AN ECONOMIC FEASIBILITY STUDY OF GRID-CONNECTED RESIDENTIAL PV SYSTEM IN MALAYSIA BASED ON NET METERING

by

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List of Abbreviations

AC	Alternating Current
AHP	Analytical Hierarchy Process
DC	Direct Current
DL	Distribution Licensees
FIAH	Feed-in Approval Holders
FIT	Fit in Tariff
HIT	Heterojunction with Intrinsic Thin layer
IBC	Interdigitated Back Contact
I_{max}	Maximum Current Produced
I_{sc}	Short-circuit current
kWh/m^2	kilo watthours per metre square
LCD	liquid crystal display
mA	milliampere
MW	megawatt
PC	personal computer
P_{max}	Maximum Power Produced
PV	photovoltaic
RE	renewable energy
SEDA	Sustainable Energy Development Authority
TNB	Tenaga Nasional Berhad
V_{max}	Maximum Voltage Produced
V_{oc}	Open-circuit voltage

SUATU KAJIAN KELAYAKAN EKONOMI SISTEM PV KEDIAMAN YANG TERIKAT DENGAN GRID DALAM MALAYSIA BERDASARKAN METERING NET

ABSTRAK

Dalam kertas ini, prestasi 4 jenis panel solar dianalisis dengan bantuan sistem mengumpul data menggunakan Arduino Uno di bawah keadaan cuaca di Malaysia. Eksperimen ini dilakukan di lokasi yang sama untuk semua 4 jenis panel untuk membuat radiasi solar, kelembapan dan suhu panel adalah sama. Data ini diambil dari 9:00AM - 16:00PM dalam masa 15 minit selang kerana ini adalah masa pengeluaran kuasa paling tinggi dalam panel. Panel solar terbaik di kalangan mereka dipilih dengan menggunakan formula untuk mencari kuasa output normal. Kuasa output kuasa didapati kerana semua panel mempunyai kawasan permukaan yang berbeza untuk membuat perbandingan dan parameter ini menyelesaikan masalah ini dengan menggira generasi solar bagi satu meter persegi untuk semua panel. Tempoh bayaran balik skim kediaman pemeteran bersih baru 4kW dikira menggunakan formula yang diguna pakai dari pelbagai jurnal. Ini dilakukan untuk memberi kesedaran kepada orang ramai tentang berapa cepat pelaburan mereka akan dikreditkan semula kepada mereka melalui memasang sistem solar dengan sistem panel terbaik (didapati daripada kajian ini) yang terdapat di pasaran Malaysia. Tempoh bayaran balik Fit in Tariff didapati berikut untuk mengenal pasti skim adalah yang terbaik di kalangan FIT dan NEM. Akhir sekali, tempoh bayaran balik skim pemeteran bersih dan Fit in Tariff untuk pasaran kediaman di Malaysia berbanding daripada sumber-sumber yang disediakan oleh Kerajaan Malaysia dan ramalan tahunan dan pengumpulan keuntungan dianalisis untuk membuat gambar yang lebih jelas skim terbaik.

AN ECONOMIC FEASIBILITY STUDY OF GRID-CONNECTED RESIDENTIAL PV SYSTEM IN MALAYSIA BASED ON NET METERING

ABSTRACT

In this paper, the performance of 4 types of solar panels is analysed with the help of data collecting system using Arduino Uno under Malaysian weather condition. The experiment is done in the same location for all the 4 types of panel to make the solar radiation,humidity and temperature of the panels are same. The data is taken from 9.00 AM to 4.00 PM in 15 minutes interval because this is the time power production in high in panels. The best solar panel among of them is chosen by applying formulas to find the Normalised Power Output. This power output is found because all the panels have different surface area to make comparison and this parameter solve this problem by calculation solar generation per metre square for all the panels. The payback period of new net metering residential scheme of 4kW is calculated using formula adopted from various journal. This is done to give awareness to the public about how fast their investment will be credited back to them via installing the solar system with the best panel's (found from this study) system available in Malaysian market. The payback period of Fit in Tariff is found next to identify which scheme is the best among FIT and NEM. Lastly, the payback period of net metering scheme and feed in tariff for residential market in Malaysia is compared from the sources provided by Government of Malaysia and the annual prediction and accumulation of profit is analysed to make a clearer picture of the best scheme.

1 Introduction

1.1 Solar energy and solar panel

Energy is the key requirement for humanity today. It guarantees better personal lifestyle. For day to day usage, continuous energy has turned into a need for humankind recently. As blood is to the body, power is to the economy of any nation so without it, economy will tremble and it will be difficult to maintain it. Everywhere throughout the world, energy is one of the main issues and each nation is searching for energy assets as its request is expanding pointedly. Non-renewable energy resources are either excessively costly or harming to the nature. Furthermore, this energy sources will be depleted in few more decades before the future generation can use it.

For reasons above, the world is moving towards renewable energy resources which will be recharged or replenish in a moderately little timeframe. In spite of the fact that hydroelectric is an extremely cheap renewable energy source, however, it is not accessible to all spots in the world. In the other hand, solar based energy has the potential to produce energy in a green way as it easily accessible. Solar energy can be drawn from solar cells [1] [2] [3].

Solar cells are comprised of semiconducting materials such as silicon, which are doped with various impurities. This produces an unequal distribution of free electrons (n-type) on one side of intersection and overabundance of holes (p-type) on opposite side of the intersection. Sunlight has photons which hit the sun oriented panels and energize the inexactly bound electrons which are allowed to move just in one direction in solar cells and in this manner electron-hole cells are made in particular intersections and power is acquired in the outer circuit [4] [5].

