Survey of Methods for Renewable and Alternate Energy at Consumer Level

by

Alif Imran B Mahaya

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CERTIFICATION OF APPROVAL

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A Project Dissertation Report submitted to the
Electrical and Electronics Engineering Programme
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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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ALIF IMRAN BIN MAHAYA

ABSTRACT

This report discusses the status of current energy sources and the requirement for alternative energy, and how it is applicable at a smaller scale. This report also describes the process of estimating and calculating power consumption of the consumer, so that the small-scale alternative energy module(s) could be implemented efficiently with minimum power loss. The efficiency of the small-scale alternative energy modules, which are solar photovoltaic, micro-hydro generation and wind power generation modules, are discussed in this report, including the factors that affect their efficiency. At the end of this report, the solution will be given for the consumers on which alternative energy method to apply based on several criteria that will be discussed further in the report.

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In the name of Allah, the Most Gracious and the Most Merciful. Alhamdulillah, all praises to Allah S.W.T for the strengths and His blessing in completing this thesis.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AC	Alternating Current
CO_2	Carbon Dioxide
DC	Direct Current
DMM	Digital Multimeter
kWh	kilo-Watt-hour
PV	Photovoltaic
SO_2	Sulfur dioxide
US	United States

CHAPTER 1

INRODUCTION

1.1 Background of Study

1.1.1 Alternative Energy

According to Oxford's Dictionary," alternative energy is a type of energy fueled in ways that do not use up natural resources or harm the environment" [1].

According to Wikipedia's definition on alternative energy, "alternative energy is a type of energy intended to replace fuel sources without the undesired consequences of the replaced fuel, such as fossil fuels or nuclear energy" [2]. The origination of the term comes from the urge to find alternatives to the fossil fuels combustion process [3]. Sources of alternative energy sources are renewable. Compared to conventional energy sources, the alternative energy produces low carbon emissions [4].

1.1.2 The Need of Alternative Energy

For centuries, people use fossil fuels as source to produce power. Commercial exploitation of petroleum which replace the use of animal oils, such as whale oil, started during the Industrial Revolution which revolves around the 18^{th} to 19^{th} century [5], and until today fossil fuels are used as a main source in power production. In an article by Kevin Rockwell, he stated that “at current rates, the world uses fossil fuels 100,000 times faster than they could form” [6]. This problem, along with other problems which will be discussed later, brought us to using alternative energy as our energy source.

The first problem is fossil fuels are depleting at a very rapid rate and they are getting harder to retrieve [7]. In 1956, M. King Hubbert proposed the Hubbert curve, which describes the production rate of the fossil fuels. He stated that the rate of fossil fuel production tends to follow a bell-shaped curve. He also assumed that after the discovery of the fossil fuel reserves, the production rate increases approximately exponentially due to the increasing discovery rate and the addition of the infrastructures for oil production. At some point of the production, a peak output is reached and the rate of production begins declining approximately exponentially because of the resource depletion [8]. Figure 1 on the next page shows an example of the curve, which describes the United States (US) Lower-48 oil production for crude oil only and the Hubbert high estimate by S. Foucher [9].

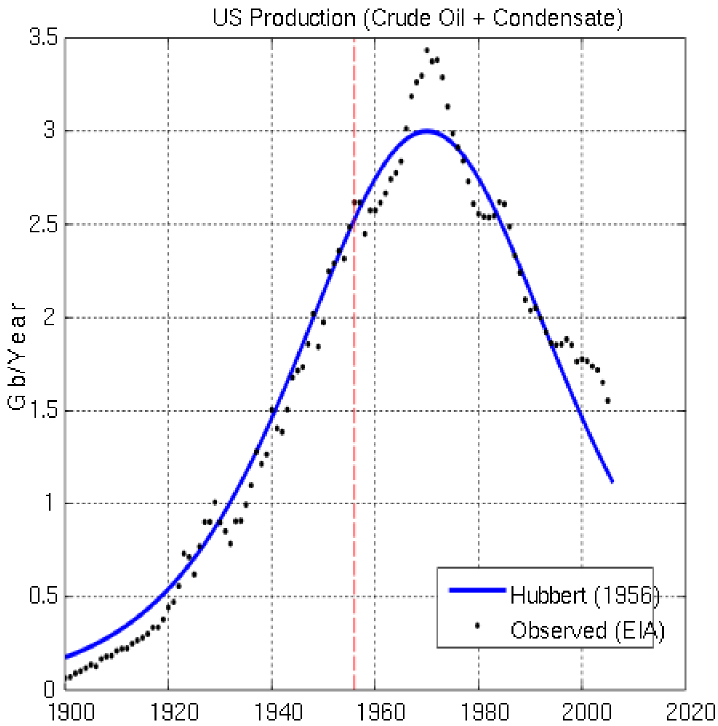

Figure 1: US Oil Production and the Hubbert Curve[9]

The second problem is that, the fossil fuels that we use today are affecting the environment. As fossil fuels are burnt, they emit carbon dioxide (CO_2) and other pollutants, such as sulfur dioxide (SO_2) which is a major component of the acid rain [6]. Due to the excessive emission of the CO_2 gas, the Earth has warmed up and the climates are changing. This results in global warming and other climatic problems.

The third problem is due to the limitation of the fossil fuels, which results in the increase of the price of the fossil fuels today. Hence, the development of small economic countries suffers. These small countries need fossil fuels not only for their power production, but also for their transportation. Thus, high price of fossil fuels will affect their development. [7].

Instead of relying solely on fossil fuels, the problems mentioned earlier could be resolved by using alternative energy sources. However, this solution is not as simple as it is discussed, since it is hard to abandon all the old methods and adapting new ones immediately [6].

1.2 Problem Statement

There are many types of methods being implemented today with regard to renewable and alternate energy. However, they are mostly dealt at a very large scale.

The objective of this project is to study the methods of alternative energy that can be directly implemented at a smaller scale, such as a small or medium enterprise where the users will get the direct benefit.

1.3 Objectives

The objectives of this study are to:

- Study the need of alternative energy
- Study the methods of small-scale alternative energy which are currently available
- Propose solutions which can be utilized directly by the consumer in Malaysia based on the methods available

1.4 Scope of Study

This research requires me to study the needs of alternative energy – why we really need alternative energy rather than rely on the current method, which uses hydrocarbons or fossil fuels as the source of energy.

This project requires an extensive research on various methods of alternative and renewable energy that could be applied directly at consumer level. This project also requires me to study on how small-scale alternative energy methods, such as solar photovoltaic module and micro-hydro energy could be applied efficiently and factors that affecting them by conducting experiments.

Calculations are needed in estimating power consumption so that the alternative energy module can be applied by the consumers in order to avoid efficiency and cost problems.

I also have to conduct experiments to study the efficiency of each alternative energy methods and factors that affecting them.

At the end of the project, I need to propose solutions that could be applied directly by consumers based on the available methods. The solutions proposed will be based on several factors, such as living condition of the consumers and the location of their house.

CHAPTER 2

LITERATURE REVIEW

2.1 The Need for Alternative Energy

For years, people have been using fossil fuels as their source of energy. However, nowadays, the fossil fuels are depleting at a very rapid rate and they are getting harder to retrieve. Currently, the usage of fossil fuels is at the rate of thousands time faster than they could be formed. This problem could lead to energy crisis in the future [7].

Based on a research by Freris & Infield (2008) on conventional source of energy, which is oil, they came across the term ‘Peak Oil’ [10]. Peak oil is defined as the maximum rate of global petroleum extraction reached based on the production rates of individual oil wells and combined production rate of a field of related oil wells. However, as the production passed the peak, it will decrease exponentially due to resource depletion [11].

Fossil fuels emit CO_2 when burnt. This is because the fossil fuels are a key part of the Earth’s long term carbon cycle. Due to excessive CO_2 emission, it would lead to global warming and climate change [6].

DeGunther (2009) also mentioned that global warming as one of the problems due to fossil fuels combustion. Based on a study from the United States' Energy Informative Administration, 81% of human induced carbon dioxide is produced by fossil fuels combustion [12]. Along with the global warming as the main problem caused by fossil fuels combustion, he also includes heat waves, hurricanes and drought as the impacts of global warming [12].

Due to so many problems caused by usage of the fossil fuels, people start looking for an alternative energy to replace the fossil fuels as their main source of energy.

The Sun is the main source of alternative energy that is easily accessible. On average, the rate of solar radiation intercepted by the Earth's surface is around 8000 larger than the average rate of the world primary energy consumption. Two other energy sources that are also regarded as alternative and renewable in view of their sustainable nature are tidal energy which is caused by the gravitational fields of the moon and the Sun, and geothermal energy from the Earth's core which is accessible in some locations through hot springs and geezers [13].

Alternative energy has its own advantages, one of them is the ability to provide all the energy services currently available from conventional energy source, such as heating and cooling. The source is naturally distributed and can also provide energy to remote areas without any means of transportation. However, the major contribution that alternative energy can make in supplying people's increasing needs will be in electrical form [13].

The alternative energy comes in different forms, and they have their own advantages and disadvantages. It is up to us to analyze which is the best method for us based on our usage.

2.2 Small-Scale Alternative Energy

Some of the alternative energy methods, such as hydroelectric and solar photovoltaic (PV) modules can be applied at a smaller scale, where consumers can directly utilize them. Small-scale alternative and renewable energy brings a lot of advantages, such as reduction in energy dependence, reduction in environmental impact of electricity production or the elimination of fuel poverty [14].

2.2.1 Solar PV

In 1905, Albert Einstein exploited the dual nature of light, in his theory of photovoltaic effect (DeGunther, 2009). In his theory, he stated that the photons act as both radiation and matter [15]. This theory leads to the invention of the modern PV cells [15].

In modern design of PV cells, the incident radiation from the sun hits the PV cell which is made from semiconductors. Electron flows were created by the impurities injected into the material [16]. Raw signal will be produced and then converted into usable electric power with the help of an inverter [16].

There are three types of silicon cells that are made of different composition of material namely the single crystal cell, or monocrystalline cell, polycrystalline cell, and amorphous silicon cell (Bonta & Snyder, 2008). The differences between these three are summarized in Table 1 [17].

Table 1: The Differences between Three Types of Silicon Cells

	Monocrystalline	**Polycrystalline**	**Amorphous-Silicon**
Physical Attributes	Produced in long cylinders and sliced into round or hexagonal wafers.	Molten silicon formed into ingots or thin sheets and then sliced into squares.	Silicon is sprayed in a thin film onto a metal or a glass backing.
Cost	Very expensive	Less expensive compared to monocrystalline	Least expensive compared to others
Efficiency	Very efficient. Approximately 25% efficiency under ideal conditions.	Efficiency is low. Approximately 15%.	Lowest efficiency. Approximately 5%.

Solar PV technology offers a lot of advantages. It has virtually unlimited supply, with no supply issues compared to fossil fuels, it is available everywhere and it may also be the only energy source that generates zero pollution (DeGunther, 2009).

However, the current technology of the solar PV has several limitations [18].The semiconductors used in solar technologies are not very effective in producing electricity since the stability of the electrons are quite high (DeGunther, 2009). The actual quantity of the light spectrum a PV can convert is unknown to us. Depending on the structure of the semiconductor, only certain wavelength of the light will cause electron/hole generation (DeGunther, 2009).

The efficiency of the solar technology could also be affected by the sun due to its intermittent factor, such as the hours of sunlight received, the angle of sunlight and the quality of sunlight received (DeGunther, 2009).

2.2.2 Micro-Hydro Generation

Micro-hydro is defined as hydroelectric power installations that usually produce up to 100kW of power (Wikipedia, 2010) [19]. Micro-hydro installations are able to provide enough power to an isolated home or a small community [19].

An example of micro-hydro generation is the run-of-river system [20]. It utilizes the kinetic energy produced by the fast moving water and converts it into electrical power (DeGunther, 2009).

However, this system also has its own advantages and disadvantages. One of the main advantages of this system is that more kilo-Watt-hour's (kWh) per cost is generated compared to any other alternative energy resource [21]. However, this system utilizes "complex electrical system designs and the mounting schemes are difficult with water pressures pushing all the time" [21].

2.2.3 Wind Power Generation

Wind is formed from the large scale movements of air masses in the atmosphere, which are created mostly by differential solar heating of the Earth's atmosphere [22]. Therefore, wind energy is an indirect form of solar energy [22]. Figure 2 on the next page shows us how wind is formed.

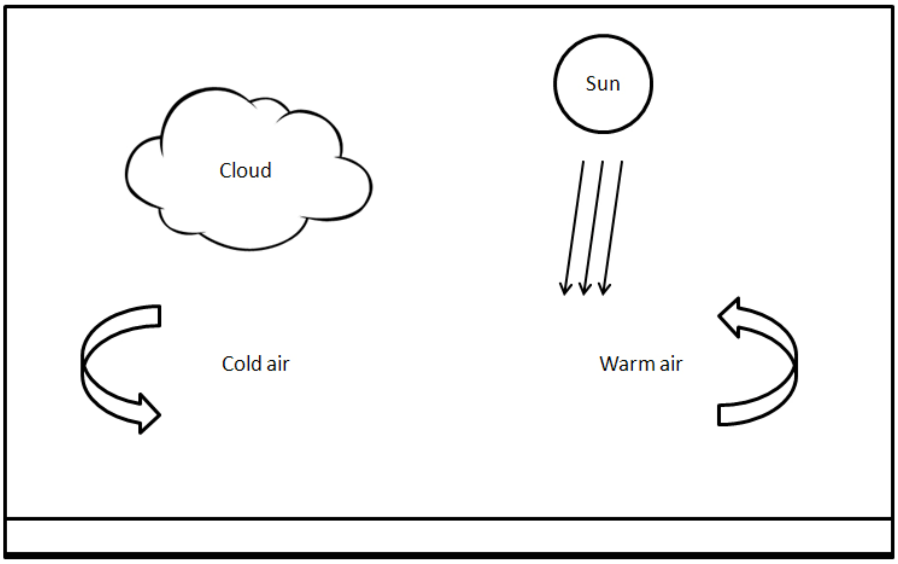

Figure 2: Formation of Wind

Energy from the wind is harnessed by means of a turbine-coupled generator. The wind pushes the vane of the turbine, which will turn the alternator's shaft. The electrical power is then produced by the alternator in the form of alternating current AC) [23]. Furthermore, DeGunther (2009) stated that in some modern designs of wind turbines, the production of energy is controlled by microprocessor units for better efficiency [23].

