Faculty of Electrical Technology and Engineering

Development of Solar PV System Design by Energy Requirement using Excel based VBA

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Bachelor of Electrical Engineering Technology with Honours

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Development of Solar PV System Design by Energy Requirement using Excel based VBA

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A project report submitted
in partial fulfillment of the requirements for the degree of
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DECLARATION

I declare that this project report entitled “Development of Solar PV System Design by Energy Requirement using Excel based VBA” is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date	:	2/1/2025

APPROVAL

I hereby declare that I have checked this project report, and, in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electrical Engineering Technology with Honours.

Signature	:	
Supervisor Name	:	Dr. AZHAN BIN AB RAHMAN
Date	:	2/1/2025

DEDICATION

I dedicate this project to my family, whose unwavering support and encouragement have been my guiding light throughout this journey.

To my parents, for their sacrifices and belief in my potential, which have inspired me to strive for excellence.

To my friends and mentors, for their invaluable guidance, motivation, and camaraderie that made this endeavor possible.

Lastly, to all those who dream of making a difference—may this work serve as a steppingstone toward innovation and progress.

ABSTRACT

Nowadays, energy is primarily generated from fuel cells and coal, which significantly harms the Earth, causing depletion of the ozone layer, global warming, and air pollution. Given these ongoing issues, there's a growing need to explore alternative energy sources to reduce reliance on fuel cells and coal for electricity production. One promising alternative is solar photovoltaic (PV) technology, which eliminates pollution associated with electricity generation. To facilitate the adoption of solar PV, a user-friendly application is being developed. Users will only need to input their monthly energy consumption data from their electricity bills. The application utilizes the "VLOOKUP" function and offers a selection of three solar PV systems and three inverters for users to choose from. Based on the input data, the application will recommend the appropriate size of solar PV system and inverter for their homes. This project aims to simplify the process for consumers to determine their solar PV and inverter requirements. Additionally, the application will provide an estimated cost for consumers interested in installing solar PV systems, enabling them to make informed decisions before engaging with solar PV installation services. The project addresses the challenge of designing photovoltaic (PV) systems, a process that typically requires complex mathematical calculations to determine energy needs, solar panel size, and inverter size. This can be especially difficult for individuals without an engineering background. To solve this issue, a user-friendly Excel VBA application called Development of Solar PV System Design by Energy Requirement using Excel based VBA was developed. This application simplifies the design process by automating calculations and providing accurate results. It has been tested using 3 solar PV panels and 3 inverters and evaluated with four types of input: small, medium, large, and invalid. The application is very accurate, and it is verified through manual calculation by analysis. By making the design process simpler and the suring results match manual calculations, this project enables users to transition to solar energy with ease. With its affordable, accessible, and precise features, this tool is an excellent solution for anyone looking to adopt solar energy, reduce dependence on non-renewable resources, and lower energy costs.

ABSTRAK

Pada masa kini, tenaga utamanya dihasilkan daripada sel bahan api dan arang batu, yang memberi kesan yang signifikan kepada Bumi, menyebabkan penipisan lapisan ozon, pemanasan global, dan pencemaran udara. Mengambil kira isu-isu yang berterusan ini, terdapat keperluan yang semakin meningkat untuk meneroka sumber tenaga alternatif untuk mengurangkan kebergantungan kepada sel bahan api dan arang batu dalam pengeluaran tenaga elektrik. Satu alternatif yang menjanjikan adalah teknologi fotovoltaik (PV) solar, yang menghapuskan pencemaran yang berkaitan dengan pengeluaran tenaga elektrik. Untuk memudahkan penggunaan PV solar, satu aplikasi mesra pengguna sedang dibangunkan. Pengguna hanya perlu memasukkan data penggunaan tenaga bulanan mereka daripada bil elektrik mereka. Aplikasi ini menggunakan fungsi "VLOOKUP" dan menawarkan pilihan tiga sistem PV solar dan tiga inverter untuk pengguna memilih. Berdasarkan data input, aplikasi akan mencadangkan saiz yang sesuai untuk sistem PV solar dan inverter bagi rumah mereka. Projek ini menangani cabaran dalam reka bentuk sistem fotovoltaik (PV), yang biasanya memerlukan pengiraan matematik yang kompleks untuk menentukan keperluan tenaga, saiz panel solar, dan saiz inverter. Ini boleh menjadi sukar terutama bagi individu tanpa latar belakang kejuruteraan. Untuk menyelesaikan masalah ini, sebuah aplikasi Excel VBA mesra pengguna yang dinamakan "Development of Solar PV System Design by Energy Requirement using Excel based VBA: telah dibangunkan. Aplikasi ini mempermudahkan proses reka bentuk dengan mengautomasi pengiraan dan memberikan hasil yang tepat. Ia telah diuji menggunakan 3 panel solar PV dan 3 inverter serta dinilai dengan empat jenis input: kecil, sederhana, besar, dan tidak sah. Aplikasi ini sangat tepat, dan ia disahkan melalui pengiraan manual berdasarkan analisis. Dengan ciri-ciri yang mampu milik, mudah diakses, dan tepat, alat ini merupakan penyelesaian yang sangat baik bagi sesiapa yang ingin menggunakan tenaga solar, mengurangkan kebergantungan kepada sumber yang tidak boleh diperbaharui, dan menurunkan kos tenaga.

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First and foremost, I express my deepest gratitude to Universiti Teknikal Malaysia Melaka and the faculty of Electrical Technology and Engineering for providing me with the opportunity and resources to undertake this project.

I am sincerely thankful to my project supervisor, Dr Azhan Bin AB Rahman, for their guidance, expertise, and constructive feedback throughout this journey. Their mentorship has been invaluable in shaping the direction and outcome of this work. I extend my appreciation to the faculty members and technical staff for their assistance and support during this project.

A heartfelt thanks to my family and friends, whose unwavering encouragement and understanding have been a source of strength and motivation. I am grateful to my peers and colleagues who shared ideas, provided constructive criticism, and collaborated to overcome challenges during this process. This project would not have been possible without the collective efforts and support of all these individuals.

Last but not least, I wanna thank me, I wanna thank me for believing in me, I wanna thank me for doing all this hard work, I wanna thank me for having no days off, I wanna thank me for never quitting, I wanna thank me for always being a giver and trying give more than I receive, I wanna thank me for trying do more right than wrong, I wanna thank me for just being me at all times.

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LIST OF SYMBOLS

w	-	Watt
v	-	voltage
A	-	Amphere
mm	-	milimeter
Pmax	-	Maximum Power
Voc	-	Open Circuit Voltage
Isc	-	Short Circuit Current
%/°C	-	Percentage of Voc per degree Celcius

LIST OF ABBREVIATIONS

PV	-	Photovoltaic
GCPV	-	Grid-Connected Photovoltaic
VBA	-	Visual Basic Application
IRENA	-	International Renewable Energy Agency
kWh	-	Kilowatt per hour
Wdc	-	Watts DC
Wac	-	Watts AC
UI	-	Utility-interactive
WP	-	Water Pumping
DC	-	Direct Current
AC	-	Alternating Current
VBE	-	Visual Based Editor
PIDGCPV	-	Pre-Installation Design for GCPV
WTH	-	Water Thermal Heating
EMF	-	Electromagnetic Feilds
NOCT	-	Nominal Operating Cell Temperature
BOS	-	Balance of System
NREL	-	National Renewable Energy Laboratory
SAPV	-	Standalone Photovoltaic
SA	-	Standalone
SaaS	-	Software as a Service

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Introduced in Malaysia, the Solar For Rakyat Incentive Scheme (SolaRIS) has greatly accelerated the country's transition to renewable energy. The government is aiming to increase the country's renewable energy capacity to 70% by 2050 [1] by incentivizing residential consumers to install solar photovoltaic (PV) systems. The program demonstrates Malaysia's dedication to cutting carbon emissions and switching to more environmentally friendly energy sources. This pledge is about laying the groundwork for the next stage of energy growth as well as satisfying environmental standards. The NEM 3.0 program and an extra quota offer for 2024 are depicted in figure 1.1.

The Net Energy Metering (NEM) 3.0 initiative builds on this success by hastening the implementation of solar PV systems across many industries [2]. NEM 3.0 contains programs like NEM Rakyat for families and NOVA for virtual aggregation, which allow energy customers to build solar PV systems and contribute to the grid. The overall quota allotment for NEM 3.0 is up to 1550 MW until December 2024 [2]. By ensuring that the momentum from the SolaRIS effort is maintained, this integrated strategy opens the door for Malaysia to become an energy-independent and sustainable nation. The idea to implement the program utilizing Excel-based VBA was inspired by recent events in the nation. Figure 1.2 displays the goals that NEM must accomplish between 2020 and 2035.

Table 1.1 The NEM 3.0 program and an additional quota offer.[2]

Initiative/Categories	Quota Allocation (M)	Quota Opening Date
NEM Rakyat Programme	350MW	1st April 2021 - 31st December 2024
NEM GOMEn Programme (Government Ministries and Entities)	100MW	1st February 2021 - 31st December 2024
NOVA Programme (Net Offset Virtual Aggregation)	1100MW	1st February 2021 - 31st December 2024

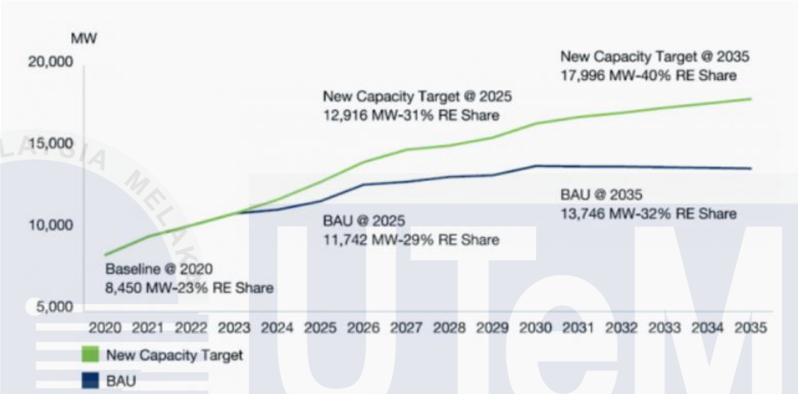


Figure 1.1 Targets to be achieved by NEM. [2]

Excel-based VBA (Visual Basic for Applications) may be a useful tool when creating project energy needs. Excel VBA makes it possible to automate repetitive processes like data extraction and analysis, which is very helpful when working with big datasets that are frequently used in energy calculations [3]. Engineers may use VBA, for example, to automatically produce reports in Excel and extract heat and material balance data from process simulations [3]. This decreases the possibility of human mistakes in data transfer while also saving time [3]. Additionally, VBA has features of its own that programmers have not fully explored.

Custom functions that compute energy requirements depending on different inputs, such as temperature, pressure, and flow rates, may be created using VBA in the context of energy development. These functions may then be applied to improve a process's energy usage and to simulate various situations. Additionally, VBA can communicate with other programs, which makes it possible to integrate Excel for more intricate calculations with more advanced engineering tools. Because of its adaptability, VBA is a vital tool in the field of energy engineering, where precision and efficiency are critical [4].

In conclusion, major advancements toward a sustainable and energy-independent future have been made possible by Malaysia's creative Solar For Rakyat Incentive Scheme (SolaRIS) [1] and the Net Energy Metering (NEM) 3.0 project [2]. These initiatives, which aim to raise the share of renewable energy to 70% by 2050 [1], demonstrate the country's dedication to reducing carbon emissions and preserving the environment. The use of Excel-based VBA improves energy project development's accuracy and efficiency even further, demonstrating how technology can be used to streamline procedures and promote the country's environmental goals. By working together, Malaysia is achieving its environmental goals and establishing a model for responsible growth and innovation in the energy sector.

1.2 Problem Statement

The problem statement for this project is that PV system design involves lengthy steps of mathematical calculation to match the system design in terms of energy requirement, PV panel size, and PV inverter size. This is true based on my experience learning the calculation steps in the PV system design course taken during the second semester of my third-year Sarjana Muda Teknologi Kejuruteraan Elektrik in the UteM study. It is expected to be more challenging for citizens who have no engineering background. Therefore, this project tries to overcome this issue by providing a user-friendly application that can be easily accessed by consumers. Even though they have very limited knowledge regarding solar PV systems. The following Sustainable Development Goals (SDGs) are in line with this approach:

a) **SDG 7 (AFFORDABLE AND CLEAN ENERGY)**: Using solar power encourages the use of clean, renewable energy sources, which means relying less on fossil fuels.

b) **SDG 11 (SUSTAINABLE CITIES AND COMMUNITIES):** User-friendly solar PV technology helps urban and rural communities promote sustainable urban development.

c) **SDG 13 (CLIMATE ACTION):** Using solar power can help reduce climate change.

Therefore, there **i**s a need to develop an application accessible to users from diverse backgrounds, not just experts, to enable homes to engage in a sustainable energy mix and potentially reduce reliance on non-renewable sources. The spread of solar PV applications poses a challenge to making sure everyone can access sustainable energy, in line with UN goals 7, 11, and 13.

