PALESTINE POLYTECHNIC UNIVERSITY

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Master Program of Renewable Energy and Sustainability

Design and Management of Hybrid Renewable Energy System: A Case Study

By

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Supervisor

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April , 2021

	TEMPUS JAMILA	

J o i n t m A s t e r o f M e d i t e r r a n e a n I n i t i a t i v e s o n r e n e w a b L e a n d s u s t a i n A b l e e n e r g y

Palestine Polytechnic University

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Master Program of Renewable Energy and Sustainability

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Thesis submitted in partial fulfillment of requirements of the degree

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ABSTRACT

In recent years, the interest in using renewable energy sources has been growing globally since they are considered as a key solution to satisfy the world increasing demand for energy and for reducing the global carbon emission. Palestinians have previously started utilizing solar energy for heating water for domestic and industrial uses. Recently, a strong trend has been made to use solar energy to convert it into electrical energy using solar cells. In addition, the geographic and topographic configuration and the prevalence of dominant bioenergy can be a very good potential for small and medium rural developments areas. This research clarified a complete design for a renewable microgrid for Al- Aroub technical College. It consists of various renewable energy systems, including the photovoltaic system, biogas as a primary energy source, a fuel cell generator and a hydrogen storage unit, which can provide electricity to developing economies. As the photoelectric generator and the methane generator provide sufficient electrical energy during the day that covers the requirements of the different loads on the farm, while the excess energy is transferred to the electrolyzer for hydrogen production and storage, and when the load needs more energy, the electric fuel cells are turned on where the hydrogen is obtained from the energy storage unit. An energy management strategy was also proposed in this study as the newly developed network control and management system, and Matlab was chosen to undertake this task. Moreover, the RETscreen Expert software that enables to determine the optimum size that meets the potential demand along with the most feasible economic values The objective of this study is to design and management of hybrid renewable energy system of Alaroub Technical collage that is located in the Hebron city which consists of 28196 kWh photovoltaic energy conversion, and 25% from load demand covered from bioenergy with Fuel cell generator and energy storage system (ESS). This study is based on identify of the optimum size that meets the possible demand along with most feasible economical values. The simulation results clearly show that the HRES consist of PV, bioenergy and small scale fuel cell generator is a more economical configuration than single renewable energy systems with battery which has a total net cost of (473570 $) , levelized cost of energy (LCOE) of (0.157) $/kWh and the lowest CO_2 emission model that was(2.1) ton per year.

الملخص

تصميم وإدارة شبكة طاقة متجددة هجينة: دراسة حالة

في السنوات الأخيرة، تزايد الاهتمام باستخدام مصادر الطاقة المتجددة على مستوى العالم لأنها تعتبر حلاً رئيسياً لتلبية الطلب العالمي المتزايد على الطاقة وتقليل انبعاثات الكربون. بدأ الفلسطينيون سابقًا في استخدام الطاقة الشمسية لتسخين المياه للاستخدامات المنزلية والصناعية. في الآونة الأخيرة، ظهر اتجاه قوي لاستخدام الطاقة الشمسية لتحويلها إلى طاقة كهربائية باستخدام الخلايا الشمسية. بالإضافة إلى ذلك، يمكن أن يكون التكوين الجغرافي والطبوغرافي وانتشار الطاقة الحيوية من الغاز الحيوي جيدة جدًا في الاقتصاديات الصغيرة والمتوسطة. أوضح هذا البحث تصميمًا كاملاً لشبكة كهربائية متجددة لكلية العروب التقنية. حيث يتكون من أنظمة طاقة متجددة مختلفة منها النظام الضوئي والغاز الحيوي كمصدر أساسي للطاقة، ومولد خلايا الوقود ووحدة تخزين الهيدروجين، والتي يمكن أن توفر الكهرباء للاقتصاديات النامية. حيث ان المولد الكهروضوئي ومولد الميثان يوفران طاقة كهربائية كافية أثناء اليوم الذي يغطي متطلبات الأحمال المختلفة في المزرعة بينما تنتقل الطاقة الزائدة إلى المحلل الكهربائي لإنتاج الهيدروجين وتخزينه وعندما يحتاج الحمل إلى مزيد من الطاقة يتم تشغيل خلايا الوقود الكهربائية حيث يتم الحصول على الهيدروجين من وحدة تخزين الطاقة. تم اقتراح استراتيجية إدارة الطاقة أيضًا في هذه الدراسة كنظام التحكم والإدارة في الشبكة المستحدثة، وقد تم اختيار Matlab للقيام بهذه المهمة. علاوة على ذلك، برنامج RETscreen Expert الذي يتيح تحديد الحجم الأمثل الذي يلبي الطلب المحتمل إلى جانب القيم الاقتصادية الأكثر جدوى ويضمن أعلى موثوقية للنظام. لذلك يكون الهدف من هذه الدراسة هو تصميم وإدارة نظام الطاقة المتجددة الهجينة لكلية العروب الفنية التي تقع في مدينة الخليل والتي تتكون من 28196 كيلوواط. ساعة لتحويل الطاقة الكهروضوئية و25٪ من الاحتياجات يتم تغطيتها من الطاقة الحيوية مع مولد خلايا الوقود ونظام التخزين. تستند هذه الدراسة إلى تصميم وإدارة وتكوين نظام هجين للطاقة المتجددة باستخدام خوارزميات برنامج RETscreen التي تتيح تحديد الحجم الأمثل الذي تحتاجه الاحمال جنبًا إلى جنب مع القيم الاقتصادية الأكثر جدوى وضمان أعلى موثوقية للنظام. تظهر نتائج المحاكاة بوضوح أن نظام الطاقة الهجين يتكون من نظام شمسي، والطاقة الحيوية، ومولد خلايا الوقود صغير الحجم، وهو تكوين أكثر اقتصادا من أنظمة الطاقة المتجددة الفردية التي تحتوي على بطارية حيث يبلغ إجمالي تكلفتها الصافية 473570 دولارًا، والتكلفة لكل كيلوواط ساعة هي 0.157 دولار وأقل نموذج انبعاث لثاني أكسيد الكربون 2.1طن في السنة.

DECLARATION

I declare that the Master Thesis entitled “Design and Management of Hybrid Renewable Energy System: A Case Study” is my own original work, and herby certify that unless stated, all work contained within this thesis is my own independent research and has not been submitted for the award of any other degree at any institution, except where due acknowledgement is made in the text.

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First, I would like to thank Allah, for His mercy on me during all my life, and praise the prophet Mohamad (peace be upon him!). I dedicate this work to my father (Emad Mohammad AbuAyyash-May ALLH give mercy to his soul), my mother, my brothers, my sisters and all the people who have contributed their precious time and efforts to help me in completing this thesis.

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List of Abbreviations

AC	Alternating current
CF	Capacity factor
CO_2	Carbone dıoxıde
CHP	Combıned heat and power
CH_4	Methane Gas
DEEPSO	Deferential evolutionary PSO
ESS	Energy Storage System
Ele	Electrolyzer
FF	Fill factor
FC	Fuel Cell
GHG	Green house gas
GBSO	Global best braın storm optimization
HMGS	Hybrıd mıcrogrıd system
HRES	Hybrıd renewable energy system
IEC	Israel Electricity Corporation
Impp	Maximum Power Point Current
I_{sc}	Short Circuit Current
I_{ph}	photocurrent from photovoltaic cell
I_d	the current passing through none linear diode
I_p	current through shunt resistance
MBSO	Modified brain storm optimization
MCB	Main circuit breaker
MILP	Mixed integer linear programing
P_{AC}	Alternative power
P_{DC}	Direct power
PPU	Polytechnic Palestine University
PSO	Particle swarm optimization algorithm
P_{PEAK}	Peak power
P_{ele}	Power for electrolyzer
P_{FC}	Fuel cell power
P_{Comp}	Compression system power
$P_{Methane}$	Methane generator power
RES	Renewable Energy Source
R_s	Series Resister
R_p	Parallel Resister
STC	Standard test condition

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Chapter 1

Introduction

1.1 Background to the Study

Using hybrid renewable energy systems for rural areas has become a best solution for those areas. The increasing desire to reduce global warming from carbon emissions has made clean alternative energy sources the world's favorite to invest in the production of energy, in addition to the price of oil, which continues to rise in price [1].

The gradual transition from the shale fuel era to the inclusion of alternative energy sources in energy production requires the embrace of new structural elements to the energy system to make it a more intelligent and efficient electrical system[2].Thinking about the supply of remote and isolated areas located far from main grid has led us to the result of so-called small hybrid microgrid systems (HMGS), which is a promising solution to the supply of energy on the one hand and reduce costs on the other hand. These microgrid are consisting of several different parallel connected resources being electronically controlled, capable of producing electricity and covering the need are designed as low -medium voltage a simple structural example of (HMGS) is shown in Figure 2.1[3].

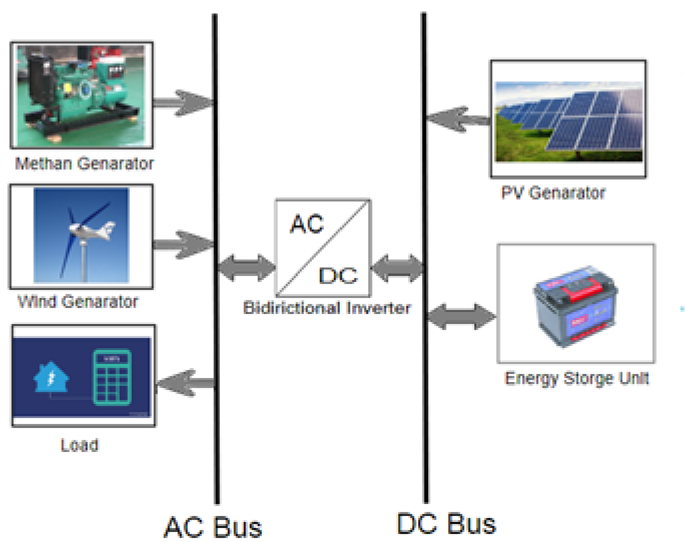


Figure 2.1. A simple structural example of (HMGS).

Animals manure fermentation to produce biogas not only produce energy but also treat agricultural plants, which rapidly was paid attention by rural society [4], also in Palestine the top electricity RES potential was biogas and solar energy [5]. But because of its discreet nature, Biogas and solar renewable energy source in this site can be on seasonal or daily basis. It has been shown that microgrid has renewable energy sources technologies in off grid, it has ability to improve the system's performance [2]– [6]. In addition, to get ability as on grid technologies, so it's necessary to has a storage units or energy carrier. Technologies of energy storage classified to capacity-oriented (compressed air , pumped hydroelectric systems , hydrogen) and access-oriented storage applications (super capacitors, ,superconducting ,batteries, and flywheels magnetic energy storage) [7]. It has several advantages and disadvantages, and there's criteria's like the transient time, operating cost efficiency and life time when choosing a fit storage technology. For example, normal battery storage is energy efficient, but the cost of energy storage is increasing high. pumped hydro can be used for large applications but it can be used only in proposed areas. Hydrogen is a perfect energy storage that because it is cleanest, lightest, and most efficient fuels, but it has low power response time [8]. It will be controlled that means more reliable, economic, effective system and should be able to efficiently produce energy. It represents micro grid system far from traditional grid failure and loses in addition energy system with environment sense. That mean instead of pollution by organic substances like cow dung we disposal from it and produce energy.

Sizing of renewable energy sources in microgrid is an important factor for its techno economic feasibility study [9]. Technology selected at unit sizing and is released on meeting requirements like using the generation technology exist and not more equipment power rating, or on satisfying constraints and got multiple aims such as reducing environmental impact like CO2 emission, running costs installation and payback periods on investment, and increasing reliability. The optimization struggles sometimes has conflicting aims and thus be complicated. An intensive litterateur review that titled the complexities related to design of RE power generation technologies microgrid has been listed [10]. The fluctuation of renewable energy sources with fluctuating demand is one of the main constraints in energy systems that rely on clean energy mainly, hence the hybrid system, which depends on both parties. [1]. In the literature review, there are several classifications of hybrid systems, which are determined according to precise criteria, in Figuer2.2 a general classifications of hybrid systems are presented:

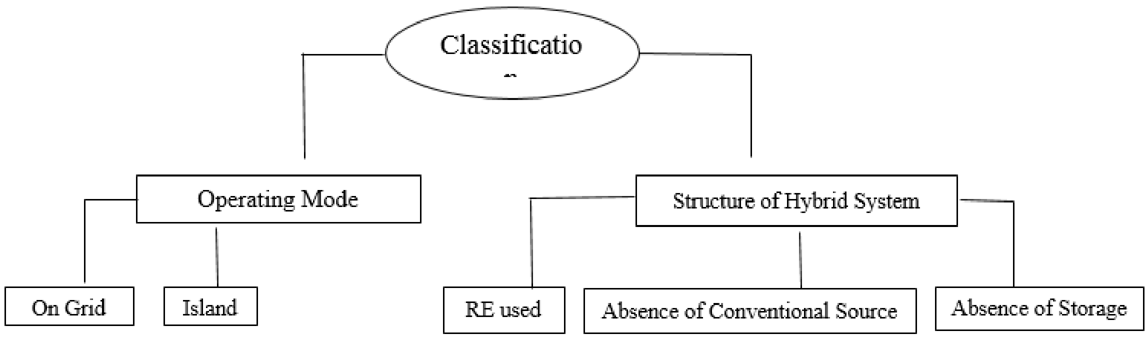


Figure2.2. A general classifications of hybrid system.

1.2 problem statement

This research has been taken 'Arroub Technical college' as case study. It suffers from shortage energy, continuous load interruption and have huge amount of animal dung from Cows and other animals dung. On other hand , it is considered a big consumer of energy (heavy machine and engine, pump, lighting, and a lot of loads), so what is the best and effective energy solution will be? For that it researched and found that modeling microgrid based on renewable energy sources(RES) particularly Solar, biogas and fuel cells with Hydrogen energy storage. Where existing a realable, effective and economic energy system with environment sense will be not easy.

So what is the solution for this uncertainty? And what is the optimal configuration? The goal of this research is to design and put power management strategy (PMS) for Hybrid renewable energy system (micro grid). It combines several energy systems together, also doing optimal configuration, economic analysis and environmental impact like CO_2 emission and other greenhouse gasses by using renewable energy management RET Screen software. In addition, it has been assumed some sensitivity analysis like internal rate of return (IRR) and fuel cost. Therefore, HMGS can supply high reliable electricity better than a PV/battery system. But the most important thing is that the components in the hybrid system have to be sized in optimal way. The idea of optimization and economic analysis depend on balancing several aspects to come up with the best decision. This is the focus of this part to reach the optimum hybrid microgrid based on renewable energy with the lowest carbon emissions and the lowest total cost possible. Three different situations will be differentiated, Base model, PV System with battery energy storage, the second model depending on

RE sources model (solar PV, bioenergy, battery storage) and the third was mixed technologies (solar, bioenergy and fuel cell with ESS). The comparison between them base on three basics: carbon emissions, top model (higher net present value), and lower cost.

Research Question(s) and Hypothesis

- How to make full design and calculation for each RES that supposed in this research?
- what is the variable inputs and conditions for each source?
- what

are the factors that be selected to do best design (areas, loads, amount of organic waste…etc.?

- How to be guided by the best way to find the best performance of the network microgrid?
- What factors should be considered in the process of differentiation between different systems of microgrid?
- Which optimal renewable energy source should we use in this area?
- What are the capacities and number of units that we should select from each source?
- What is the final total cost of each model while not forgetting carbon emissions?
- What is the best technology for energy storage in this research?

1.2 Objectives

1) To design Hybrid system (micro grid) consist of solar, bioenergy and fuel cell with ESS that can supply continuous and high reliable electricity service.
2) To do power management strategy(PMS) between RES and energy storage unit to get the best performance and high efficiency.
3) Making environmental sense by disposal from organic waste and animals dung effectively to produce electricity and agricultural fertilizer from bioenergy system.
4) Study the economic feasibility of all proposed scenarios configurations with emphasis on the lowest cost and highest operation taking into account carbon emissions, using RET screen software.

1.3 Research Significance and Relevance

- Small hybrid networks are a promising solution to provide electricity to remote and isolated areas, which sometimes rely mainly on unreadable source, that any development in this area is an achievement in itself because of the value of the use of science in helping humanity.
- Animals manure fermentation to produce energy and treat agricultural plants, which rapidly was paid attention by rural society.
- Reducing un certainty in RE source by using Hydrogen energy storage integrated with fuel cell.
- The proposed system will be able to produce enough and realable energy for all loads on the farm. Also have the ability to connect on the main grid and exchange between two systems to satisfy high reliable. Also sell exceed energy to main grid or give the energy to the electrolyzer to produce the energy as Hydrogen so that will give a good economic benefits for the farm.
- Use a new comprehensive tool to evaluate the technical and financial hybrid networks and measure the actual performance of facilities and the amount of energy savings, RET Screen Tool is used to achieve this target.
- Thinking about the supply of remote and isolated areas located far from anchor points has led us to the result of so-called small hybrid microgrid systems (HMGS), which is a promising solution to the supply of energy on the one hand and reducing costs. These micro grids are Consisting of several different parallel connected resources being electronically controlled, capable of producing electricity and optimally covering the need.

1.4 Thesis Structure

The thesis contains five chapter as follows:

- Chapter 1: Introduction.

  It provides the researcher with a brief introduction of the problem statement for this research. After that, the objective of this thesis is explained and motivation.

- Chapter 2: Literature review.

  The principle of renewable energy and using new technologies for the production of different forms of energy, as well as the integration between renewable energy sources and energy storage unit.

- Chapter 3: Design of hybrid system.

  The current background of renewable energy used in this study thus provides the basic theory of solar and biogas energy. It illustrates sources of renewable energy systems which includes design analyses and mathematical equations.

- Chapter 4: Methodology.

  It includes the data needed to obtain optimization techniques applied to the hybrid system by RET Screen software and built power management strategy between them and techno_ analysis for winner model.

- Chapter 5: Result.

  This chapter provides with RET Screen results, Excel, PV sys, Power Word Simulator and Homer. also a comparison and a discussion of the obtained result and summary is providing.