CHAPTER 3

METHODOLOGY

3.1 Procedure Identification

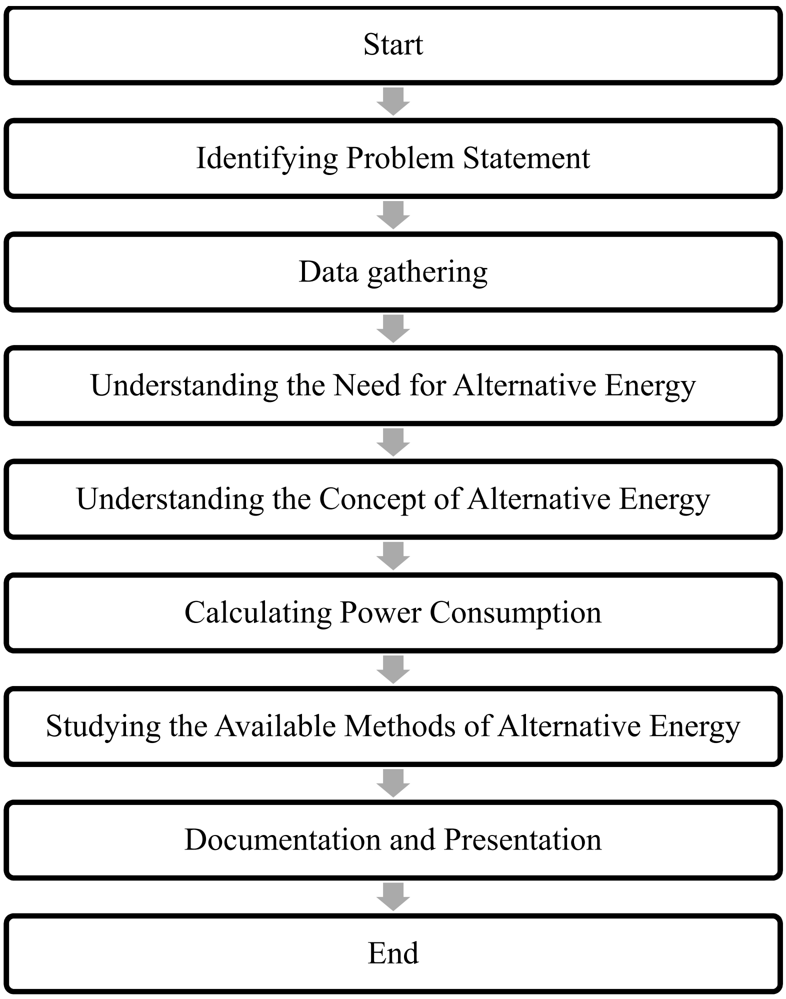

Figure 3: Flowchart for FYP1

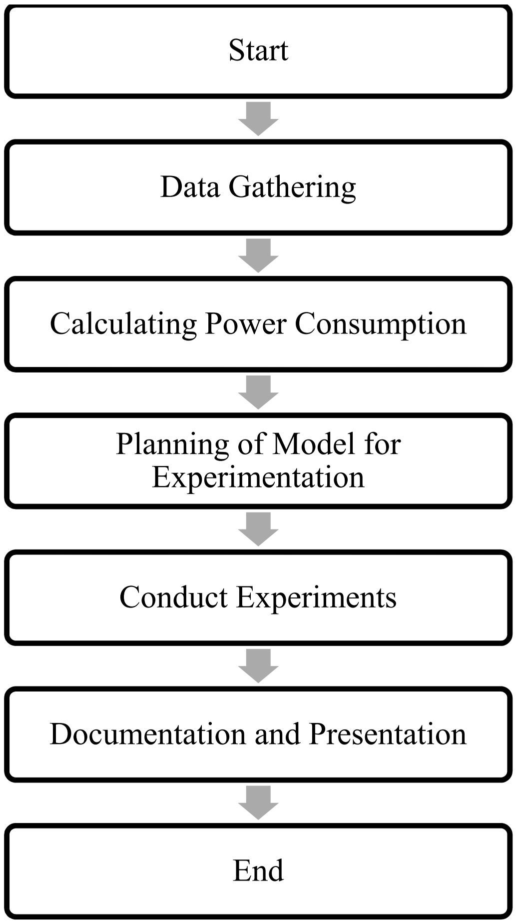

Figure 4: Flowchart for FYP2

The Gantt Charts for both FYP1 and FYP2 are included in Appendix A.

3.2 Tools and Equipments Used

3.2.1 Digital Multimeter

The digital multimeter (DMM) is used to measure the voltage and current produced by the alternative energy modules in their experiments. The configurations of the DMM are shown in the figures below.

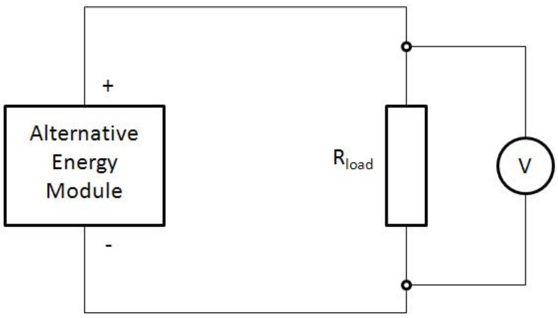

Figure 5: Checking the Voltage Produced

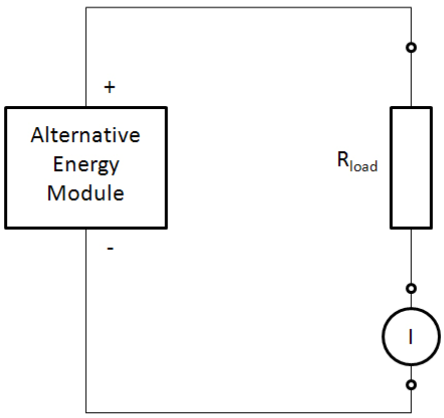

Figure 6: Checking the Current Produced

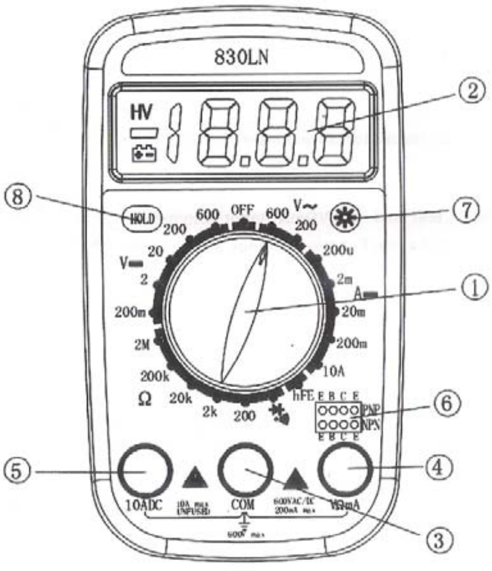

Figure 7: The 830LN Digital Multimeter [24]

The specification of the DMM is summarized in the table as follows

Table 2: General Specification of the 830LN Digital Multimeter [24].

Dimensions	105 mm x 60 mm x 27 mm
Weight	140 g
Power Supply	9V battery
Work Temperature	0^oC ~ 40^oC
Storage Temperature	-15^oC ~ 50^oC

Table 3: Technical Specifications of the 830LN Digital Multimeter [24]

Max Input Voltage (DC)	600V
Max Input Voltage (AC)	$600V_{rms}$
Overload Protection	0.2A/250V fuse
AC Frequency Range	45 Hz – 400 Hz
Open Voltage	< 2.8V

3.2.2 Solar Panel

The solar panel is used in the solar PV experiment. The specification of the solar panel is summarized in the table as follows.

Table 4: Specification of the Solar Panel

Model No.	JHGF005W/12V
Dimensions	200 mm x 290 mm x 17 mm
Cell Type	Mono
Test Conditions	AM1.5, $E = 1000W/m^2$, $T_c = 25^oC$
Rated Maximum Power	5Wp
Maximum System Voltage	715V
Rated Output Voltage	17.28V
Rated Output Current	0.29A
Open-Circuit Voltage	21.24V
Short-Circuit Voltage	0.33A

Figure 8: The JHGF005W/12V Solar Panel [25]

3.2.3 60W Reflector Bulb

The reflector bulb is used to simulate the sun for the solar PV experiment. However, the results obtained are not very convincing. The result will be discussed in more details in the next chapter. The specification of the bulb is summarized in the table as follows.

Table 5: Specification of the Reflector Bulb

Brand	Sylvania
Model	HB015580
Pin Type	E27
Power Consumption	60W
Diameter	80 mm
Beam Angle	80^o
Input Voltage	230V – 240V

Figure 9: Reflector Bulb [26]

3.2.4 12V DC Bulbs

The 12V Direct Current (DC) bulbs are used to simulate the fluorescent lamps in House #3, in which will be explained in the next chapter. The specification of the bulbs is summarized as follows.

Table 6: Specification of the 12V DC Bulbs

Input Voltage	$12V_{DC}$
Power Consumption	3W

The dimension of the bulb is shown in the figures below.

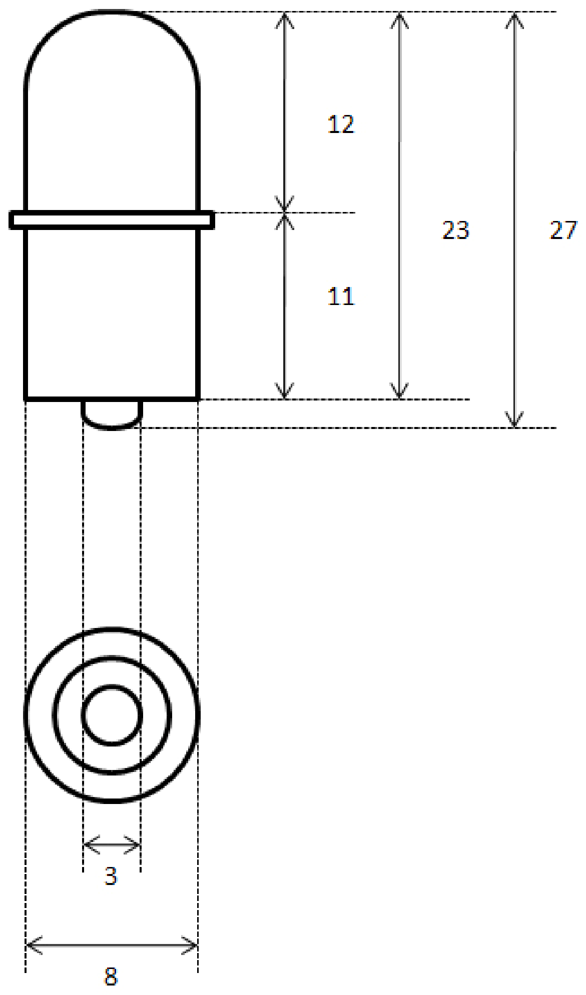

Figure 10: Dimension of the 12V DC Bulb (n mm)

3.2.5 12VDC Cooling Fan

The 12V DC fan is used to simulate the ceiling fan in House #3. The specification of the fan is summarized as follows.

Table 7: Specification of the 12V DC Fan

Brand	NIDEC Beta SL
Model	D08T-12PH
Dimensions	80 mm x 80 mm x 25 mm
Input Voltage	12V
Input Current	0.18A
Rated Speed	3400 rpm
Noise	34 dBa

Figure 11: The Nidec Beta SL 12V DC Fan [27]

3.2.6 DC Motors

The motors are used as DC generators for the micro-hydro module experiment. The DC motors are tested for its speed and torque. Since the pressure of the water from the tap and the submersible pump are low, it is advisable to use a low torque DC motor. Thus, I decided to use the Mabuchi's RF500TB DC motor. The specifications of the DC motors are summarized in the tables below. The datasheet for the motors are included in Appendix B.

Table 8: Specification of RF-500TB DC Motor [28]

Operating Voltage's Range	1.5V ~ 12.0V
Nominal Voltage	6.0V
No-Load Speed	2700 rpm
No-Load Current	0.020A
Speed at Maximum Efficiency	2180 rpm
Current at Maximum Efficiency	0.084A
Torque at Maximum Efficiency	1.13 mN·m
Power Output	0.33W
Stalling Torque	5.88 mN·m
Stalling Current	0.35A

Table 9: Specification of FC-130RA/SA DC Motor [29]

Operating Voltage's Range	2.4V ~ 3.0V
Nominal Voltage	3.0V
No-Load Speed	185000 rpm
No-Load Current	0.36A
Speed at Maximum Efficiency	14170 rpm
Current at Maximum Efficiency	1.18A
Torque at Maximum Efficiency	0.92 mN·m
Power Output	1.36W
Stalling Torque	3.92 mN·m
Stalling Current	3.85A

Table 10: Specification of RS-555PC/VC DC Motor [30]

Operating Voltage's Range	9.0V ~ 30.0V
Nominal Voltage	12.0V
No-Load Speed	4800 rpm
No-Load Current	0.17A
Speed at Maximum Efficiency	4240 rpm
Current at Maximum Efficiency	1.30A
Torque at Maximum Efficiency	25.6 mN·m
Power Output	11.4W
Stalling Torque	221 mN·m
Stalling Current	9.90A

Table 11: Specification ofM34E-3C (R-1646451) DC Motor [31]

Rated Voltage	6.0V
Voltage Range	4.2V ~ 7.0V
Rated Load	0.78 mN·m
Rated Speed	2400 rpm
Rated Current	165mA
Starting Torque	2.94 mN·m
Rotation	CW

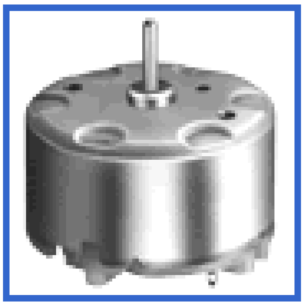

Figure 12: Mabuchi's RF-500TB DC Motor [28]

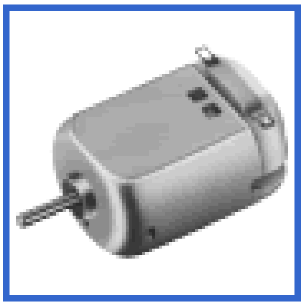

Figure 13: Mabuchi's FC-130RA/SA DC Motor [29]

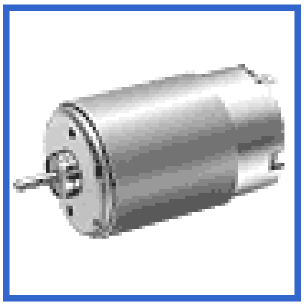

Figure 14: Mabuchi’s RS-555PC/VC DC Motor [30]

Figure 15: Mitsumi’s M34E-3C DC Motor [31]

3.2.7 Turbines

The turbine used in the micro-hydro experiment is obtained from an aquarium filter. The turbine is coupled with the DC Motor’s shaft. The design of the turbine is shown in the figure on the next page.