1.3 Project Objective

The primary goal of this initiative is to develop an accessible application designed for individuals without technical expertise who wish to set up a photovoltaic (PV) system with a high degree of precision. The specific aims include:

a) To develop an Excel-based application capable of accurately calculating the number of solar panels and PV inverters required for a solar PV system based on energy requirement.

b) To assess the VBA program's probability with a wide range of input.

c) To verify the accuracy of the result from the application using manual calculation.

1.4 Scope of Project

The scope of this project is defined as follows:

a) The goal of this initiative is to develop solar systems that are integrated into the GCPV, or domestic electricity grid.

b) This VBA script uses the VLOOKUP function to obtain data.

c) The project has three models of solar PV and three models of PV inverters.

d) Developing software to calculate the number of solar panels and photovoltaic inverters needed for a Grid-Connected Photovoltaic (GCPV) system that is customized to a household's energy needs.

e) Developing software to determine the overall cost of a certain model of solar power and photovoltaic inverter.

f) The Sustainable Energy Development Authority's (SEDA) guidelines and requirements for Grid-Connected Photovoltaic (GCPV) system design and installation will be adhered to by the project.

g) The project was meant to be used for solar PV with a power output of less than 50 kw.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter describes the use of Excel-based VBA for designing energy-efficient solar PV systems. This chapter first discusses the final review, earlier research, and earlier research comparisons. The history of PV systems is presented in this chapter, which also forms the generator for solar PV systems. In turn, this chapter also discusses web-based design tools and applications for projects. At last, learn how Microsoft Excel serves as the primary project medium.

2.2 Background study

A thorough background investigation is essential to every good research project, and photovoltaic (PV) system comprehension is no exception. This first section lays the groundwork by giving the evolution of technology a historical backdrop. This article will specifically examine the fundamental idea of producing electricity from sunshine, delving into the photovoltaic effect, and how solar cells cooperate to create a working system. After that, the background research deconstructs a PV system's fundamental parts, elucidating the functions of solar panels, inverters, mounting frameworks, and electrical wiring. You'll also explore the real world of web-based PV design software, which offers intuitive tools to streamline system design and maximize efficiency. Lastly, the background research looks at how data analysis, performance report creation, and simple PV system calculations may be done with a well-known program like Microsoft Excel. You can acquire a thorough understanding of PV systems and be ready to go deeper into this intriguing and always-changing topic by thoroughly going over these five areas.

2.2.1 History of Photovoltaic (PV) system

The photovoltaic effect was discovered in the 19th century by French physicist Alexandre-Edmond Becquerel, and this finding forms the basis of solar energy. This phenomenon explains why some materials, when exposed to light, produce electricity. Although PV systems were first the subject of study because of this discovery, a useful application did not appear until 1954. The first silicon photovoltaic cell that could be used was invented by Gerald Pearson, Calvin Fuller, and Daryl Chapin at Bell Labs in the United States. With its innovative design and 6% efficiency, this invention was a significant turning point. At last, it was able to convert sunlight into electricity strong enough to run household equipment. But even with this advancement, the prohibitive cost of solar technology prevented widespread deployment. Essentially, Becquerel's discovery laid the foundation for the development of high-efficiency silicon cells, which opened the door for further improvements in solar panel technology. The solar energy-converting device created by Gerald Pearson, Calvin Fuller, and Daryl Chapin is seen in Figure 2.1. The first conventional photovoltaic cells were produced in the late 1950s and were mostly utilized to power spacecraft in the 1960s.

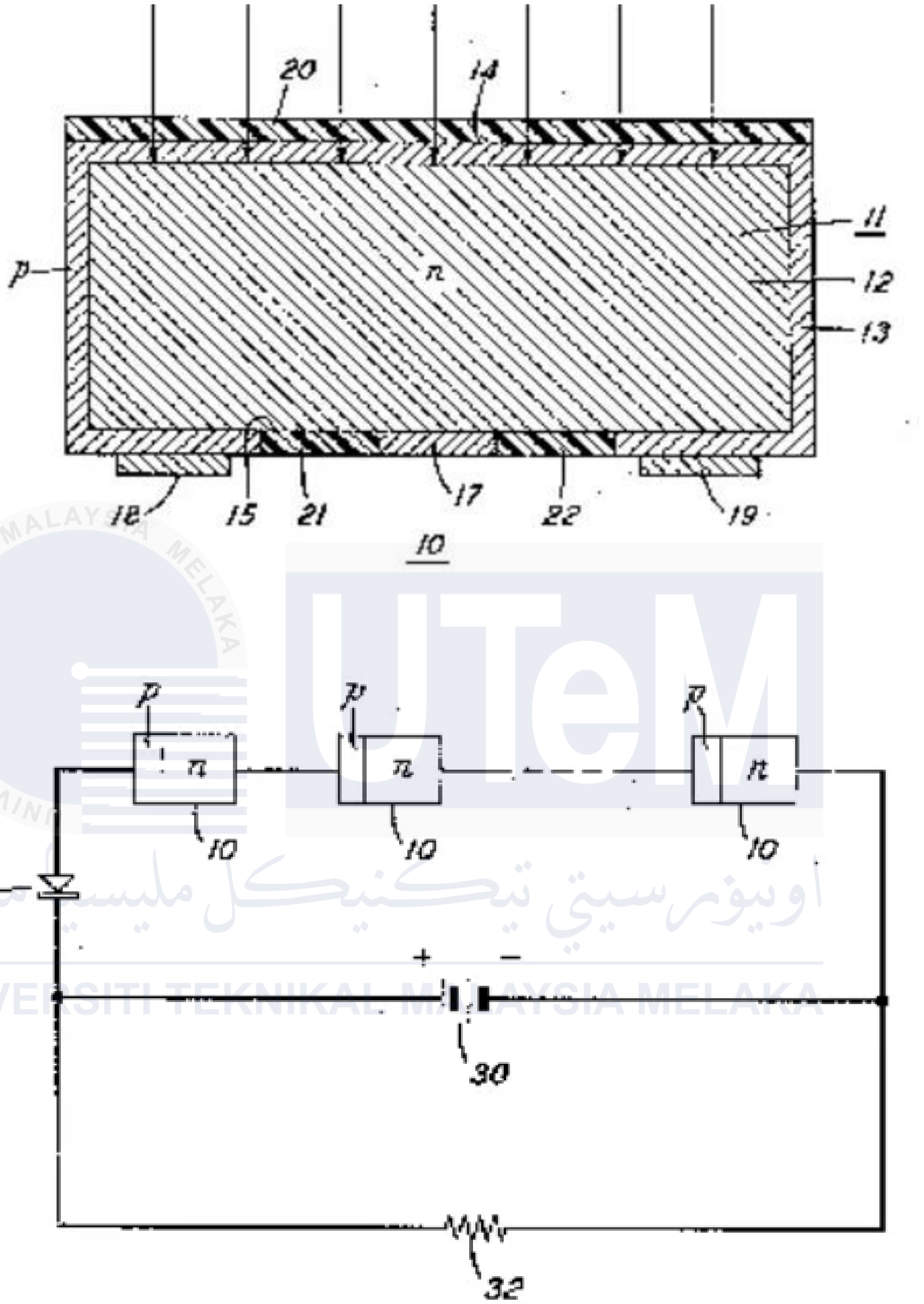


Figure 2.1 Solar Energy Converting Apparatus

Since the late 1950s, Sharp Corporation has dominated the solar cell market and has been actively engaged in research and development (R&D) since 1959. This commitment paid off in 1963, when the first silicon solar cell photovoltaic module was created. This ground-breaking module produced 242 watts, making it the biggest PV system at the time. The 1970s oil crisis sparked interest in renewable energy sources around the world and led governments to make significant investments in PV system research and development. With solar products that power residences, massive solar plants, lighthouses, and even satellites, Sharp has remained a leader in this industry.

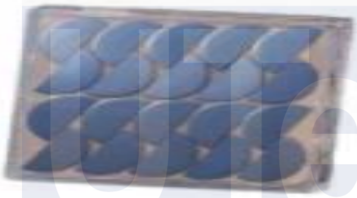


Figure 2.2 The first mass production of single-crystal solar cells.

Improved solar panels are still being produced. With time, solar technology has improved in its ability to convert sunshine into electricity and happily, has also gotten more affordable. The development of thin-film technology in the 1990s made it possible to produce solar panels that are lighter and more flexible. Combining solar energy with other cutting-edge technology, such as electric vehicles and battery storage, is very popular these days. These days, solar panels can be found everywhere in offices, residences, isolated areas, and even to power tiny gadgets. Researchers are always trying to improve solar panels, with the goals of maximizing energy output, minimizing expenses, and extending their lifespan. This involves conducting trials with novel materials and varying the panels' own designs.

2.2.2 Component of Solar PV system

Solar panels, commonly known as photovoltaic (PV) modules, are the central component of a solar PV system. These panels are composed of numerous smaller components known as solar cells, which are typically silicon-based. These solar cells' function is to collect solar radiation and convert it to electrical energy. Think of those microscopic solar cells as building blocks. The larger units, known as solar panels or modules, are formed by connecting them together (as in Figure 2.3). By doing this, we can harness more solar energy and produce more electricity. Examining a single solar cell in greater detail reveals its interior structure, like looking inside (as in Figure 2.4).

There are multiple layers to this little powerhouse, and each one is essential to the process of turning sunlight into electricity. Solar panels aren't just for single buildings. Like building bricks, these individual modules can be joined to form bigger arrays. Consider a group of solar panelists cooperating with one another. One of the main benefits of solar energy is its modular construction. A PV system can be designed to fulfill practically any electricity need, whether it's powering a tiny house or a large office building, by connecting one or more arrays to the electrical grid (the vast network that supplies power to households and businesses). Additionally, a wide variety of solar panel types are available, providing solutions to fit a range of requirements and price points. Solar panels come in a variety of flavors, each with unique advantages.

The three most popular varieties (as in Figure 2.5) are thin-film, polycrystalline, and monocrystalline. The most efficient solar panels are monocrystalline ones which convert the maximum amount of sunshine into power. The top performance can be explained by the fact that it is composed of a single, pure silicon crystal. Contrarily, polycrystalline panels are somewhat less efficient than monocrystalline panels since they are composed of several silicon crystals. Still, it's usually more reasonably priced. Thin-film panels complete this group. When weight is an issue or there are curved surfaces involved, these flexible and lightweight solutions make sense. Even though they might not be the most efficient, they provide benefits in some situations.

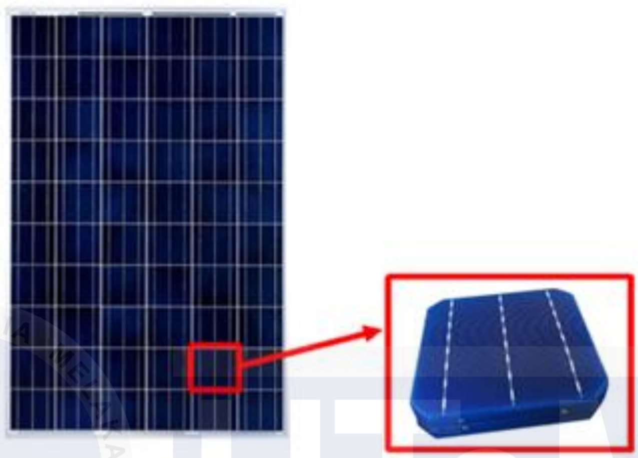


Figure 2.3 Solar panel and piece of solar cell.

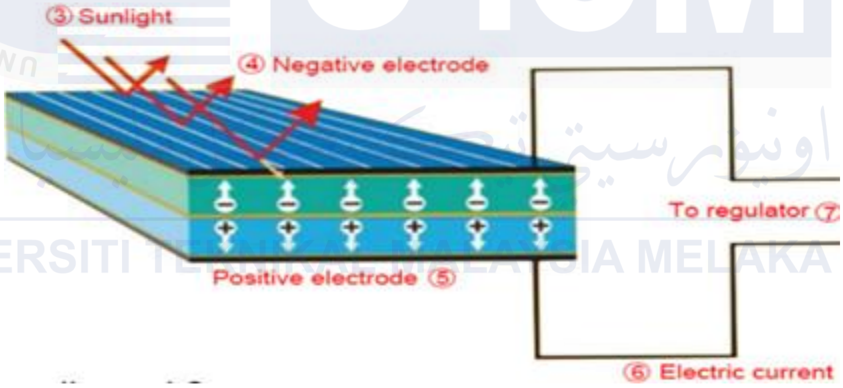


Figure 2.4 Cross section of solar cell.

Figure 2.5 Most common solar panels.