- Chapter 6: Conclusion Remarks

  This chapter contains summary for this research and some future recommendations.

Chapter 2

Literature review

2.1 introduction

Extensive review of literature was investigated in this research to familiarize what is already known about design and management of microgrid based on RE sources as optimal design, operation, and scaling with minimum cost taking into account carbon emissions.

2.2 Solar Energy System

solar cell convert sun radiation directly into electrical energy. The photovoltaic phrase means ’photo’ meaning light and ’voltaic’ is producing electrical energy. The solar cell is made from semiconductor material like silicon. It consists of a P-type semiconductor and an N-type semiconductor. The current flows through a circuit between the two electrodes. PV cells are joined together in series and/or parallel to increase voltages, currents and power levels. Photovoltaic modules consist of a number of PV cells. A photovoltaic array consisting of modules. A photovoltaic cell, PV module and array are shown in Figure2.3. [11]

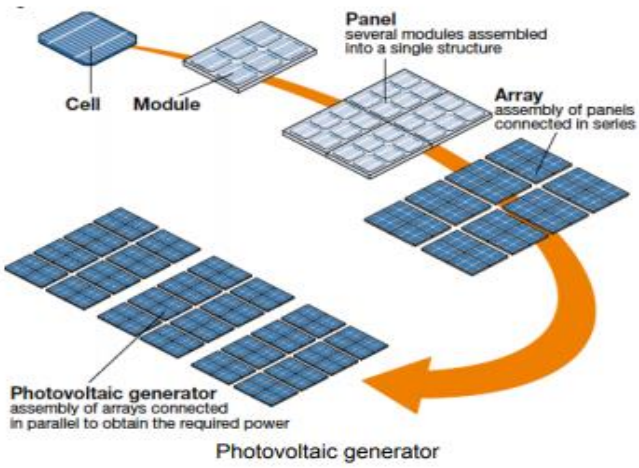
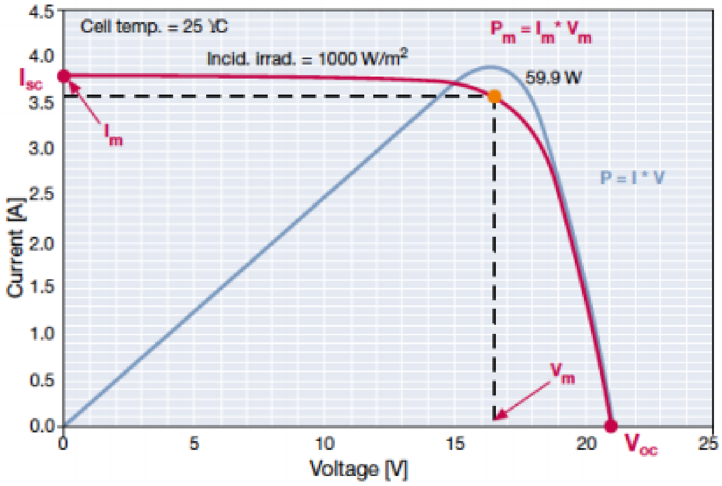


Figure 2.3: Photovoltaic cell, PV module and PV array. [11]

The character performance of a PV cell rely on conditions (solar radiation and temperature) and technology of manufacturing. The curve of current –voltage (I-V) which determines the behavior of a photo- voltaic cell is represented in Figure2.4.



2.4: The I-V and P-V characteristics of typical PV module with defining FF[12].

Important electrical Parameters that define the performance of PV cell are short circuit current (Isc) ammeter used in this case. The value of Isc changes in function of solar radiation and significantly change with temperature, in other side open circuit voltage (Voc). It's the voltage of a PV module measured at no load case. The maximum power point of a photovoltaic is a point on the (I-V) or (P-V) characteristics and the power generated in this point is maximum, where measured in Watts (W). Its value can be calculated by the product V max and Imax. Fill Factor (FF) is an important performance indicator. It illustrates the ratio of output power at maximum power point to the power computed. The FF is obtained according the following Equation 2.1[11].

$$\mathrm{FF} = \frac{V_{mpp} \times I_{mpp}}{V_{oc} \times I_{sc}} \tag{2.1}$$

Typically, crystalline silicon photovoltaic voltage is between 0.67 and 0.74. If the I-V curves of two PV modules have the same values of Isc and Voc, the array with the higher fill factor (squarer area , so it will generate maximum power. Also, any impairment that reduces the fill factor will reduce the output power [12]. The equivalent circuit consists of a real diode in parallel with a current source. The current source produces the current I_{ph} and the current I_d flows through diode. Two resistances, Rs and Rp, are included to model the contact resistances and the internal PV cell resistance respectively. The values of these two resistances can be determined from measurements or by using curve fitting methods based on the I-V characteristic of PV [13-14]. The equivalent electrical circuit for a PV cell or module is illustrated in Figure2.5.

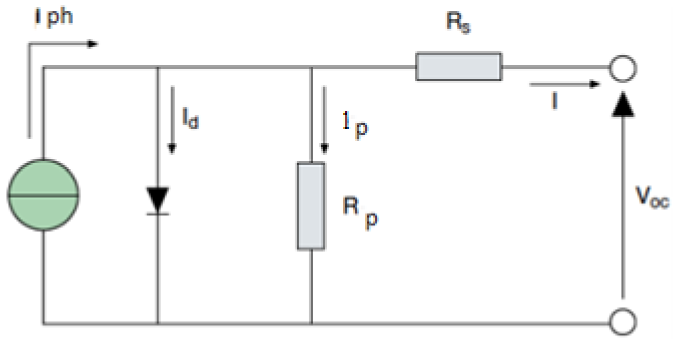


Figure 2.5: Equivalent of PV cell.

Solar radiation and the ambient temperature affected on current (I_{ph}). The (I-V) curve of photovoltaic cell can be plotted by the fo Equation 2.2[11], the terminal current of the model (I_L) is given by

$$I = I_{ph} - I_d - I_p \qquad (2.2)$$

Where:

Rp	Parallel Resister
Iph	photocurrent from photovoltaic cell
I_d	the current passing through none linear diode
Ip	current through shunt resistance

2.3 Biogas Energy System

Biomass is an energy resource and RE fuel that mean it's very important source in our life. Bioenergy is specified as a gases mixture generated from the anaerobic fermentation of organic waste by bacteria that need many days to form. In the wild, swamp or marsh is a very less oxygen area that suitable for this fermentation [15]. The rest of agricultural products is a perfect resource for bioenergy. Woods and remnants of the harvest can be converted by thermal conversion to produce energy, vegetable oils and animal fats to produce biodiesel, or starch crops to produce ethanol. Moreover, bioenergy can be produced also from animal manures. Cows manure left on the land will be through natural fertilization that will generate biogas [16]. Biogas can also be. Anaerobic process in it currently produced less industry waste compared to aerobic fermentation [15]. The biogas that collected is flammable and this gives several cases for utilization. So there's a lot of popular uses like flaring, thermal (home, water, etc.) and inner combustion. Internal combustion engines are attached to electrical generators that generate electricity for on farm use or sale to an electric company. Anaerobic digestion of organic materials by microorganisms able to utilize molecules other than oxygen as hydrogen acceptors. More simplistically, the bacteria must be in an environment without oxygen. The process of anaerobic digestion on a molecular level includes different types of bacteria. The process in general however can be expressed in Equation 2.3 [15].

$$\text{Organic Matter} \longrightarrow CH_4 + CO_2 + H_2 + N_2 + H_2S \qquad (2.3)$$

In [17] 2018, it illustrates the biogas potential in west bank region spatially Bethlehem perspective also techno-economic analysis evaluation and technical analysis for existing like this plant in the network more over power flow and power losses. A biogas digester, also known as a methane digester, is a piece of equipment which can turn organic waste into usable fuel. In addition to providing a source of renewable fuel, and they help to dispose of waste materials which would otherwise be discarded[18]. The biogas digester relies on bacterial decom- position of biomass, waste material which is biological in origin, ranging from kitchen scraps to cow dung[19]. The bacteria preferred in the digestion process have many conditions for effective operation including temperature, pH and acidity, moisture, and substrate nutrients [20].There are many factors that affect the rate of biogas production, one of them is a temperature. For the digesting bacteria to work at high efficiency, a temperature of 95F (35˚C) is best [21].Especially in temperate climates, digesters should be supplied with an external supply of heat to keep them around 95F (35˚C). Several methods to get this way which heat the outside of digesters (e.g., compost piles, light bulbs, and water jackets) could be more effectively used as insulation. For acid condition of a material, the symbol” pH” is used. Most living processes take place in the range of pH 5 to 9. The pH suitable for fermentation is between (pH 7.5-8.5). During the initial acid phase of digestion, which may be about two weeks, the pH may decrease to 6 or less, in other hand a great deal of CO_2. Conversion between biogas and electrical energy is very important [17], so the potential biogas energy per year in Bethlehem from different animal manure has been shown in Table 2.1.

Table 2.1: The potential biogas energy per year in the Bethlehem region [17]

Animal	Heads at Bethlehem	Manure (kg/day)	Total Manure (kg/day)	Fluid Dung (kg)	The total influent (Q)	Water (kg)	Digester Volume (m^3)
Cow	1742	30	52260	8362	104520	52260	5226
Sheep	43981	1.82	79798	12768	159596	79798	7979.78
Goat	30469	1.82	55282	8845	110564	55282	5528.20
Chicken	227839	0.15	34176	5468	68352	34176	3417.59

Calculation the potential of biogas uses the biogas energy that can be produced per animal unit and the number of the animal unit. Animal unit is specified as 1000 pounds of animal. There are about 95 million animal units that could give about 928 trillion BTU (about 1 quad) of renewable energy per year. The possible electrical energy from biogas for each animal type shown in table2.2

Table2.2 : Potential electrical energy production from biogas for different animals in Bethlehem perspective[17].

Animal	Biogas (L/Kg)	Biogas (L/day)	Methane %	Methane (L/day)	Methane (m^3/day)	Electricity (kWh)
Cow	40	2090400	60	1254240	1254	2621.36
Sheep	60	4787868	63	3016357	3016	6304.17
Goat	60	3316922	63	2089661	2090	4367.39
Chicken	70	2392310	70	1674617	1675	3499.95
The Total electricity (kWh)				**16792.8884**		

2.4 Power Management Strategies

The main aim for the Power Management Strategy (PMS) in the selected system is to satisfy the load requirements. The difference between On grid system and off grid system is that inverters, which are tied to the main traditional grid, must have same line frequency synchronization able to deliver the excess power to the grid. Net meters, not same the ordinary meters, it able to record consumed or generated power in an exclusive summation format that is produced by the solar power and biogas system [24].In this site the electricity feeder is Israel Electric Corporation(IEC) company and that make some difficulties in this research and it has system in RE sources deferent from Palestinian companies, so it uses separately meter for RE production deferent of consumption meter and you have to meet your load just and no injected energy from Palestinian RE project and any injected RE energy in there grid you have to pay penalty. Figure 2.6 Shows the used strategy in IEC.

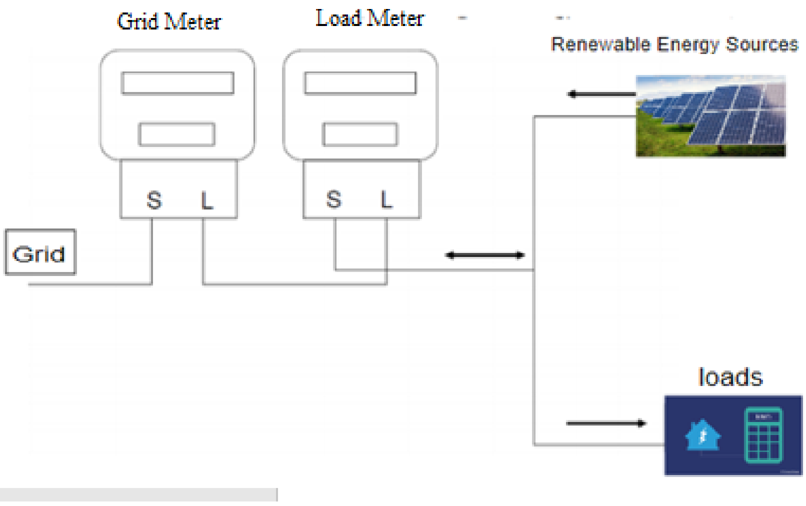


Figure 2.6: Net Metering Strategy in IEC**.**

To solve this problem sometimes we adjust the inverter in low voltage point so if the RE energy excess go to the grid the PV system for example will shut down but it was difficulty way so the other way is to make storage unit like hydrogen unit with electrolyzer and use this energy to analysis the water and store hydrogen in energy tube storage and the other quick way to put in parallel resistive load like Heater or fans to disposal from this excess energy.

2.5 Optimization of Micro Grid

Kartite and cherkaoui (2019), The authors presented a valuable and comprehensive review of hybrid renewable energy, in addition to a review of the operating systems and different structures and software's used to assess the overall behavior of (HRES) [1].Dulăua and Bicăa (2019), The author specified the maximum capacity of a hybrid network with the lowest possible cost so as to ensure the coverage of the demand, the results of optimization were given for one day. [25]While The authors Arai et al. [26] **s**everal evaluation techniques for the best operational performance of a hybrid network, we recall of these techniques, such as particle swarm optimization (PSO), global-best brain storm optimization (GBSO), modified brain storm optimization (MBSO), differential evolutionary PSO (DEEPSO),The research took into account one of the most important determinants of the use of RE sources, namely the uncertainty of the outputs, and came out with the best operational performance of the network using Global-best Brain Storm Optimization (GBSO) . The author was based on real data from the region sub-Saharan -Africa , and Mixed Integer Linear Programming (MILP) to find a new predictive design and a new algorithm of optimization. The algorithm was compared and tested with another method to find the optimal design and annual performance of an existing hybrid network in sub-Sahara -Africa.

Morettia et al, [27] While Kumar et al [28] found the most sustainable and suitable networks for a remote mountainous region in India, the research addressed in an extended way 23 options Relying on the adaptation of different sources of renewable and conventional energy and storage for off-grid system. Performance was assessed based on four basic criteria: environmental economic, social and technical, In addition to twenty non-essential criteria for 29 scenarios . Results were shown for the generation and storage systems of the network based on the growth of daily, monthly and annual demand. It is noteworthy that this study is rarely expanded when compared to other studies of the same categoryIn 2018, Konneh and Lofty, [29] The research was taken from Sierra Leone in sub-Saharan Africa as a study area to improve people's access to pride and thus improve the overall economic situation. The author relied on Optimization technology, Multi-objective Particle Swarm Optimization performance of a hybrid network in return for the lowest possible cost. While Xu [30] and others, HOMMER was an effective network assessment tool that showed the ideal network for each region in Myanmar over different time periods. The author made a trade-off to assess the economic performance of small microgrid in rural Myanmar.In 2018 Senthi Kumar et al. [31] This research was more specific to the partial loss, where the author relayed on Hybrid Nelder (MOPSO) technique to create the highest operational a-Mead and Cuckoo Search (HNMCS) algorithm to try to reduce the losses in hybrid networks, by raising the production capacity of generators that distribute clean renewable energy. Husein and Chung [32] used (MDSTool) as a tool and found a very interesting result that is, the optimal grid can cost 42% less and 15% less carbon emissions. Obara and others (2018), [33] The author adopted a genetic algorithm to evaluate the operational and productive of a hybrid network on a remote island.In 2017, Jayachandran and Ravi.G [3], used MATLAB to find that, the authors found that the establishment of small hybrid networks in an area of Sundarban-India can be the best way to access electricity. A hybrid network is designed as an island area ,and PSO technology is used as a power management tool, scaling microgrid components and the lowest possible cost to produce the best microgrid possible Adefratat and Bansal [34], The Markov technique was used to realize that the use of renewable energy resources in the hybrid system improves and increases system reliability ,this is because the use of renewable energy resources reduces the cost of annual maintenance and carbon emissions.In 2016 Siddaiah and Saini [35], The author provided a literary review of the various mathematical optimization models that were used and developed on the basis of such objective function, economic and environmental assessment and reliability. Fathima and Palanisamy [36], proposed a valuable review in 2015, They have highlighted the concept of HRES) ,with different techniques and differentiation tools, through previous literary readings. By 2014, Salih and others [37], used an isolated Transceiver Station site in Sudan as a study case to find the best and optimum design for a hybrid microgrid that supply the power to the remote station , they used HOMER as a tool to find the optimum microgrid with minimum costs of operation and maintained and best flow energy. A study on a hybrid micro - solar hybrid that stands alone was used to deliver electricity to remote areas was conducted by Akikur and others in 2013 [38], they also presented a comparative study of hybrid projects based on solar energy from around the world carried out over the past 12 years. Mohammadi and others in 2012 [39], The authors used PSO technology to find the best hybrid system connected to the main grid by exchanging power between the distributed power generators and the core grid. The researches also presented the design of the best hybrid network Which varies depending on different market types, such as pool market or bilateral electricity market kornelakis and Marinakis [40], The author considered that the PSO algorithm is the optimal algorithm for optimization technique, to solve the complex problems related to the trade-off of hybrid microgrids. Three remote islands in the Maldives have been the focus of the study of hybrid microgrids with plenty of alternative energy sources there ,Nayar C et al. [41], were involved in this study in 2008.A study in some remote areas of Senegal showed that the cost of energy from standalone on RE sources-based grid is the cheapest. This study was accomplished by Anyi M et al. in 2010,[42].Kaldellis J, in 2010, [43]. The hybrid system, which consists of diesel generator, batteries, and inverter, is the best energy saving solution for isolated communication networks according to the study. In Ref [44], the researchers adopted Mixed Integer Linear Programming (MILP) optimization technique in Peninsular Malaysia as study case, the target was the minimum CO_2 emissions. In [45] researchers found that standing at a constant distance from both reducing carbon emissions and maintaining credibility and reliability comes as a result of maximum reliance on alternative energy sources while at the same time scheduling the highest efficiency of generators, activating the energy storage system and reducing reliance on the main grid. Another optimization technique was used in [46].