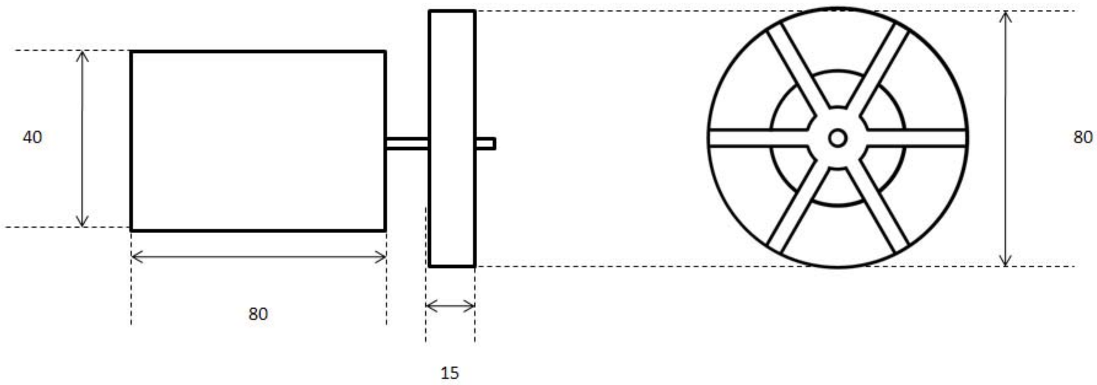

Figure 16: Dimensions of the Micro-Hydro Turbine (in mm)

3.2.8 Submersible Pump

The submersible pump is widely used in aquarium filters. This pump could operate under water so that the circulation of the water in the aquarium could be maintained. This pump is used in the micro-hydro experiment therefore the water could be re-used throughout the experiment. It is also used to simulate the continuous flow of water.

Figure 17: Submersible Pump

The specification of the submersible pump is summarized in the table as follows.

Table 12: Specification of the Submersible Pump

Input Voltage	220V – 240V
Frequency	50 Hz
Powetr Consumption	28W
H_{max}	2.0 m
Q_{max}	1400 L/h
Maximum Temperature	35^{o}C

3.2.9 Windmill Generator

The windmill generator is an educational kit by Green Science. This kit is used in the wind power's experiment. The kit is modified so that the voltage produced by the DC motor could be measured. The circuit configuration of the experiment is shown in the figure as follows.

Figure 18: The Windmill Generator by Green Science [32]

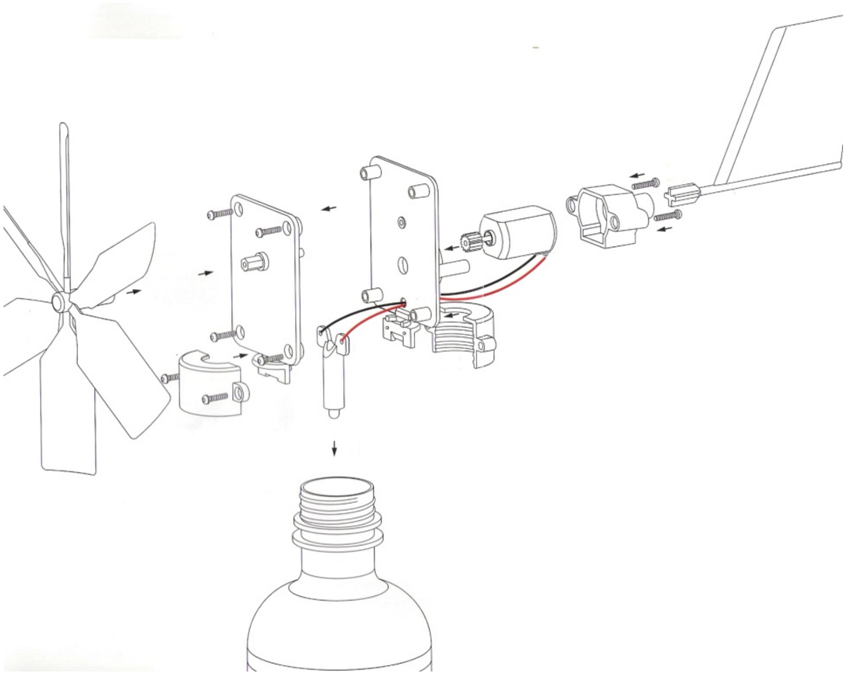

Figure 19: Components of the Windmill Generator Kit [33]

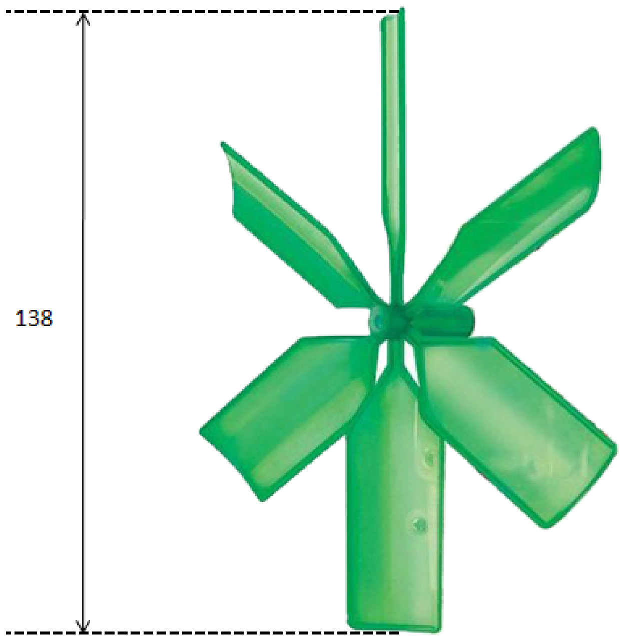

Figure 20: The Dimension of the Kit's Rotor (in mm)

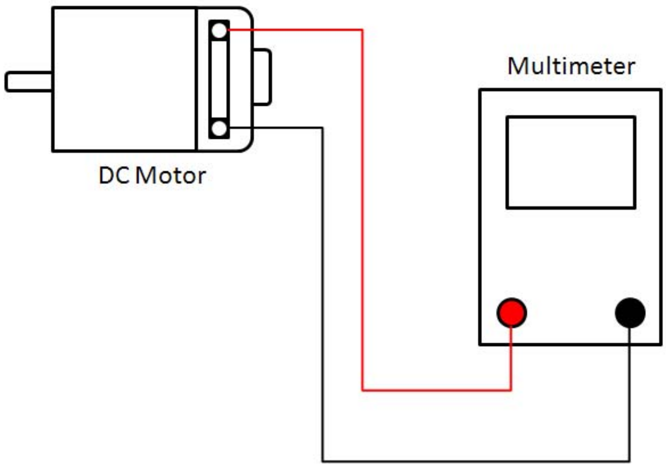

Figure 21: Circuit Configuration for Wind Power Experiment

3.3 Small-Scale Alternative Energy

As discussed in the previous chapter, alternative and renewable energy methods could be applied directly at consumer level. This method is called small-scale alternative and renewable energy method. Some notable energy production methods include solar PV module, micro-hydro generation, and small-scale wind power generation.

3.4 Estimating Power Consumption

In order for the effective use of small-scale alternative energy module to operate at its optimum efficency, we have to estimate the value of the consumer’s power consumption. The estimation is done by taking the average values of past months’ electricity bills. From the value obtained, we could estimate the power consumption of the house. Thus, the module could not only operate at higher efficiency, but the consumers could also avoid unnecessary energy loss.

For this project, I have obtained data from five different houses with different living styles. The results obtained are shown in the next chapter.

3.5 Experimentation

For this project, several experiments have been conducted in order to find the efficiency of each module and the factors that affect their efficiency. Based on the results obtained, solutions will be proposed to the consumers depending on the criteria which will be discussed in the next chapter.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Calculating Average Power Consumption

4.1.1 Introduction

The main purpose of calculating the average power consumption is to estimate the power consumption in one's house before installing any alternative energy module to reduce efficiency and cost problems. If the generated power is larger than the consumption, this will cause power loss. For instance, if a house with 1000W of power consumption uses a 2000Wp solar panel module; there will be power loss of about 1000W. By calculating the power consumption and estimating the average power consumption, not only the module could operate at higher efficiency, but the consumers could also avoid unnecessary energy loss.

In order to determine the power consumed, the average values of past months' electricity bills from different houses is taken into account. The randomly chosen samples show that different living conditions produce different amount of consumption values.

4.1.2 Methods

- The total power consumption for each month, in kWh are obtained from past months' electricity bills
- The average value / mean value and the median value are taken
- If necessary, bills with low values of power consumption are omitted for better average value

An example of calculation is shown below.

Table 13: Mr. A's Total Power Consumption

Months	Total power consumption, kWh
Jan 2010	115
Feb 2010	137
Apr 2010	45
May 2010	77

The median value of the given data is shown below

$$P_{Median} = \frac{77 + 137}{2} = 107\ kWh$$

The average value of the power consumption, P_T, is shown below

$$P_T = \frac{115 + 137 + 45 + 77}{4} = 93.5\ kWh$$

The results obtained from these houses are shown on the next page.

Table 14: Living Condition of Each House

Houses	Conditions
1	Lots of appliances Heavy usage of appliances 4 people family Occupied everyday
2	Lots of appliances Medium usage of appliances 2 people family Occupied only during the weekends
3	Lots of appliances Medium usage of appliances 4 people family Occupied everyday
4	Lots of appliances Heavy usage of appliances 5 people family Occupied everyday
5	Lots of appliances Medium usage of appliances 5 people family Occupied everyday

4.1.3 Power Consumption of Each House

The power consumption of each houses are obtained from past electricity bills and are tabulated into the tables below.

Table 15: House #1's Power Consumption

Month	**Usage, kWh**
January 2009	706
February 2009	708
March 2009	623
April 2009	862
May 2009	887
June 2009	940
August 2009	851
September 2009	861
Average Power	804.75
Median	856

Table 16: House #2's Power Consumption

Month	**Usage, kWh**
April 2009	78
May 2009	103
January 2010	108
May 2010	113
June 2010	221
Average Power	124.6
Median	108

Table 17: House #3's Power Consumption

Month	**Usage, kWh**
November 2009	149
December 2009	133
January 2010	226
February 2010	244
April 2010	253
May 2010	225
June 2010	166
Average Power	199.43
Median	225

Table 18: House #4's Power Consumption

Month	**Usage, kWh**
May 2009	610
December 2009	596
February 2010	711
March 2010	393
April 2010	506
Average Power	563.2
Median	596

Table 19: House #5's Power Consumption

Month	Usage, kWh
January 2010	227
March 2010	223
April 2010	253
May 2010	249
June 2010	230
Average Power	236.4
Median	230

Note: All results and calculations are based on real data

4.1.4 Data Interpretation

Based on the results obtained, we can see the average power consumption of a normal house (without excessive loads, occupied daily) is approximately around 220 kWh to 230 kWh per month. A list of typical appliances used by the consumers and their wattage values is included in Appendix C.

Wattage, as defined by Collins Dictionary on TheFreeDictionary.com, is "power, especially electric power, measured in watts" and "the power rating, measured in watts, of an electrical appliance" [34]. Most appliances have their wattage values stamped on the bottom or back of the appliance, or on its nameplate [34].

Although the wattage value is not given, we can still estimate the power consumed. This is done by finding the current drawn and multiply the current obtained by the voltage used by the appliance. Most appliances in Malaysia use voltage between 220 and 240V. The amperes value might be listed at the same place as of the wattage. If the value is not given, we can use a clamp-on ammeter, to measure the current flowing through it [34].

Based on a study by the United Nations Development Program, it was stated that the average family size in Malaysia is 4.6 people per family [35]. From these results, House #3 is chosen for the model for this experiment because there are currently 4 people living in the house with medium usage of applications.

The assumption layout of the house is with minimal electrical appliances that consist of only lamps and fans. All other appliances are not included for this model. This is mainly because lamps and the fans are widely used compared to other appliances. This layout will be used to determine the total power consumption for the scaled-down model. An approximate layout of House #3 is shown on the next page. The total power consumption of House #3 for only lamps and fans is shown in the table on the next page.

Table 20: Total Power Consumption

Appliance	Wattage, W	Quantity	Total Wattage, W
36 W Fluorescent Tube	36	6	216
18 W Fluorescent Tube	18	2	36
Ceiling Fan	50	5	250
		Grand total	502

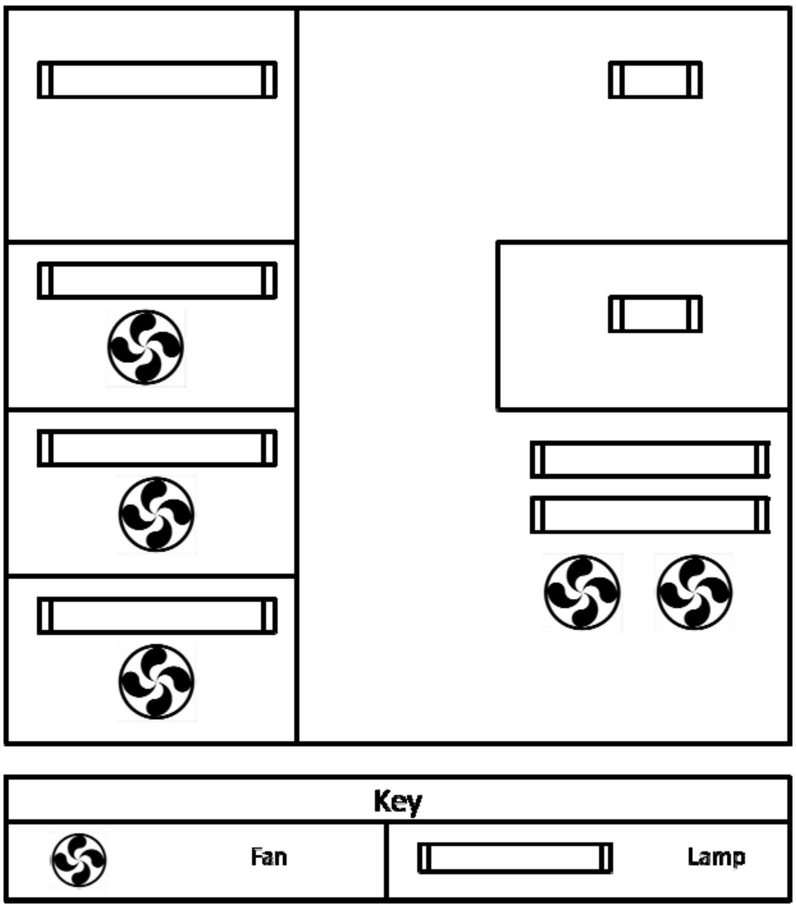

Figure 22: Assumption Layout of House #3

Based on the assumption layout of House #3 mentioned earlier and the following suggested circuit diagram as shown below, we can see that the model is scaled-down to 4% from the approximate layout in terms of power consumption.