2.2.2.1 Summary of solar panel type

The goals you have for the solar energy system will determine which solar panels are best for your construction project. To help you get started, Table 2.1 describes the three most prevalent types. However, there's more to think about. Consider the location of the panels (open field, rooftop), the type of technology (polycrystalline, thin-film, and monocrystalline, each with advantages and disadvantages), and the specifics listed in the panel's datasheet. You'll be well on your way to selecting the ideal solar panels for your project by considering each of these factors.

Table 2.1 Summary table of the three most common solar panel types.

Solar Panel Type	Material	Efficiency	Cost	Appearance
Monocrystalline	Constructed from a single, extremely pure silicon crystal.	High (over 20%)	Highest	Round-cornered cells, either blue or black.
Polycrystalline	A few silicon crystals melted collectively.	Medium (below 20%)	High	Rectangular blue cells
Thin Film	Various materials	Low (7% up to 15%)	Lowest	Blue or black homogeneous surface.

2.2.2.2 Datasheet

The datasheet for 78HL4-BDV 615-635 W is chosen in Figure 2.6. The power output specifications, which fall between 615 and 635 watts, must be taken into consideration. For 530W, the temperature coefficient of Voc is -0.25%/°C, the temperature coefficient of Isc is 0.045%/°C, the voltage at Pmax is 47.20V, the current at Pmax is 13.03A, the open circuit voltage is 56.69V, and the short-circuit current is 13.68A. To guarantee the best results, every specification needs to be looked at.

78HL4-BDV 615-635 Watt

Mechanical Characteristics

Cell Type	N- type Mono-crystalline
No. of cells	156 (78×2)
Dimensions	2465×1134×30 mm
Weight	34.0 kg
Front Glass	2.0 mm, Anti-Reflection Coating
Back Glass	2.0 mm, Heat Strengthened Glass
Frame	Anodized Aluminium Alloy
Junction Box	IP68 Rated
Protection Class	Class II
IEC Fire Type	Class C
Output Cables	4.0 mm² (+): 400 mm , (-): 200 mm or Customized Length

Packaging Configuration

Pallet Dimentions	2525×1140×1251 mm
Packing Detail (Two pallets = One stack)	36 pcs/pallets, 72 pcs/stack, 576 pcs/ 40'HQ Container

Specifications (STC)

Maximum Power - Pmax [Wp]	615	620	625	630	635
Maximum Power Voltage - Vmp [V]	47.20	47.37	47.54	47.70	47.86
Maximum Power Current - Imp [A]	13.03	13.09	13.15	13.21	13.27
Open-circuit Voltage - Voc [V]	56.69	56.82	56.95	57.08	57.21
Short-circuit Current - Isc [A]	13.68	13.74	13.80	13.86	13.92
Module Efficiency STC [%]	22.00	22.18	22.36	22.54	22.72
Power Tolerance	0 ~ +3 %				
Temperature Coefficients of Pmax	-0.29 %/°C				
Temperature Coefficients of Voc	-0.25 %/°C				
Temperature Coefficients of Isc	0.045 %/°C				

STC: Irradiance 1000W/m², Cell Temperature 25°C, AM=1.5

Specifications (NOCT)

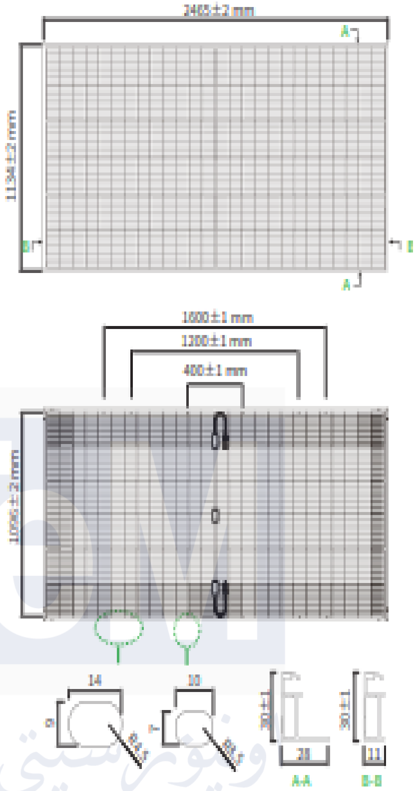
Maximum Power - Pmax [Wp]	463	467	471	475	479
Maximum Power Voltage - Vmp [V]	44.39	44.54	44.69	44.83	44.98
Maximum Power Current - Imp [A]	10.44	10.49	10.54	10.59	10.64
Open-circuit Voltage - Voc [V]	53.85	53.97	54.10	54.22	54.34
Short-circuit Current - Isc [A]	11.04	11.09	11.14	11.19	11.24

NOCT: Irradiance 800W/m², Ambient Temperature 20°C, AM=1.5, Wind Speed 1m/s

Application Conditions

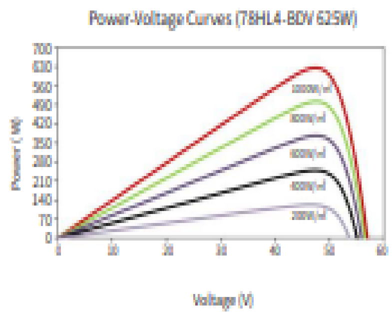
Operating Temperature	-40 °C ~ +85 °C
Maximum System Voltage	1500 VDC (IEC)
Maximum Series Fuse Rating	30 A
Nominal Operating Cell Temperature - NOCT	45±2 °C
Refer. Bifacial Factor	80±5%

Engineering Drawings



Note: For specific dimensions and tolerance ranges, please refer to the corresponding detailed module drawings.

Electrical Performance



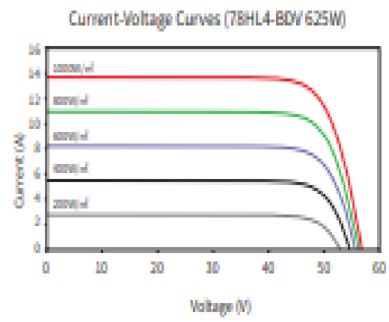


Figure 2.6 Datasheet of 78HL4-BDV 615-635 W.

2.2.2.3 Inverter

The inverter is a vital part of any solar PV system. Imagine your solar panels as a bunch of lemons, full of DC (direct current) electricity, which isn't the same electricity used to power your household appliances. The inverter helps with that. As a kind of juicer, this crucial component converts the direct current (DC) electricity from your solar panels into alternating current (AC), which may then be used in your house or recycled back into the power system (see Figure 2.17). However, the inverter's function is not limited to conversion. It serves as a smart manager for your whole solar system, making sure your panels run as efficiently as possible to produce the maximum amount of electricity. Additionally, the inverter monitors the total energy generation of your system and notifies you of any possible problems. If an issue is found, it can even cut the system off from the power grid for safety.

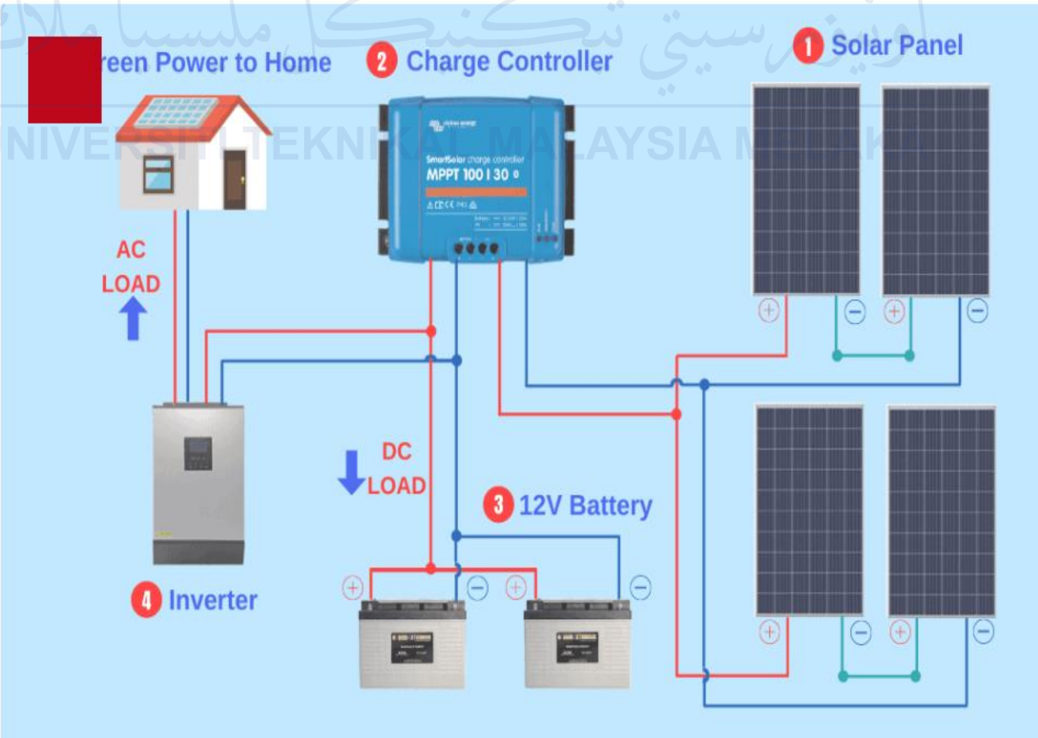


Figure 2.7 Block diagram of Solar Panel Inverter.

Just as there are various types of juicers, there are different kinds of inverters utilized in solar PV installations. The most popular kind is the string inverter (as in Figure 2.8), which functions similarly to a big juicer and can handle several lemons (solar panels) at once. Multiple solar panels can be connected to one inverter, which transforms the DC electricity into AC for your house or the grid. Although there are other kinds of inverters, string inverters are the most widely used variety.

Figure 2.8 SMA Sunny Boy 3.0 / 3.6 / 4.0 / 5.0 / 6.0.

The "juicers" of your solar system, inverters, are available in various sizes to suit your requirements. The most popular kind joins several panels into a single unit and is called a string inverter (Figure 2.8). However, there are alternatives: central inverters, which are massive juicers for massive solar farms with tons of panels; standalone inverters for off-grid systems that convert DC power stored in batteries into usable AC electricity; and microinverters, which are tiny juicers attached to each panel (as in Figure 2.9) for simpler design and individual panel optimization.

Figure 2.9 Enphase IQ8 Microinverter (MC4).

2.2.2.4 Solar connection

Like adding batteries, connecting panels in series, from positive to negative, increases voltage and creates the illusion of more lights in a single string. The current is increased when panels are connected in parallel, with all positives and negatives clustered together, much like when several light strings are put into one outlet. Like connecting several light strings in series and then putting those groups together in parallel, the series-parallel (as in Figure 2.10) connection combines both techniques to provide a larger voltage and current. Recall that the wiring in your system must match the voltage requirements of your inverters for it to operate correctly. It is best to use identical models when connecting panels in series to maximize performance. "Solar panel strings" are these sets of interconnected panels that make up the foundation of your solar power system (as in Figure 2.11).

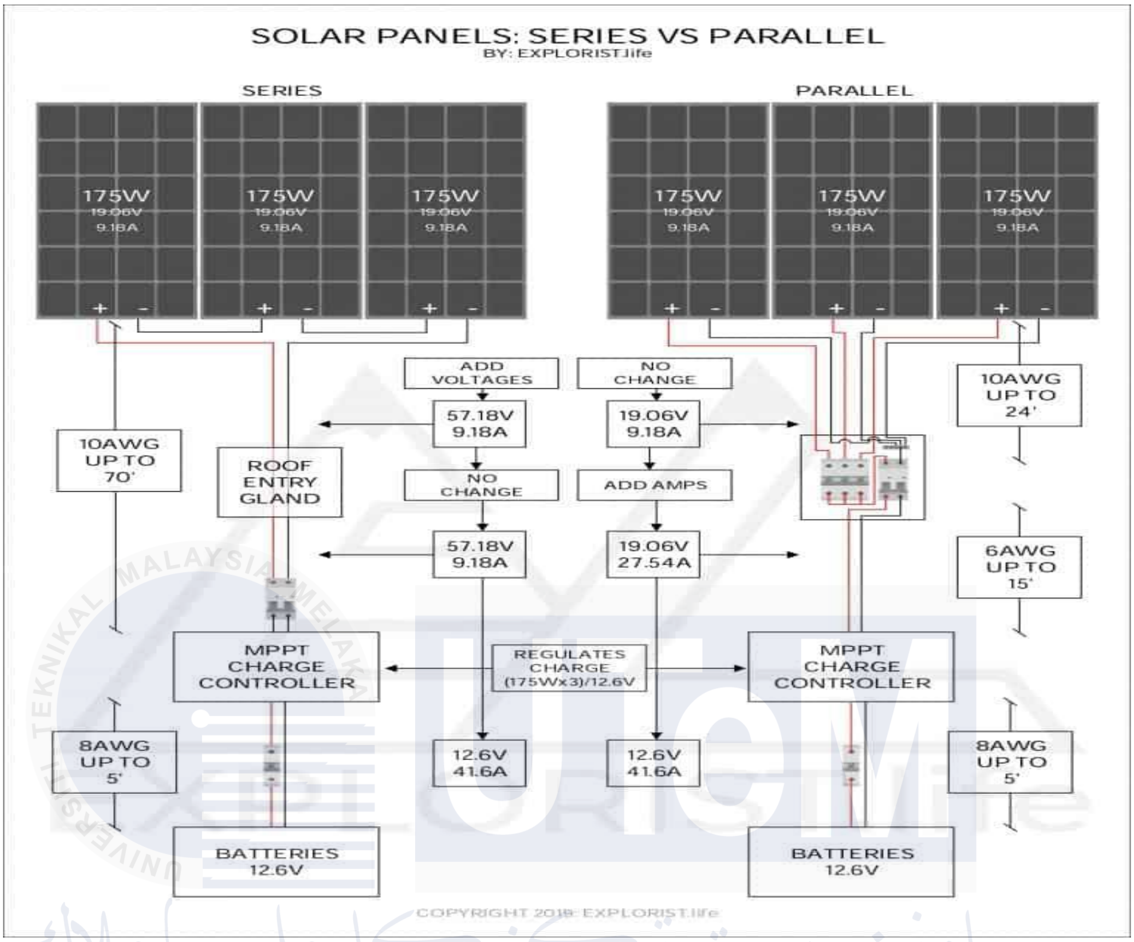


Figure 2.10 Series and parallel solar panel wiring.