2.7 Renewable Energy Storage Systems(ESS)

In [47], This paper gives us surveys at the beginning the literature on the latest applications. Then, operating cases for energy storage systems in smart grids and potential modern use case, which have been field operated, are presented, discussed and subsequently assessed technically and economically. Storage technologies can be divided in four groups according to the energy they store:

– chemical,

– mechanical,

– electrical,

– thermal.

It has different properties which predestine or eliminate them for particular use cases. Moreover, storage systems are in different stages of technical development and testing, Some technologies, e.g. adiabatic compressed air energy storage or hydrogen storage, are still in early stages of technological development. Although large-scale demonstration projects, e.g. lithium battery storage systems, are slowly extending long-established and commercialized storage systems such as pumped-storage power plants, an eye still has to be kept on their cost[47].

In this research Hydrogen with fuel cell technology has been selected as storage energy system and

PMS was built to get high efficiency and realable system with low un certainty.

Chapter 3

Design of Hybrid Renewable Energy System (HRES)

3.1 Introduction

This chapter presents a design for solar, biogas, and fuel cell with energy storage system (ESS).

3.2 Design of Hybrid Renewable Energy System

3.2.1 Biogas System Design

Based on [15], [17] experiments, the experimental setup used in this work consists of a bioreactor called digester with a capacity of 800 liters having a cylindrical shape (1.65 m high and 1.25 m diameter) and a bio- gas storage. The temperature of the digestion equal to 37 C ◦ is ensured by a water heater and a warm water circulation pump in closed circuit. In addition, homogenization of the substrate during experiments is done by hand stirrers introduced inside the bioreactor. Once the digester is fed with 440 kg of diluted (30%)and homogenized cow-dung, it has to be closed in order to create an anaerobic environment necessary for the anaerobic digestion processes. The fermentation of 440 kg of cow-dung in an 800-liter digester gave biogas production of 26.9 m^3 with an average content of 61% in CH_4, value considered optimal and energy equivalent to1567 kW.h /month. Arroub Technical college' have a 41 cow and 50 sheep, 12 tons per year of cow-dung 50 kg per year of sheep-dung and digester with a capacity of 1413 liters, having a cylindrical shape 3 m high and 1. 5 m diameter. Bioenergy potential in Al Arroub Technical college is illustrated in Table 3.1 .

Table 3.1 : Bioenergy potential in Al Arroub Technical college .

Animals	Heads at The Farm	Kg/ head	Total (kg/y) manure	Total manure (kg/day)
Cow	**41**	**12000**	**492000**	**-**
Sheep	**50**	**50**	**2500**	**-**
			494500	**1354.7**

Every 10 days are fermentation process and manure was 13550 kg.So based on [17], 27 m3 of methane gas has potential to produce 52.2 kWh/ day.

3.2.2 Design of Solar Energy System

In this section we took the maximum load as starting point and worst case, in other hand we can take land as starting point but after researched that no problem for the land area, there was existing more than 2000m^2.We will place solar panel rooftop of three departments and also cows shads. The minimum load was16540 kWh /month in August and the maximum load was 27566 kWh /month in December. Also as mention before. that energy produces by biogas equal 1567kWh /month. The maximum load selected to calculate Solar energy (worse case), so the energy produces by PV system equal energy (load) minus energy come from (methane gas) for there the net energy from solar system is 25999 kWh /month. Keep in your mind that was additional correction factor to PV system that load growth 8.45% from load growth formula [48]. So the final energy from PV system is approximately 28196kWh.Based on [11], from equation 3.1 Power AC equal 188 kWp. From equation 3.2 $P_{ower\ DC}$ equal 277kW, from equation 3.3 area equal 1977m^2,), also the number of modules equal 1163 and number of string was 20 so the actual input voltage was 592v, so the inverter ranges is of 570-620 v, which fits nicely with MPPT range. This suggests using array with (20×4), So the number of array is equal 15 array and the number of inverters was 15. Units have been listed in Table 3.2.

Table 3.2. solar system units' design.

Units	Numbers
modules	1163
strings	20
Array	20*4
inverters	15

$$P_{peak} = \frac{P_{ac}}{radiation} \tag{3.1}$$

$$P_{dc} = \frac{P_{ac}}{Conversion\ efficincy} \tag{3.2}$$

$$Area = \frac{p_{dc}}{1kWh \times \eta_{pv}} \tag{3.3}$$

3.2.3 Design of Energy Storage System _Hydrogen Generation (PEM Electrolyzer) System

To make this system more realable and reduce uncertainty, we used energy storage system(ESS) so fuel cell with electrolyzer represent complete system, so when we get excess energy from biogas and solar systems we can use this energy to analyze the water by electrolyzer and store the hydrogen energy. In other hand we will use fuel cells when we surfing from shortage in bio_pv energy system as backup system. In [48], We use a fuel cell device to produce electricity by a chemical interaction. Each fuel cell has two electrodes are the anode and cathode. The reactions that generate electricity take place at the electrodes. Every fuel cell also has an electrolyte, which transfer electrically charged particles from one electrode to the other, and a catalyst, which speeds the reactions at the electrodes. Hydrogen is the main fuel, but fuel cells also require oxygen. One great appeal of fuel cells is that they generate electricity with very little pollution much of the hydrogen and oxygen used in generating electricity ultimately combine to form a harmless byproduct, called water. One detail of terminology: a single fuel cell produce a tiny amount of direct current (DC) electricity. Many fuel cells are usually assembled into a stack. Cell or stack, the principles are the same. There are various kinds of fuel cells, and each

operates a bit differently. But in general terms, hydrogen atoms enter a fuel cell at the anode where a chemical reaction strips them of their electrons. The hydrogen atoms are now "ionized," and transfer a positive electrical charge. The negatively charged electrons give the current through wires to do work. If AC is needed the DC output of the fuel cell must be tie with device called an inverter.

Anode Reaction: $H_2O \rightarrow 2H+ + 12O_2 + 2e$ (3.4)

Cathode Reaction: $2H+ + 2e \rightarrow H_2$. (3.5)

For ESS with fuel cell design in this research we assume it as stand by generator with rated power 10kW that turned on when the load on peak .Based on [48] study of 10 Kw and 25 Kw Fuel cell system, we assume 10kW in this research, so based on a market review that defined and estimated market needs, technological readiness, and barriers to implementation, Battelle take 10 kW and 25 kW (net) fuel cell power systems for material handling equipment (MHE). A 10 kW fuel cell power system was able to this Class 6 equipment as well as several lift codes of Class 1 and 2 equipment. The power system is satisfied by a standard temperature PEM fuel cell hybridized with an appropriate means of energy storage for peak demands and transient response.

Chapter 4

Methodology and Specification

In this work, done collected the data for solar, wind speed and data load required for Al Arroub Technical Collage on monthly basis and analysis of loads 24 hours be provided, and deal with building the structure of the hybrid energy system, analyzing the parameter and price of the system component

4.1 Proposed Area and Weather Data

The proposed area was "Palestine Technical University, Al-Arroub agricultural School" (31.6. Latitude, 35.13 Longitude) , 938 heights. It divided to 3 zone university, school and farm.as shown in Figure 4.1.

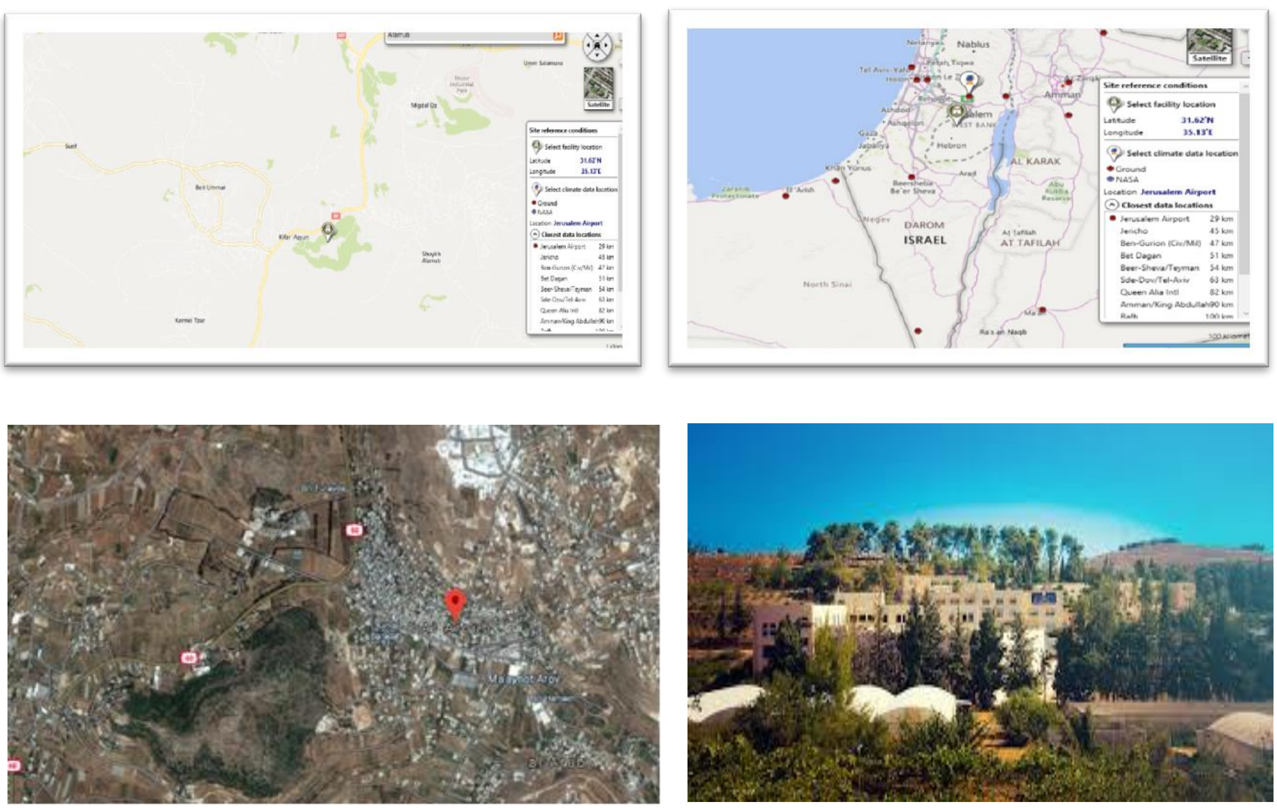


Figure 4.1: Satellite and Real Images of the area (RET Screen Climate Database).

the observation data have been obtained from Jerusalem Ground Weather Station and last update was in Jan,2020. Proposed site _climate data location VS facility location is illustrated in Figure 4.2.

	Unit	Climate data location	Facility location	Source
atitude		31.9	31.6	
ongitude		35.2	35.1	
limate zone		4B - Mixed - Dry		Ground+NASA
levation	m	759	938	Ground – Ground
leating design temperature	°C	2.0		Ground
ooling design temperature	°C	31.2		Ground
arth temperature amplitude	°C	23.1		NASA

Figure 4.2: Proposed site _climate data location VS facility location.

In Table 4.1 is shown Average monthly temperature, Relative humidity, Average Solar Radiation, Atmospheric pressure and wind speed at proposed site.

Table 4.1 Average monthly temperature, Relative humidity, Average Solar Radiation, Atmospheric pressure and wind speed.

Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days 18 °C	Cooling degree-days 10 °C
	°C	%	mm	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	7.7	76.1%	41.73	3.37	96.3	3.2	11.7	319	0
February	8.2	73.4%	34.14	4.20	96.2	3.5	13.3	274	0
March	10.4	70.8%	22.02	5.30	96.0	3.7	17.5	236	12
April	15.1	58.6%	10.19	6.81	95.8	3.4	23.9	87	153
May	19.1	53.6%	4.72	7.83	95.8	3.6	28.3	0	282
June	21.4	56.0%	0.53	8.57	95.6	4.2	31.2	0	342
July	23.1	59.5%	0.07	8.40	95.4	4.5	33.7	0	406
August	23.1	64.4%	0.11	7.85	95.5	4.1	33.8	0	406
September	21.8	64.8%	1.29	6.73	95.8	3.6	31.2	0	354
October	19.1	63.5%	10.40	5.28	96.0	2.8	25.5	0	282
November	14.1	66.7%	17.10	3.74	96.2	2.8	18.8	117	123
December	9.7	73.5%	30.54	3.05	96.3	2.7	13.3	257	0
Annual	**16.1**	**65.0%**	**172.84**	**5.94**	**95.9**	**3.5**	**23.6**	**1,291**	**2,361**
Source	Ground	Ground	NASA	Ground	NASA	Ground	NASA	Ground	Ground

From the above data, the solar radiation plot can be drawn as in Table 4.1. The annual average solar radiation is calculated as of 5.94 kWh/m2/day. Also presents solar radiation for location in kWh/m2/day for each month during the year also hourly solar radiation along the year which equals 8760 hours. Starting from January where the value goes up gradually to reach highest point at Summer then decrease in autumns to December. Obviously, the highest solar radiation value is about 8 kWh/m2/day in Jun and the lowest solar radiation value about3.05 kWh/m2/day in December as shown in figure 4.3. Also in Figure 4.4 is illustrated the annual max wind speed which is calculated as of 3.5m/s the figures present wind speed for location in m/s for each month during the year. It is obvious that the highest wind speed value is about 4.5 m/s in July, and the lowest wind speed value seems to be about 2.7 m/s in December. Also Figure 4.5 shows Atmospheric Pressure with Air Temp in this area.

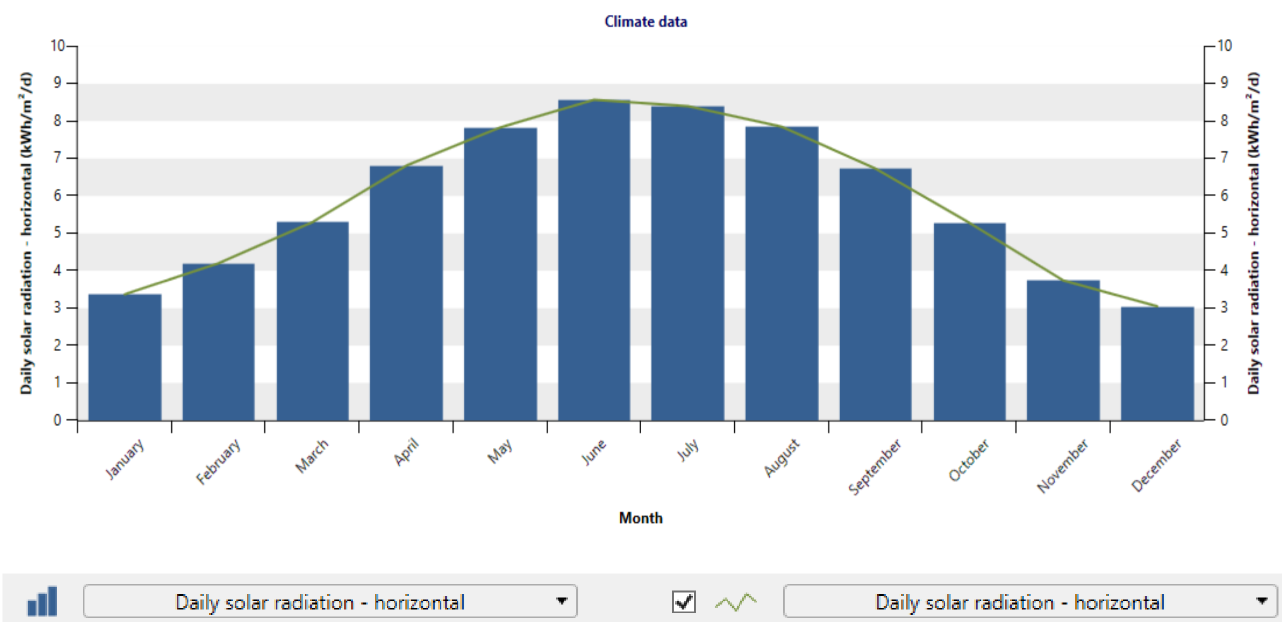


Figure 4.3 Monthly Average Solar Radiation with Daily Average Radiation.

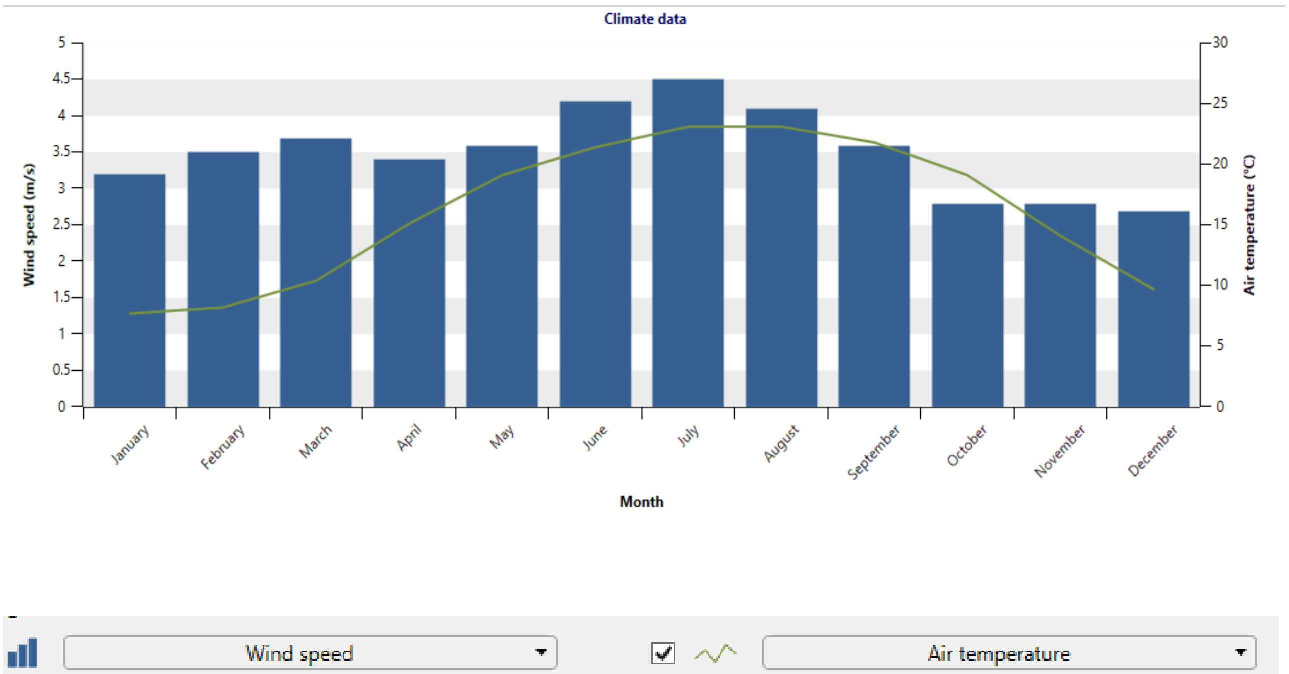


Figure 4.4 Monthly Wind Speed with Air Temp.