Table 21: Total Power Consumption of the Circuit

Components	**Power Consumption, W**	**Quantity**	**Total Power Consumption, W**
12V Bulbs	3	5	15 W
12 V Fan	7.2 W	1	7.2 W
		Total , W	22.2 W

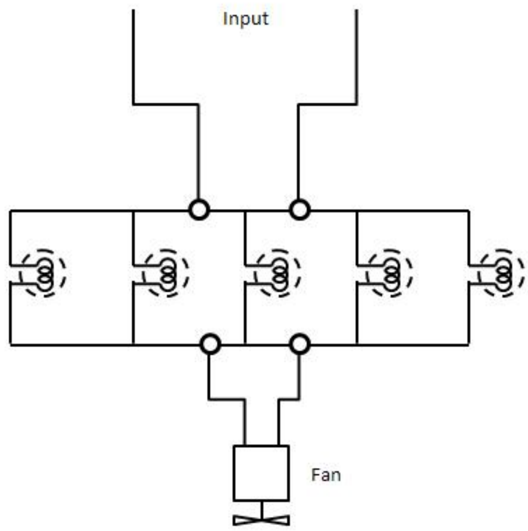

Figure 23: Suggested Circuit Diagram of the Model for Solar Panel Experiment

4.2 Solar PV

4.2.1 Introduction

Solar panels are made from semiconductors. As discussed earlier in Chapter 2, the electricity produced in a solar PV is from the flow of the electrons in the semiconductor. During the manufacturing process of solar panels, P-type impurities and N-type impurities are injected into the material [16]. P-type impurities leave a shortage of electrons and N-type of impurities provides excess of electrons.

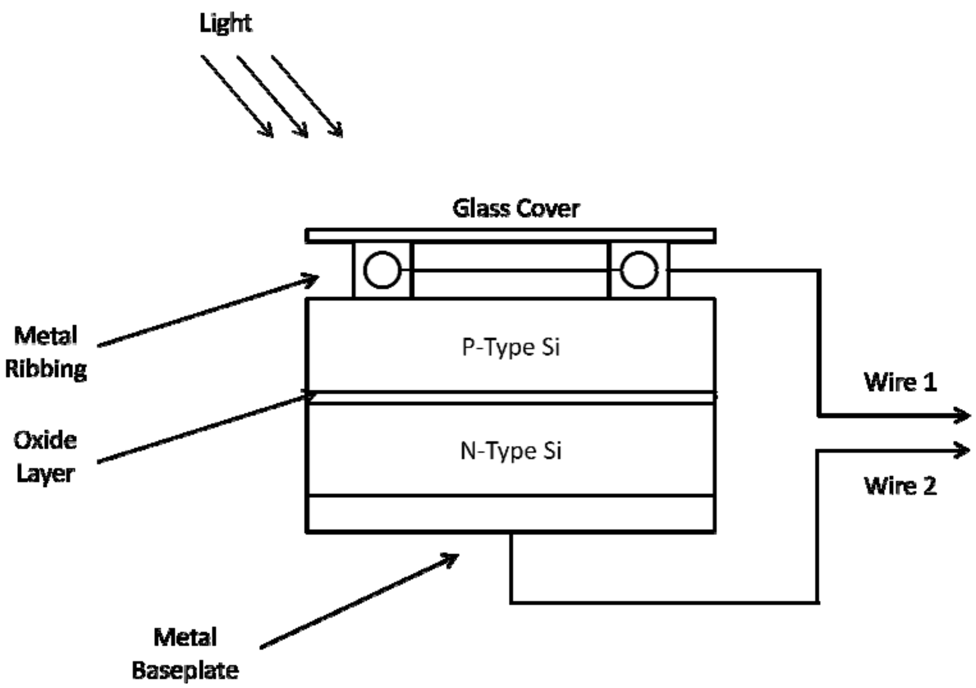

Figure 24: Typical Structure of a PV Semiconductor [36].

As shown in the figure above, a thin layer of oxide is placed between the substrates to ensure that electricity will only flow when there is light [16].

4.2.2 Applications

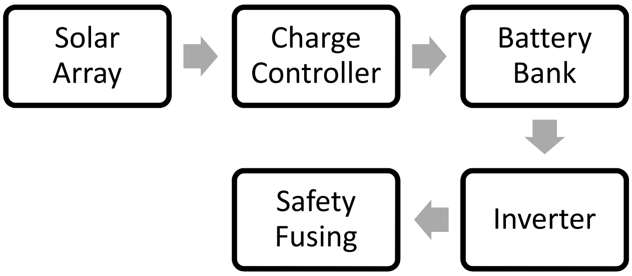

Figure 25: Components of a Typical PV System

Based on the figure above, a typical PV system comprises of 5 major components. The first component, the solar array collects, transmits, converts stores and manages the power from the Sun. The second component, the charge controller is used to keep the batteries at a proper level and prevents overcharging which could damage the batteries. The battery bank is used for storage and backup purposes. Deep-cycle batteries are used in this system. The inverter then converts the DC power generated into a usable AC power. The final component, the safety fusing acts as an interconnection between the system and the appliances in the house. Currently, there are two types of solar PV system available. They are:

- Grid-Tied System
    - The system is connected to the utility grid. When there is excess energy produced, the power is supplied back to the utility grid. When there is no production (during the night), the power is supplied from the utility grid.
- Off-Grid System
    - The system is not connected to the utility grid. The system will provide its own energy. Deep-cycle batteries are used as a source for backup energy.

4.2.3 Results

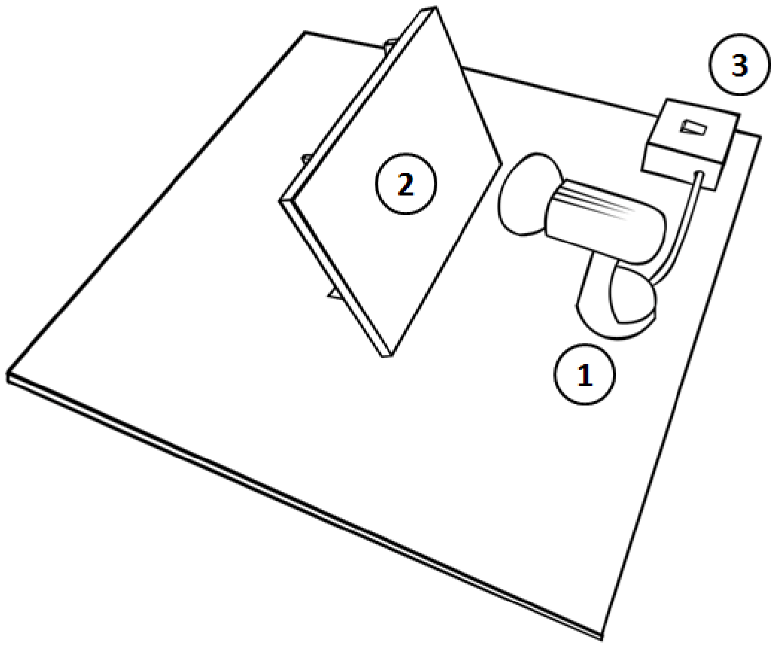

Figure 26: Solar Panel Experiment

The Solar PV module, as depicted in the figure above is used to help me enhancing my understanding of the efficiency of the Solar PV and the factors that affect its efficiency. The Solar PV module comprises of 3 components. The first component is the 60W reflector bulb that simulates the solar energy from the Sun, as discussed in the previous chapter. The second component is the 5Wp Solar Panel. The third component is the main switch to the module. It connects the power supply from a 13A 3-pins plug to the reflector bulb.

The 60W reflector bulb is placed onto a special holder, where it can be tilted as shown in the figure below. The purpose of this holder is to simulate the angle of the sunlight.

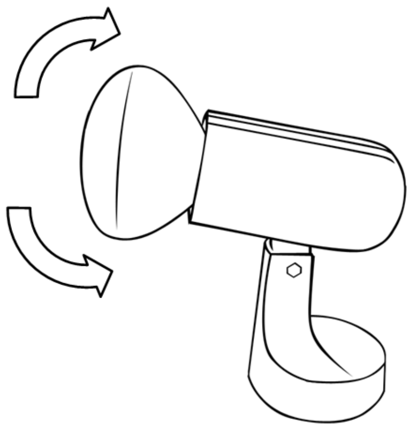

Figure 27: Bulb Holder

The Solar Panel is placed onto a designated frame made of aluminum. The frame is tilted as depicted in the figure below.

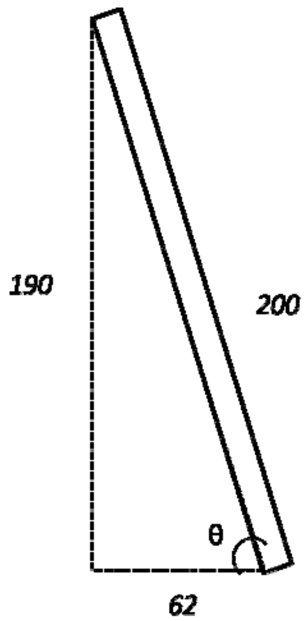

Figure 28: Fixing the Solar Panel into the Designated Frame

The calculation of the angle θ is shown below.

$$\sin\theta = \frac{h}{x}$$

$$\sin\theta = \frac{19}{20} = 0.95$$

$$\theta = \sin^{-1} 0.95 = 71.80°$$

The output of the Solar PV can be connected to the circuit of House #3's model to simulate a condition where all of the applications in the house are supplied by the Solar PV. The generated output is measured as shown in the figure below.

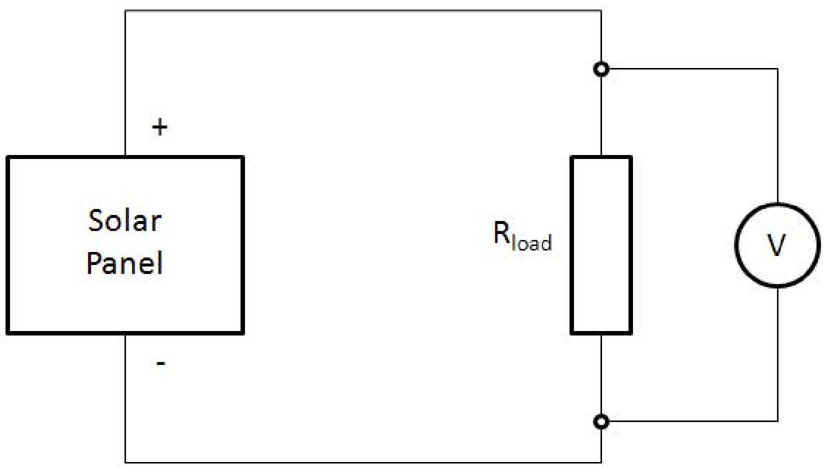

Figure 29: Solar Panel's Voltage Measurement

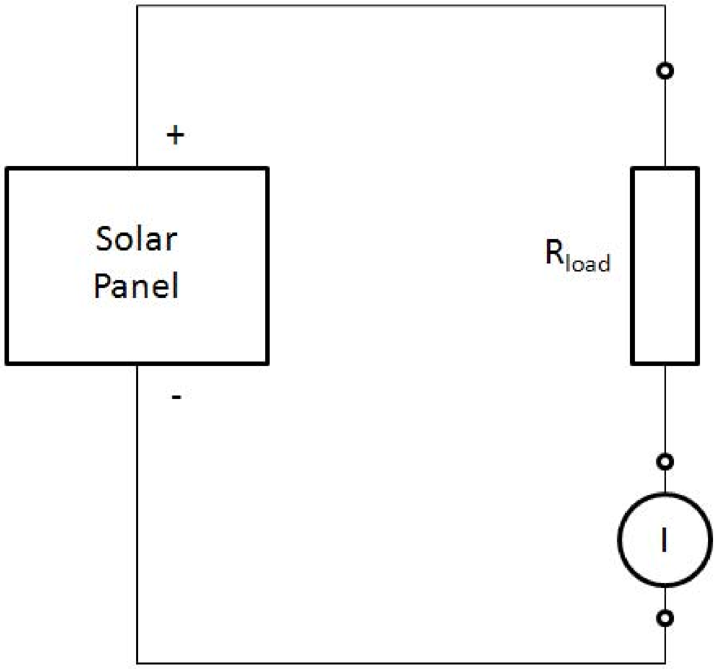

Figure 30: Solar Panel's Current Measurement

The Solar Panel is tested under different conditions by using the light from the Sun, 10W Fluorescent Tube, 40W Reflector Bulb, and 60W Reflector Bulb. The Solar Panel is also tested under different weather conditions. The results from the experiment are shown in the tables on the next page.

Table 22: Generated Output (Different weather condition)

Weather Condition	Voltage Output	Current Output
Sunny Day	20V	0.25A
Cloudy Day	16.03V	30.2mA

Table 23: Generated Output (Household lightings)

Type of Lighting	Generated voltage, V
10W Fluorescent Lighting	9
40W Reflector Bulb	16.5
60W Reflector Bulb	17.5

Figure 31: Sunny Day

Figure 32: Cloudy Day

4.2.4 Discussion

Based on the results, we can see that when the solar panel is exposed to the Sun, it produces larger output compared to the output produced to the output produced when it is exposed to household lightings. There are several factors that could cause the differences of the output.

The first factor is insolation. As defined in Wikipedia, insolation is a measure of solar radiation energy received on a given surface area in a given time [37]. It is commonly expressed in W/m^2. The average insolation for the Earth is approximately 250 watts per square meter [37]. However, the actual figure varies with the Sun's angle at different times of the year, the distance of the sunlight travels through the air, and the quality of the sunlight due to atmospheric haze and cloud cover [37].

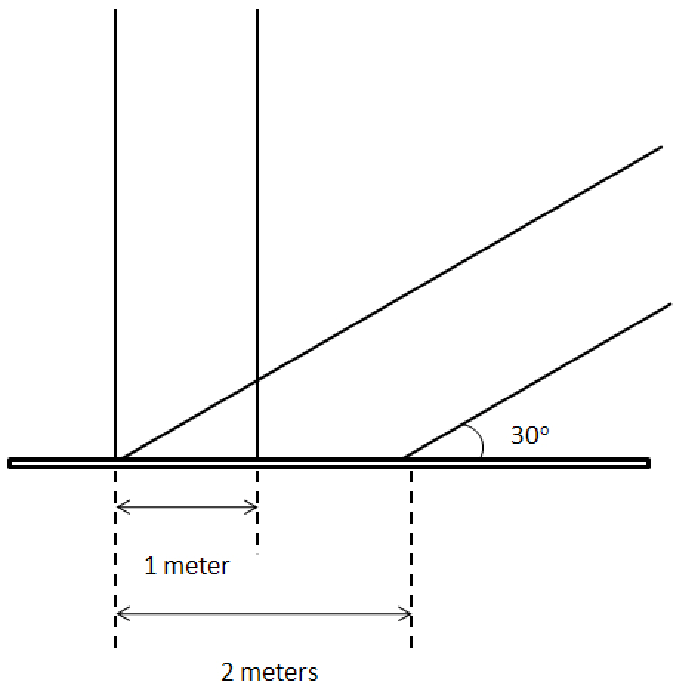

Figure 33: Effect of Sun's Angle to Insolation of the Sun [33]

The insolation of the Sun into a surface is the largest when the Sun shines directly to the surface [37]. As the angle increases between the surface and the direction of the rays of sunlight, the insolation is reduced in proportion to the cosine of the angle [37]. As shown in the figure above, we can see that the sunlight hitting the ground at a 30° angle spreads the same amount of light over twice as much area [37]. Thus, that is why the Polar Regions are much colder than the Equatorial region [37].