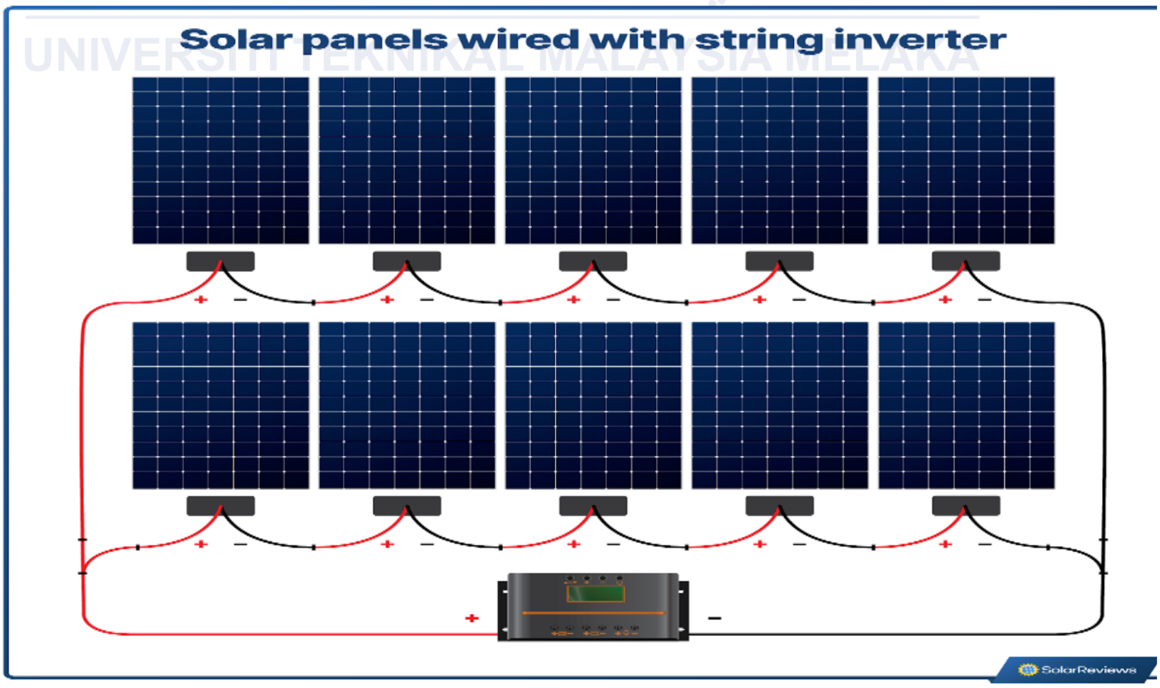


Figure 2.11 String wiring.

2.2.2.5 Structure

For years to come, solar panels will need a robust mounting solution, much like a picture needs a strong frame. These mounting structures must be resilient enough to endure inclement weather. There are five primary categories to select from: 1. Building Applied Photovoltaics (BAPV) are enormous solar panels that are usually used in solar farms. They are supported by racks or frames that are fixed to the ground and spaced a few inches above the surface. 2. In open areas where panels are directly supported by sturdy ground-mounted frames, ground-mounted racks are perfect. 3. Pole-mounted racks, which are ideal for confined spaces, suspend the solar panels from flagpole-style poles. 4. A different strategy is used by Building Integrated Photovoltaics (BIPV), which integrates into the structure itself. 5. The most sophisticated choice are tracking systems, which include sophisticated mounts that rotate your panels to face the sun continuously throughout the day, optimizing the amount of energy you produce. The primary distinction between BAPV and BIPV is integration; BAPV is installed on top of the building structure, while BIPV becomes integrated into it. The following figure 2.12 compares BAPV and BIPV.

Figure 2.12 The variations between BAPV and BIPV.

2.2.2.6 Solar cable

To link solar panels and arrays to the solar power grid and to enable the transmission of DC solar energy throughout the system, cabling is an essential component of PV system design. Solar cables are pre-installed in panels and have the proper connectors on them. Three basic types of solar cables DC solar cables, solar DC main cables, and solar AC connecting cables are frequently used in PV systems. Main DC solar cables are very popular for outdoor installations and are available in diameters of 2mm, 4mm2, and 6mm2. Several kinds of cables are required to finish a solar power project. A DC $6mm^2$ cable is used in solar panel systems to connect PV panels and inverters, including junction boxes (as in Figure 2.13). On the other hand, AC cables are used to connect substations and inverters.

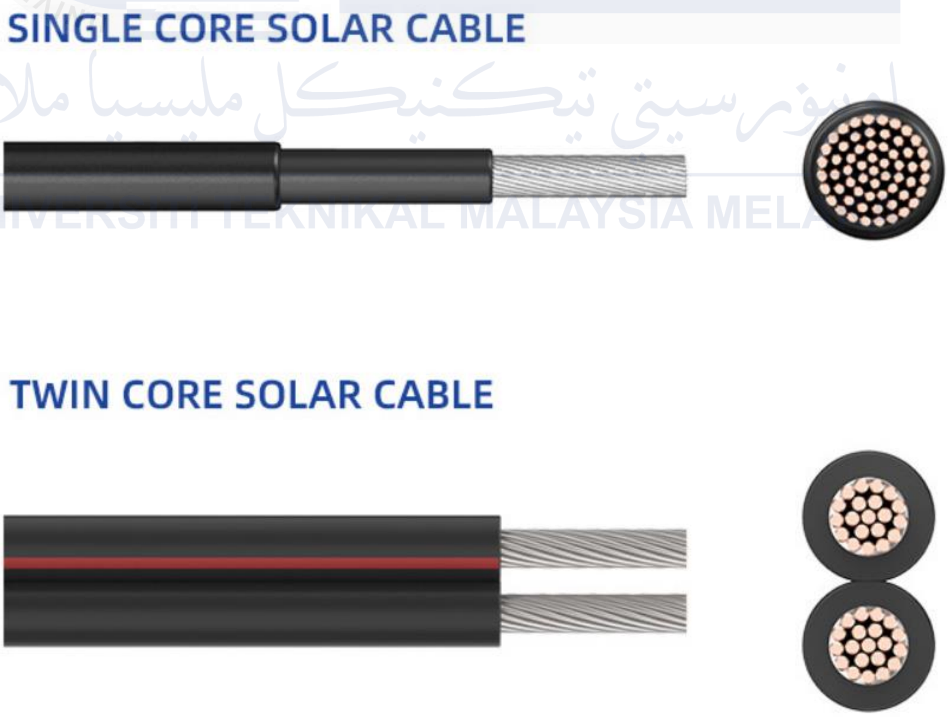


Figure 2.13 Photovoltaic 6 DC 6 mm2 Single Core and Twin Core Solar Cable for Solar Panel Systems.

2.2.2.7 Type of battery

The battery bank, a vital component of a solar PV system, stores extra energy produced during the day for use at night or during times when there is less sunlight. As Table 2.2 illustrates with a comparison of the several types of battery banks that are available, lead-acid batteries are the most widely used kind in PV systems. Battery storage can function as a dependable backup power source during blackouts. A solar PV system's watt-hour consumption must be ascertained before choosing the right battery bank. Purchasing high-quality batteries is also essential if you want to protect the system's integrity and lower the chance of performance deterioration.

Table 2.2 Battery bank comparison.

Battery Type	Capacity & power	Life	Maintenance	Cost	Safe
Lead - acid	Small	Short	Needed regularly check.	The cheapest	Trustworthy and secure but with potentially harmful materials.
Lithium - ion	Largest	Longest	Minimal maintenance.	The highest	Great energy density but needs to be handled carefully and with safety measures.
Flow battery	Large	Long	Minimal maintenance.	Highest than Lithium-ion	Safe.

2.2.2.8 Solar structure

A solar panel is composed of multiple layers: photovoltaic cells, which convert sunlight into energy; a junction box that regulates electricity flow; a protective glass front; an encapsulant for shock absorption; a metal frame for strength and heat dissipation; and a back sheet to keep moisture out. The panel may be a component of a system that includes a charge regulator to safeguard batteries and is placed atop a stand for the best possible solar exposure.

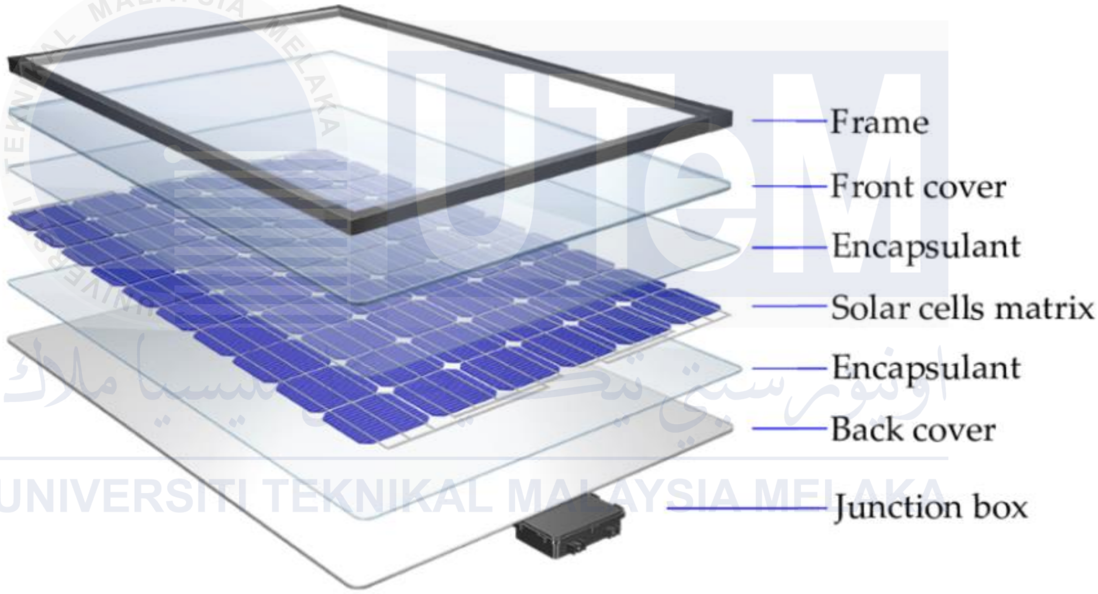


Figure 2.14 The structural (layers) of Solar PV modules.

2.2.2.9 Percentage of solar energy in future

Solar energy has enormous future promise in the fight against climate change. Solar power is a groundbreaking technology. By reducing carbon emissions significantly and perhaps providing 25% of global electricity demands by 2050, solar power can have a significant influence [1]. To get there, we need to raise the use of solar panels eighteen times around the world, with Asia leading the way. All the good news? Solar energy is now more affordable than traditional fuels and will continue to do so due to innovation. Beyond the benefits to the environment, this increase in renewable energy might create roughly 18 million new jobs globally by 2050 [1].

2.2.3 Web-based PV design and application

When it comes to PV system design, a variety of software programs and tools are essential for maximizing system effectiveness, affordability, and performance. Researchers and engineers may model, simulate, and analyze many elements of PV systems with these programs. Applications like RatedPower pvDesign, Open Solar, PVWatts Calculator, Aurora Solar, and HelioScope are available for the design, modeling, and simulation of PV systems.

A comprehensive online platform created especially for experts in the solar sector is called Aurora Solar. It enables users to produce intricate solar designs that optimize energy production and provide precise shade analysis for industrial, commercial, and residential projects. In addition, the platform creates expert suggestions, connects with other tools, promotes cooperation, provides financial modeling tools to calculate ROI and payback periods, and instructs customers about solar energy. Aurora Solar is beneficial for installers, designers, and sales teams since it streamlines the whole solar project lifecycle.