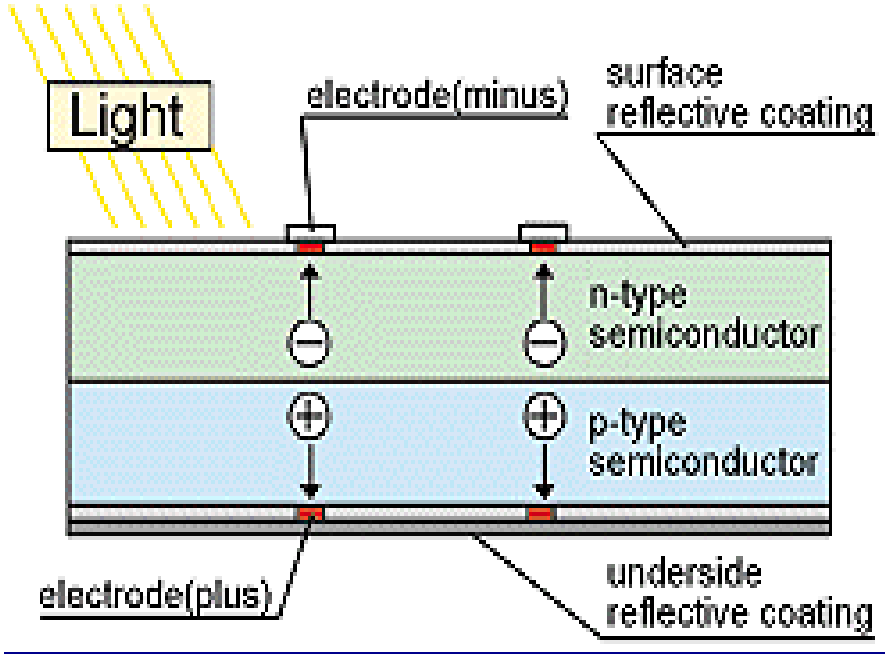

Figure 1: The cross-section of an ordinary solar panel [6].

1.2 **Malaysian climate for Solar Energy Production**

Lying in between one and seven degrees north of the equator, Malaysia appreciates a tropical atmosphere. The attributes of Malaysian climates are wind speed is for the most part light with yearly wind speed beneath 3.1 m/s. However it can be up to 9 m/s amid Northeast storm. The relative humidity is viewed as high with the mean monthly relative humidity falls inside 70-90% and the normal temperature is 26 Celsius. For the most part, Malaysia has two unmistakable seasons. The dry season happens amid the Southwest monsoon from May to September and the Northeast storm blows amid middle of November till March, which conveys the rainy season to the nation [7].

In this way, Malaysia is perfect for extensive scale sunlight based power establishments because of its area in the central of the earth. Table 1 is a rundown of yearly normal sun-powered radiation in different towns in the nation. From the table, Kota Kinabalu, Bayan Lepas and George Town get the most elevated amount of sun radiation

in Malaysia. As indicated by the agency of the Renewable Energy Unit (PTM), Penang, and Sabah are the best two spots to harness power from the sun [8]. In fact, all the places in Malaysia are suitable for photovoltaics energy generation from as observed from Table 1 below.

Table 1: Average Yearly Solar Radiation (kWh/m^2) in several important places in Malaysia (average radiation throughout the year) [9].

Irradiance Yearly	Average value (kWh/m^2)
Kuching	1470
Bandar Baru Bangi	1487
Kuala Lumpur	1571
Petaling Jaya	1571
Seremban	1572
Kuantan	1601
Johor Bahru	1625
Senai	1629
Kota Bharu	1705
Kuala Terengganu	1714
Ipoh	1739
George Town	1785
Bayan Lepas	1809
Kota Kinabalu	1900

1.3 Basic system of Net- Metering

Net-Metering is a new government policy to reward the implementation of solar system in residential and commercial buildings that replacing the Fit in Tariff. The system consist of sun-powered PV modules/panels for changing solar daylight into DC supply, an inverter for changing the DC to AC with the goal that it can be utilized at home or provided to national grid system or both, home, bi-directional meter and national grid system. A capacity system like a battery can likewise be inserted into the system. Energy production from solar panels, inverter, and home is unidirectional while it is bidirectional between home, meter and grid [10].