The second factor is the intermittent attribute of solar energy. Intermittent, as defined by Collins Dictionary means “occurring occasionally or at regular or irregular intervals” [38].The light from the Sun is considered as an intermittent energy source because the quantity of the light received varies with different Sun angle, locations and time of the year [37].

The angle of the sunlight also plays an important role in the efficiency of solar PV. Assuming that the solar PV is a rectangular plane, as we change our perspectives, the shape of the plane could become a parallelogram with odd angles [39]. The solar panel also uses the same principle. The more surface area that is exposed to the light, the higher the output

The number of hours of sunlight a day received in a certain area is another factor [39]. In Malaysia, we have naturally abundant sunshine [40]. Malaysia received about 6 hours of sunlight per day. However, the duration of sunlight varies due to seasonal and spatial variation [36]. For example, Alor Setar and Kota Bharu receive about 7 hours per day of sunshine while Kuching only receives about 5 hours of sunshine [40].

The quality of sunlight is also another important factor [39]. As stated by DeGunther, “sunlight changes along with the weather” [39]. For instance, in a cloudy area, we still receive a lot of solar energy. However, the light is diffused by the clouds. Air pollution and smog could also affect the quantity of sunlight received. Depending on the composition of the smog, spectral filtering could occur, and this could decrease the efficiency of the PV [41].

4.3 Micro-Hydro Module

4.3.1 Introduction

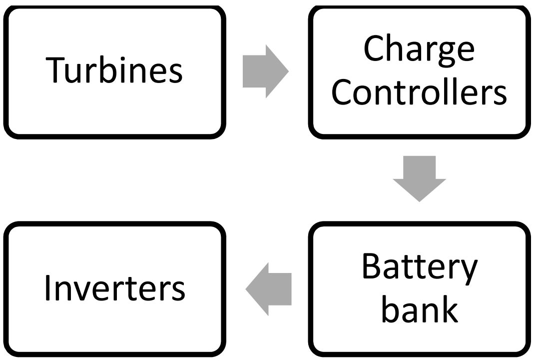

Figure 34: Components of a Typical Micro-Hydro System

A turbine is a type of a rotary engine that is capable to extract energy from a fluid flow and converts it to useful work [42]. In a micro-hydroelectric generation; there are two types of turbines that are available to choose, depending on the situation [43]. They are impulse-type turbines and reaction-type turbines.

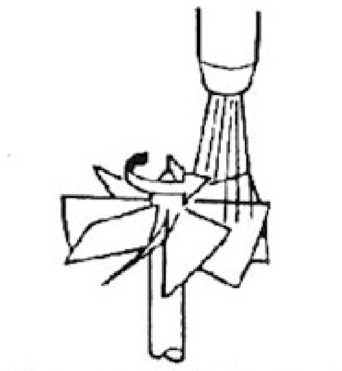

Figure 35: Impulse-Type Turbine [44]

The impulse type turbine has the same operation principle as in water mills, which the water strikes the turbine runner and pushes it to rotate in a circle [45]. This type of turbine works best in sites where the water spruce has a head pressure of at least 20 feet [45]. For reaction-type of turbine, it requires a larger amount of water flow than impulse-type turbines. They can operate with much smaller head pressure [45].

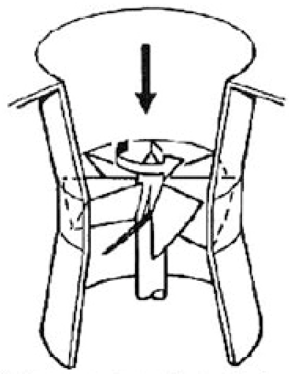

Figure 36: Reaction-Type Turbines [44]

The charge controller is used to divert the excess DC loads that otherwise could damage the batteries [45]. If the excess power generated by the turbine is not regulated, it could cause the turbine to overwork, which could produce dangerous overvoltage [45]. The batteries used in a typical micro-hydroelectric system are the deep-cycle lead acid batteries [45].This type of batteries, unlike the regular batteries used in automotive, are specially designed to be regularly discharged to its maximum capacity possible [46].The inverters then will transform the DC electricity from the battery bank into a usable AC power.

The derivations of the power from a typical micro-hydro module are shown on the next section [47].

4.3.2 Power in Micro-Hydro

The power available from a micro-hydro power is given by,

$$P_{net} = eQgh \text{ kW} \quad (1)$$

Where e = the overall efficiency of the hydropower system;

Q = the volume flow rate (m^3/s);

g = the gravitational constant, 9.81 (m/s^2);

h = height (m);

The energy released by the water at a given height is in the form of potential energy, where

$$E_{pot} = mgh \text{ J} \quad (2)$$

Where m = mass of water (kg);

G = the gravitational constant (m/s^2);

h = height (m);

Let mass of the water, *m* is defined as the product between water density, *r* and the volume, *V*,

$$E = Vrgh \text{ J} \quad (3)$$

Power is defined as energy per second,

$$P = \frac{E}{t} = rQg \quad \text{W} \tag{4}$$

Where Q = flow rate of the water (m^3/s);

However, in the actual situation, there are losses caused by the system. These losses may be produced from water friction within the pipe and heat losses from the generator which cause the power produced to be smaller than the theoretical value [47].

$$P_{net} = erQgh = e \times 1000 \times Q \times 9.81 \times h \text{ W} \tag{5}$$

Thus, the overall efficiency, e of hydropower is included in the equation. Generally, the efficiency value for micro-hydroelectric system is around 40 to 60 percent [43]. For practical purposes, the power equation could be simplified as follows,

$$P_{net} = eQ \times 9.8 \text{ kW} \tag{6}$$

4.3.3 Results

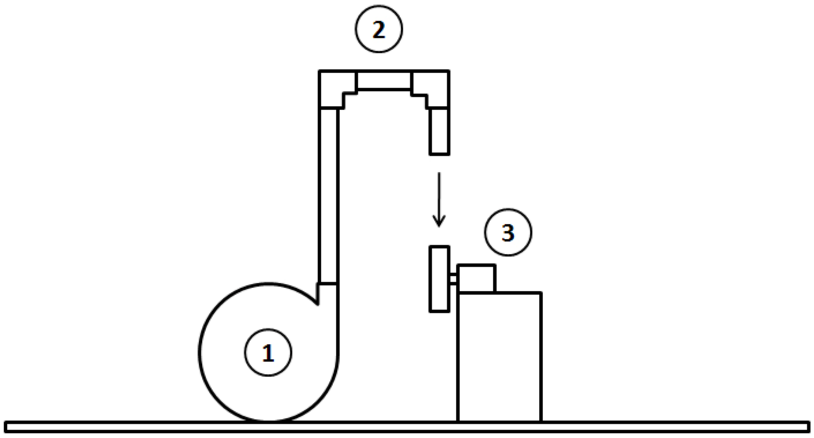

Figure 37: Suggested Design for the Micro-Hydro Module

The suggested layout of the module is shown in the figure above. The module comprises of 3 components. The first component is the submersible pump. The second component is the piping. The third component is the generator. The submersible pump is used to maintain the circulation of the water, so that the water in the tank will be re-used. The pump is also used to simulate the continuous flow of water in streams and household piping.

The DC motor is coupled with plastic turbines which are obtained from aquarium accessories. For this experiment, I have tested two designs of turbines, which are shown in the figures on the next page.

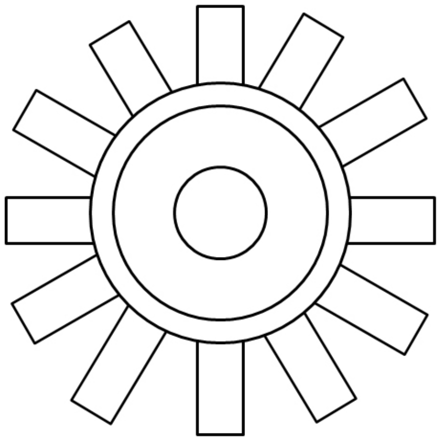

Figure 38: Turbine Design A

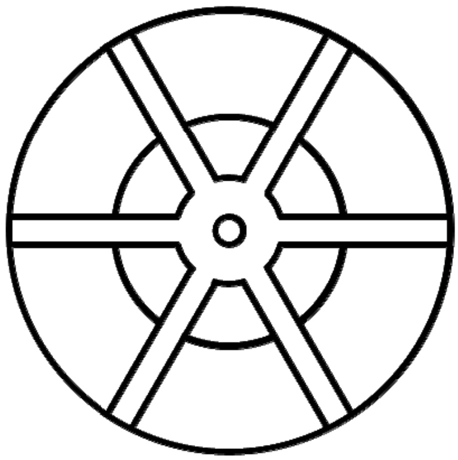

Figure 39: Turbine Design B

Based on the tests I have done, it is observed that Design B produces higher and more stable output compared to Design A. when the pressure of the water or the flow rate of the water is high, Design B is more suitable. Since the fins in Design A are not encased like in Design B, the water are easily dispersed, thus producing less output.

The generator is made from a DC motor. A DC motor could operate as a generator if the shaft is turned by external force.

The micro-hydro module is tested under different flow rate of water, which is produced by the submersible pump and the tap from students' apartment in UTP. The flow rate is measured by measuring the time that is required to fill a certain volume. The calculations are shown on the next page.

For the household's tap, a 600 ml bottle is filled with water in 1.49 seconds.

$$Q = \frac{600\ ml}{1.49\ s} = 402.68\ \ ml/s$$

$$Q = 0.403\ L/s$$

The same method is applied to measure the flow rate of the submersible pump. The voltage produced by these flow rates are shown in the table below.

Table 24: Measured Output Voltage

Source	**Flow Rate**	**Voltage Produced**	**Current Produced**
Household Tap	0.403 L/s	0.683V	30.1mA
Submersible Pump	0.28 L/s	0.341 V	10.3mA

4.3.4 Discussion

Based on the experiments, we could see that the power output is very low because of the flow rate, Q and the height, h are very small. These two variables are crucial in micro-hydro generation. However, the efficiency of the system could also be affected by the generator itself. In this case, the efficiency of the model might be affected by the DC motor itself.

An experiment has been conducted to estimate the DC motor's efficiency. The output power generated by a DC motor is theoretically the same as the power consumed if the shaft is turned at its rated speed. Two DC motors of the same type are both coupled together as depicted in the figure below.

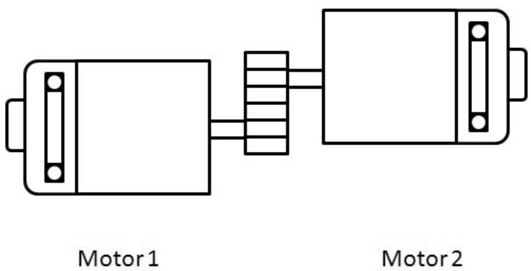

Figure 40: Measuring the Efficiency of DC Motor

Motor 1 is connected to a 9V battery, and motor 2 is connected to a digital multimeter to measure the output voltage that will be produced. The voltage and current of the 9V battery are to be assumed as constant. The datasheet of the 9V battery is included in Appendix D. The current produced will also be assumed to be constant. The voltage produced is 6.31V. The efficiency of the DC motor is calculated as follows.

$$\eta = \frac{Vo}{Vin} \times 100\% = \frac{6.31}{9.0} \times 100\% = 70.11\%$$

The efficiency might be affected by the coupled gears or improper placement of the motor.

For consumers who do not have access to rivers, the micro-hydro generation could still be applied to their household's pipeline as depicted in the figure below.

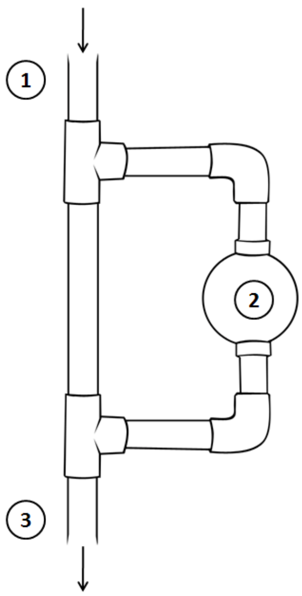

Figure 41: The Concept of Micro-Hydro Generation in Household

Based on Figure 41, we can see the incoming water is supplied from the supplier. However, rather than supplied directly to the consumer, a T-Joint, drives some of the water to the micro turbine. The water used to turn the turbine, will be flowed into the main pipe.

However, a special attention for the design of the turbine must be considered. The water pressure must be maintained so that higher output will be produced and the pressure of the water supply for the consumers is not affected. The turbine should be designed where it could maximize the output produced even with a small flow rate.

The turbine should be designed carefully therefore, the water quality will not be affected by the turbine so that the water will be safe for the consumers to use. The design of this turbine is still ongoing and it requires a different study to achieve the best design of the turbine so that it could be utilized by the consumers without any problems.

4.4 Wind Power Module

4.4.1 Introduction

As discussed earlier in Chapter 2, wind is produced by the large scale of movement of air masses in the atmosphere.

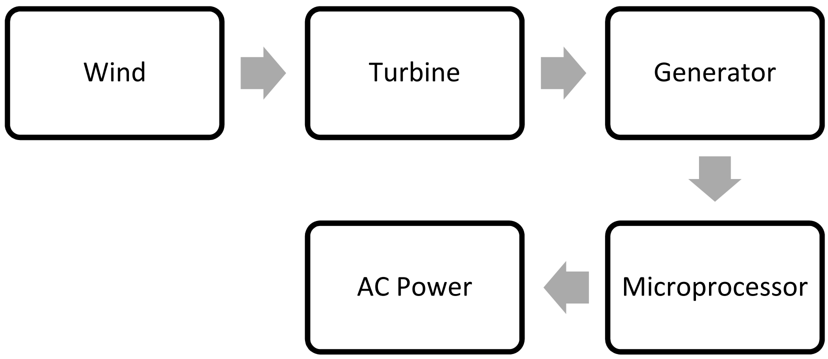

Figure 42: Operating Principles of a Typical Small-Scale Wind Generator

The figure above shows us the basic operating principles of wind power generation. The wind pushes the vane of the turbine. The alternator (generator) is then turned by the propeller. In some modern designs of wind turbines, the production energy is controlled by microprocessor units for better efficiency. AC power is produced by the alternator. The turbine comprises of three main parts, which are the rotor itself, the enclosure and the tower. The function of these parts is summarized as the following table.

