and participation in professional societies and meetings.	PO12	

3.2Aspects of Program Outcomes (POs) Addressed

The following table shows the aspects addressed for certain Program Outcomes (POs) addressed for Project and Thesis.

List Program Outcomes (POs) that can be addressed. Also, for each of the POs with multiple aspects, list the aspects that can be addressed.

	Statement	Put Tick (√)	Different Aspects	Put Tick (√)
PO2	**Problem analysis:** Identify, formulate, research literature and analyze complex electrical and electronic engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences. (K4)	(√)	engineering sciences.	(√)
PO3	**Design/development of solutions**: Design solutions for complex electrical and electronic engineering problems and design systems, components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations. (K5)	(√)	Public health	(√)
			Safety	(√)
			Cultural	(√)
			Societal	(√)
			Environmental	(√)

PO4	**Investigation:** Conduct investigations of complex electrical and electronic engineering problems using research-based knowledge(K8) and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.	(√)	Design of experiments	(√)
			Analysis and interpretation of data	(√)
			Synthesis of information	(√)
PO5	**Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex electrical and electronic engineering problems, with an understanding of the limitations. (K6)	(√)	**Homer software**	(√)
PO6	**The engineer and society:** Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions to complex electrical and electronic engineering problems. (K7)	(√)	Societal	(√)
			Health	(√)
			Safety	(√)
			Legal	
			Cultural	(√)
PO7	**Environment and sustainability:** Understand and evaluate the sustainability and impact of professional engineering work in the solution of complex electrical and electronic engineering problems in societal and environmental contexts. (K7)	(√)	Societal	(√)
			Environmental	(√)
PO8	**Ethics:** Apply ethical principles embedded with religious values, professional ethics and responsibilities, and norms of electrical and electronic engineering practice. (K7)	(√)	Religious values	(√)
			Professional ethics and responsibilities	(√)
			Norms	
PO9	**Individual work and teamwork:** Function effectively as an individual, and as a member or leader in diverse teams and in multi-	(√)	Diverse teams	
			Multi-disciplinary settings	

	disciplinary settings.			
PO10	**Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.	(√)	Comprehend and write effective reports	(√)
			Design documentation	(√)
			Make effective presentations	(√)
			Give and receive clear instructions	(√)
PO11	**Project management and finance:** Demonstrate knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.	(√)	Engineering management principles	(√)
			Economic decision-making	
			Manage projects	(√)
			Multidisciplinary environments	(√)
PO12	**Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the context of electrical and electronic engineering related technological change.	(√)		(√)

3.3Knowledge Profiles

The following table shows the Knowledge Profiles (K3 – K8) addressed in EEE 4700 for Project and Thesis.

K	Knowledge Profile (Attribute)	Put Tick (√)
K3	A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline	**(√)**
K4	Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline	
K5	Knowledge that supports engineering design in a practice area	**(√)**
K6	Knowledge of engineering practice (technology) in the practice areas in the engineering discipline	**(√)**
K7	Comprehension of the role of engineering in society and identified issues in engineering practice in the discipline: ethics and the engineer's professional responsibility to public safety; the impacts of engineering activity; economic, social, cultural, environmental and sustainability	**(√)**
K8	Engagement with selected knowledge in the research literature of the discipline	**(√)**

3.4Project implementation

Adopting modern engineering through the use of HOMER software for designing, system configuration, load Analysis, renewable resource analysis, system optimization, environmental impact analysis, simulating and performance evaluation and implementation planning the hybrid photovoltaic (PV) and fuel cell system for the Future Hybrid of Photovoltaic and Fuel Cell project in Kanifing, with the use of these methodology can satisfy the community's unique requirements and successful achievement of the project.

The preparation of a comprehensive management plan and budgetary implications for the Future Hybrid of Photovoltaic and fuel cell project in kanifing involves careful consideration of project management planning, monitoring and reporting, financial and budgetary implications aspects. Considering these, provide to illustrate how these elements can be practically implemented to ensure the success and sustainability of the project in the unique context of Kanifing, The Gambia.

3.5Use of Complex Engineering Problems

The development of a viable solution for the Future Hybrid of Photovoltaic and Fuel Cell project in Kanifing requires a holistic approach that integrates health, safety, cultural, societal, and environmental considerations. By addressing these aspects, the project not only becomes technically successful but also contributes positively to the well-being and sustainability of the community. The examples provided illustrates practical actions that align with this holistic approach.