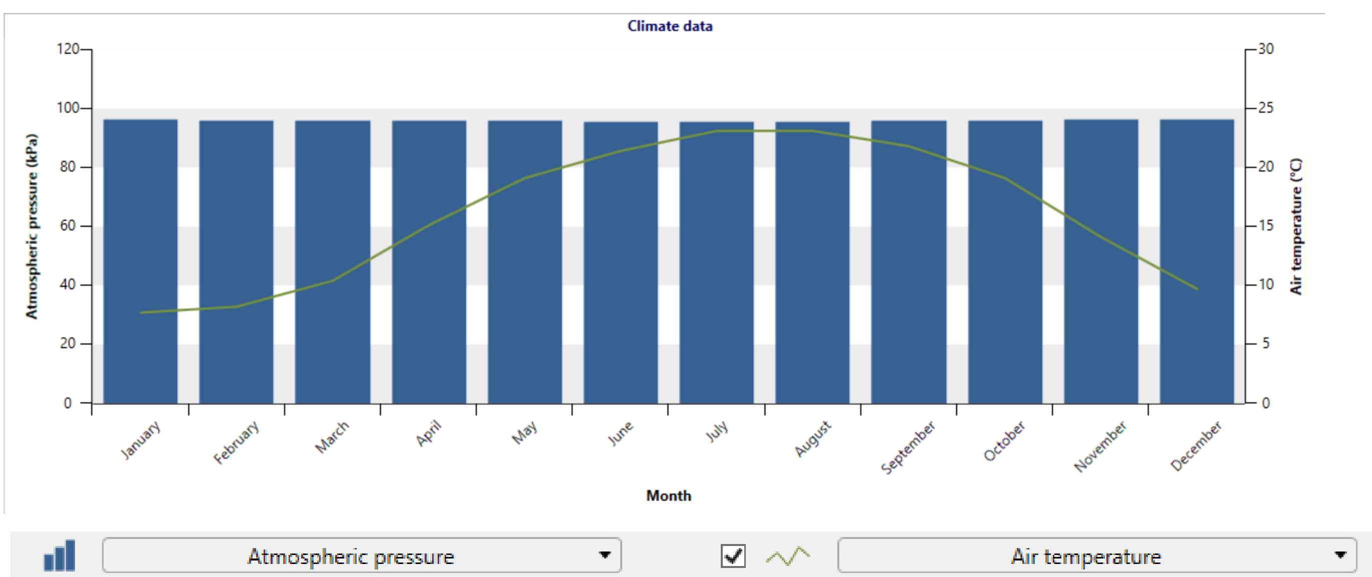


Figure 4.5 Atmospheric Pressure with Air Temp.

4.2 Specification Component of HRES

The proposed system was Bioenergy, Solar energy, Fuel cell with ESS as shown in Figure 4.6

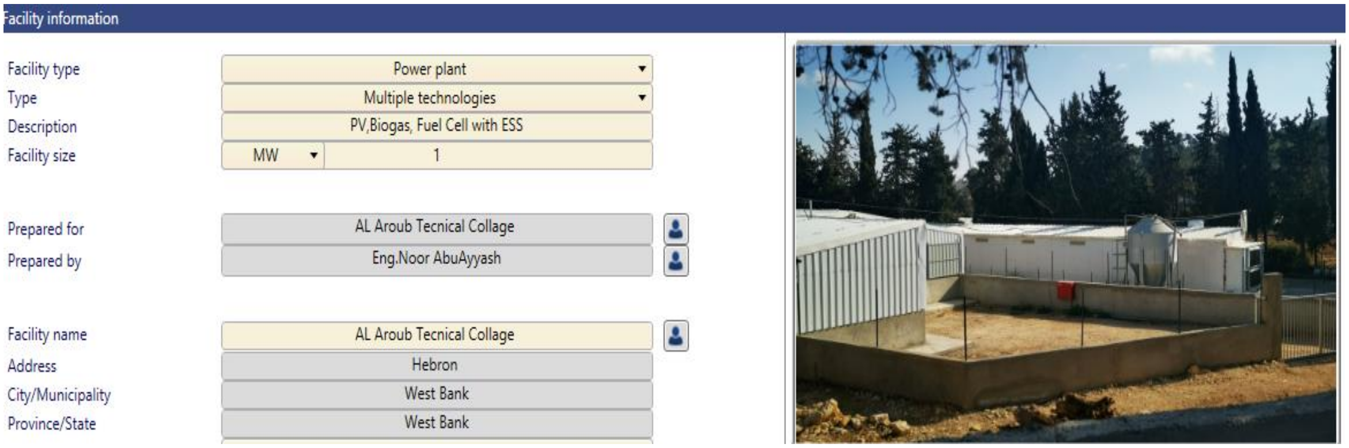


Figure 4.6 Facility Information.

In addition, the indication about energy production cost for different technologies by benchmark analysis around this area is given in Table4.2 .

Table4.2 : Benchmark Analysis _Energy Production Cost $/kWh

Energy production cost - Central-grid - Range ($/kWh)			Key assumptions (Minimum | Maximum)			
Technology	Minimum (Typical)	Maximum (Typical)	Capacity (kW)		Fuel rate | Capacity factor (%)	
Gas turbine - Natural gas	0.048	0.259	1,000,000	100,000	$0.10\ \$/\mathrm{m}^3$	$0.80\ \$/\mathrm{m}^3$
Gas turbine - combined cycle - Natural gas	0.042	0.202	1,000,000	100,000	$0.10\ \$/\mathrm{m}^3$	$0.80\ \$/\mathrm{m}^3$
Hydro turbine	0.064	0.328	1,000,000	100	75%	25%
Photovoltaic	0.157	0.335	1,000,000	10	22%	13%
Photovoltaic - Tracking system	0.134	0.316	1,000,000	10	30%	17%
Reciprocating engine - Diesel (#2 oil)	0.183	0.432	100,000	1,000	0.60 $/L	1.20 $/L
Reciprocating engine - Natural gas	0.051	0.322	100,000	1,000	$0.10\ \$/\mathrm{m}^3$	$0.80\ \$/\mathrm{m}^3$
Reciprocating engine - Biogas/Landfill gas	0.047	0.148	100,000	10	$0.0\ \$/\mathrm{m}^3$	$0.0\ \$/\mathrm{m}^3$
Solar thermal power	0.275	0.429	1,000,000	10,000	30%	20%
Steam turbine - Coal	0.063	0.114	1,000,000	100,000	11.5 $/t	115 $/t
Steam turbine - Biomass/Municipal solid waste	0.146	0.270	100,000	1,000	0.5 $/t	50 $/t
Wind turbine	0.088	0.330	1,000,000	1,000	35%	14%
Wind turbine - Offshore	0.182	0.334	1,000,800	10,800	43%	28%

General assumptions:
Note: Typical cost values in Canadian $ as of January 1, 2016. Purchasing power parity (Exchange rate) approximately 1.25 CAD = 1 USD.
Higher heating value (HHV), Inflation rate 2%, Fuel cost escalation rate 2%, Discount rate 9%, Project life: 20 yrs, Debt ratio 70%, Debt interest rate 7%, Debt term: 15 yrs, Income tax analysis: No

4.2.1 Specification of PV module

In Microgrid based on RE system, the PV module technical specification must suitable the distribution of PV modules among the inverters and also the area. The PV system use ESR_228p with rated power output 228 W under standard test conditions (STC) meaning radiation 1 kW/m^2, a cell temperature of (25 C^o), normal operating temperature (NOCT), are considered. The technical Specification for PV panel and Inverter parameters are shown in Table 4.3 and Table 4.4 respectively

Table 4.3 Data sheet _Technical parameters of PV Specification(ESR_228p)

Item	Technical Specification
Model	**ESR_228p**
Rated Power (W)	**228**
Open circuit voltage Vsc(V)	**37.8**
Short circuit current Isc(A)	**8.30**
Efficiency	**14%**
Area (m^2)	**1.7**

Table 4.4 Data sheet _Technical parameters of Specific inverter (20000TL)

Item	Technical Specification
Model	**Sunny Tripower 20000TL**
Max DC power(W)	**20450**
Max input voltage Vsc(V)	**1000**
Voltage Input Range	**580_800**
Max input current Isc(A)	**36**
Efficiency	**97%**

For this area the best tilt angel was approx for fixed system was 29.3^0as shown in Figure 4.7

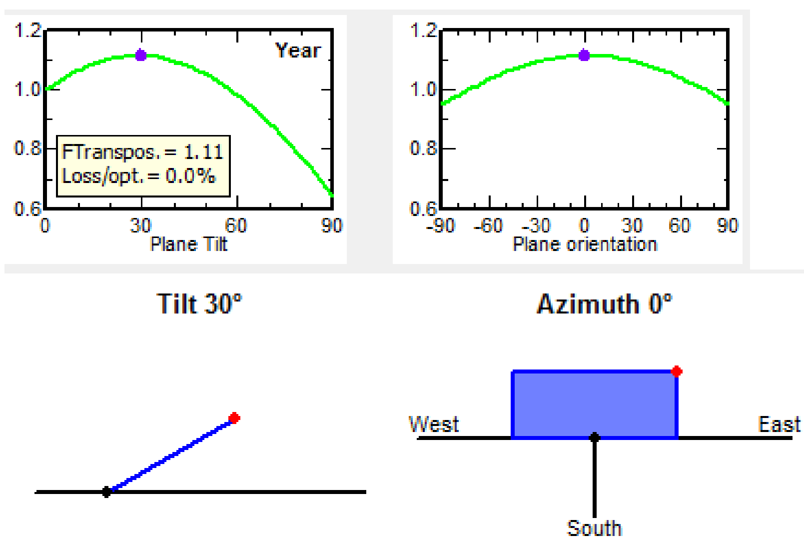


Figure 4.7 from PVsys data base illustrates the best average tilt angel yearly it was approx. 30^0

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Using Shutting down the inverter for protection from interruption and ground-fault detection circuit fault current isolation, and solar power load isolation. This way is recently going through a developmental process, and it is expected to become a mandatory requirement in future installations. So we use main AC and DC breaker, disconnected to get this goal. In PV system ,combiner fuse (MCB DC)/string. Grounded has been put, means that a conductor connects to the metallic frame of an electrical device. Also using Grounded conductor to conductor that is intentionally grounded. In PV systems it is usually the negative of the dc output for a two-wire system or the center-tapped conductor of an earlier bipolar solar power array technology as shown in Figure 4.8.Equipment grounding conductor does not carry current and is generally a bare copper wire that may also have a green insulator, other important protection lightning protection in geographic locations, for locations where lightning is a common occurrence, the PV system and outdoor devices must be protected with appropriate lightning arrestor devices an special grounding that could provide a practical mitigation and a measure of protection from equipment damage and burn out.So surge arrestor has been used to prevent the hazard. Also surge arrester has been installed on line to line voltage for biogas system .For PV system it exists inside PV inverter also every important calculation needed in protection side has been listed in equations 4.9 ,4.10 and 4.11.

$$\text{MCB rating} = 1.25 \times 1.25 \times \text{Isc(pv)} \tag{4.1}$$

$$\text{Array disconnector fuse} > \text{Number of string} \times \text{MCB rating /string} \tag{4.2}$$

$$\text{Inverter fuse} > 1.25 \times (\text{inverter output power /output voltage}) \tag{4.3}$$

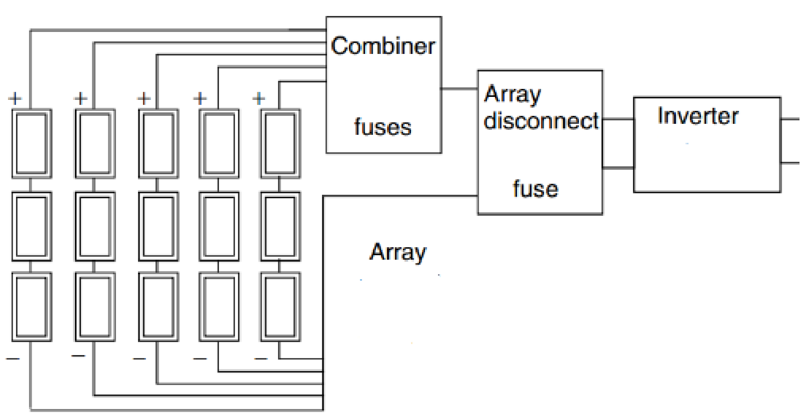

Figure 4.8: PV system protection design layout.

4.2.2 Specification of Bioenergy system

As we mentioned before bioenergy system design depends on many factors, the predicted manure and amount, the needed power production, and finally the max capacitive of the line. Beside that the available manures in the area. The design will include two digesters (one main digesters and other one post digesters). Assuming the expected amount of gas generated in the digesters and the targeted power production, one gas engines with the capacity of 6kW for each one. Combined heat and power (CHP) type will be used. The electricity power will not be injected into the grid and the heat power will be used for heating the digesters. The digester containers must be absolutely gas and water proof, as well as airtight. They are built from ferroconcrete and each digester has contained a stirrer, which is so important for protecting the substrate guaranteeing and homogeneous that the gas generated was evenly discharged [17]. Data sheet _Technical parameters of Specific biogas generator is illustrated in Table 4.5

Table 4.5 Data sheet _Technical parameters of Specific biogas generator.

Suitable gas: Biogas.
Gas consumption: 1.5m^3/kW.h. 400V 50 Hz.
Running Power 6 kW. Peak Power 6.3kW.

The digester we design was tow in parallel on of them has been existed in the farm that shown in Figure 4.9. More over Protection calculation was plus 25% from rated currant for MCB. Surge arrestor we put it on line to line voltage 400V.

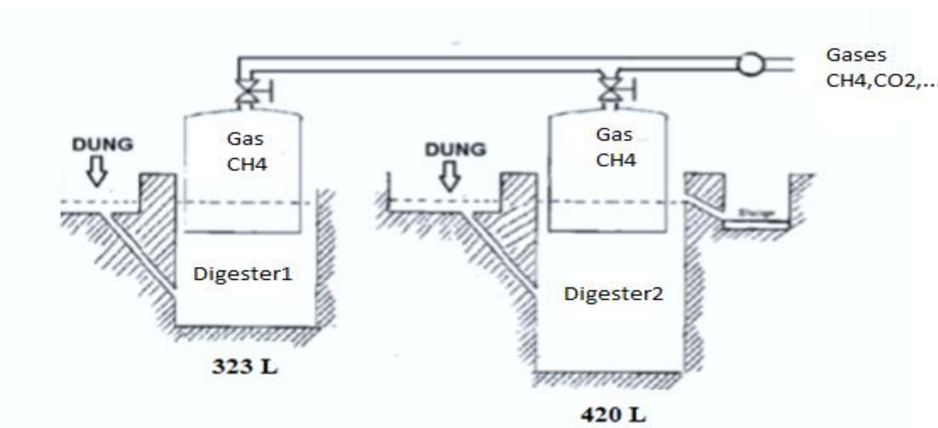

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Figure 4.9: Two digester design in parallel.

4.2.3 Specification of Energy Storage System _Hydrogen Generation (PEM Electrolyzer) System

Based on [48] study, the fuel cell system with hydrogen ESS rated power was 10 kw as stand by generator the electrolyzer has been took its energy from excess power and that will be suitable for this connection electrical point as we mentioned before (IEC), 10 kW system has been selected in this research, so based on market study that defined and evaluated market requirements, technological readiness, and barriers to implementation, Battelle has 10 kW and 25 kW (net) fuel cell power systems for material handling equipment (MHE). A 10 kW fuel cell power system was able to this Class 6 equipment as well as several lift codes of Class 1and 2 equipment. Figure 4.10. is illustrated PEM System Schematic for 10 kW and 25 kW MHE Applications[48].

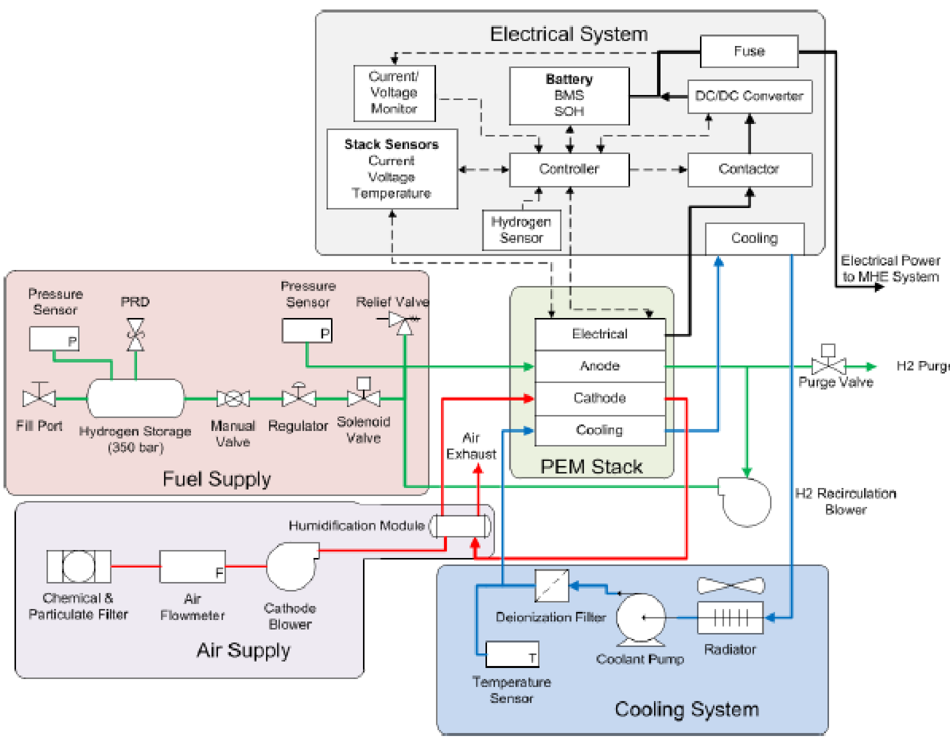


Figure 4.10. PEM System Schematic for 10 kW and 25 kW MHE Applications [48].