Table 25: Main Parts of a Wind Turbine

Component	**Function**
Rotor	To convert the wind's kinetic energy into rotational energy
Nacelle or enclosure	Houses the drive train, which usually includes gearbox and a generator. However, for smaller scale wind energy systems, they do not require any gearbox
Tower	Supports the rotor and drive train

4.4.2 Power in Wind Energy

The power available in the wind is given by the equation below [48].

$$P = 0.5 \times \rho \times A \times C_p \times V^3 \times N_g \times N_b \text{ W} \tag{7}$$

Where P = total power in the wind (W);

ρ = density of the air (kg/m^3);

A = rotor's swept area (m^2);

V = velocity of the wind (m/s);

C_p = power coefficient;

N_g = generator coefficient;

N_b = gearbox coefficient;

As discussed earlier, wind is formed by moving air molecules, which have mass [49]. Any object in motion carries kinetic energy [50]. Thus, wind possesses kinetic energy. The standard expression for kinetic energy is given by the following equation [50].

$$E_k = \frac{1}{2}mv^2 \quad \text{J} \tag{8}$$

Where E_k = kinetic energy (J)

m = mass of object (kg)

v = velocity of object (ms^{-1})

Air has a known density, for example at sea level; the air density is at 1.23 kg/m^3. Thus, the mass of air hitting the wind turbine, or the rotor's swept area at a given time is given by the following equation [49].

$$\frac{m}{t} = v \times A \times \rho \quad \text{kg/s} \tag{9}$$

Where m = mass of air (kg)

t = time taken (s)

v = velocity of air (ms^{-1})

A = rotor's swept area (m^2)

ρ = air density (m^3/kg)

Based on the above equation, we can derive the equation for the mass as follows,

$$m = t(vA\rho) \;\; \text{kg} \tag{10}$$

The energy produced by the wind on the turbine is derived by inserting the mass equation into the kinetic energy equation,

$$Ek = \frac{1}{2}(tvA\rho) \times v^2 \text{ J} \quad (11)$$

It is known that power is the work performed at a given time [51]. Thus, the power in the wind is given by the following equation,

$$P = 0.5 \times \rho \times A \times V^3 \text{ W} \quad (12)$$

The density of air is the mass per unit volume of Earth's atmosphere [52]. There are several factors that affect the density of air, such as altitude and temperature. As altitude increases, the density of air increases and air density varies with temperature [52]. The graphs for the two relationships mentioned are included in Appendix E.

The swept area of the rotor is the area of the circle outlined by the wind generator's rotating blades [53]. For a conventional rotor, as shown in Figure 44, the rotor's swept area is given by the equation on the next page,

Figure 43: A Conventional Rotor [54]

$$A = \pi \times \left(\frac{d}{2}\right)^2 \text{ m}^2 \tag{13}$$

Where A = rotor's swept area;

π = approximately 3.1416;

d = diameter of the rotor blade;

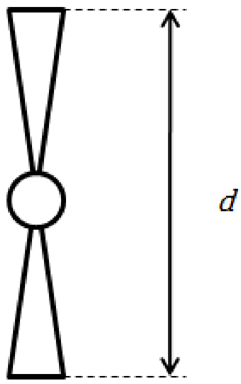

Figure 44: Diameter of the Conventional-Type Rotor Blade

The velocity of the wind is measured in meter per seconds. As given in the equation, the wind power, P is very dependent on the velocity. The power increases cubically as velocity of the wind increases. In large scale wind energy system, the speed of the rotor can be maintained by means of gearbox. However, for smaller scale wind energy system, the velocity of the wind is a direct function of the wind power [55].

$$P \propto V^3 \tag{14}$$

The power coefficient, C_p describes the efficiency of a turbine as it converts the kinetic energy in the wind to electricity [56]. In other words, C_p is the power efficiency of the wind turbine. In wind power, C_p is limited by Betz' Law. As stated in Betz' Law, the theoretical maximum kinetic energy that can be captured by the turbine is only 59.3% [57]. If a turbine has 100% efficiency, it will capture all the kinetic energy from the wind, bringing the air into standstill [58]. Since there is no air flow, there will be definitely no air to drive the turbines [58]. Thus, there will be no work produced by the turbines.

4.4.3 Results

The Windmill Generator is used to study the relationship between the wind speed and the output produced by the wind generator. However, since it is not very windy in UTP and to overcome this problem, a car's air-conditioner is used instead. Using an anemometer, the speed of the wind produced by the air-conditioner is measured at each speed setting (e.g. Speed 0, Speed 1). The table below summarized the results obtained from the wind experiment.

For this experiment, the air temperature is 15^{o}C. Based on the table shown in Appendix E, for 15^{o}C, the air density is 1.2250 kg/m^3. The power from the wind is calculated as given in Equation 12.

Table 26: Wind Speed – Voltage Generated

Wind Speed, v (m/s)	**Voltage Generated, V (V)**
0	0
4.3	0
5.3	2.49
8.6	4.44
10.8	6.79

Table 27: Wind Speed – Power Generated

Wind Speed, v (m/s)	**Power Generated, P (W)**
0	0
4.3	0.43
5.3	0.81
8.6	3.47
10.8	6.86

4.4.4 Discussion

Based on the results obtained from the experiment, it is apparent that the power output of the windmill generator depends solely on wind speed. So, it is very important that the wind turbines should be located in a clear area and without any obstructions. Generally, a typical wind energy system must be mounted at least 30 feet above the ground and at least 200 feet away from obstructions [55]. Examples of good sites and bad sites for windmill setting are shown in the following figures.

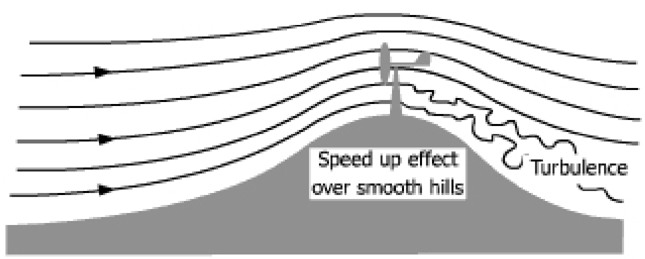

Figure 45: Example of a Good Site [59]

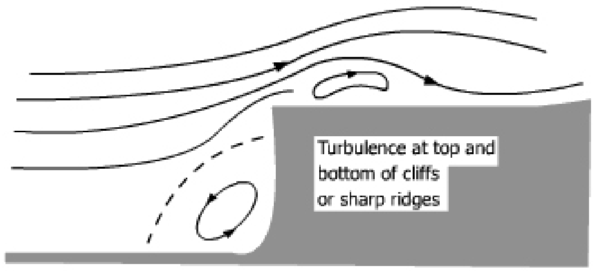

Figure 46: Example of a Bad Site Due to the Turbulence [59]

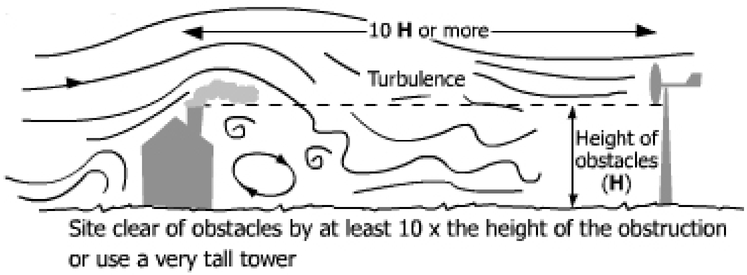

Figure 47: Example of a Bad Site Due to Obstruction [59]

In order to produce the maximum output, the blades of the rotor of the wind turbine have to be aligned properly so that it is perpendicular to the wind direction [60]. Should a wind turbine placed horizontally with the wind, the wind would act on both sides, thus effectively canceling each other [60].

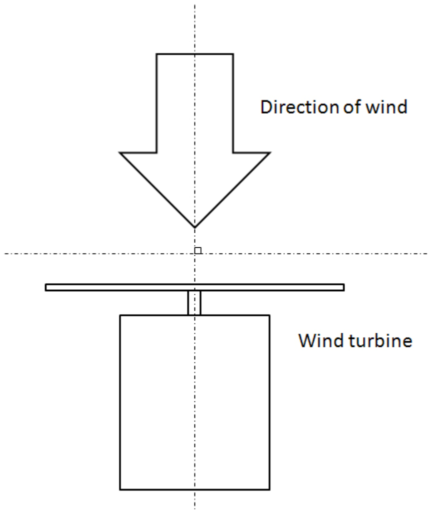

Figure 48: θ at 90°

Based on the figure, θ is the angle between the turbine's rotor and the direction of the wind. At θ = 90°, the power generated is at maximum value. As the angle changes, the generated power decreases.

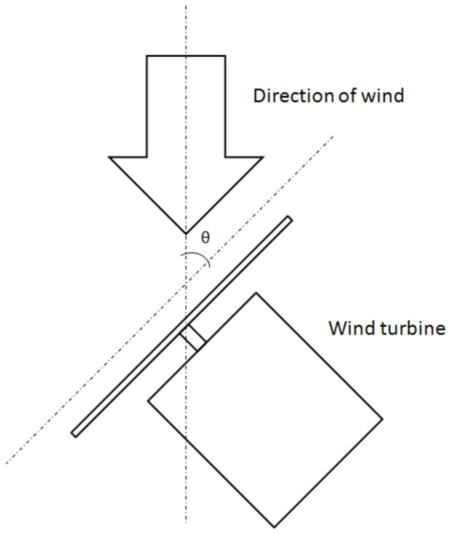

Figure 49: θ at 45°

4.5 Power Distribution

Based on the results obtained from the models, we have discussed the factors that affect their efficiency. The total output power produced is calculated as follows.

For solar PV model,

$$P = VI = 20 \times 0.25 = 5W$$

For micro-hydro model,

$$P = eQgh = 0.5 \times (0.403 \times 10^{-3}) \times 9.81 \times 0.2 = 0.395mW$$

For wind power model,

$$P = 0.5 \times \rho \times A \times C_p \times V^3$$

$$P = 0.5 \times 1.2250 \times 0.015 \times 0.593 \times (5.3)^3 = 0.811W$$

Based on the power calculated above, it is obvious that the most reliable energy source is solar energy. If consumers wanted to apply all the three methods for their house, the suggested power distribution is shown in the results below.

Table 28: Suggested Power Distribution

Alternative Energy Method	Distribution Percentage
Solar Energy	60 – 90
Wind Power	10 – 30
Micro-Hydro	0 – 10

The power distribution stated in the previous table will vary for different consumers. For example, Consumer A is living in a rural area where it is always hot and windy, and is near to a river. Should he apply all the three alternative energy methods above; the suggested power distribution can be summarized in the figure below.

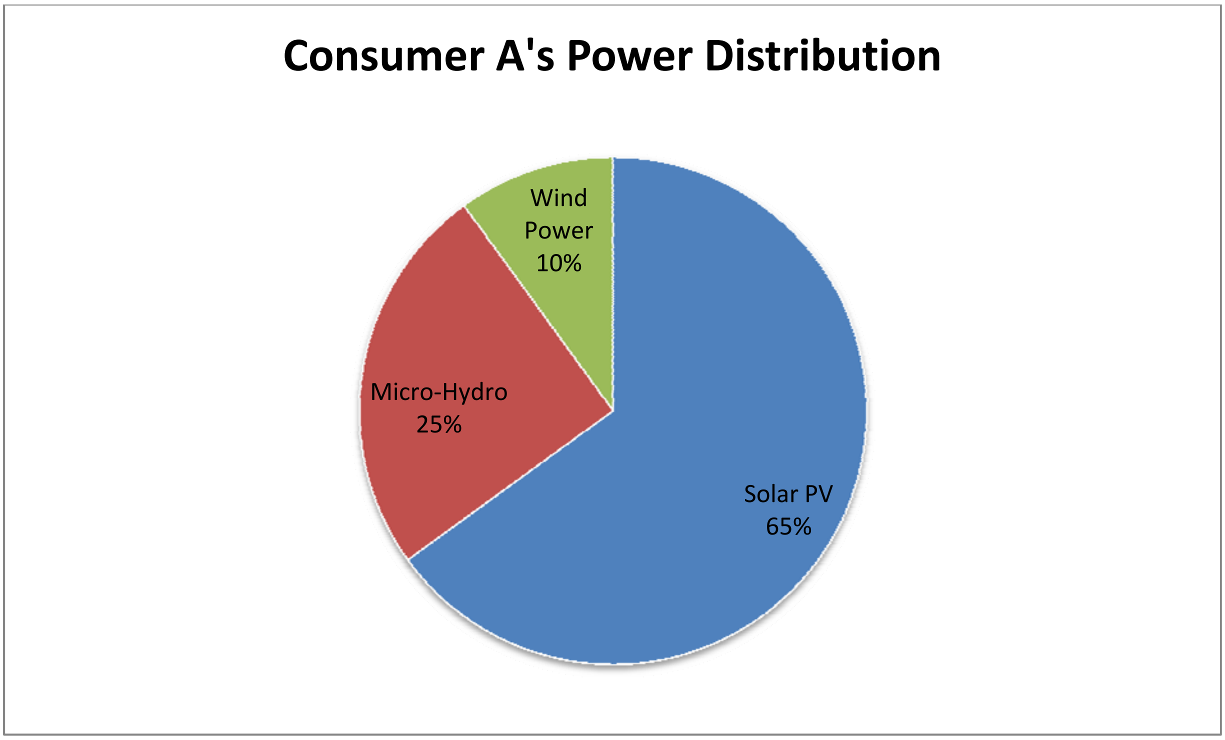

Figure 50: Power Distribution for Consumer A

Consumer B, on the other hand, lives in the city. There are no rivers near his apartment and there is no suitable place for wind turbine installation. However, he could install a micro-hydro turbine in his house. Thus, the power distribution can be summarized in the figure below.