There is strong emphasis on preparing various technical reports and design documentation, simulation report, feasibility report and risk assessment report for the future hybrid of photovoltaic and fuel cell project in Kanifing, will reflects a commitment to effective communication, knowledge transfer,and project transparent management. The examples will provide illustrates how these documentation efforts contributes to addressing complex engineering challenges and ensuring the success of the project.

3.6Socio-Cultural, Environmental, And Ethical Impact

With the consideration of socio-cultural factors in the Future Hybrid of Photovoltaic and Fuel Cell project for Kanifing is essential for its successful implementation and acceptance within the community and empowerment. By addressing health, safety, culture, and societal aspects, the project can positively impact the well-being of residents while respecting and celebrating the unique cultural identity of Kanifing Estate. The examples provided illustrate practical ways to achieve this holistic approach.

With the analysis of the environmental impact for the Future Hybrid of Photovoltaic and fuel cell project in Kanifing is a critical step in ensuring the project's sustainability and alignment with environmental conservation goals. By conducting a comprehensive assessment and implementing environmentally friendly practices by reducing carbon footprint and ecological preservation, the project contributes to positive environmental outcomes while providing clean and sustainable energy to the community. The examples provided illustrates practical steps to achieve these environmental considerations.

The development of a viable solution for the future hybrid of photovoltaic and fuel cell project in Kanifing involves a holistic approach that encompasses health, safety, cultural, societal, and environmental aspects. By emphasizing ethical engineering practices, the project aims to not only provide a sustainable energy solution but also contribute positively to the well-being and development of the community. The examples provided illustrates practical ways to achieve these objectives.

3.7Attributes of Ranges of Complex Engineering Problem Solving

The following table shows the attributes of ranges of Complex Engineering Problem Solving (P1 – P7) addressed for Project and Thesis.

P	**Range of Complex Engineering Problem Solving**	**Put Tick (√)**
Attribute	Complex Engineering Problems have characteristic P1 and some or all of P2 to P7:	
Depth of	**P1:** Cannot be resolved without in-depth engineering	**(√)**

knowledge required	knowledge at the level of one or more of K3, K4, K5, K6 or K8 which allows a fundamentals-based, first principles analytical approach	
Range of conflicting requirements	**P2:** Involve wide-ranging or conflicting technical, engineering and other issues	
Depth of analysis required	**P3:** Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models	
Familiarity of issues	**P4:** Involve infrequently encountered issues	
Extent of applicable codes	**P5:** Are outside problems encompassed by standards and codes of practice for professional engineering	
Extent of stakeholder involvement and conflicting requirements	**P6:** Involve diverse groups of stakeholders with widely varying needs	
Interdependence	**P7:** Are high level problems including many component parts or sub-problems	

3.8Attributes of Ranges of Complex Engineering Activities

The following table shows the attributes of ranges of Complex Engineering Activities A5) addressed for Project and Thesis.

A	**Range of Complex Engineering Activities**	**Put Tick (√)**
Attribute	Complex activities mean (engineering) activities or projects that have some or all of the following characteristics:	
Range of resources	**A1:** Involve the use of diverse resources (and for this purpose resources include people, money, equipment, materials, information and technologies)	**(√)**
Level of	**A2:** Require resolution of significant problems arising from	

interaction	interactions between wide-ranging or conflicting technical, engineering or other issues	
Innovation	**A3:** Involve creative use of engineering principles and research-based knowledge in novel ways	
Consequences for society and the environment	**A4:** Have significant consequences in a range of contexts, characterized by difficulty of prediction and mitigation	
Familiarity	**A5:** Can extend beyond previous experiences by applying principles-based approaches	

3.9Conclusion

Kanifing leads the country in energy needs, with steady annual growth. Power outages plague the region, disrupting economic activities and daily life of its inhabitants.

Feasibility study evaluates technical integration of fuel cell and solar technologies.
No prior studies specific to Kanifing's renewable energy project research on hybrid fuel cell and solar systems show promising results for Kanifing's energy needs.

Modern engineering tools use (HOMER software) for system design schematic integrates the components (Diesel generator, converter, load, electrolyzer, fuel cell, solar PV, hydrogen tank, and battery).

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