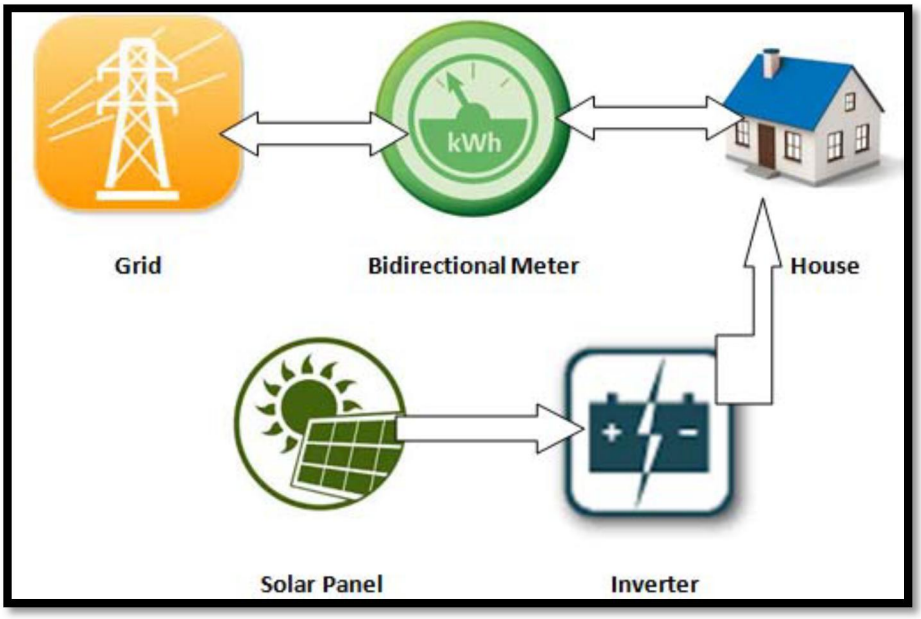

Figure 2: The Basic Net Metering system for the residential area which shows the function of bidirectional meter that calculate the difference between the used power and the generated power [11].

By refering to Figure 2, if the client (house) creates more electrical power per hour than the client utilizes the utility electrical system, the client won't be paid for that energy, yet the client gets a 'credit', which is connected to future bills. This "credit" can either as

"kWh" moving over to one month from now bill or some decided on money related term that moved over to upcoming bill, contingent upon one nation net-energy metering policy. Statistics demonstrated that power request development in Peninsular Malaysia keeps on declining for three back to back years in spite of the nation's sound monetary development. In 2015, top request experienced negative growth without precedent for recorded history. The system recorded a peak request of 16,822MW which is 79MW lower than the most astounding peak request of 16,900MW accomplished in 2014. This clearly shows that solar technology is the key factor that recently influences the negative growth of the peak demand. With this 500MW policy that recently announced by the government, the peak demand of our grid system can decrease further and save numerous amount of energy, workers, and pollutions [12].

1.4 **Basic system of Fit in Tariff**

Fit In Tariff is the government old policy to encourage the use of renewable energy in Malaysia. Unlike the Nett Metering,the solar energy is sold to the utility by using a seperated meter from the house meter with a specific tariff and a specific years of contract which is set by the authority (usually renewable energy council) [12]. Figure 3 explained that the electricity generated by the solar panel is sold to the utility by specific rate for every year until the contract ends. Usually, the tariff rate of FIT is higher than buying price tariff and the tariff rate gradually decrease each year. It also shows that the electricity used by the house is measured using different meter and paid isolately.

Figure 3: The basic system of Fit in Tariff which explains the import and export of the electricity produced in solar panel [13]

The fundamental idea of FIT is that the distribution licensee, as TNB pays the power producer a premium for the clean and steady energy produced and sent out to the power grid system. The duration of power sell is managed by the type of renewable energy utilized for power generation. For sun-based energy, it will be 21 years [12].

1.5 **Problem Statement**

Finding the suitable solar panel for our residential place is one of our major problem in developing our home PV system. Different type of solar panels has different type of efficiency accordingly to various factors such as efficiency and cost. It is stated that the efficiency of the polycrystalline solar panel is approximately 15%, monocrystalline is 17%, HIT panels is 19.5% and IBC solar panels is 20% efficiency under standard condition [14].

There is various factor affecting the efficiency or performance of solar panels such as climate of the areas, shading, temperature, solar radiation, and humidity. In this study, more analysis about this panel's performance in Malaysia weather condition which is the tropical weather is discussed. Four of the panels are chosen because it is easier to get and it is the most common panels used in Malaysia. By performing this, a new client to the solar power system in Malaysia will have a guidance on selecting the correct solar panels accordingly to their affordability. Efficiency and fill factor is the most important indicator for the performance of PV panels. Ideal characteristic of PV panel will produce a perfectly rectangular I-V curve.

There are two methods that perform the billing of solar panel energy which is net-metering and Fit in Tariff. The accurate and correct estimation of the payback period of the net-metering scheme for a residential market (4kW) is also calculated in this study. This can help the society to install more panels according to their needs and the investment won't face any loss. Besides that, the power utility company (TNB) with the help of government, don't have to concentrate anymore in building new hydroelectric power plant, coal power plant and more. Instead, maintaining the grid system which is already there will be the only focus.

1.6 **Objectives**

The objectives of this project:

a) To investigate the performance of different photovoltaic technology which is HIT, IBC, monocrystalline and polycrystalline in Malaysian tropical weather.
b) To estimate the payback period of a new net metering scheme for a residential market (4kW).
c) To compare the payback period of the net metering scheme and feed in tariff for the residential market in Malaysia.

1.7 **Project Scope**

In this project, the performance of the different type of PV panels will be analysed. PV panels that are being analysed are polycrystalline, monocrystalline, HIT and IBC. All the data measured will be collected by using Arduino Uno microcontroller. After finding the best panel to be used in Malaysian climate, the estimation of the payback period of a new net metering scheme for the residential market (4kW) will be done. This is to ensure the consumers that use solar panels to generate energy and sell back the energy to the utility faces no loss in their investment or on other words, generate more profit by installing net-metering scheme on their house. Finally, comparing the net metering scheme and feed in tariff for the residential market in Malaysia is done in this project to find the best policy produced by the government to the resident.

1.8 Project Outline

This thesis has five main chapters. The first chapter is the introduction that covers the background of the project, problem statement, objectives and project scope.