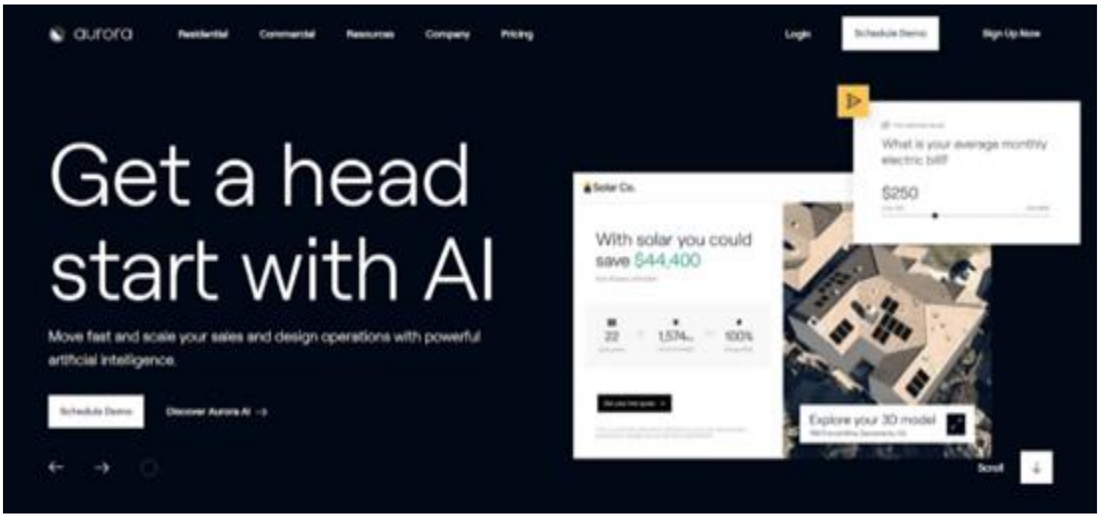


Figure 2.15 Aurora Solar Page.

A feature-rich web-based photovoltaic (PV) tool called PVsyst helps solar enthusiasts, engineers, and designers with the planning, sizing, and modeling of solar PV systems. It makes it possible to investigate, size, and simulate PV systems in detail hourly. It also generates fully printed reports with specialized graphs and tables. The program maintains component and meteorological data, giving users access to an extensive database necessary for precise system simulation. Additionally, PVsyst simplifies the study of solar systems, provides teaching aids, and lets users compare simulation findings with real data. Experts can efficiently communicate findings using comprehensive reports, graphs, and tables. They can also export data for additional analysis or tool integration. PVsyst is a useful tool for solar specialists all around the world since it is an effective instrument for planning, evaluating, and optimizing PV systems.

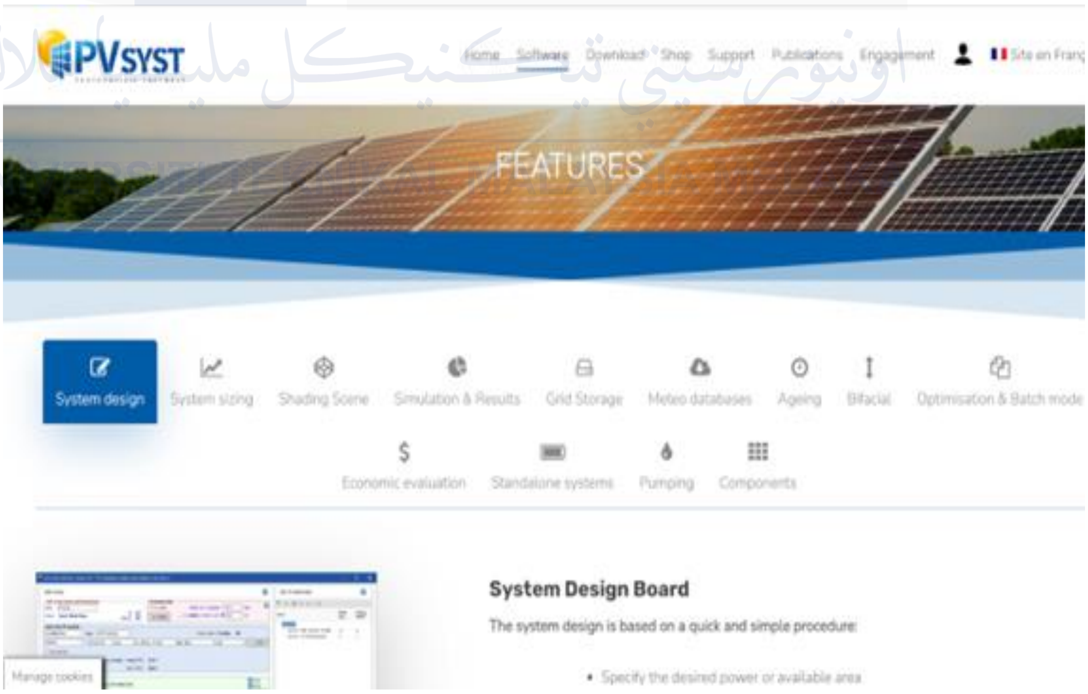


Figure 2.16 PVSyst web based.

Professionals in the solar sector can use OpenSolar, a web-based solar design and proposal program that leads the world. In contrast to many other products, Open Solar provides its powerful capabilities without charge. What distinguishes it is as follows: With the fastest, easiest, and most accurate 3D design tool on the market, solar experts can produce dependable and financially sound proposals from their desk or out in the field. It is feasible to integrate current CRM systems and business tools seamlessly with an open API. Interactive, customizable proposals can be produced online or as PDFs, guaranteeing successful outreach to possible customers. In addition, Opensolaris comes with an integrated CRM, electronic scheduling, hardware catalogs, permitting, real-time customer alerts, and e-signatures, which let solar experts oversee the whole process from conception to completion. Opensolaris empowers businesses globally and is trusted by solar specialists in over 130 countries.

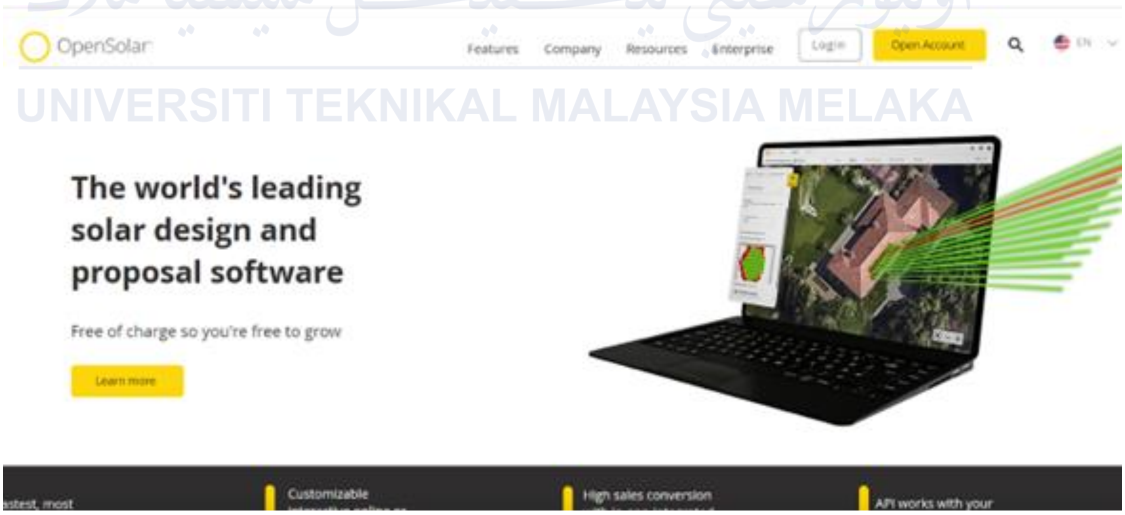


Figure 2.17 OpenSolar Homepage.

A potent web-based software tool called System Advisor Model (SAM) was created by the National Renewable Energy Laboratory (NREL). It is an important tool for experts in the field of renewable energy. The main facets of SAM are as follows: It is a free desktop program that is used to analyze energy technologies from a techno-economic perspective. It supports researchers, policy analysts, engineers, project managers, and technology developers in their investigations into the financial, technical, and economic viability of renewable energy projects. Second, a variety of renewable energy systems can be modeled by users, such as biomass, concentrated solar power (CSP), wind, wave, and tidal energy, photovoltaic (PV) systems, and battery storage. Various ownership and financial arrangements can also be investigated. Third, SAM offers capabilities including financial modeling, proposal creation, energy yield estimation, databases for component and climatic data, tools for instruction and comparison. In conclusion, SAM enables experts to evaluate the viability of renewable energy projects, enhance designs, and reach well-informed conclusions.

Figure 2.18 System Advisor Model (SAM) section.

A web-based sales and design tool for solar industry professionals is called HelioScope. It provides several important features: First, users can use 3D modeling and satellite imagery to model solar PV systems with its 3D design engine. Fast and precise shading analysis is made possible by this intuitive interface, which is especially helpful for home solar installations. Secondly, HelioScope comes with a comprehensive financial calculator for figuring out project expenses, profits, and payback times. Third, the drag-and-drop proposal editor allows users to draft polished proposals. Finally, HelioScope is a flexible option for solar experts because it can be used from any current browser on PCs, laptops, and mobile devices.

Figure 2.19 HelioScope Homepage.

2.2.4 Microsoft Excel

A flexible spreadsheet program for organizing, analyzing, and visualizing data is Microsoft Excel. Users can enter data, execute computations, and generate formulas using its grid-like interface. Excel's large function library makes complicated computations easier to understand, and it provides a variety of chart types for data display. Real-time co-authoring is made possible by collaboration tools and features like pivot tables, which also help with data analysis. Excel is still a vital tool for professionals all over the world, whether they are handling budgets, keeping track of sales, or producing reports. Among the functions used in Microsoft Excel are VLOOKUP and HLOOKUP.

With Excel's sophisticated VLOOKUP function, you can look up a value in a table and get the related data from a different column. It's important to remember the following while using VLOOKUP: By default, it starts by doing an exact match, searching the leftmost column for values, and returning information from the columns on the right. Second, when the fourth argument is set to TRUE, you can also use it for approximate matches, which is helpful for determining the greatest number that is less than the lookup value. Third, VLOOKUP consistently retrieves matching data from columns to the right after searching for values in the leftmost column. It also returns the first occurrence of a variable to handle duplicates. Finally, it is flexible for a range of situations because wildcards can be used for incomplete matches. Keep in mind that VLOOKUP is a useful technique for effectively retrieving data in Excel. A basic VLOOKUP function used to find a value in a spreadsheet is shown in Figure 2.20. Many examples of VBA code that can be used to automate processes can be found in Excel. (refer to Figure 2.21) displays a simple VBA code sample. Examples include adding serial numbers to a list, formatting cells based on predetermined standards, and creating a macro to clear the contents of a region of cells. Other examples include creating a pivot table from a data set, a custom dialogue box to request input, and a user-defined function to carry out a particular computation. Numerous websites, such as Excel Off the Grid, Excel Champs, Automate Excel, FreeCodeCamp, and The Spreadsheet Guru, offer samples of Excel VBA code.

Syntax

```
=VLOOKUP(lookup_value,table_array,column_index_num,[range_lookup])
```

- *lookup_value* - The value to look for in the first column of a table.
- *table_array* - The table from which to retrieve a value.
- *column_index_num* - The column in the table from which to retrieve a value.
- *range_lookup* - [optional] TRUE = approximate match (default). FALSE = exact match.

Figure 2.20 VLOOKUP Function with the help of a simple syntax.

```
Sub InsertTextinCell()
    ' Target the cell "A1" in the active worksheet
    Range("A1").Value = "Excel is Awesome"
End Sub
```

Figure 2.21 Basic example of VBA code.

2.3 Previous work by other

This study will examine the wealth of information provided by past studies conducted by various experts in the field in this part. These studies offer significant perspectives, approaches, and results that will influence the state of knowledge on the subject and form the foundation of this work. This paper aims to contextualize the research within the larger academic landscape and highlight potential research gaps or untapped regions by analyzing these earlier efforts.

2.3.1 A Low-Cost Automated Test Bench for Server Power Supply in Excel VBA

Big data has caused an explosion in data, necessitating the processing and storage of massive amounts of data on strong servers. The foundation of contemporary enterprises is this vital data, sometimes known as big data. The amount of data created, replicated, stored, and consumed globally in 2020 alone was an astounding 64.2 zettabytes, a fourfold increase since 2015. Installed storage capacity must rise in tandem with this data flood, and by 2020 it will have reached an astounding 6.7 zettabytes. The reliable operation of servers, which are essential for gathering, organizing, processing, and storing data, depends on a strong power supply. The task of converting incoming AC power to the DC voltage needed by server components like motherboards, hard drives, and peripherals falls to server power supply units, or PSUs. Server PSUs have a crucial role; thus, it is necessary to provide constant quality, dependability, and cost-effectiveness through careful design and extensive testing. Testing confirms that the PSU satisfies all the functional and safety requirements listed in its design documentation. PSU testing has historically been done by hand, which has been associated with repetition, onerous paperwork requirements, and a significant risk of human error. This method is inaccurate and time-consuming, not to mention inefficient.