4.3 Economic data

The annual real interest rate considered.7%,and in Palestine, the most important types in the consumer price index are food and non-alcoholic beverages (35 percent of the total weight);

transport (14 percent) and miscellaneous goods and services (12 percent). In addition the index includes: electricity, water, housing, gas and other fuels (9 percent); clothing, footwear (5 percent); alcoholic beverages and tobacco (4 percent); health (4 percent); communication (3.5 percent); education (3.4 percent); recreation and culture (2 percent) and restaurants and hotels (2.0 percent)[49]. .So the inflation rate in Palestine for electricity service was 1.6% in 2019 . The microgrid lifecycle was 25 years., and maximum annual capacity shortage 0.1 % (constrain)There are two economic factors mentioned in this study, total net present cost (CNPC), capital recovery factor(CRF) and levelized cost of energy (LCOE) as shown in equation 4.12, 4.13 and 4.14 respectively.

$$C_{NPC} = \frac{C_{TANN}}{CRF\ (i\ .N)} \tag{4.4}$$

$$CRF_{i\ N} = \frac{i(1+i)^{N}}{(1+i)^{N-1}} \tag{4.5}$$

$$COE = \frac{NPV\ of\ total\ cost}{NPV\ of\ electrical\ energy\ produced\ over\ life\ time} \tag{4.6}$$

Where :

C_{NPC} : the net present cost .

C_{TANN}: annualized cost

i: the annual discount rate .

N: the project life time .

$CRF(i.N)$: capital recovery factor.

COE: levliezed cost of energy .

4.4 Load Analysis

In this section we used two software PVsys and Homer to make load analysis and Excel sheet to derive load growth formula for this area. The average load was 31.5 kW (267MWh /year) as shown in figure 4.11 and 4.12 respectively.

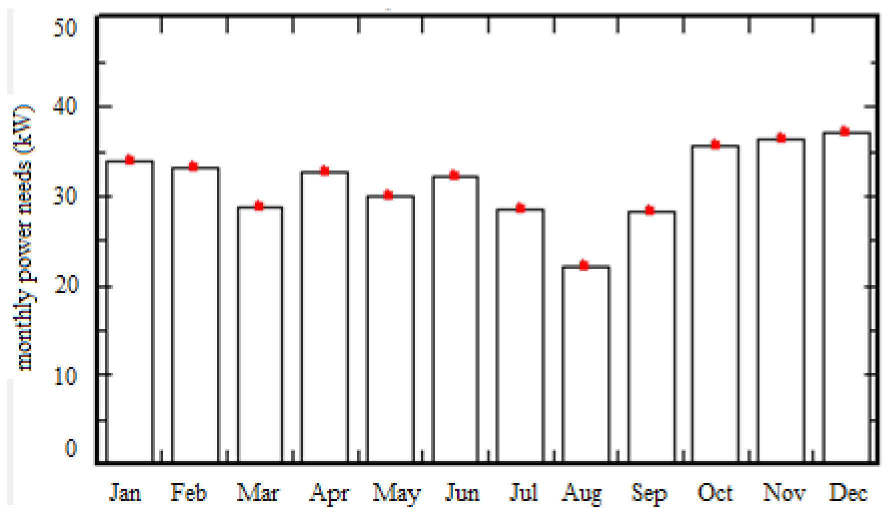


Figure 4.11:The average daily power needs in kW per month.

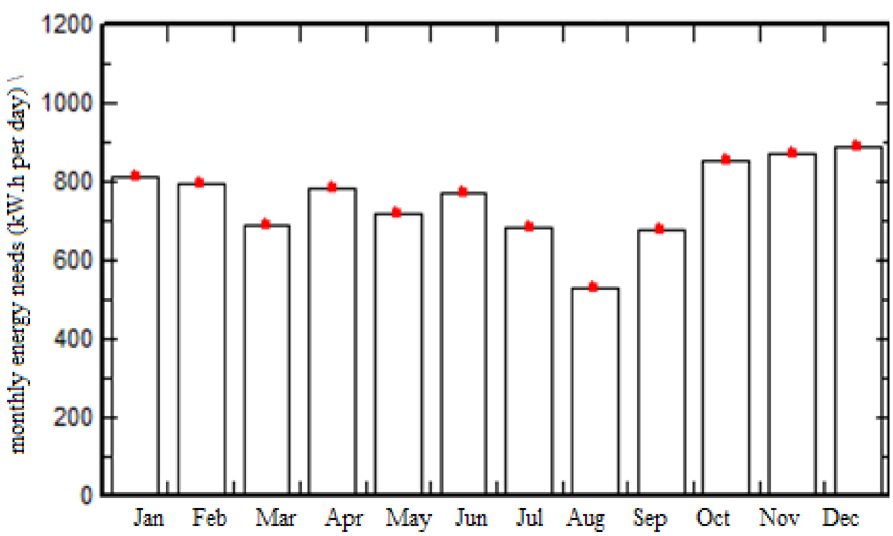


Figure 4.12 :The average monthly energy needs in kW.h /day.

The maximum average load was in December and the lowest one on August as shown in Figure 4.13.

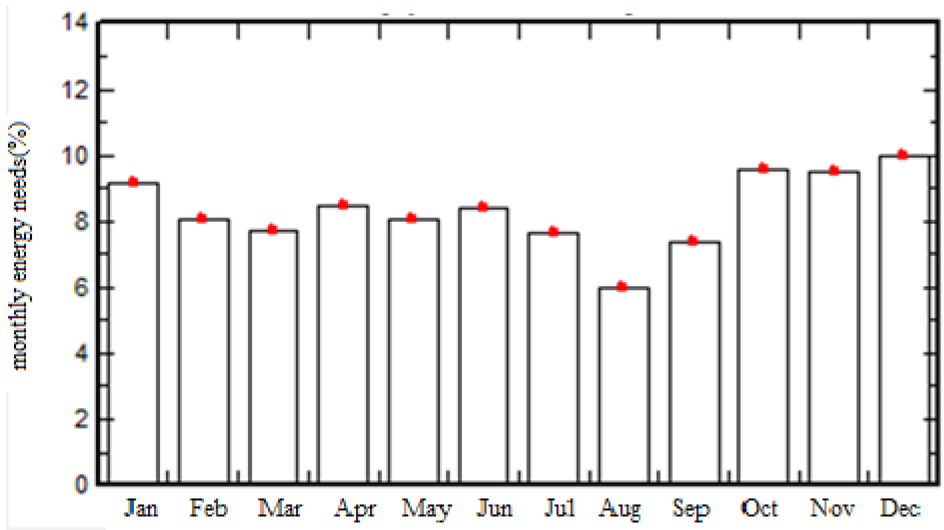


Figure 4.13: Average monthly energy needs in percent**.**

In Figure 4.15 illustrates hourly average value in day, it was 31.5kW and 756kWh/day.

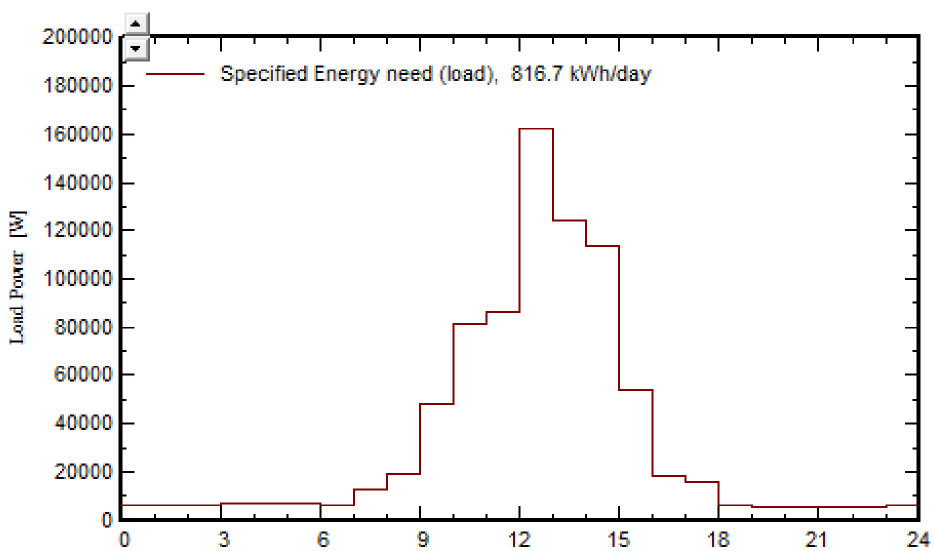


Figure 4.15 :hourly load in kW.

So the average load was 31.5 kW All previous data in 2013 ,to solve this problem load growth formula has been founded and derived from previous years data (2008_2013) as shown in Table 4.6.

Table 4.6 load growth table from (2008_2020).

Year	Number	Actual and Predicted Value(kW)
2008	1	200
2009	2	210
2010	3	232
2011	4	250
2012	5	284
2013	6	300
2014	7	325.35
2015	8	352.842075
2016	9	382.6572303
2017	10	414.9917663
2018	11	450.0585706
2019	12	488.0885198
2020	13	529.3319997

So the formula was in equation 4.15

$$Load\ growth\ formula\ = (End\ value/Start\ value)^{\frac{1}{n-1}} - 1 \qquad (4.15)$$

$where\ n\ is\ the\ number\ of\ values$.The result **was 8.45%** annual load growth.

4.5 Layout HRES

The system that was considered: A stand-alone network based on RES , there are many alternative energy options available and energy storage technology including:

1. PV solar array
2. Methane turbines
3. Fuel cell
4. Hydrogen storage unit
5. Dump load
6. AC/DC converter

7. Boiler
8. Electrical loads

➢ **System Block diagram**

Figure 4.16 is illustrated system components.

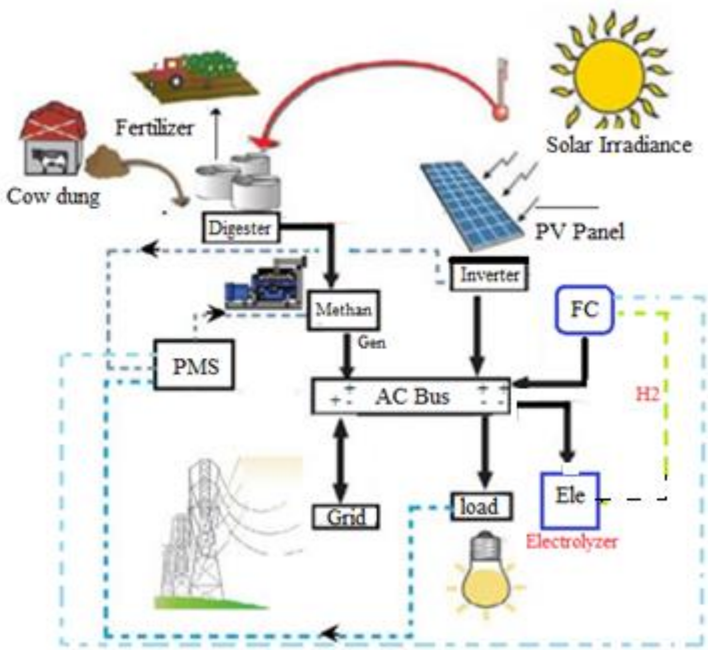


Figure 4.16. system block diagram.

Alaroub technical college has Main distribution board as shown in figure 4.17 also it has emergency system in red color. The system line diagram also shown in figure 4.18.

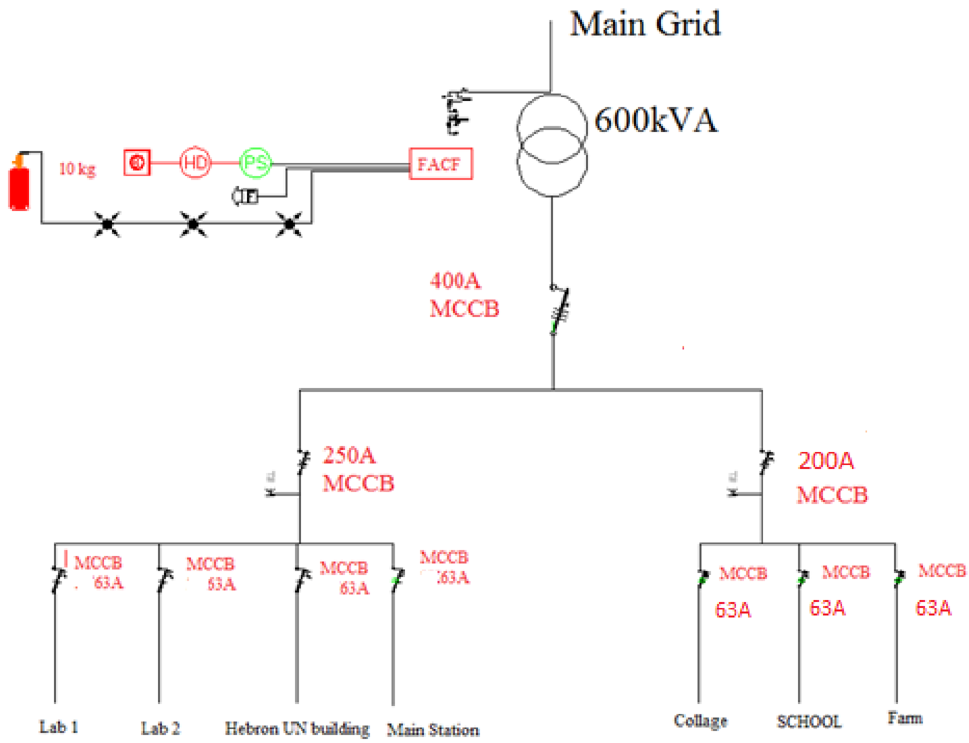


Figure 4.17. Main Distribution Board

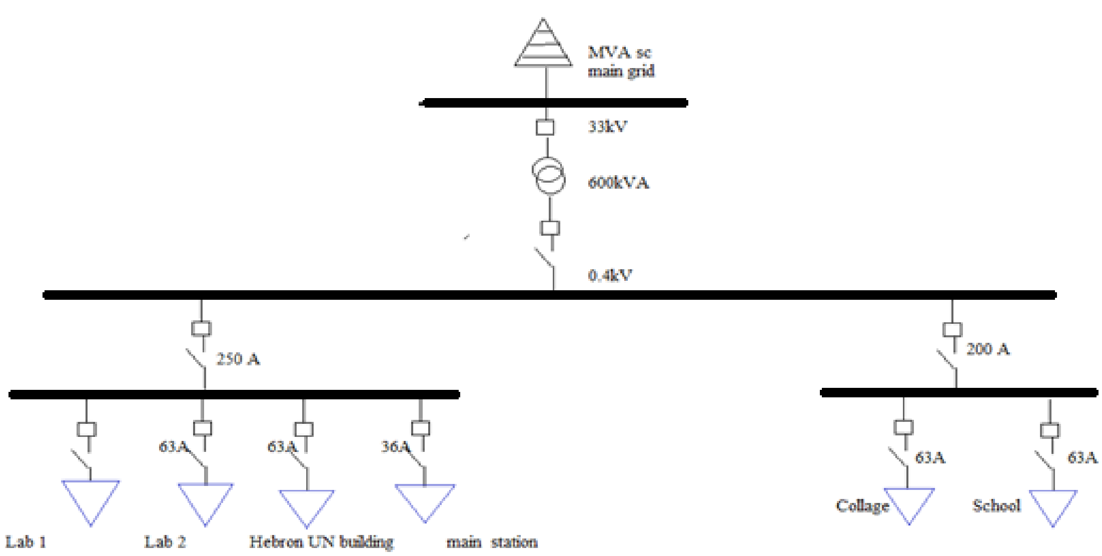


Figure 4.18. Single line diagram.

4.5.1 PV Array Layout

In this section ,display a SketchUp figures is illustrated to show solar system of the block diagram which was introduced in the previous section ,where is used the approximate dimensions in this program.First of all Figure 4.19 is shown PV layout with full system in general.

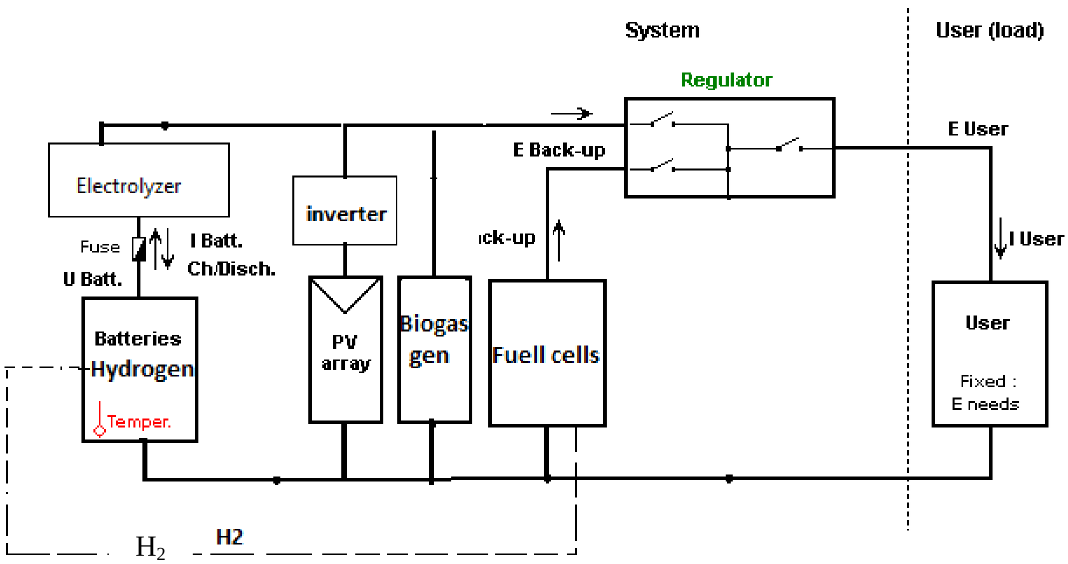


Figure 4.19. PV layout in the full system.