Chapter 2 covers the Literature Review of the project. In this chapter, the overview of the Solar Energy, Solar Radiation in Malaysia, PV panels, PV system, factors affecting PV panels performance in systems, Net-Metering, Fit in Tariff and performance of different solar panels in Malaysian Climate. This chapter also explained the basic knowledge about efficiency of solar cells

Chapter 3 describes methodology of this project. It represents the method to carry out this project. All methodology such as testing solar panel for I-V characteristics, system testing, and calculation.

Chapter 4 will discuss result and discussion of the project. The result will be represented in a table and graphical form. The performance of different PV panels in Malaysian climate will be discussed in this chapter. The estimation of the payback period of a new net metering scheme for the residential market (4kW) is also calculated.

Chapter 5 represent the conclusion of the project and the future improvement can be made. This is done to help the future generation that wants to do this project have a strong guidelines and have some early precautions.

2 Literature Review

2.1 Introduction

Malaysia has been a tropical country with an average of 12 hours of daylight every day. It produces 1400 and 1900 kWh/m² of solar energy every year with the highest radiation estimated at 6.8 kWh/m² in August and November [15]. The ideal climatic condition makes photovoltaic to be in an ideal shape to produce power and the applications are likewise extremely flexible [16]. Malaysia atmosphere encounters the high sun radiation conditions for the most part from 11.00am to 3.00pm which corresponds with the peak generation of power by PV [17]. In this study, the experiment is planned to carry out from 9 am to 4 pm in the evening to get the optimum performance of the panel.

2.2 Microcontroller for the measurement of PV

There are various types of microcontrollers such as Arduino Uno and Raspberry Pi. In this study, Arduino Uno is used mainly because it is cheap, ready to use and large community to help. Arduino Uno is usually called as the microcontroller computer where its platform is simple and the coding is easy as well. It can run one program at a time and repeatedly [18]. According to a research in Uttar Pradesh, a PV analyser is created in the research and the analyser's ability is the same as the one required in this study. The analyser contains Arduino UNO, Arduino MEGA, light sensor, temperature sensor, voltage sensor and current sensor [19]. It was tried for different commercially available PV panels of various types and sizes. The recorded results are reliable and have comparable performance to the commercially available PV analysers. The format of planned framework is appeared in Figure 2 where the connection of all the components

is illustrated and in this study this circuit is modified by replacing the data display in PC monitor to LCD display because it is more portable to a computer monitor.

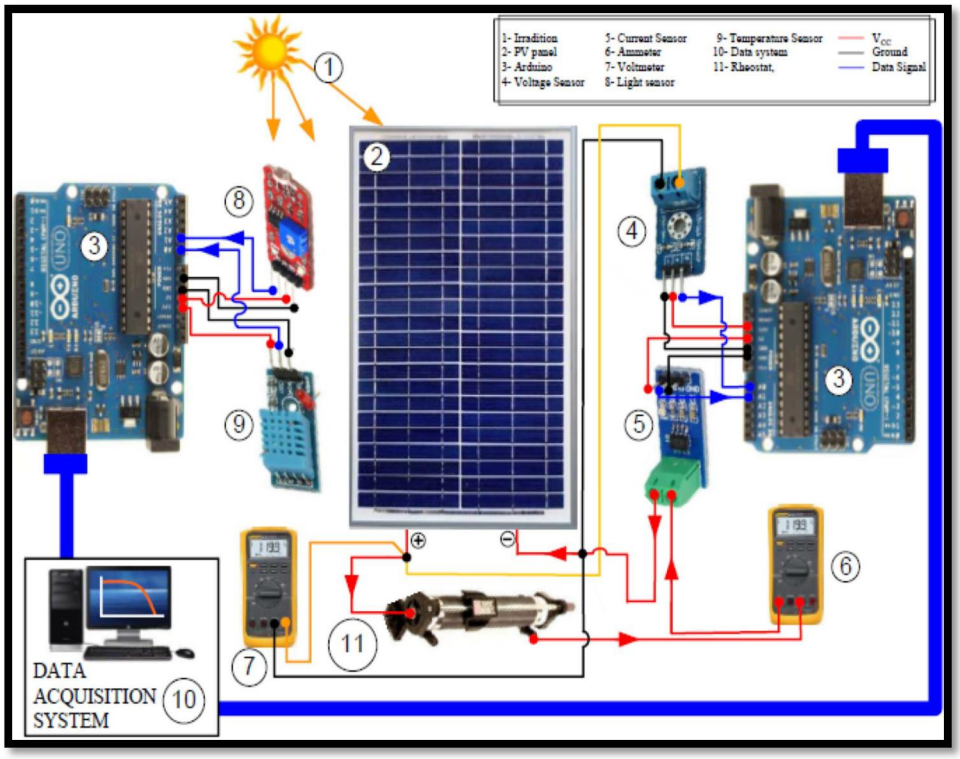

Figure 4: Layout of the Designed System for the monitoring of Current and Voltage in Solar Panel [19]

Besides that, the data collecting circuit is modified by removing the voltage sensor, temperature sensor, Photo resistor Light sensor (VEE00067), Temperature and Humidity Sensor Module (DHT11), and Arduino Mega. This is done to simplify the circuit and cut down the cost. On the other hand, if this circuit is used exactly, it would cost a lot and it is more time consuming to set up for different solar panels compare to the one used in this study.