Thankfully, automation presents a strong substitute, removing these shortcomings and offering a testing process that is more precise and dependable. Furthermore, automation is quite helpful in meeting strict development deadlines. Even with all automated testing's benefits, a lot of development projects still use manual techniques because of the perceived difficulty and expense of implementing automation. A wide range of PSU test automation systems, from pricy to affordable, have been offered over the last ten years. Current solutions often fall into two categories: low-cost options with restricted functionality or costly, commercially available ones that dramatically increase development costs. To close this gap, this study suggests a unique strategy that unites functionality and cost. Even with all automated testing's benefits, a lot of development projects still use manual techniques because of the perceived difficulty and expense of implementing automation. A wide range of PSU test automation systems, from pricy to affordable, have been offered over the last ten years. Current solutions often fall into two categories: low-cost options with restricted functionality or costly, commercially available ones that dramatically increase development costs. To close this gap, this study suggests a unique strategy that unites functionality and cost.

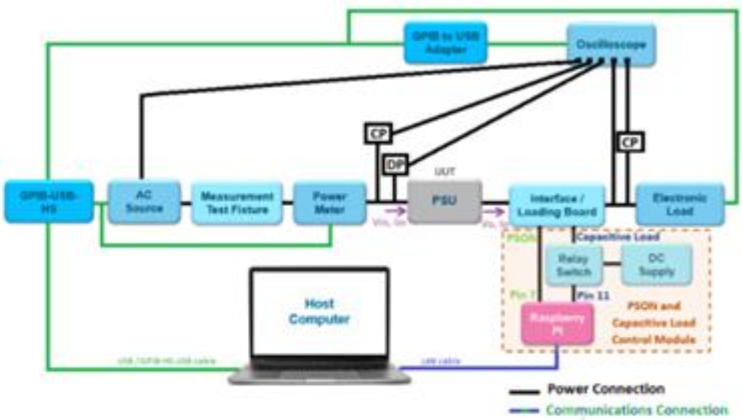


Figure 2.22 Configuration of the Automated Test Bench. [5]

2.3.2 Pre-installation design simulation tool for grid-connected photovoltaic system using iterative methods

When applied correctly, photovoltaic (PV) technology is one of the most promising and can meet global demand. Grid-connected PV systems and stand-alone PV systems (SAPV) are the two primary uses for PV systems. GC PV. While SAPV is an off-grid system, it integrates PV technology with the main grid. PV modules provide DC electricity for the GCPV system, which is a modular system that uses inverters to convert DC power to AC power output. Accurate system sizing is one of the most crucial aspects of GCPV implementation since it prevents oversizing or under sizing, both of which can have a big influence on investment. For PV system component manufacturers, R&D teams, systems integrators, and end users, a precise pre-sizing tool is essential for PV system installation. Tools for simulation are among the most popular techniques for determining PV generation potential within anticipated operating constraints at a specific location. The market now offers computer simulation tools in seven primary categories: analysis and planning, economic evaluation, photovoltaic industry-related, performance simulation, monitor and control, and more tools; solar radiation maps; and tools for site investigation. Pre-Installation Design for GCPV (PIDG CPV), a user-friendly simulation tool presented in this earlier work, was created to provide energy users or PV installers with a first assessment of PV system sizing to establish the ideal setup of the GCPV system. It makes use of an iterative technique that is integrated with a Microsoft Visual Basic application and inserted in Macro Excel. Three limitations are covered by the simulation tool: money, energy requirements, and space. The program also has an embedded database with PV modules, inverters, and climatic information for every state in Malaysia. An overview of the simulation techniques for GCPV system sizing, economic analysis, and performance analysis is given in this section. The user input, database portion, and calculation section are its three primary components. The consumer, energy installer, or user must decide the kinds of PV modules, inverters, site locations, and system constraints based on a selection menu created by the simulation tool's embedded database.

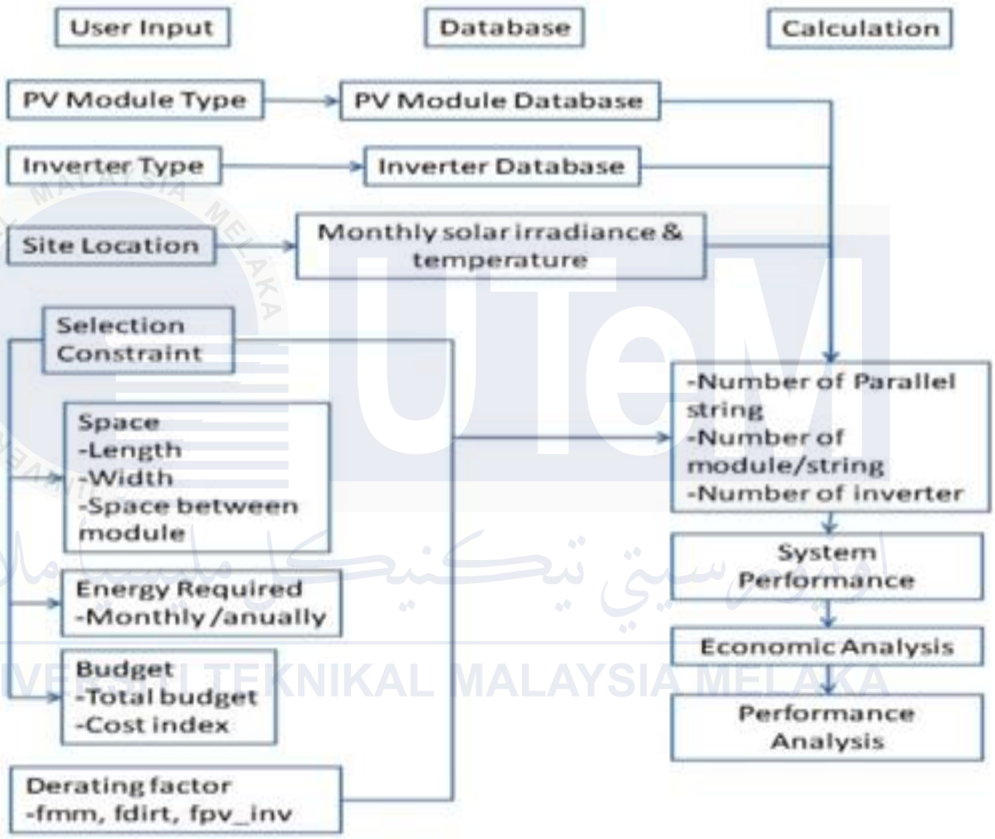


Figure 2.23 Block diagram of simulation steps. [6]

2.3.3 Applications of Excel VBA in Data Calculation and Charts Creation of Mineral Resource Economics

The economics of mineral resources mostly depend on data analysis and visualization. This study investigates the automation of these processes using Excel VBA (Visual Basic for Applications). Like Visual Basic 6 (VB6), which it replaced, VBA is an event-driven programming language that is integrated into Microsoft Excel. With the use of dynamic-link libraries (DLLs), users can access sophisticated functionality, automate tedious operations, and develop custom routines. Resource economists make use of VBA's Excel data processing and storage features. To construct custom subroutines (UDFs) and use the Excel Visual Basic Editor (VBE) for development, VBA code communicates with the spreadsheet. One important calculation that VBA automates is the annual growth of mineral resources. It eliminates the need for repetitive manual activities by using loop programs like "For-Next" loops to iterate through data sets, do computations, and even automate the development of charts based on the processed data.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
2	Coal(Gt)	0.00%	-0.52%	-1.43%	0.00%	-1.97%	0.00%	-1.14%	-0.48%	-0.61%	-0.27%	-0.69%	6.31%	-0.52%	-0.79%	-3.17%	0.34%
3	Iron ore(Gt)	0.00%	-0.76%	-2.29%	0.00%	-1.25%	-0.47%	-0.79%	-0.96%	-0.65%	-0.81%	-0.99%	10.78%	0.00%	-1.35%	-0.61%	10.84%
4	Magnitite(10 Kt)	0.00%	-0.94%	-1.96%	-0.34%	-0.60%	-0.89%	-4.40%	-8.83%	-0.33%	-0.08%	-0.34%	27.84%	-1.51%	0.08%	-2.09%	0.41%
5	Phosphorite(10 Kt)	0.00%	-0.01%	-14.80%	0.00%	-0.01%	0.00%	0.00%	-0.08%	-0.11%	-0.12%	-0.16%	43.77%	-0.03%	-0.09%	-0.11%	-0.09%
6	Potassium shale(Kt)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
7	Magnesite(10 Kt)	0.00%	-0.41%	-0.28%	-0.42%	-0.49%	-0.77%	0.00%	0.00%	-0.02%	-0.18%	-0.35%	131.45%	-0.17%	-0.16%	-4.60%	-0.18%
8	Oulopholite(10 Kt)	0.00%	0.00%	0.00%	0.00%	-0.06%	-0.12%	-0.11%	-0.15%	-0.19%	-0.40%	-0.23%	-0.24%	-0.32%	-2.49%	-0.52%	-1.47%
9	Bentonite(Kt)	0.00%	-0.03%	0.00%	-1.70%	-0.07%	-0.90%	-1.60%	-0.40%	-0.18%	-0.21%	-0.27%	4.77%	-0.19%	-0.37%	-0.31%	0.25%
10	Zeolite(10 Kt)	0.00%	-0.10%	-0.07%	-0.25%	-0.12%	-0.31%	-0.07%	-0.01%	-0.02%	-0.03%	-0.02%	357.36%	0.00%	0.00%	-1.26%	13.15%
11	Copper(t)	0.00%	-3.45%	-2.91%	-3.24%	-1.97%	-0.70%	-0.51%	-2.36%	12.97%	3.18%	-2.05%	-0.50%	-1.98%	-1.86%	-0.70%	-1.07%
12	Lead(t)	0.00%	20.34%	-0.05%	42.79%	-2.12%	0.38%	-0.46%	-1.10%	4.53%	6.69%	8.82%	-9.70%	2.53%	7.79%	5.02%	-0.04%
13	Zinc(t)	0.00%	1.45%	-0.01%	4.34%	2.84%	2.10%	-0.06%	-0.48%	3.49%	3.06%	0.10%	-0.57%	-0.34%	1.77%	2.43%	-0.87%
14	Limestone(10 Kt)	0.00%	3.00%	5.23%	-4.55%	6.14%	1.32%	-0.24%	6.06%	5.41%	3.41%	6.28%	-5.14%	3.30%	20.13%	0.28%	15.46%
15	Gold(Kg)	0.00%	-5.29%	87.63%	13.26%	12.80%	-18.75%	-9.82%	-1.01%	15.57%	5.99%	12.55%	-20.90%	-4.87%	-14.14%	-6.61%	-1.02%
16	Glass sandstone(10 Kt)	0.00%	-0.57%	-0.53%	-0.51%	-0.60%	-1.69%	-0.78%	-0.59%	0.51%	19.60%	17.47%	6.73%	-0.44%	1.37%	-1.22%	5.61%
17	Kaolin (Kt)	0.00%	0.00%	99.68%	0.00%	-5.98%	0.00%	-0.42%	-0.21%	0.00%	-0.64%	-0.21%	-0.56%	0.00%	-0.56%	0.00%	0.00%

Figure 2.24 The result of calculation for annual increment of mineral resources. [7]

2.3.4 Product metrics for spreadsheets A systematic review

Spreadsheets can be prone to errors. Although spreadsheets are frequently far smaller than typical software applications, the bug density is probably higher in spreadsheets. Researchers are using software engineering tools, such as metrics, to pinpoint areas that need improvement in spreadsheet quality. These indicators, which have been used to estimate risk and forecast errors, can be correlated with the size or complexity of the spreadsheet. But current spreadsheet metrics can overlap and frequently lack explicit definitions, making them challenging to understand and apply consistently. The objective of this work is to tackle this problem by compiling an extensive list of spreadsheet metrics and evaluating their advantages and disadvantages.