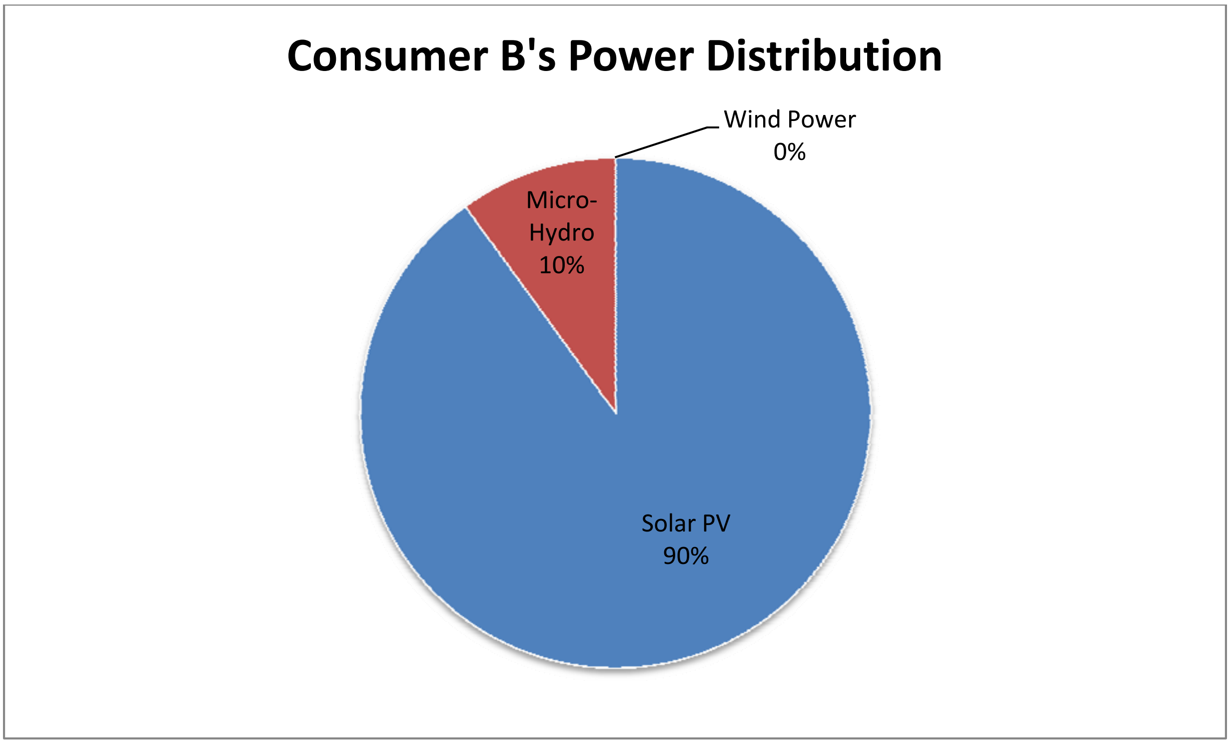

Figure 51: Power Distribution for Consumer B

4.6 Factors Influencing in Choosing the Alternative Energy Methods

4.6.1 Location

In Malaysia, the weather condition such as the solar radiation, the rainfall distribution and wind flow varies with the location.

There are four notable seasons, which are the Southwest Monsoon, Northeast Monsoon and two shorter periods of inter-monsoon seasons [40]. The Southwest Monsoon season is usually falls in the second half of May, or early June and ends in September [40]. The Northeast Monsoon season usually commences in early November and ends in March [40].

Table 29: Wind Speed in Various Locations [61]

Location	Wind Speed (Knots)	Wind Speed (m/s)
Bandar Seri Begawan	6	3.09
Penang	5.25	2.70
Kuala Lumpur	4.25	2.19

The geographical factor also contributes in influencing the wind flow in Malaysia. The table above shows the average wind speed for 12 months in three different locations, namely Penang, Kuala Lumpur and Brunei (which represents Sabah and Sarawak).

As discussed in the previous section, the duration of the sunlight received in Malaysia varies according to location. Alor Setar and Kota Bharu receive about seven hours of sunshine per day, while Kuching receives only five hours of sunshine per day [40]. On extreme condition, Kuching receives only 3.7 hours of sunshine per day in January, while Alor Setar receives a maximum of 8.7 hours of sunshine per day in the same month [40].

4.6.2 Living Condition

The population of Malaysia is composed of people of different ethnicity, religious beliefs and culture. The different cultural background led to different lifestyles. Besides, the size of the family also affects the living style. For example, a bachelor lives differently compared to a family of four. As the lifestyle varies with cultures and the size of a family, so does the power consumption in their house. According to a study by the UNDP, the average of family size in Malaysia is 4.6 people per family [35].

4.6.3 Current Technology Available

Most of the alternative energy modules today are available in two different types of technology, which are the Grid-Tied System and the Off-Grid System. The Grid-Tied system, as defined by Wikipedia, "is a semi-autonomous electrical generation system" or "grid energy storage system which link to the mains" to supply excess energy back to the utility grid [62].

The Grid-Tie System is useful for consumers with high power consumption. The cost for battery with large storage capacity is very high. Thus, by applying this type of system, the consumers could reduce their capital cost of their investment in alternative energy. Should energy is produced more than the power consumption; the excess energy could be supplied back into the utility grid. When there is no energy production, power is supplied from the utility grid.

The Off-Grid System is useful for consumers who live in a rural area where it is physically impossible to connect the house to the utility grid. In this system, it uses deep-cycle batteries as a backup source of energy.

4.7 Choosing the Suitable Method

Based on the factors we discussed earlier, several scenarios have been created and the power distribution for each scenario is estimated. A suitable solution is given for each of the scenario.

Consumer A is living in a rural area where it is hot and windy. His house is close to a river. His family size is 3. Most of his appliances are necessary appliances, such as lightings and fans.

Consumer B is living in a city. He lives in an apartment. His family size is 4. He uses most of his appliances regularly.

Consumer C lives on a beach. His family size is 6. He has a lot of appliances and uses them most of the time. There are no rivers in a radius of 1 km. It is very windy most of the time.

Consumer D lives in the city. He works in a small firm of 10 to 15 people. Most of the appliances are important for their work, such as computers, server and photocopy machine. The power distributions of each scenario are shown in the figures on the next page

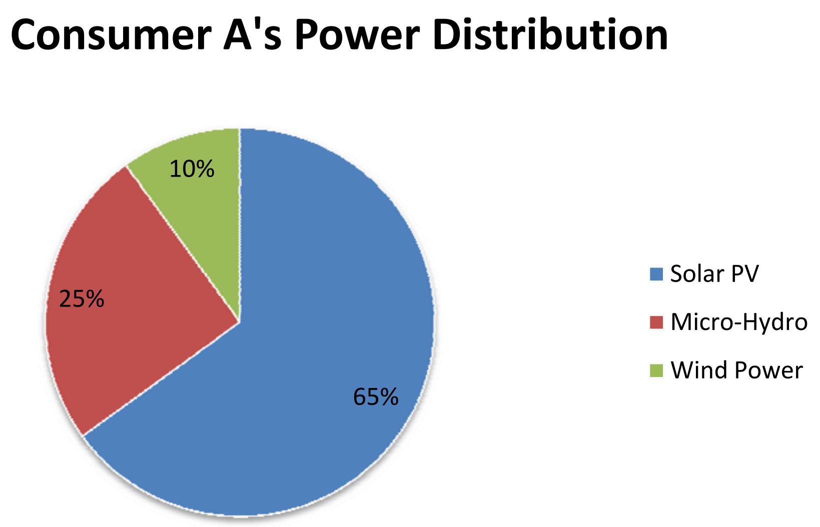

Figure 52: Power Distribution for Consumer A

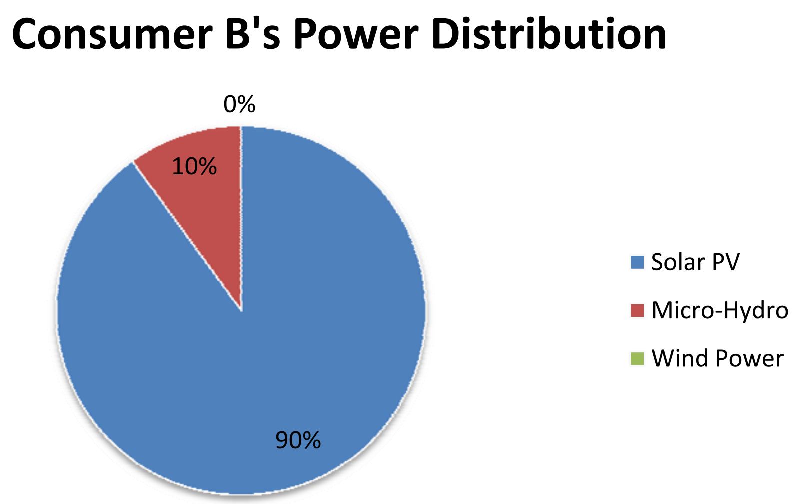

Figure 53: Power Distribution for Consumer B

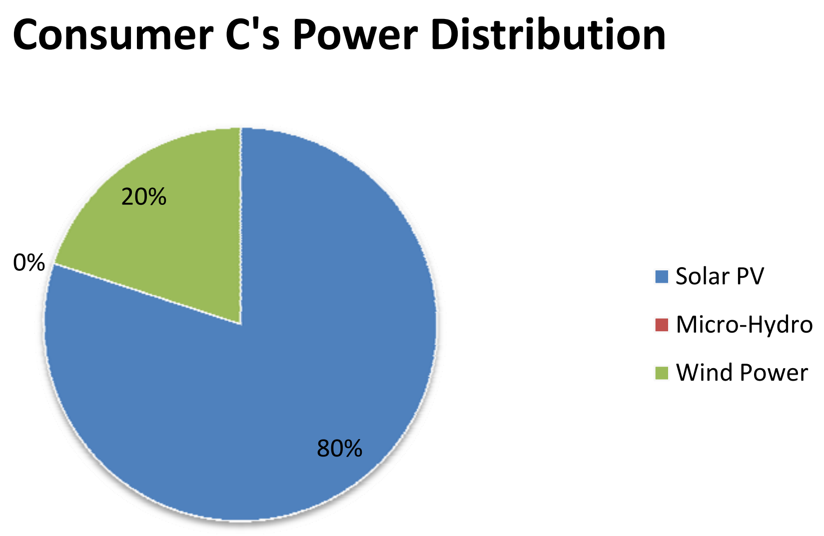

Figure 54: Power Distribution for Consumer C

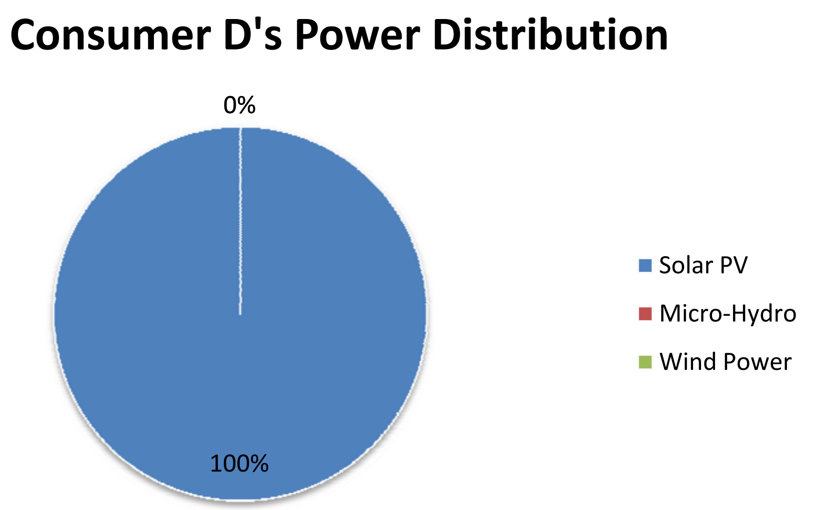

Figure 55: power Distribution for Consumer D

The solutions for these scenarios are summarized in the table on the next page.

Table 30: Suggested Solution for the Scenarios

Scenario	Solution	Justification
A	Off-Grid Solar PV Off-Grid Micro-Hydro Off-Grid Wind Power	All source of alternative energy are available to him. He has a small family, and since he is in a rural area, it would be better if all the alternative energy systems are independent.
B	Grid-Tied Solar PV Grid-Tied Micro-Hydro	Because he is living in an apartment, there might not be any appropriate space for him to install wind turbines. He could install the micro-hydro system to his water supply. Since he lives in a family of four, it would be better if the systems that he will be using are connected to the utility grid.
C	Grid-Tied Solar PV Grid-Tied Wind Power	There are no rivers available within his area, so he could only rely on Solar PV and Wind Power. Since it is a family of six and there are a lot of appliances. Thus, the systems that he will apply to his house must be grid-connected.
D	Grid-Tied Solar PV	Most of the appliances in the office are important for their work. In order to maintain their productivity, all the appliances should not be broken down due to power supply problems. Thus, grid tied solar PV is the best choice because the stability of the power is guaranteed.

Based on the results given from the survey and from my experiments' results, it is suggested that solar PV is the best method. Although the performance of the solar PV could be affected by the intermittency factor of the Sun, it is proven that solar PV produces more output from the micro-hydro power and wind energy.

Malaysia is a tropical country with hot temperatures throughout the year. As discussed earlier, on average, Malaysia received approximately six hours of sunlight per day. Thus, the performance of solar PV is still good.

For Sabah and Sarawak, although they received only 3.7 hours of sunlight per day on an extreme condition, it is suggested for them to use solar PV. To solve the sunlight duration problem, it is suggested that they should opt for grid-connected solar PV system. Through net metering, the consumers could sell back the excess power to the utility grid, reducing the cost in electricity.

For micro-hydro and wind power, based on the results obtained, they are proven to be not feasible for Malaysian consumers. Thus, the suggested solution for Malaysian consumers is the grid-connected solar PV system.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Based on the study, the available alternative energy methods which are solar PV, micro-hydro and wind power have been covered. A study had been conducted to ensure their applicability at a smaller-scale; therefore, consumers could implement them directly.

This study also discusses how consumers' power consumption can be estimated. The reason for estimating their power consumption is that unnecessary power loss can be avoided thus maximizes the efficiency of the alternative energy module.

In addition, the factors that affect the efficiency of these modules have also been discussed in view of the research and experiments conducted. Nevertheless, to implement these energy methods, there are several factors need to be considered for instance, the location of the house, the family size of the consumers and how the appliances are being utilized.

5.2 Recommendation

It is hoped that this study could be further pursued in order to achieve the best solution that is directly applicable to the consumers. This study could also be enhanced by implementing a system to alternative energy modules discussed so that the various types of alternative energy methods could be regulated depending on the consumers' location.