2.3 **Criteria for choosing solar panel**

Everyone have a specific need to buy a product from a market. In the context of solar panel, quality of the panel is an important factor and this information can be easily found on the Internet. As a rule of thumb, usually most European brands are trustworthy, Germany the most has the best quality standards [21]. While in China, the solar panels work accordingly to the market demand and usually the quality depends on its cost. Common tips for knowing it is not a good panel are no information is displayed on the panel, and its performance is unknown in the websites [21].

Another important criterion is the warranty of the solar panel. It should be clear stated the responsibility that the company will take if there is any accidents/faulty. The entire cost of removing, transporting, replacing, and reinstalling any defective panels within a range of time should be the company's responsibility. The company that does not offer this usually aren't confident enough on their own product.

Installation area also playing important role in determining good solar panel. The type of panel that is installed in the roof influenced the roof that the panel is planned to install. For instance, aesthetic concerns usually present when the panel is installed in the front of the house. In this case, the thin film is commonly selected as it is frameless. For a large unshaded roof, the monocrystalline and polycrystalline panel are a good choice as it is highly efficient and maximize the energy yield. Lastly, thin film modules can be used for the roof that is partially shaded for part of the day because it operates better than crystalline modules under shading [22].

2.4 Renewable Energy Policy in Malaysia

Malaysia is now preparing many ways to reduce the production of energy from natural gasses, coal, and petroleum. Tenaga Nasional Berhad (TNB) is the biggest power supplying company for the peninsular Malaysia. This utility company in association with the government planned to do the net-metering system in bigger scale as it is more natural, economic for long term usage and it does not support pollution.

Malaysia is going to move into an enormous arrangement for net-energy metering. Malaysia will be actualizing 500 megawatts (MW) of limit with respect to net energy metering starting 2016 until 2020, with 100MW capacity limit a year in Peninsular Malaysia and Sabah. 500MW of sun-based energy is comparable to 7% of national power supply company (TNB) total generation capacity. The improvement of major key arrangement for net-energy metering in the nation must be in an all-encompassing way. The effect to the utility and to the ratepayer must be surveyed in due diligent [12].

2.4.1 Net Metering in Malaysia

A system in which sun based boards (solar panels) or other renewable vitality generators are associated with an open utility power network and surplus power is exchanged onto the grid, permitting clients to counterbalance the cost of power drawn from the utility. Net metering is not quite the same as the present Fit in Tariff (FIT) system since it permits anybody which can create power to offer it back to the grid instead of bidding for a Feed-in-Tariff quota to be qualified to offer back power to the grid. There are many favorable circumstances to net metering.

Firstly, it can permit numerous more private and business property owners to partake in the generation and distribution of renewable energy. Besides that, presenting net metering can smooth out the demand for power during peak periods. Peak periods is normally amid working hours when workplaces are running their ventilating units at to the max and when manufacturing plants are working at the full limit. This is additionally the time when the sunlight based power producing potential is at its most noteworthy [23].

2.4.2 Fit in Tariff in Malaysia

In Malaysia, Fit in Tariff is officially started on 2014 and the tariff is designed on the same time [12]. Malaysia's Fit in Tariff (FIT) system obliges Distribution Licensees (DLs) to purchase from Feed-in Approval Holders (FIAHs) the power created from renewable assets (renewable energy) and sets the FIT rate. This is clearly shown in Figure 5 and this figure also explained that DLs will pay for renewable energy provided to the power grid for a particular time.

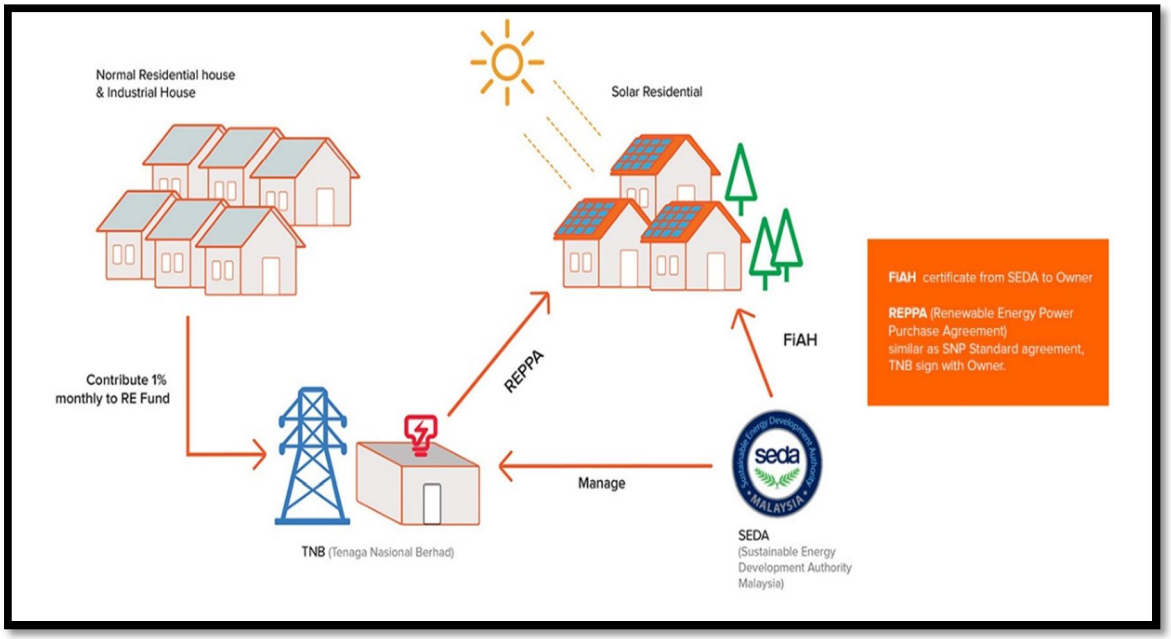

Figure 5: A mechanism whereby utility provider (TNB) is obliged to purchase renewable energy generated by renewable energy developer at a premium tariff [24].