1) AL Arroub Farm Roof top current situate:

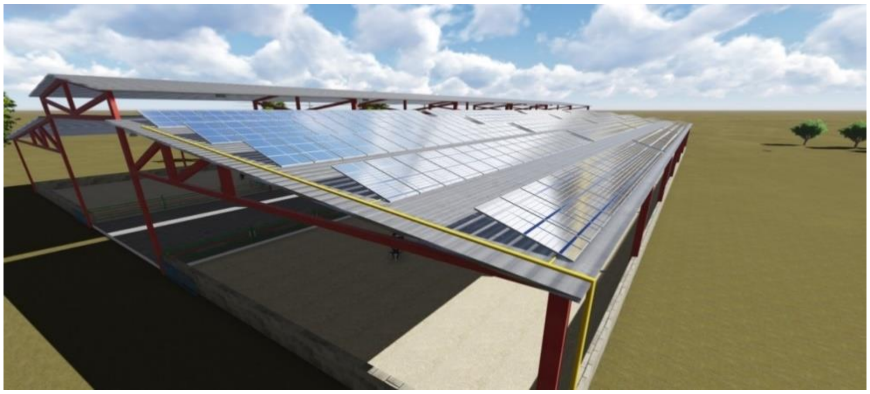
Figure 4.20. The Current Status of the Southern Side of the AL Arroub Farm

Figure 4.21. The Current Status of the Northern Side of the Al Arroub Farm

2) Al Arroub Farm after the addition of solar panels

Figure 4.22. The South Side of the animal sheds after Adding of Solar Panels

3)Electrode earthling system:



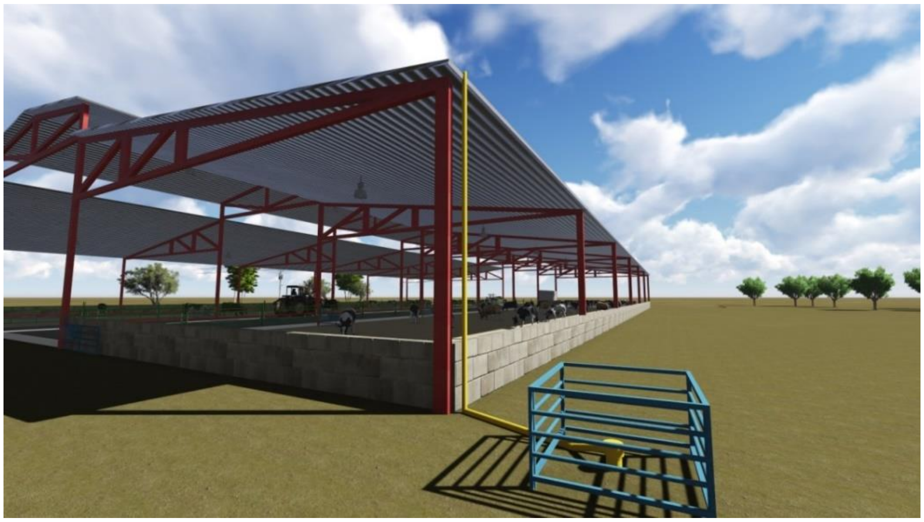


Figure 4.23.Earthling of Solar System

4)Grid :

Figure 4.24. Grid layout.

4.5.2 Bioenergy system Layout

For bioenergy source the system layout is illustrated in Figure 4.25 .

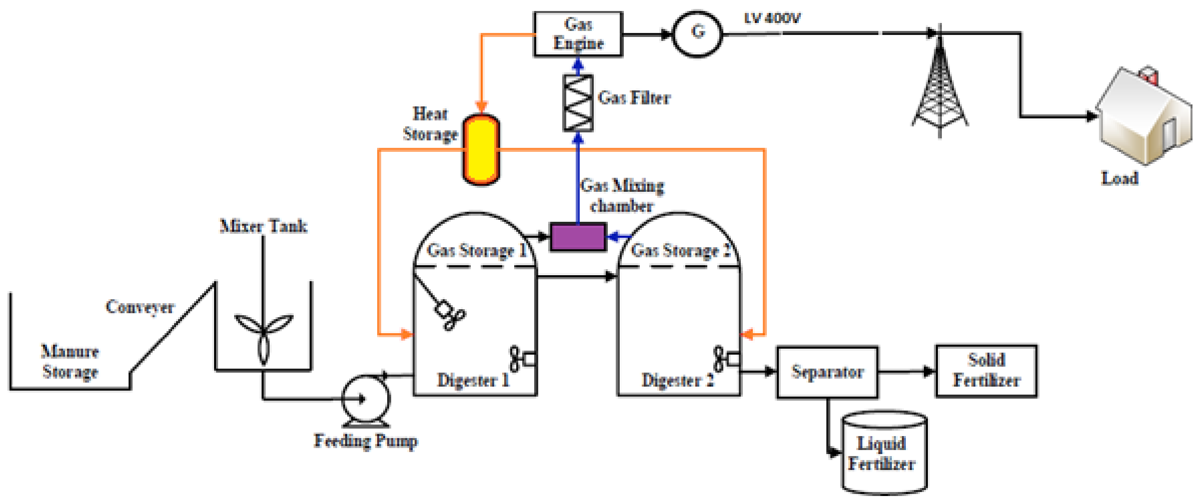


Figure 4.25: Bioenergy system layout **[17].**

4.6 Power Management Strategy

For control side , power mangment strategy was built and satisfid theses conditions :

If $P_{net} > P_{load}$, electrolyzer will work and use this energy to get hydrogen and store it untill we need it .
If $P_{net} < P_{load}$, FC will work and use hydrogen from energy storage .

Also the base RE sources will be solar system and biogas genarater at the on peak fuel cell will work. power mangment strategy is shown in Figure 4.26

Where:
P_{net} equal = $P_{pv} + P_{methan}$
P_{ele}:power for electrolyzer
P_{fc}: Fuel Cell Power
P_{comp} :compresion system power.

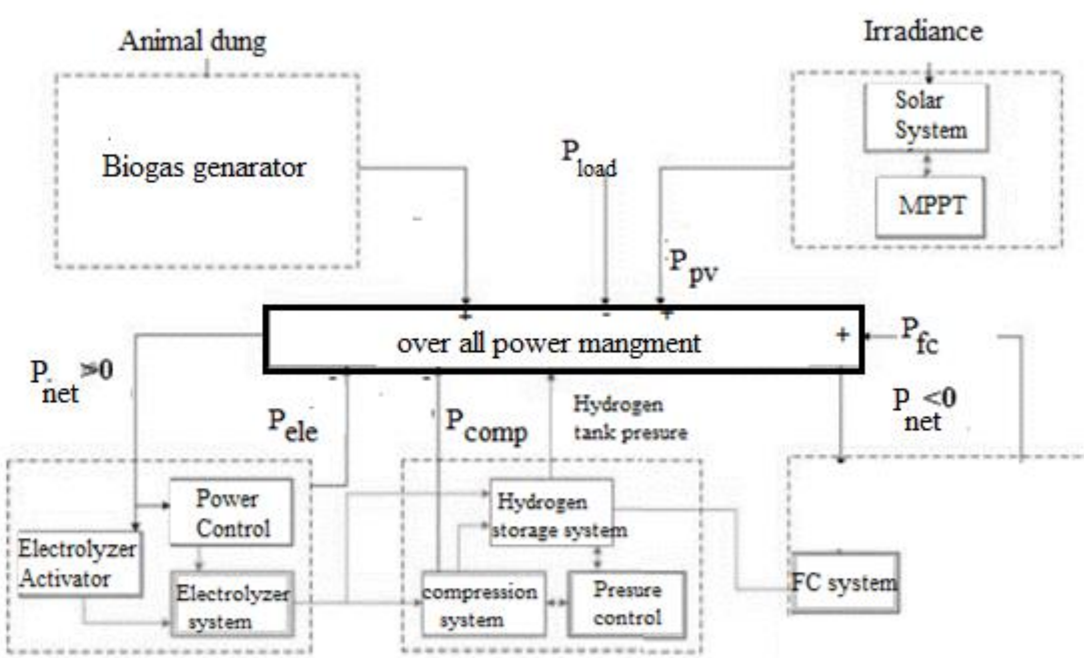


Figure 4.26: power management strategy.

Algorithm has been simulated in MATLAB as following in Figure 4.27:

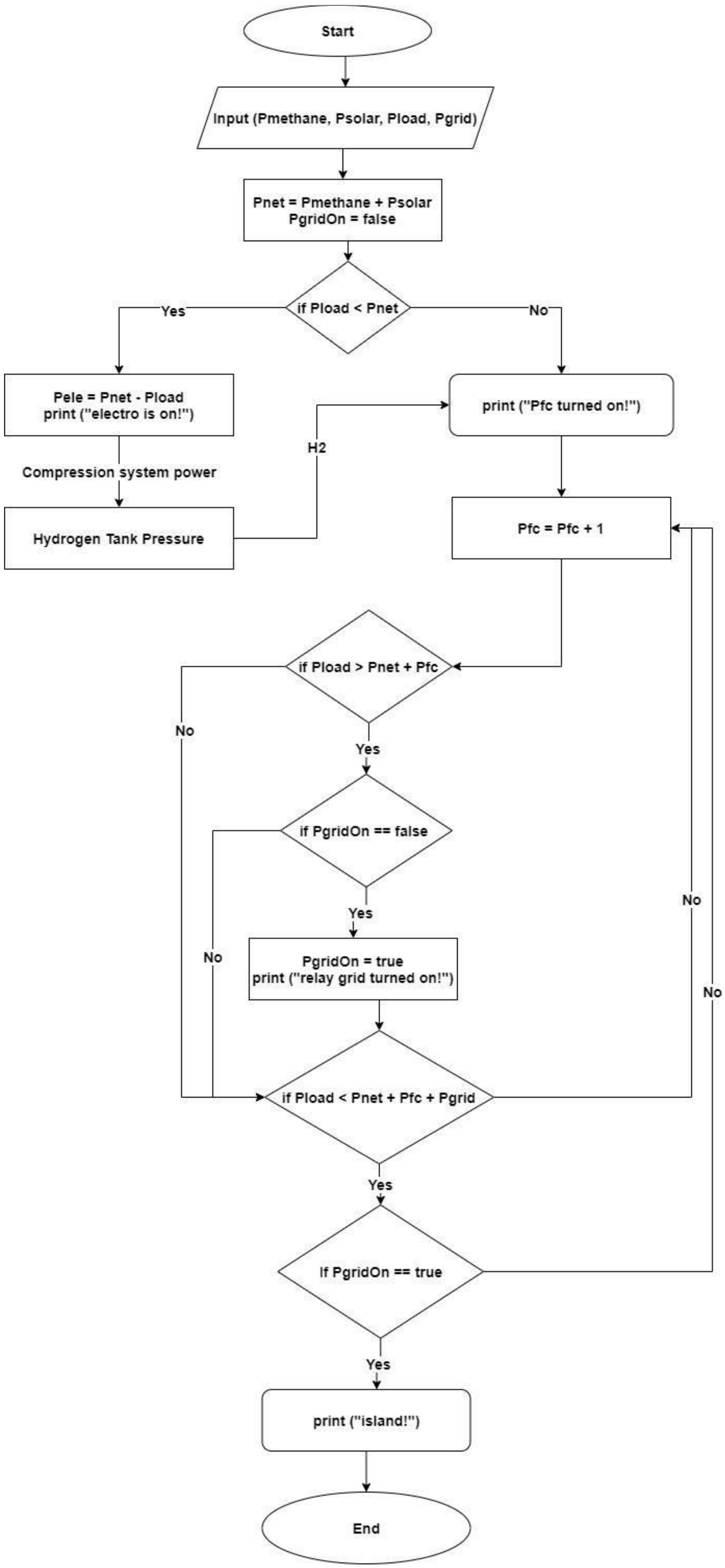


Figure 4.27. Power management strategy flowchart.

Chapter 5

Analysis and Discussion of Results

5.1 Overview

As stated in previous chapters, some renewable energy generation systems such as solar and wind energy seem to be not fully reliable since they are cannot meet stable electricity demand due to several reasons. Power generation using bioenergy and solar energy can be unstable since the first depends on methane production and the later depends on sun light during daytime not to mention that they are both subject to any change in weather conditions. Therefore, this puts us in a need to design a hybrid system that is made up of bioenergy and solar power for the proposed site. A system that can produce highest amount of energy production, within the existing space available, at the lowest possible price. In this chapter, the results of the study are presented and discussed with reference to previously- mentioned aim of the study, which was to design a hybrid system using solar , bioenergy and energy storage system as sources for energy. The results obtained from this study were put RETscreen software optimization analysis and are presented in this chapter. Results of the proposed optimized Bio-Solar hybrid energy generation system with hydrogen energy storage system are thoroughly analyzed and the conclusions of findings are drawn. In order to get the best efficient model and to better understand the results, three scenarios are suggested as shown in Table 5.1. Three models were built depending on RETScreen Expert platform ,three virtual models and the structural design of the research is shown in Figure 5.1.

Table 5.1 Types of models .

model number	What is the model!!
1	Base model, PV System with battery energy storage
2	depending on RE sources model (solar PV, bioenergy, battery storage).
3	Mixed technologies (solar ,bioenergy, fuel cell with ESS)

Each model focused on threer key aspects of the results:

1. Cost configurations charts
2. Cash flow over 25 year
3. Carbon emissions as(ton/year

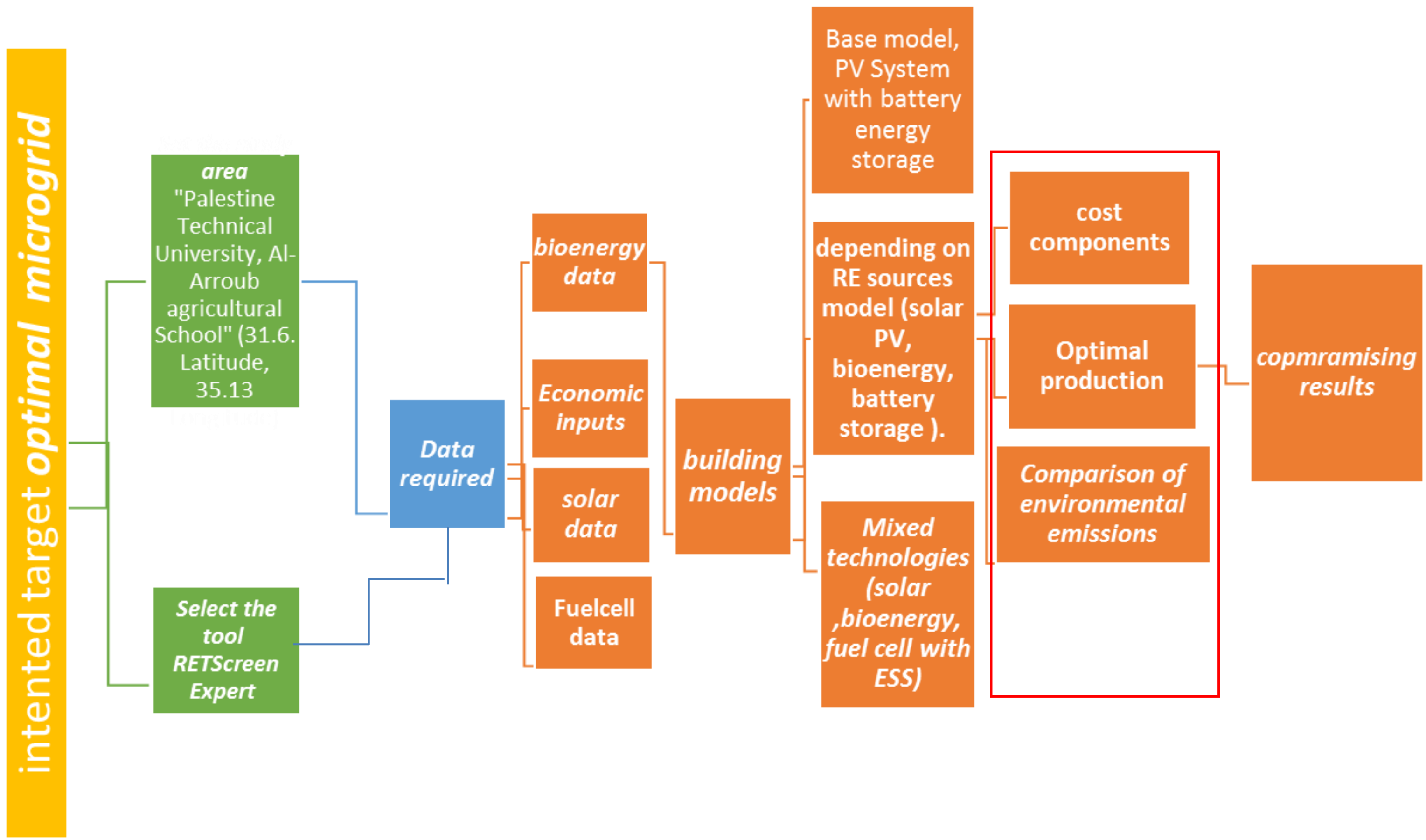


Figure 5.1. The structural design of the research

5.2 Results of a Base model, PV System with batteries energy storage.

In this model, solar with battery energy storage (like off grid system) have been proposed to cover all load requirements without need of Israel Electric Corporation(IEC) company .The net present value(NPV) was 0.371859M$ and that good indicator that this model is good but not enough. So the other factor LCOE was 0.7 $ /kWh and this value had been assumed as high cost that's due using battery storage system about 25% of demand .Also the environment sense has been mentioned in this study. The carbon dioxide emission was the other indicator, it was 117.5 t/year and that because using battery as energy storage system.The Figure 5.2 is shown the results of optimization for each hour a long year (i.e. 8760 hour). The Figure also presents the output of the PV for all hours during the year applied by applied steps that was explanted in previous chapter, starting from January where the value rises up to reach the highest point at summer then decrease in autumns all the way to December.