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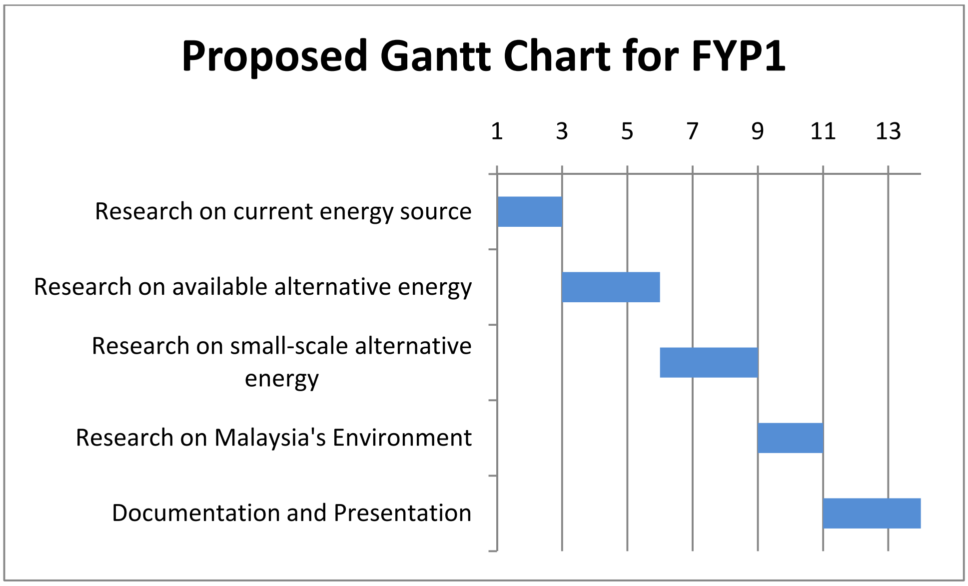
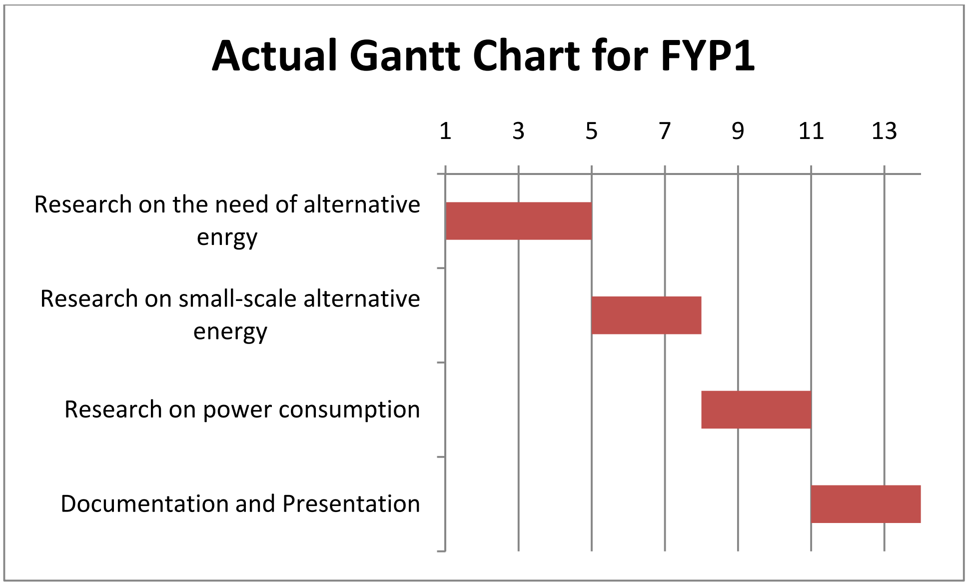
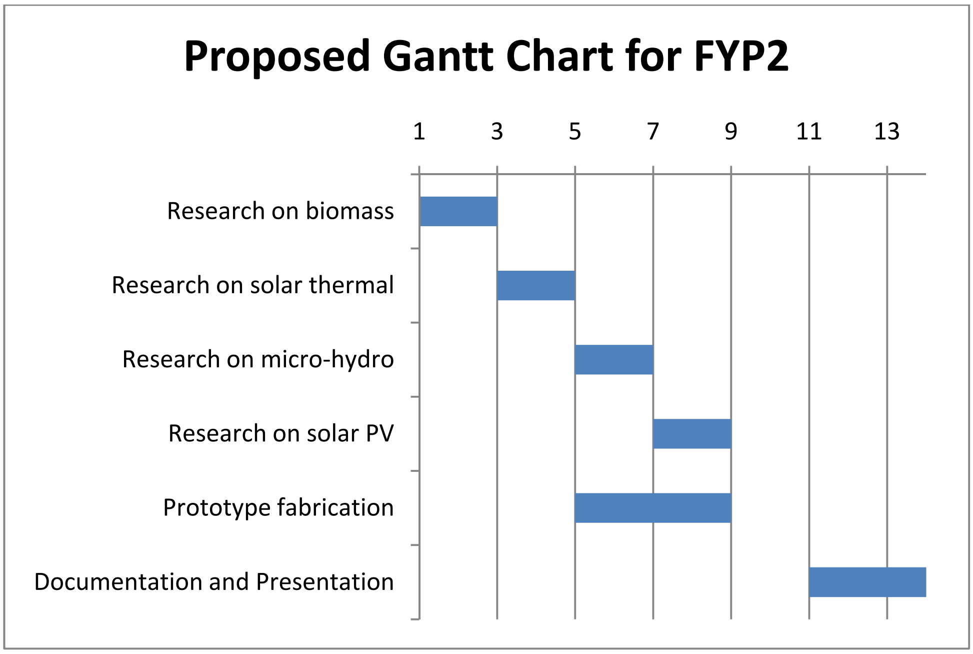
APPENDICES

APPENDIX A

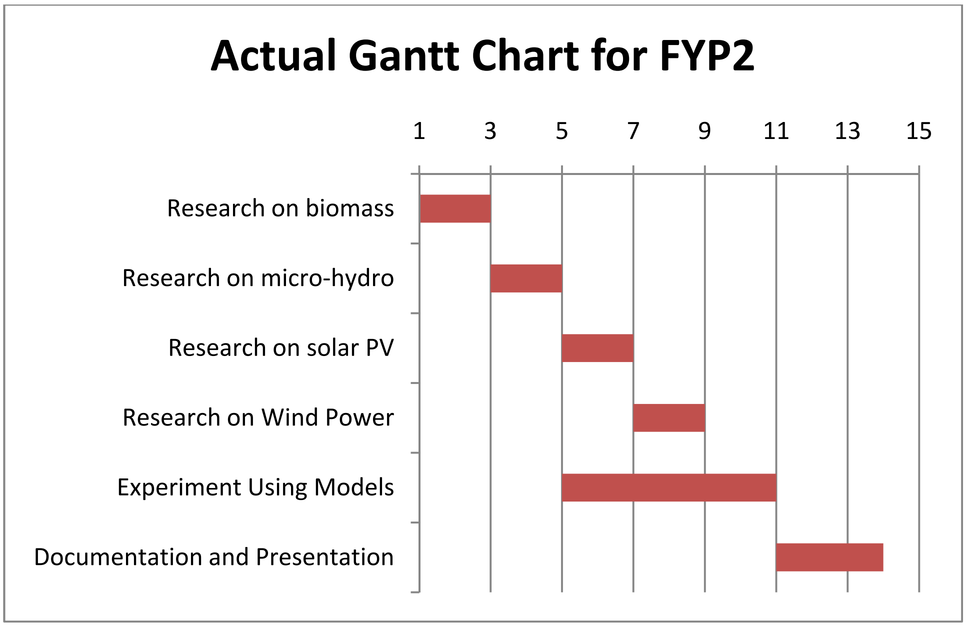
GANTT CHART FOR FYP1 AND FYP2


Proposed Gantt Chart for FYP1
1
3
5
7
9
11
13
Research on current energy source
Research on available alternative energy
Research on small-scale alternative energy
Research on Malaysia's Environment
Documentation and Presentation


Actual Gantt Chart for FYP1
1
3
5
7
9
11
13
Research on the need of alternative enrgy
Research on small-scale alternative energy
Research on power consumption
Documentation and Presentation



Proposed Gantt Chart for FYP2
1
3
5
7
9
11
13
Research on biomass
Research on solar thermal
Research on micro-hydro
Research on solar PV
Prototype fabrication
Documentation and Presentation



Actual Gantt Chart for FYP2
1
3
5
7
9
11
13
15
Research on biomass
Research on micro-hydro
Research on solar PV
Research on Wind Power
Experiment Using Models
Documentation and Presentation

APPENDIX B

DATASHEETS FOR DC MOTORS

APPENDIX C

LIST OF TYPICAL APPLIANCES' WATTAGE VALUES

C-1 List of Typical Appliances' Wattage Values

Appliances	Wattage, W
Aquarium	50 – 1210
Clock radio	10
Coffee maker	900 – 1200
Clothes washer	350 – 500
Dishwasher	1200 – 2100 *
Dehumidifier	785
Electric blanket – Single / Double	60 / 100
Fans	
• Ceiling	65 – 175
• Window	55 – 250
• Furnace	750
• Whole house	240 – 750
Hair Dryer	1200 – 1875
Heater (portable)	750 – 1500
Clothes iron	1000 – 1800
Microwave oven	750 – 1000

Appliances	**Wattage, W**
Personal Computer • CPU – awake / asleep • Monitor – awake / asleep • Laptop	 120 / 30 150 / 30 50
Radio	70 – 400
Refrigerator (frost-free, 16 cubic feet)	725
Televisions (color) • 19” • 27” • 36” • 53” – 61” • Flat screen	 65 – 110 113 133 170 120
Toaster	800 – 1400
Toaster oven	1225
VCR / DVD	17 – 21 / 20 – 25
Vacuum cleaner	1000 – 1440
Water heater (40 gallon)	4500 – 5500
Water pump (deep well)	250 – 1100
Water bed (with heater, no cover)	120 – 380

APPENDIX D

DATASHEET FOR 9V BATTERY

APPENDIX E

RELATIONSHIP OF AIR DENSITY WITH TEMPERATURE AND ALTITUDE

E1 Relationship Between Altitude Increment and Air Densities.

The condition is to be assumed at 20^{o}C, starting from sea level.

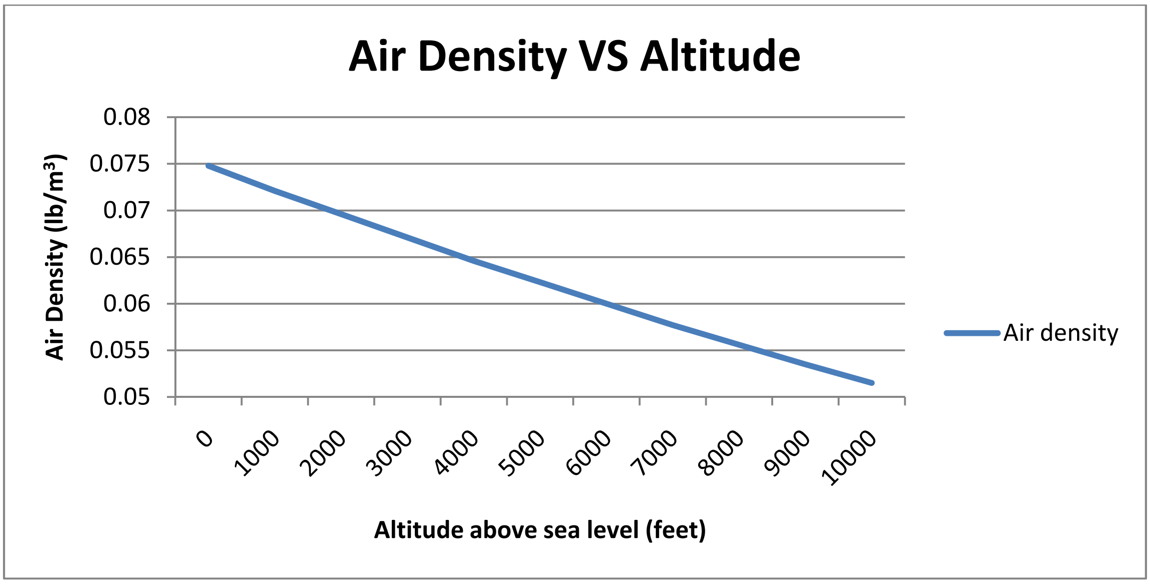
20^{o}C = 68^{o}F

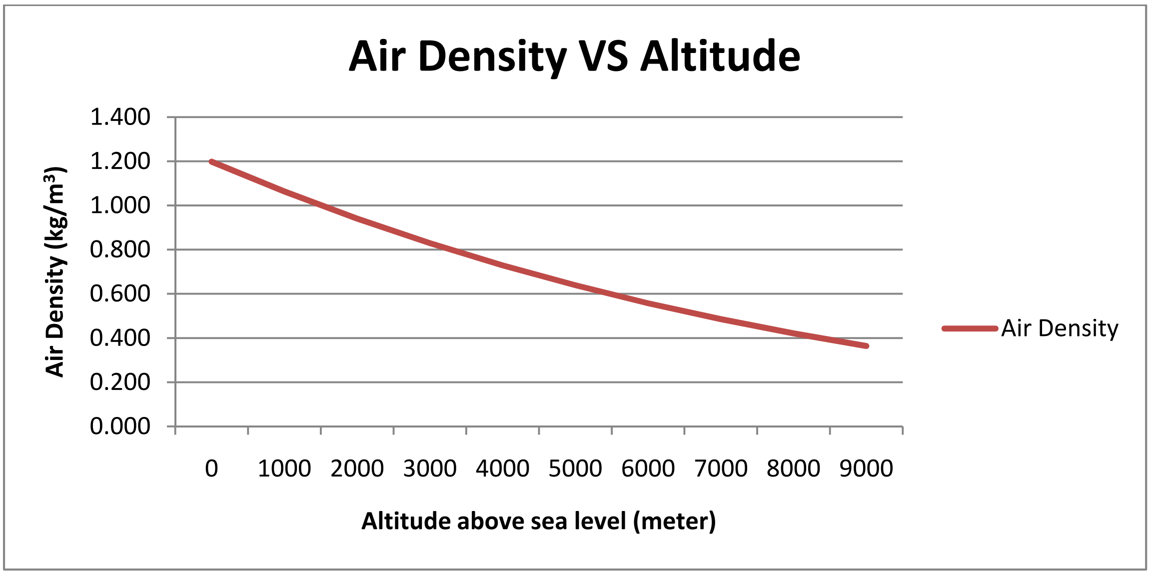
1 m = 3.281 ft

1 lb/ft^{3} = 16.018 kg/m^{3}

Elevation (feet)	**Air density (lb/ft^{3})**
0	0.0748
1000	0.0721
2000	0.0696
3000	0.0671
4000	0.0646
5000	0.0623
6000	0.06
7000	0.0577
8000	0.0556
9000	0.0535
10000	0.0515

Elevation (m)	**Air Density (kg/m^3)**
0	1.198
1000	1.064
2000	0.940
3000	0.830
4000	0.729
5000	0.639
6000	0.557
7000	0.485
8000	0.421
9000	0.364


Air Density VS Altitude
Air Density (lb/m³)
0.08
0.075
0.07
0.065
0.06
0.055
0.05
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Altitude above sea level (feet)
Air density


Air Density VS Altitude
Air Density (kg/m³)
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Altitude above sea level (meter)
Air Density

E2 Relationship Between Altitude Increment and Temperature.

The condition is to be assumed at sea level.

Temperature (^{o}C)	Air Density (kg/m^3)
-25	1.4224
-20	1.3943
-15	1.3673
-10	1.3413
-5	1.3163
0	1.292
5	1.269
10	1.2466
15	1.225
20	1.2041
25	1.1839
30	1.1644
35	1.1455