By ensuring access to the network and setting a positive cost for each unit of renewable energy, the FIT system would guarantee that renewable energy turns into a reasonable and sound long haul venture for organizations, enterprises furthermore for people. The terminologies related to FIT such as DLs, FiAH, and more is explained in Table 2.

Table 2: The key terminologies related to Feed-in-Tariff in Malaysia [3].

Key Terminologies in FIT	Explanation
Distribution Licensees	Companies holding the permit to convey power (e.g. TNB, SESB, NUR).
Feed-in Approval Holder	An individual or organization who holds a bolster in endorsement testament issued by SEDA Malaysia. The holder is qualified to offer renewable energy at the FIT rate.
FIT rate	Fixed premium rate payable for every unit of renewable energy sold to Distribution Licensees. The FIT rate varies for various renewable assets and introduced limits. Reward FIT rate applies when the criteria for extra conditions are met.
Indigenous	Renewable assets must be from inside Malaysia and are not transported in from different nations.
Duration	Period of which the renewable power could be sold to dissemination licensees and paid with the FIT rate. The term depends on the qualities of the renewable assets and innovations. The term is 16 years for biomass and biogas assets, and 21 years for little hydropower and sun oriented photovoltaic advances.

2.5 **Net Metering Advantages over FIT**

NEM can counterbalance its clients bill and pay for power utilized as a part of overabundance while FIT is ensured contract to offer power as a rule for a long stretch. NEM also needed no agreement, simple and easy to actualize while in FIT permits the client to offer all the energy in case the client are ready to produce more than the needed

power. NEM acts like an impeccable fence against rising power costs while in FIT Price is normally incompletely recorded to increase [25]. This is the reason Net-Metering is chosen over FIT in this study for the analysis of payback period of the 4kW residential scheme. Besides that, Malaysia also planning a lot of initiative to make the citizen aware of the net-metering scheme as it brings a lot of benefits.

2.6 **Factors affecting the solar payback range**

There are various reasons that affect the payback period of a solar system investment. Before that, it is crucial to know that payback period is one of the important factors to attract people in Malaysia to involve themselves in solar energy generation. Usually, the investor will look for low payback period to generate more money without the hassle of considering the previous investments. First of all, the amount of usable energy that the installed PV system produces. The amount of direct sunlight received by the panel directly proportional to the output of the system. Next, the price of grid electricity in the region where the system is placed. In markets with high utility rates, the payback period is comparatively shorter. Available taxes and rebates from the government and amount of daily sunlight hours are also an important factor in considering the payback period [26].

3 Methodology

3.1 Introduction

A series of steps were carried out during the progress of this study. More information about the 4 types of solar panels which are HIT, IBC, monocrystalline and polycrystalline is collected and the panel's availability is checked in the laboratory. Reading of the solar panel's current and voltage is taken on a sunny day according to the solar radiation meter bought earlier. Calculation of net metering and payback period of solar panel is analysed in various websites and journals. Net metering scheme and feed in tariff for the residential market in Malaysia is compared to last.

The books and journals were studied to give a better understanding about the solar panels in detail and the economic analysis of the energy. After the reading is done, the review was looked up for the similar study that found the efficiency of the solar panels.

3.2 Microcontroller to measure PV performance.

In this research, Arduino Uno microcontroller, Current Sensor ACS 712, and LCD 16 x 2 were used to measure PV performance. The details and specifications of all this components is found below.

3.2.1 Arduino UNO

Arduino microcontroller family is one of the simplest and easiest microcontrollers to use in simple data collecting system. It contains everything expected to bolster the microcontroller; essentially associate it to a PC with a USB link or power it with an AC-to-DC connector or battery to begin. With Arduino UNO, accomplishing something incorrectly will not be a problem, and the worst case scenario with this microprocessor is

just replacing the board itself if there is any faulty [27]. Table 3 shows the specification of Arduino Uno in detail.

Table 3: Arduino Uno Technical Specification which will help in the integration of Arduino Uno with the sensors [27] [20].

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analog Input Pins	6
C Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
LED_BUILTIN	13
Length	68.6 mm
Width	53.4 mm
Weight	25 g

3.2.2 Current Sensor

The model of the current sensor chip in this project is ACS712ELC-05B. The pin 5V power supply is used to power up the current sensor. The analogue signal received is sent to the Arduino using Pin Analog In. The ground pin is connected to the ground in the Arduino. These modules can be measured plus (+) or minus (-) 5A, corresponding to the analogue output 185mV/A [20]. Figure 5 shows the connection of the current sensor with Arduino and LED to make sure the sensor is working properly before the sensor is used to take the reading.