	A	B	C	D	E	F
1		Coffee Consumption: Department 1				
2		Employee				
3	Quarter	Anderson	Bourne	Connor	Dredd	Total
4	1	35	1745	80	98	=SUM(B4:E4)
5	2	47	21	51	66	=SUM(B5:E5)
6	3	46	12	46	39	=SUM(B6:E6)
7	4	74	15	57	43	=SUM(B7:E7)
8	Total	=SUM(B4:B7)	=SUM(C4:C7)	=SUM(D4:D7)	=SUM(E4:E7)	=SUM(F4:F7)

(a) Department 1

	A	B	C	D	E
2		Department			
3	Quarter	Departement 1	Department 2	Depratment 3	Total
4	1	=Department1!F4	=Department2!F4	=Department3!F4	=SUM(B4:D4)
5	2	=Department1!F5	=Department2!F5	=Department3!F5	=SUM(B5:D5)
6	3	=Department1!F6	=Department2!F6	=Department3!F6	=SUM(B6:D6)
7	4	=Department1!F7	=Department2!F7	=Department3!F7	=SUM(B7:D7)
8	Total	=Department1!F8	=Department2!F8	=Department3!F8	=SUM(B8:D8)

(b) Total

	A	B	C	D	E
1			Investment Options		
2	Input				
3	Coffee / year	=Total!E8			
4	Service years	3			
5	Coffee total	=B3*B4			
6					
7	Comparison				
8	Type	Investment	Coffee price	Yearly service	Total
9	Capsule	100	0,3	100	=B9+C9*B5+D9*B4
10	Drip	250	0,15	100	=B10+C10*B5+D10*B4
11	Automatic	800	0,1	200	=B11+C11*B5+D11*B4

(c) Investment

Figure 2.25 Formula views of different worksheets used to explain concepts and metrics. [8]

2.3.5 Applications of Excel VBA in Data Processing of Magnetic Survey

One geophysical method used in mining to find precious minerals is magnetic surveying. By monitoring changes in the Earth's magnetic field, this technique can detect the existence of underground materials or geological formations. This data is gathered using devices known as magnetometers, and it is then saved in Excel or text files. Geophysicists frequently preprocess the data using Excel VBA (Visual Basic for Applications) scripts to study the data further. There are various reasons why this preprocessing is required. A crucial first step is to locate and draw attention to abnormal data items. Rather than the minerals of interest, structures like buildings or power lines can be the source of these anomalies, which show up as distorted locations with noticeably higher or lower magnetic strength relative to nearby points. By automating the process of flagging these anomalies, VBA facilitates the geophysicist's ability to concentrate on pertinent data. Adding information for missing data points is a further preprocessing operation. Sometimes physical impediments prevent measurements from being made at certain sites. Based on gaps in the current data sequence, VBA can be used to identify these missing points and then substitute placeholder data, like line and point numbers. This guarantees an entire dataset for additional examination and the production of magnetic contour maps, which graphically depict fluctuations in the Earth's magnetic field and facilitate the identification of possible mineral resources.

	A	B	C	D	E	F
1	Line No.	Point No.	X	Y	Height	MagneticValue
2	230	190	743500	3685840	116	50814. 58
3	230	192	743500	3685860	115	50806. 49
4	230	194	743503	3685880	116	50796. 01
5	230	196	743500	3685900	117	50782. 86
6	230	198	743500	3685921	118	50788. 33
7	230	200	743495	3685940	118	50796. 79
8	230	202	743500	3685961	119	50818. 47
9	230	204				
10	230	206	743500	3686000	119	50827. 86
11	230	208	743504	3686020	119	50830. 17
12	230	210	743508	3686040	119	50902. 27
13	230	212	743519	3686060	119	50595. 98
14	230	214				
15	230	216				
16	230	218				
17	230	220	743500	3686140	117	50866. 49
18	230	222	743506	3686160	117	50853. 8
19	230	224	743501	3686180	119	50846. 43
20	230	226	743500	3686200	119	50861. 07
21	230	228	743500	3686220	119	50871. 09
22	230	230	743500	3686240	120	50899. 88
23	230	232	743500	3686260	121	50889. 03
24	230	234	743500	3686281	122	50884. 2

Figure 2.26 Result of Inserting Information of Missing Points. [9]

2.3.6 Applying Excel VBA to implement comparison among physical experiment data.

This section covers automating statistical analysis in sports research with VBA (Visual Basic for Applications) and Excel's built-in data analysis features. Sports researchers have historically compared numerous groups using single-component analysis of variance (ANOVA), followed by manual approaches for multiple comparisons. This is a difficult and prone-to-error process. The authors provide an Excel workaround that uses VBA to automate multiple comparisons and ANOVA. By making data entry and analysis simpler, this lowers errors and boosts productivity. Based on sample size equality, the system chooses the proper multiple comparison test automatically. The shot-put outcomes from three different teaching methods and the 100-meter sprint effectiveness of four different teaching methods are compared by the authors as two examples of how to implement the solution. The technology finds significant differences between groups and produces easy-to-understand results, such as p-values. This study shows how Excel's built-in data analysis features for sports research may be expanded with VBA. Using this method to analyze sports data increases accuracy and efficiency by automating ANOVA and multiple comparisons.

Table 2.3 Result multiple comparison. [10]

Source data	Comparable group	Mean Deviation	QT (0.01)	α = 0.01	QT (0.05)	α = 0.05
2	1	0.11765	0.19386		0.158	
2	3	0.15294	0.19386		0.158	
2	4	0.22353	0.19386	*	0.158	*
1	3	0.03529	0.19386		0.158	
1	4	0.10588	0.19386		0.158	
3	4	0.07059	0.19386		0.158	

2.3.7 Distance-based and stochastic uncertainty analysis for multi-criteria decision analysis in Excel using Visual Basic for Applications

This tool uses a multicriteria lens to analyze decisions to support the management of water resources. After allowing users to specify criteria, alternatives, and weights for each, it uses two MCDA approaches to determine ranks. It also takes uncertainty into account by using distance-based and stochastic approaches to analyze how changes in performance and weight can affect rankings. This all-inclusive strategy aids in the decision-making of managers of water resources. They can comprehend the impact of uncertainty on the ultimate ranking in addition to assessing possibilities according to preferences. This enables individuals to recognize important variables and make well-reasoned decisions that consider different viewpoints. Users can define alternatives, assign weights to different criteria, and carry out uncertainty analysis with them. The program uses both stochastic and distance-based techniques to deal with uncertainty. The distance-based approach examines the ways in which differences in performance and weights might affect rankings. It pinpoints the most important elements influencing the ultimate ranking. The stochastic approach evaluates the model using Monte Carlo simulation and integrates probability distributions to indicate uncertainty. This approach offers information on each alternative's probability of reaching a specific ranking. By considering a range of uncertainties and stakeholder viewpoints, this program assists managers of water resources in making well-informed decisions. It facilitates the assessment of options according to preferences and aids in comprehending how uncertainties affect the ultimate ranking.

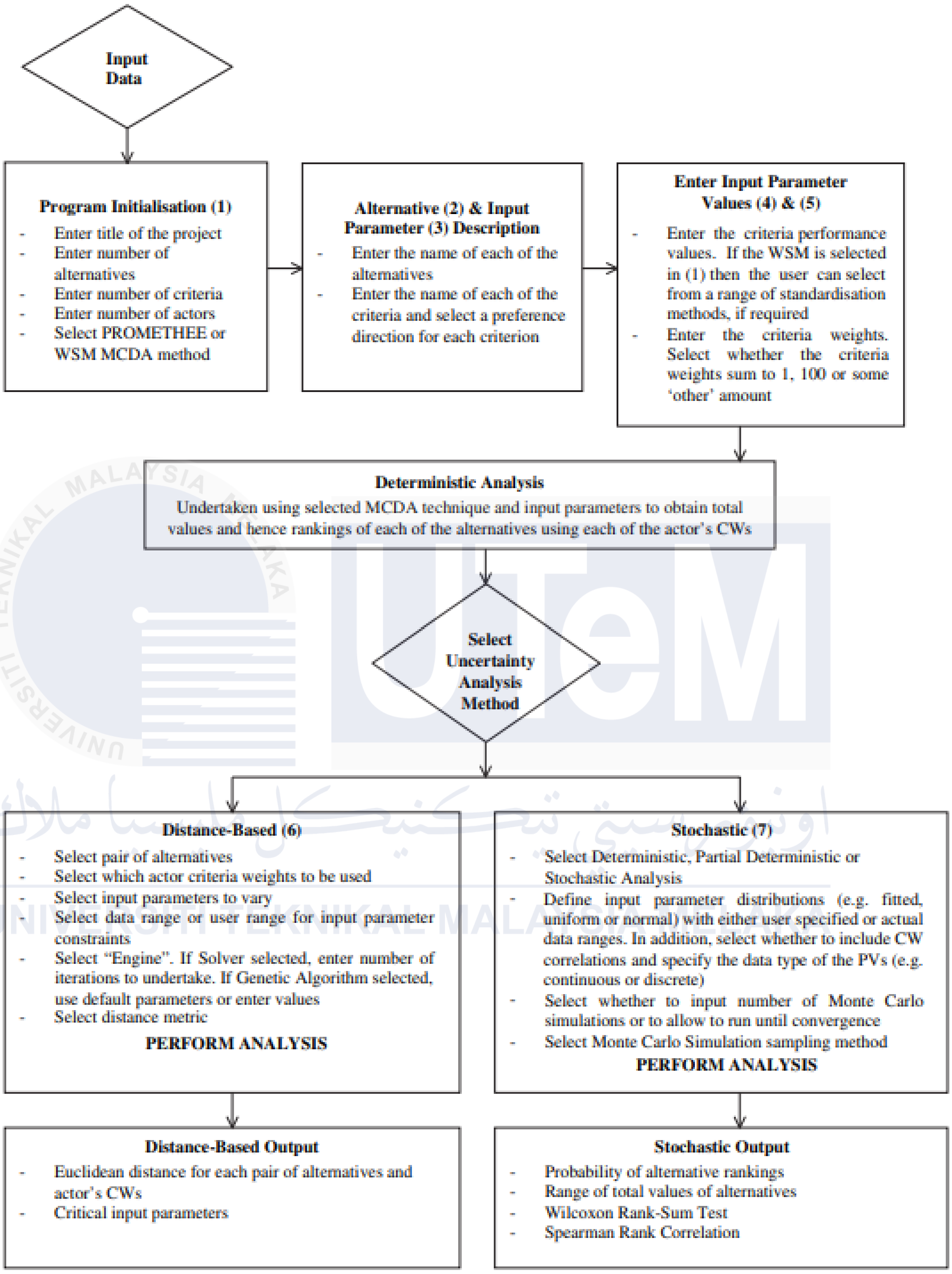


Figure 2.27 Program structure. [11]

2.3.8 Tlahuitolli-ce A Novel Solar Energy Program for the Design of Photovoltaic Systems

A software tool called Tlahuitolli-CETM was created to assist those with limited knowledge of solar energy in the design of photovoltaic (PV) systems. In contrast to conventional techniques, Tlahuilli-ceTM considers several variables that may impact the system's effectiveness, such as temperature fluctuations, wiring constraints, and actual meteorological data. This increases the design's precision. The application is easy to use and provides valuable advice during the design phase. Additionally, users can enter their own data for a more personalized appearance. The documentation for the program is also available in Spanish, which opens it up to a wider audience who might not speak English. Tlahuilli-CETM, in general, makes PV system design easier for non-specialists.

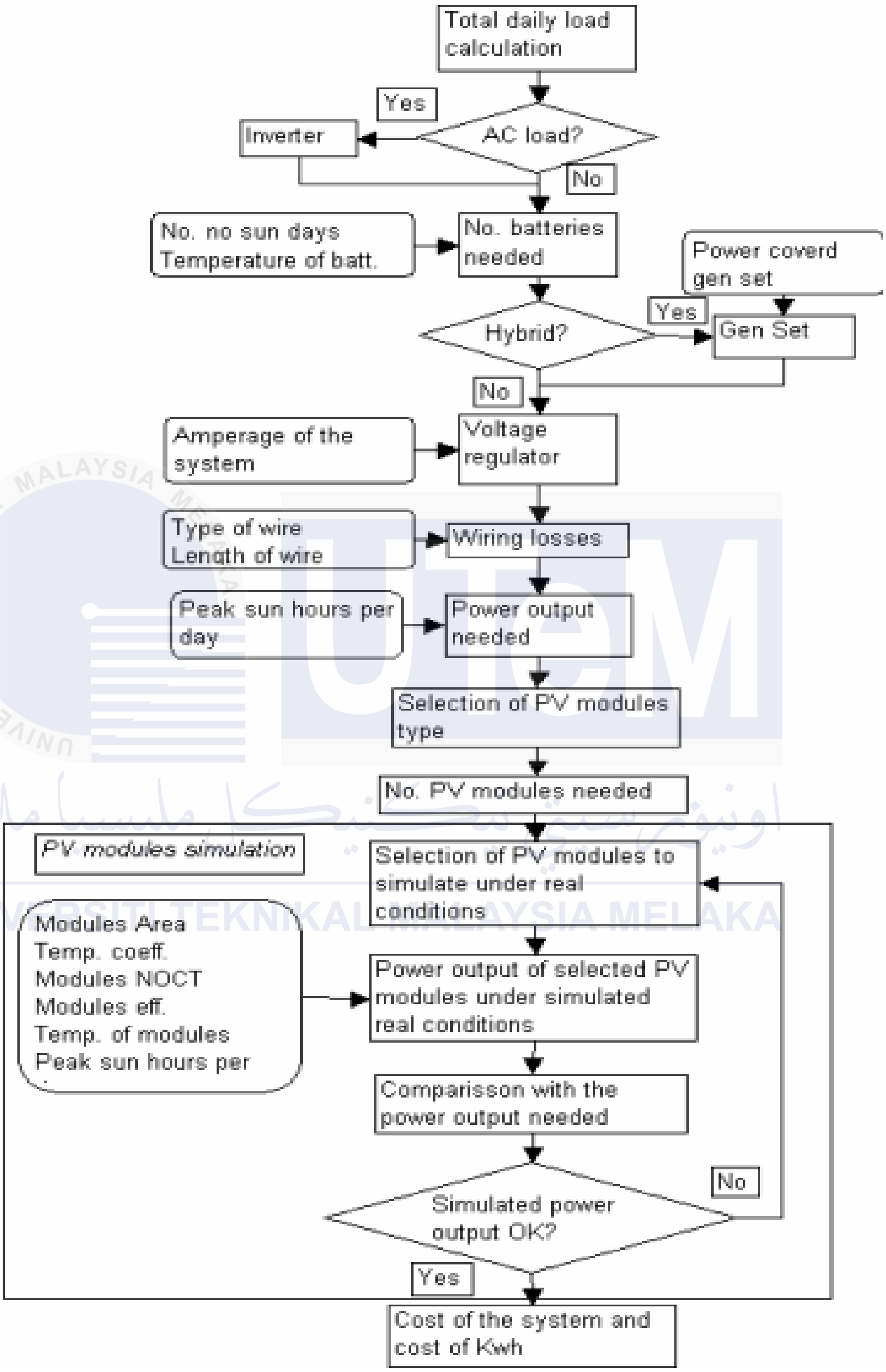


Figure 2.28 Flowchart of Tlahuitolli-ce. [12]