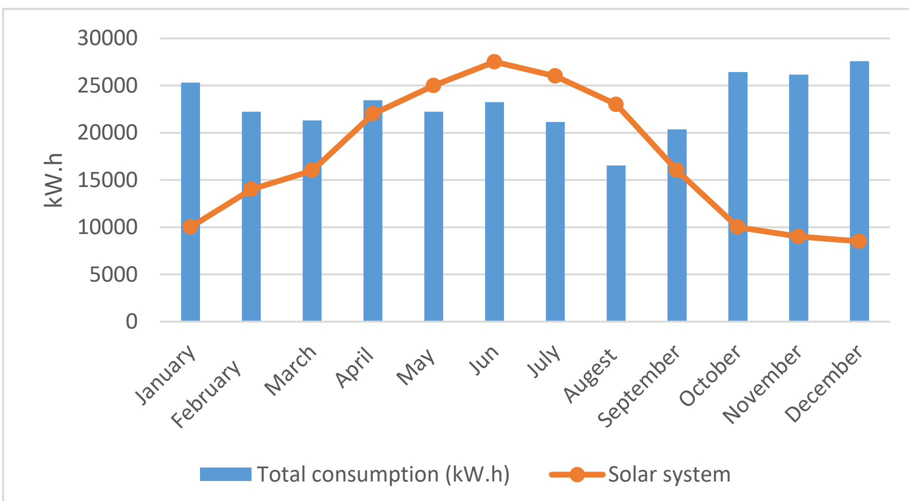


Figure 5.2. Output energy of the PV and battery for a year.

the proposed solar system with a capacity of 188 kWp able to generate 207,000 kWh/y; an output that can cover 75% of demand and the battery covered the rest . The Cost configurations are divided into four sections, capital costs, replacement costs, operating cost, and salvage over 25 years. Now look at next Figure5.3 which represents the cost components for this model .

Figure 5.4 and Figure 5.5 respectively are shown the net and cumulative cash flow of the PV system with battery . As shown in the graph, the payback period of investment starts after 17 years and 4 months

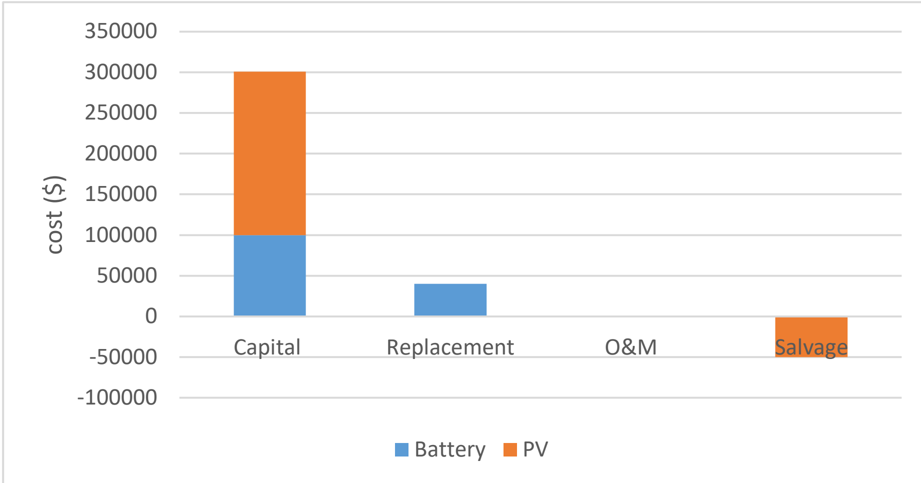


Figure5.3 The cost components for model 1.

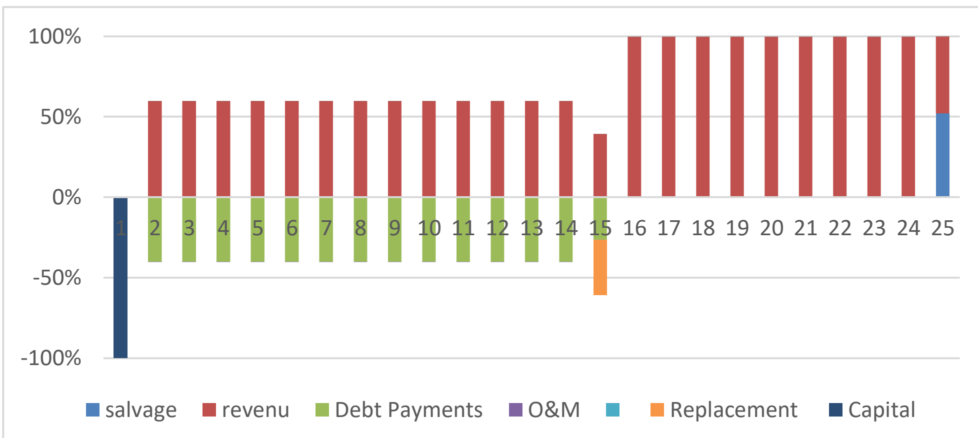


Figure 5.4 Cash flow in Model 1 .

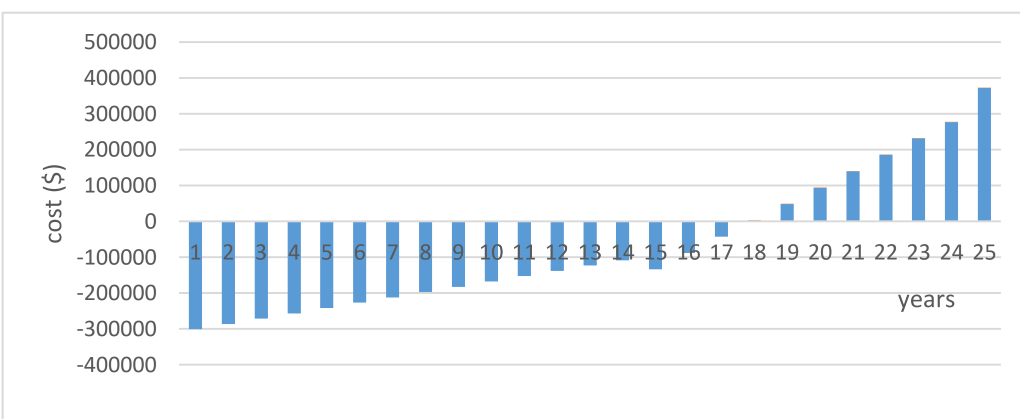


Figure 5.5 Cumulative cash flow in Model 1 .

In addition it was very important to overlook the environmental dimensions of the different models. Therefore, evaluating the performance of the networks was an important factor in carbon emissions, especially since there are financial taxes to be paid per ton of harmful emissions to the environment. In this model carbon dioxide emission was 2.1 ton/yr. .

5.3 Results of a depending on RE sources model (solar PV, bioenergy, batteries storage).

In this model, it has been used solar with bioenergy system and energy storage units(batteries) as energy sources .The net present value(NPV) was -0. 403796M$ and that bad indicator that this model is not profitable and not good for the investor. The environment sense has been mentioned in this study. The carbon dioxide emission was the other indicator, it was 4.3 t/yr and that because using battery as energy storage system also biogas fermentation emitted carbon dioxide about 40% of biogas was CO_2.The Figure 5.6 presents the output of the PV ,biogas and battery for all hours during the year applied by applied steps that was explanted in previous chapter.

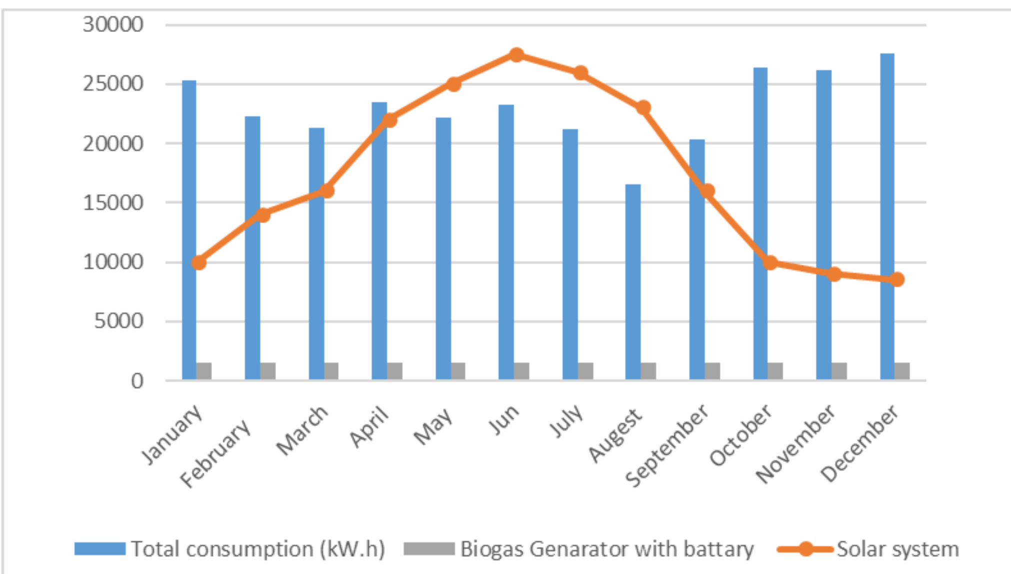


Figure 5.6 . Output of the PV ,biogas and battery for a year.

The Cost configurations are divided into four sections, capital costs, replacement costs, operating cost, and salvage over 25 years. Now look at next Figure5.7which represents the cost components for this model .

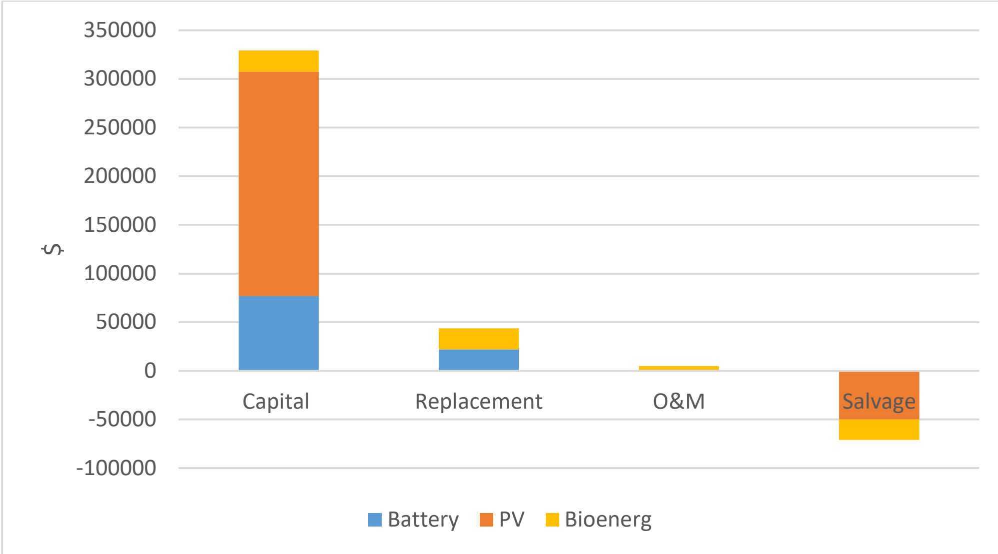


Figure5.7 . The cost components for model 2**.**

Figure 5.8 and Figure 5.9 respectively are shown the net and cumulative cash flow of the PV_bio system with battery . As shown in the graph,. The payback period of investment not occur.

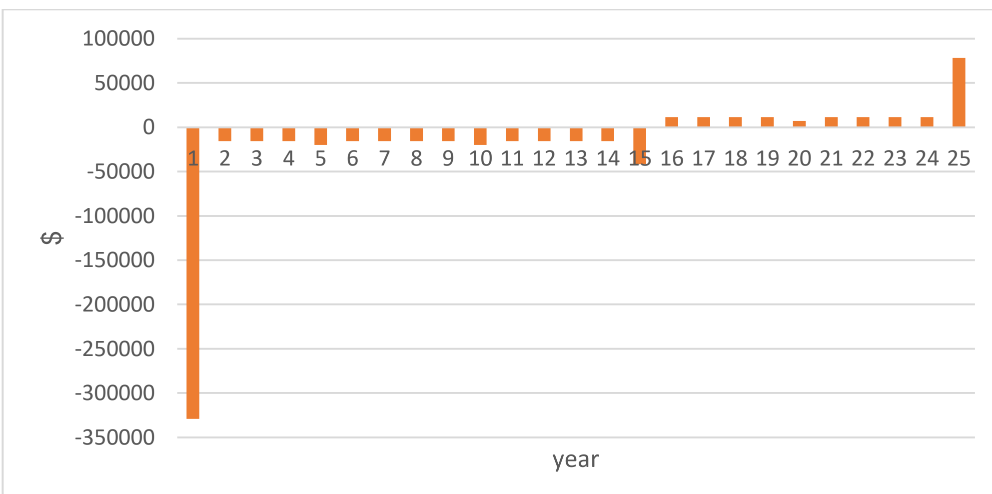


Figure 5.8 Cash flow in Model 2 **.**

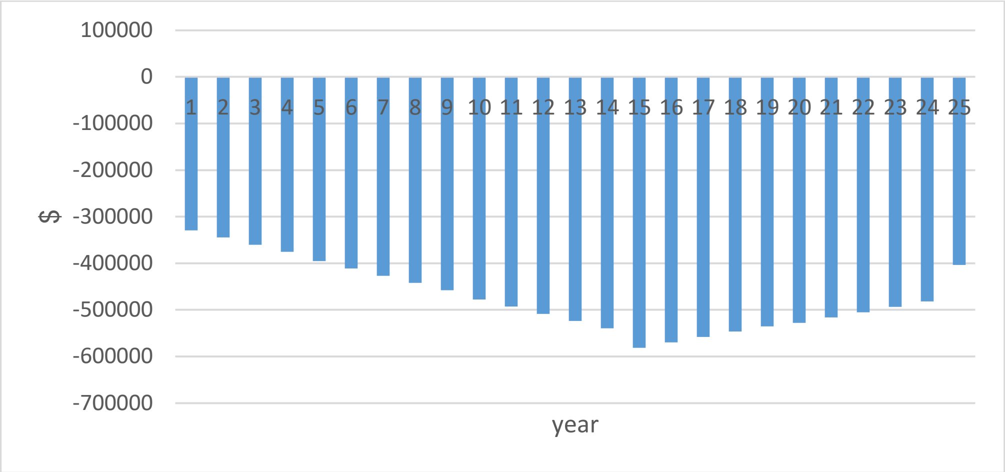


Figure 5.9 Cumulative cash flow in Model 2 .

5.4 Results of Mixed technologies (solar, bioenergy, fuel cell with ESS 10kW)

In this model, it has been used solar with bioenergy system and Fuel cell energy storage units(batteries) as energy sources. The net present value(NPV) was 0.473570 M$ and that good indicator so this model good for the investor. The carbon dioxide emission was the other indicator, it was 1.5 t/year and that because using hydrogen battery as energy storage system. The average load consumption and embedded generation was illustrated in Figure 5.10 , so when the load is more than embedded generation the fuel cells work and generate electricity at on peak as stand by generator in other hand when the embedded generation is more than load electrolyzer uses this exceed energy to analysis water and store hydrogen as fuels for fuel cells.

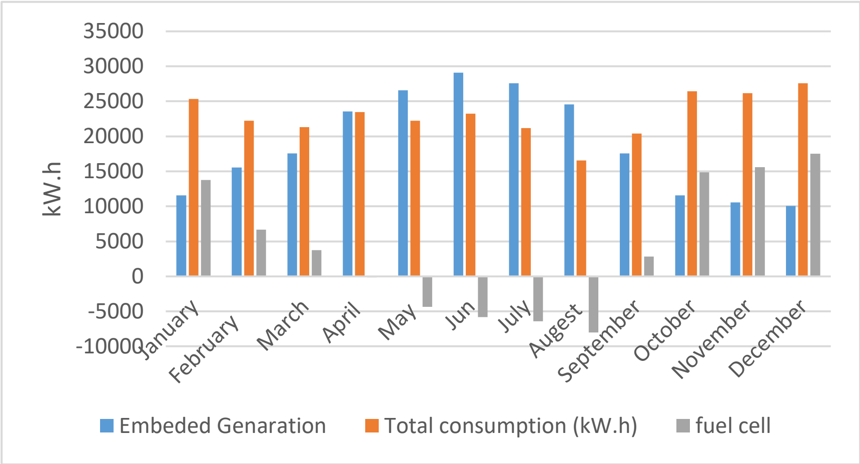


Figure 5.10: The average load consumption and embedded generation

Solar system with a capacity of 188 kWp able to generate 207,000 kWh/y; an output that can cover 75% of demand and the FC with biogas generator covered the rest . The Cost configurations are divided into four sections, capital costs, replacement costs, operating cost, and salvage over 25 years. Now look at next Figure5.11 which represents the cost components for this model .Bioenergy generator had replacement cost about 4330$ each 5 years and Fuel cells every 15 years with salvage value that make FC with hydrogen storage system better than traditional battery.

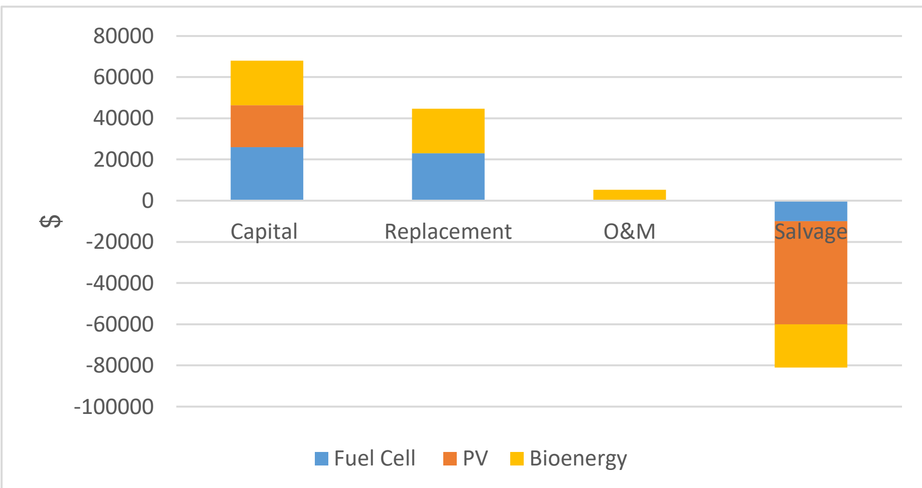


Figure5.11 . The cost components for model 3.