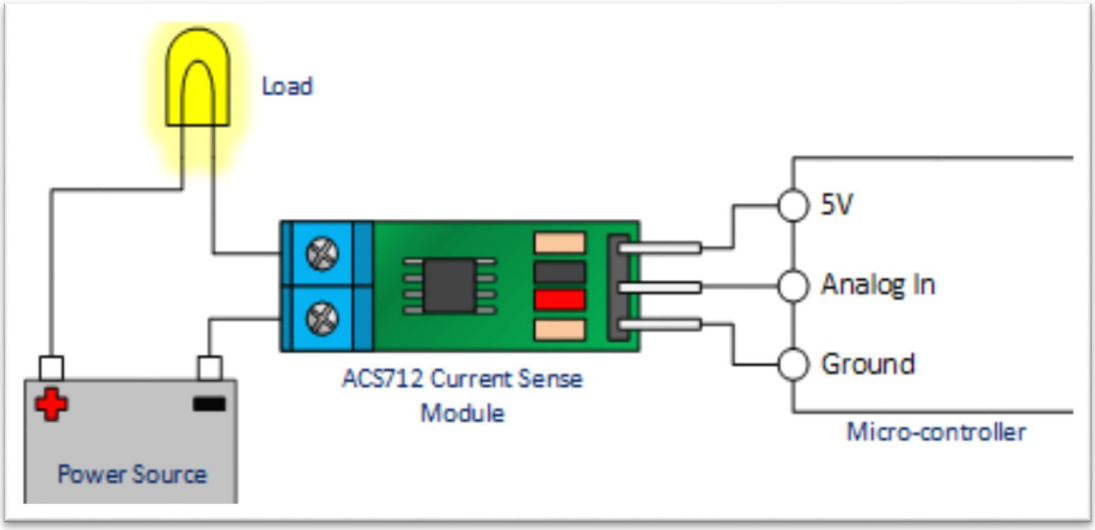

Figure 5: Simple connection of Hall Effect current sensor to test whether the current sensor is still working [16]

Although there are many alternative to measure the current from the solar panels such as Solar Meter and highly accurate ammeter, the current is chosen to be used in this study because it is cheap, portable and can be integrated with the Arduino Uno to make the data collection easier.

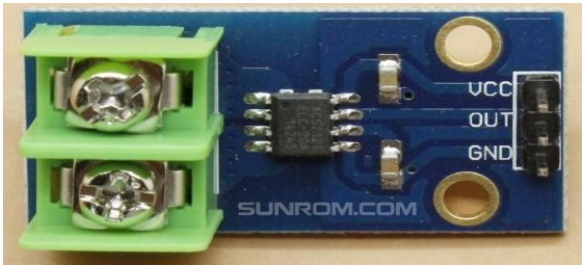

Figure 6: ACS712 Current Sensor which is used to measure current of solar panels [28].

3.2.3 16 × 2 Character LCD 1602A

LCD (Liquid Crystal Display) screen is an electronic show module and locates an extensive variety of utilizations. A 16x2 LCD show is an exceptionally essential module and is commonly utilized as a part of different gadgets and circuits. These modules are favoured more than seven fragments and other multi-segment LEDs. The reasons being:

LCDs are conservative; effectively programmable; have no constraint of showing uncommon and even custom characters, animation and so on. A 16x2 LCD implies it can show 16 characters for each line and there are 2 such lines. In this LCD each character is shown in 5x7 pixel lattice. This LCD has two registers, to be specific, Command and Data and figure 7 shows the pin diagram of the LCD module used.

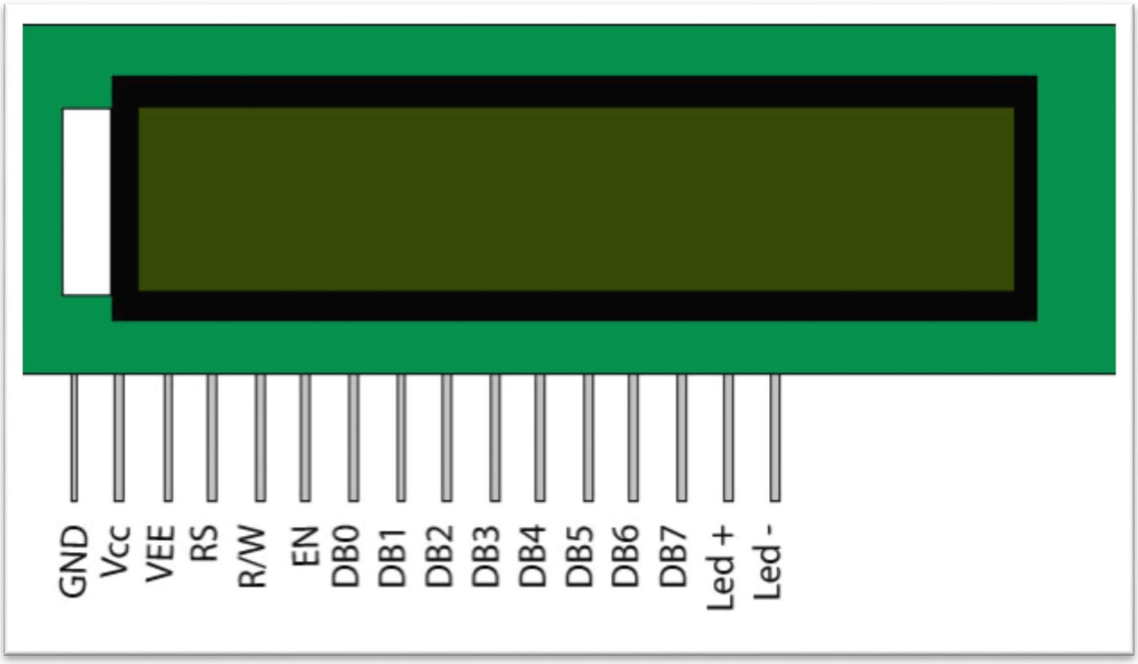

Figure 7: Pin Diagram of Character LCD 1602A where each pins have specific function and it must be integrated with Arduino Uno via coding. [28]

The command register stores the command code given to the LCD. A command is a direction given to LCD to do a predefined assignment like initializing it, clearing its screen, setting the cursor position, controlling the presentation and so forth. The information register stores the information to be shown on the LCD. The information is the ASCII estimation of the character to be shown on the LCD. Snap to take in more about the inward structure of an LCD. Table 4 shows the function of all the pins in the LCD and its function in detail.

Table 4: Pin Description of Character LCD 1602A [29].

Pin No	Function	Name
1	Ground (0V)	Ground
2	Supply voltage; 5V (4.7V – 5.3V)	Vcc
3	Contrast adjustment; through a variable resistor	V_{EE}
4	Selects command register when low, and data register when high	Register Select
5	Low to write to the register; High to read from the register	Read/write
6	Sends data to data pins when a high to low pulse is given	Enable
7	8-bit data pins	DB0
8		DB1
9		DB2
10		DB3
11		DB4
12		DB5
13		DB6
14		DB7
15	Backlight V_{CC} (5V)	Led+
16	Backlight Ground (0V)	Led-

3.3 **Types of photovoltaic panels.**

There are many types of photovoltaic technologies. Commercial PV panel technologies can be essentially separated into three main types which are monocrystalline, polycrystalline, and thin-film panels. Monocrystalline silicon panel is produced using pure monocrystalline silicon with a single nonstop crystal lattice cross section structure [30]. This is the oldest and most developed of the three technologies.

A monocrystalline panel can be identified from the solar cells which all appear as a single flat colour. These cells are highly efficient and more costly due to the manufacturing procedures require for very complicated operations and fabricated by 'electronic-grade' silicon [31]. Other advantages are monocrystalline cells are space-efficient which means it has high efficiency. Thus, sufficient power in a small area covered by the panel can be provided. It also has long life span and performs better at low temperature [32]. Figure 8 shows the difference in the surface structure of the monocrystalline and polycrystalline solar panels. .

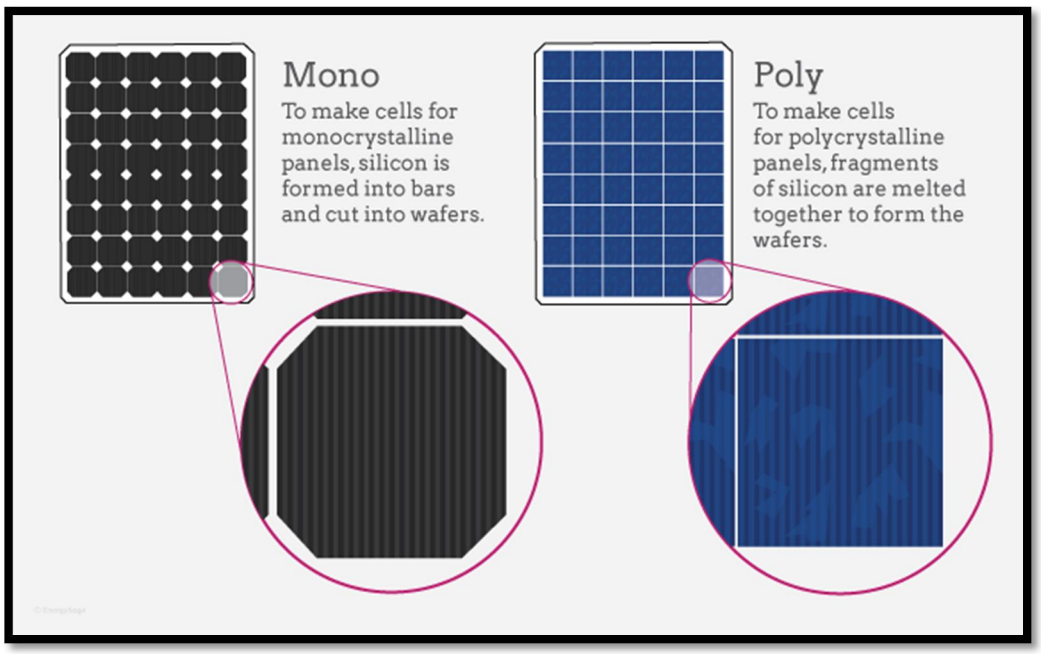

Figure 8: The difference in the structure of monocrystalline and polycrystalline solar cells [33].

Polycrystalline technology, on the other hand, is made using cast multi-crystalline ingot. The ingot begins as a silicon crystal "seed" set in a vat of liquid silicon. However, as opposed to drawing the silicon crystal seed up as with monocrystalline the vat of silicon is essentially permitted to cool. This creates unmistakable edges and grains structured in the polycrystalline cell. The polycrystalline is slightly inferior compared to Monocrystalline on the grounds that this panel were somewhat less efficient, however, as a result of the less expensive strategy by which polycrystalline can be created combined with just marginally lower efficiencies [14].

Polycrystalline sunlight based panels have a tendency to have marginally lower heat tolerance than monocrystalline sun-powered panels [32]. Polycrystalline sun based panels will have a tendency to have a higher temperature coefficient than solar panels made with mono cells. This implies as heat expanded output for this sort of cell will fall less. However, in reality, these distinctions are minor [32].