Figure 5.12 and Figure 5.13 respectively are shown the net and cumulative cash flow of the PV_bio system with FC and ESS. As shown in the graph the payback period of investment was 4years and 6 months.

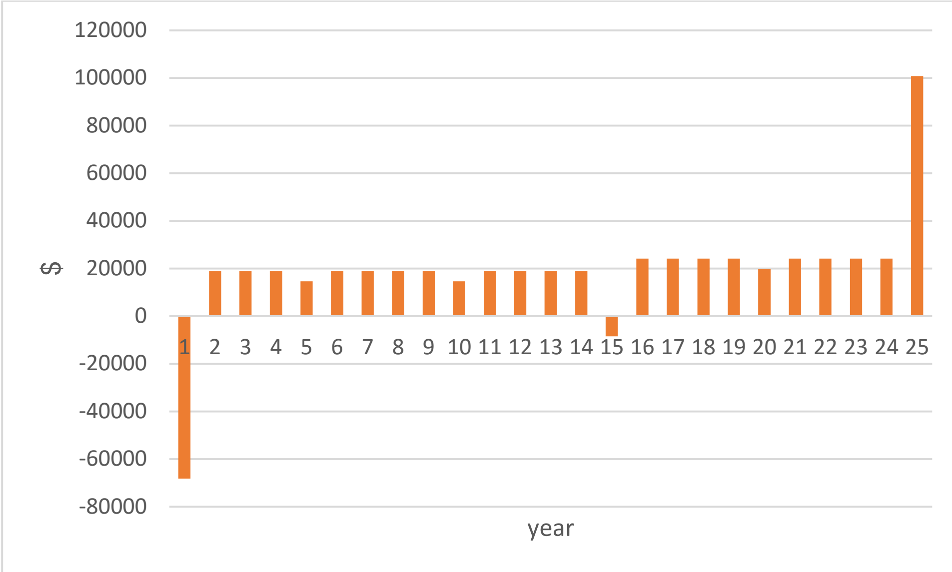


Figure 5.12 Cash flow in Model 3 .

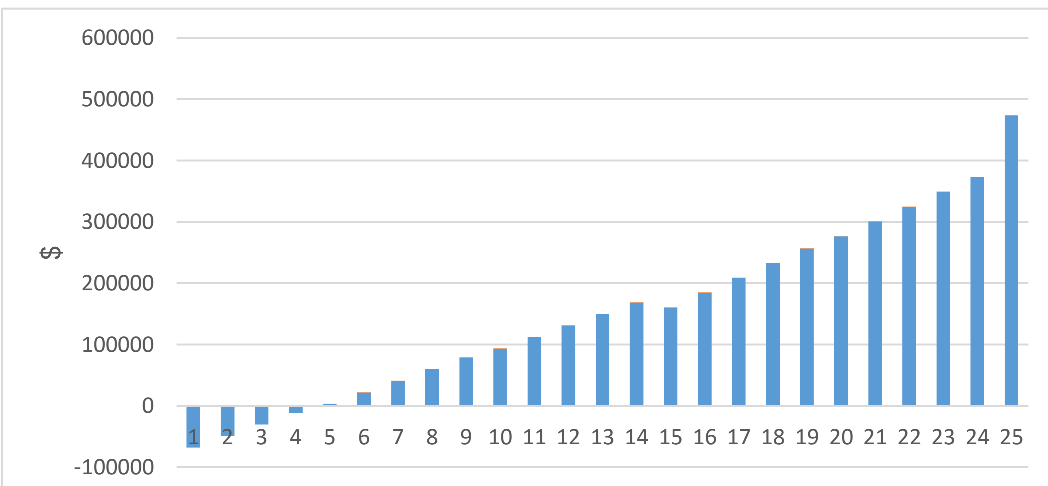


Figure 5.13 Cumulative cash flow in Model 3 .

5.5 Summarize the most important economic output of the three models

An overview of the economic outputs have been shown in Table 5.2 , that the third model is the best economically feasible model, e. A closer look at LCOE of the model 2 noted that the cost price of model is as high as possible, due to the high investment and replacement cost. If we look at the model 3 that depends on RE sources completely, we will notice that the levelized cost is Relatively low. Also if we look at CO2 emissions, model 3 is the less one and model 1 is the higher one. Note that the third model is the best environmentally friendly option with the lowest emissions. So the winner model is the third model .

Table5.2 Economic outputs .

Item	Model 1	Model 2	Model 3
Net present value, M$	***0.371859***	***-0.432000***	**0.473570**
Levelized cost of energy, $/kWh	**0.7**	**-**	**0.157**
Co_2 emission (ton/year)	27.6	56.8	2.1

The following Figures 5.14 ,5.15and 5.16 respectively show the one main gas of harmful emissions, namely carbon dioxide, knowing that there are other harmful gases, including sulfur dioxide, net present value for each model and finally levelized cost of energy.

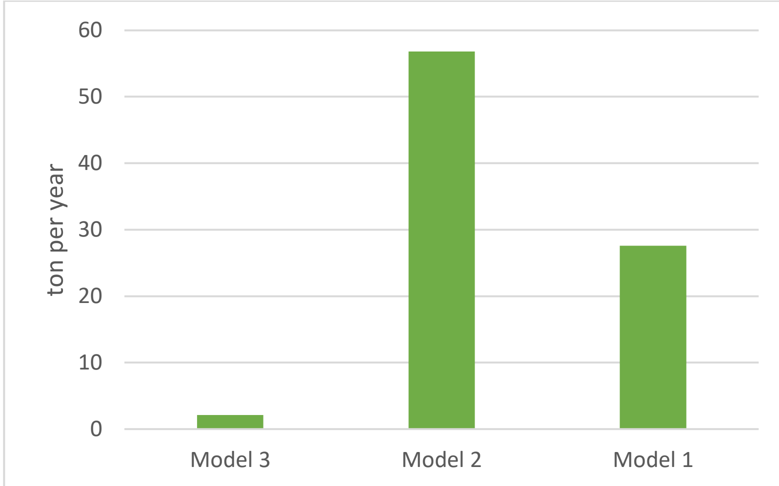


Figure 5.14 .CO_2 emission reduction (ton/year).

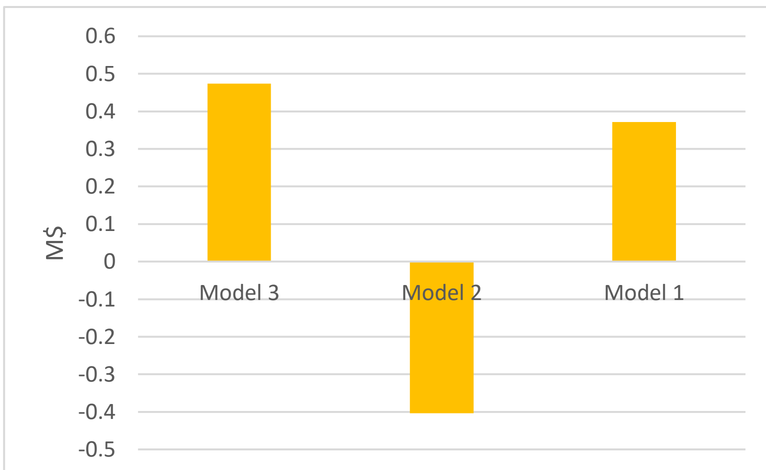


Figure 5.15. Net present value(M$) .

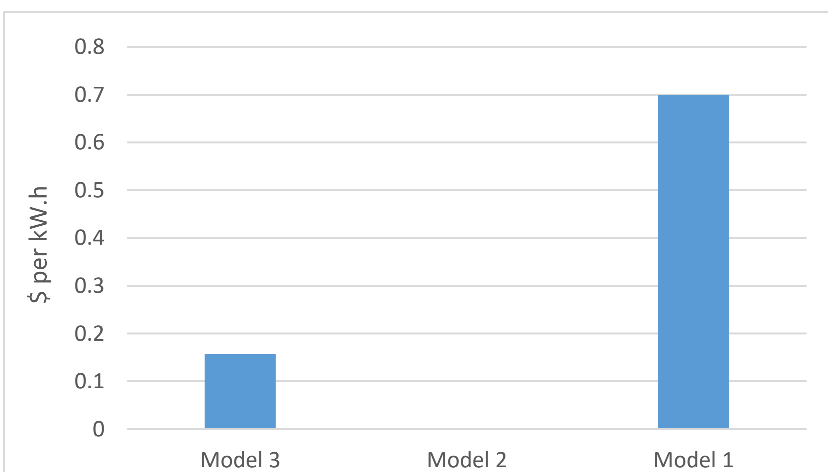


Figure 5.16. Levelized cost of energy, ($/kWh**).**

Conclusion Remarks

6.1 Summary

Microgrid based on renewable energy systems are becoming rapidly spread that because of high fuel cost. solar system and methane energies, have high availability particularly in rural electrification spatially in Palestine. In this thesis, a hybrid renewable energy system is designed to supply electricity for Alaroub technical college in Hebron, Firstly, the load is specified and statistically stated on yearly and monthly basis. Secondly, the solar, biogas and fuel cell with energy storage unit data is collected. Thirdly, the structure of hybrid renewable power with ESS is built and the parameters price of component parts are discussed. Finally, the power management strategy and optimization models introduced. In addition, photovoltaic (PV) and methane power system have a higher capability to deliver continuous power with reduced energy storage so the results is better utilization factor of control equipment and power conversion than single sources. Power load management in microgrid PV-methane generation systems have been proposed in this study. So the system was connected to the grid as on grid system, but it could also work in island mode if the grid was not existing. The system uses hybrid renewable sources biogas and solar energy with FC and ESS. Biogas from Cow and other animal dung to produce energy that gave environment sense by disposal it usefully. Fuel cell with hydrogen ESS used in this system to become more realable system and behave like off grid. Main purpose of this project is to investigate electrification of 'Arroub Technical college for rural development area, consists of photovoltaic generators, methane generator and FC with ESS. The advantage that energy system with environment sense, Isolated Micro- Grids with Renewable Hybrid Generation, more reliable Hybrid system with combines several energy systems together. The photovoltaic generator (PV) also methane generator produced during the day enough electric power cover the requirements of the different loads in the farm while the e excess power stored in hydrogen energy storage units, the other case methane and solar generator are not able to cover the all requirements of the different loads in the farm so the FC generator will provide the load energy requirements from ESS as integrated system . Finally The system have ability to connect on the main grid and exchange between tow system to satisfy high reliable and sell exceed energy to main grid so that will give a good economic benefits for the farm, so it will represent micro grid system far from traditional grid failure and loses.A design of hybrid renewable energy system (HRES) which consist of solar bioenergy from animals farm and 10 kW fuel cell generator with ESS energy was implemented and studied by employing a RETscreen optimization software to achieve optimal configuration . PMS was built for this system to satisfying realability and high certainty based on Matlab algorithms. In addition to the modeling of system component and optimal energy, the sizing technique has been put to the test by considering weather data, technical data of component and economic detail. In this work, the optimization problem was formulated to achieve a minimum LCOE for the system components and to ensure that the load is served effectively with minimum CO_2 emission . Three different scenarios differentiated, the first one was base model, PV System with battery energy storage ,the second depending on RE sources model (solar PV, bioenergy, battery storage)and finally Mixed technologies (solar ,bioenergy, fuel cell with ESS) ,so the scenarios discussed in this thesis considered important design perspectives which can highly affect the cost of energy obtained from renewable energy such as initial cost operating and maintenance cost,replacement cost and salvage value. The comparison based on three basics: carbon emissions, top design, and lower cost. Using RETScreen Expert: decision intelligence tool available to all by the Canadian government, to help make decisions on renewable energy projects and evaluate their performance. The winning model is a hybrid model that relies Mixed technologies (solar ,bioenergy, fuel cell with ESS).The best ratios were 75% solar and 25 %bioenergy with fuel cell and ESS with LCOE of 0.157$/KWh with the payback of investment during about 5 years. Its concluded that, the initial cost of projects based on clean sources is the highest possible, in contrast to the lowest operational and maintenance costs. The RETScreen was a reliable and highly specialized tool in the economic and environmental aspects to evaluate the performance of microgrid.

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6.2 Recommendations

In this thesis, it is obvious that the HRES can be good way to supply the electricity and reduced the cost of electric energy spatially in rural and development areas. In addition, this system helps to control the global warming and reduce the pollutant emission. The optimal design of PV-bio energy and fuel cell with small scale hydrogen ESS conversion system can further be remodeled with a grid for the domestic. The optimal design of PV- bioenergy with ESS conversion system can further be remodeled by adding other types of renewable sources in order to make HRES more reliable.

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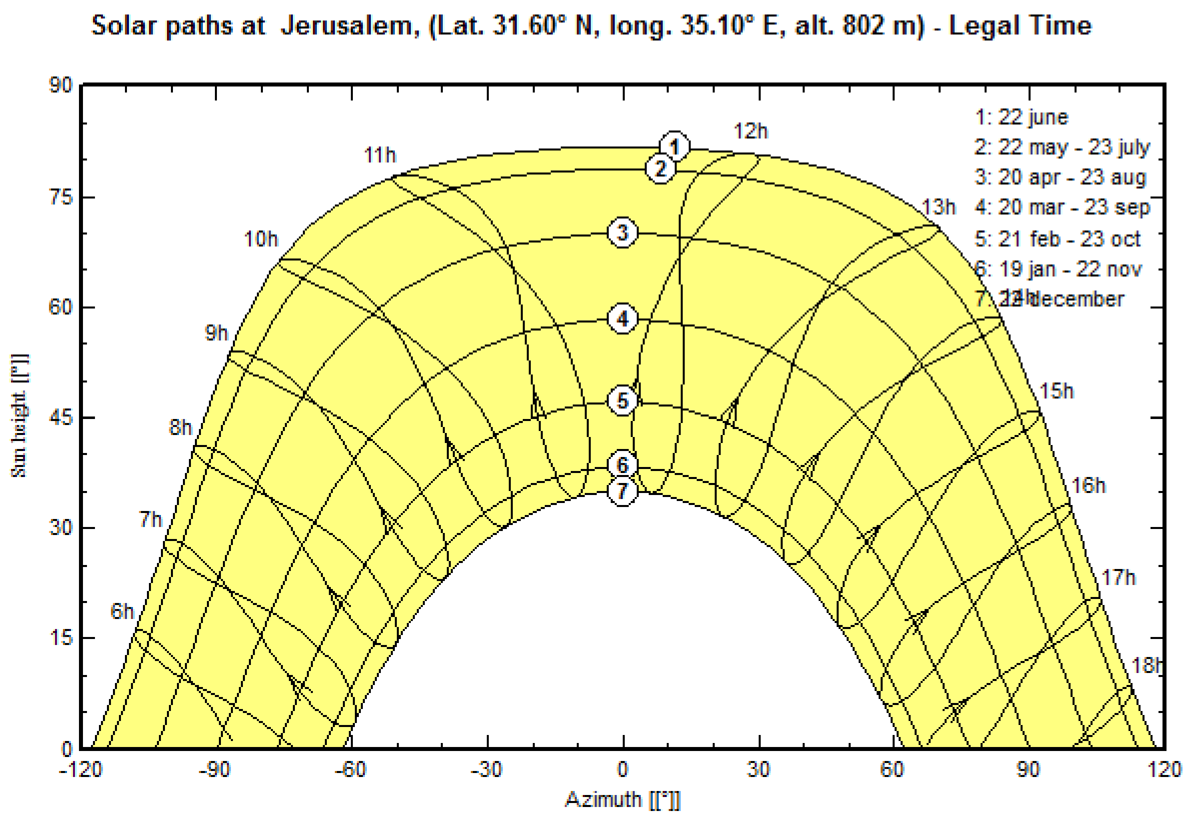
Appendix A : Solar data in Alaroub Technical Collage



Appendix B : Power management strategy code in Matlab

```
Pmethane = input("enter P methane")
Psolar = input("enter P solar")
Pload = input("enter P load")
Pgrid = input("enter P grid")
Pnet = Pmethane + Psolar
Pfc = 0
PgridOn = false;

if Pload < Pnet
%run electro.
%++hydrogen
 Pele = Pnet - Pload
 fprintf('electro is on!')
end

if Pload >  Pnet
% run FC
%--hydrogen
fprintf('\n P FC turned on!')

 while 1
    Pfc = Pfc + 1;

    if Pload  > Pnet + Pfc
     if (PgridOn == false)
       % turn on Pgrid
       fprintf('\n relay grid turned on! \n')
       PgridOn = true
     end
    end

    if Pload  < Pnet + Pfc + Pgrid
     if (PgridOn == true)
       % turn off Pgrid
       fprintf('\n island!')
     break
     end
    end
 end
end
```

Bıogas Generator data sheet

Parameter of Biogas Generator Set	
Type	Biogas Generator
Suitable gas	Biogas/LPG
Rated Power(BIOGAS/LPG)	6000W/7600W
Max. Power(BIOGAS/LPG)	600W/8000W
Frequency	50HZ
DC Output	12V 8.3A
Generator Type	Single-phase Brush Motor
Engine Type	CC168F
Bore X Stroke	88 x 64mm
Displacement	389cc
Ignition System	T.C.I.
Engine oil capacity(L)	0.59
Gas consumption(m3/h)	3.5
Standard Equipment	Waterproof European Socket
	V-Type DC Socket
	AC Circuit Breaker
	DC Circuit Breaker
Dimensions	Passive and flying lubricant
Colour	your choice
Certificates	ISO 9001:2008, CE
Size	710*710*600mm
Weight	95kg