2.3.9 The analysis of several commonly used Excel function in accounting practice

Excel is a flexible program that is frequently used in accounting for a range of activities, such as processing, analyzing, and making decisions. The applications of two popular Excel functions, IF and VLOOKUP, are described in this document. The IF function assesses a condition and, depending on the result, returns a certain value. It can be used, for example, to allocate grades according to a table of scores. Conversely, VLOOKUP looks for information in a table depending on a given value. It is helpful for jobs that require reference data from many tables, such as computing taxes or locating product details. Three real-world instances of these functions' application in accounting are provided in this document. The first example shows how to award grades according to student scores using IF. To account for progressive tax brackets, the second example combines IF functions to compute employee income tax. The final example demonstrates the use of VLOOKUP to extract sales numbers for products from a huge database. Accounting professionals can greatly increase their productivity and accuracy while handling financial data in Excel by becoming proficient in these features.

	A	B
1		
2	Product	Quantity
3	725C4066K-AP-8	400
4	990Y4145K-AP-4	4
5	999E-200S	1544
6	A200X@2-3	77
7	A318-D6001-0.15L	31
8	A7005M@2-4	264
9	DEX808-15	8
10	DN81601-20	184
11	DP63007-4	176
12	DP65005-20	4
13	DP66005-4	106
14	DPZ001-3.5	308
15	GAD04-20	351
16	KBZ01-3	135

Figure 2.29 The results of the table. [13]

2.3.10 Developing Industrial strength simulation models using Visual Basic for Application (VBA)

Manufacturing systems can be modeled and examined using arena simulation software. Although it comes with built-in tools for reporting and data input, VBA (Visual Basic for Applications) allows you to expand its functionality. You can use VBA to build robust macros that automate processes in Arena. For example, VBA can be used to import data into Arena from Excel spreadsheets, removing the requirement for human data entry. This can cut down on errors and save time. The simulation results from Arena can also be formatted and exported into Excel using VBA. As a result, analyzing the data and producing graphs and charts may be considerably simpler. All things considered, VBA can improve the efficiency and streamlining of the Arena modeling process.

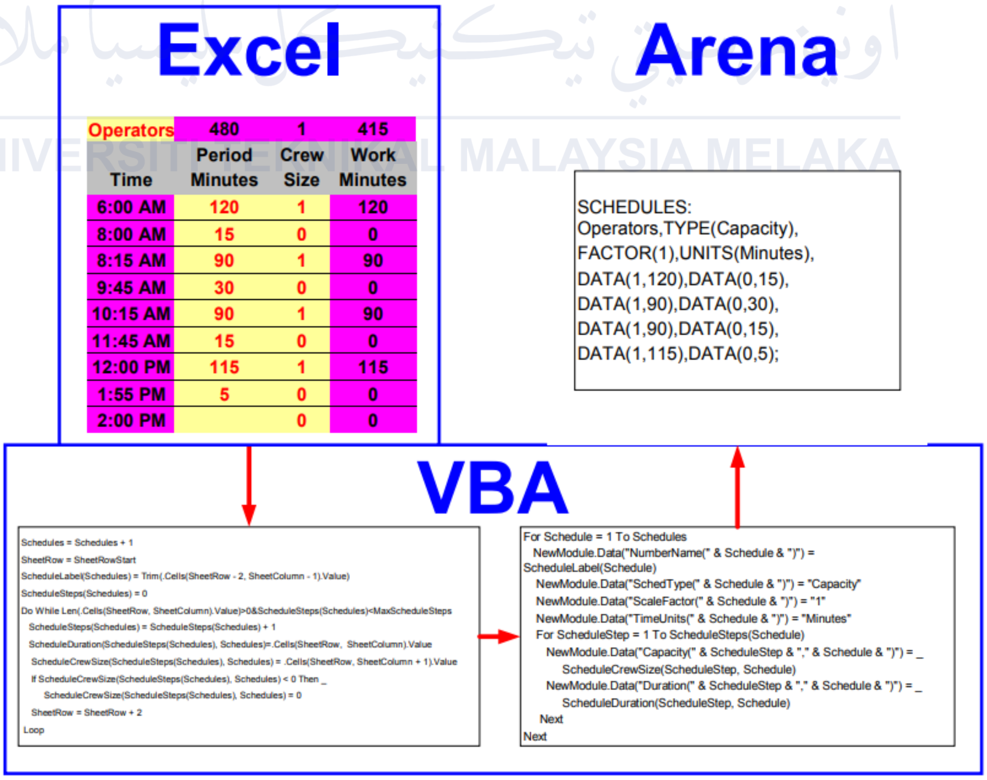
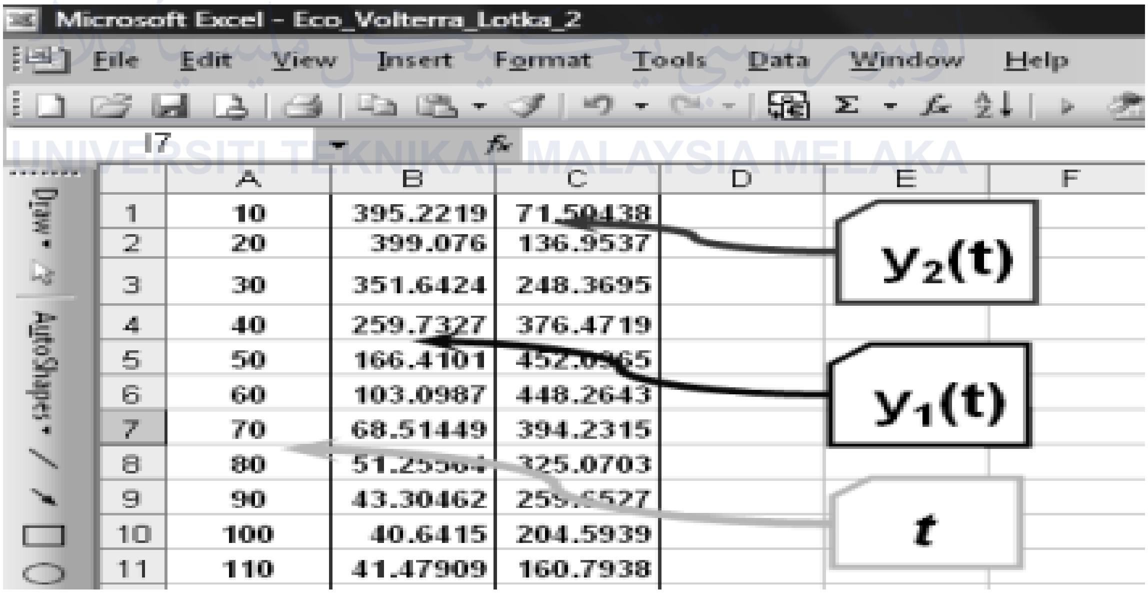


Figure 2.30 VBA Data Exchange, Excel to Arena. [14]

2.3.11 Methodology of Laboratory Workshops on Computer Modeling with Programming in Microsoft Excel Visual Basic for Applications

This essay makes the case that Microsoft Excel VBA is a useful resource for instructing students from a variety of backgrounds in computer modeling. Software for traditional computer modeling can be costly and complicated. However, VBA is already included in Excel, a tool that many students are familiar with. Students can write programs that mimic real-world issues using VBA. Students are better able to understand the fundamental ideas of computer modeling thanks to this practical method. The use of VBA to resolve traditional ecological issues is covered in the article. The author makes the case that discrete and continuous modeling issues can be resolved with VBA. Excel's familiarity and ease of use make VBA an effective teaching tool for computer modeling fundamentals.



	A	B	C	D	E	F
1	10	395.2219	71.50438			
2	20	399.076	136.9537			
3	30	351.6424	248.3695			
4	40	259.7327	376.4719			
5	50	166.4101	[illegible]			
6	60	103.0987	448.2643			
7	70	68.51449	394.2315			
8	80	[illegible]	325.0703			
9	90	43.30462	[illegible]			
10	100	40.6415	204.5939			
11	110	41.47909	160.7938			

Figure 2.31 Results of numerical simulation in defined Excel worksheet in preliminary defined cells range. [15]

2.3.12 BELT3843 PV SYSTEM DESIGN

Solar PV system design is about creating a system that turns sunlight into electricity. It involves figuring out how many solar panels and batteries you need based on how much power consumers use, the space consumers have (as figure 2.32), and consumers budget. Students will learn about different types of solar panels and inverters (the part that changes the power from DC to AC), and how to connect them in the best way. Students will also learn how to calculate the right size for everything, so students get the most out of their solar system.

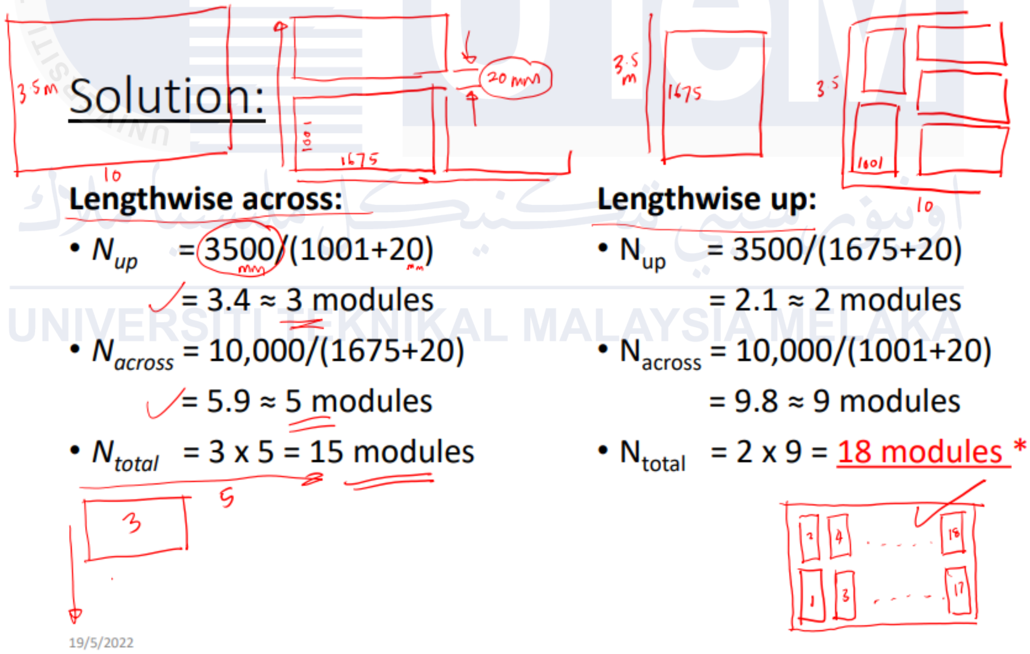


Figure 2.32 Some of calculation form based on space note [16]

2.4 Comparison work by other

Table 2.4 The details of the project from different authors.

Bil. / Reference	Author	Title	Application	Remark
1. [5]	Joan Cabugaya, Marianne Sejara	A Low-Cost Automated Test Bench for Server Power Supply in Excel VBA	The program's purpose is to gather test data and provide Excel-formatted reports. Using a combination of GPIB, USB, and LAN connections, the test bench employs a range of instruments for control.	• We will automate certain inspections, such as voltage regulation, efficiency, and overload handling, to enhance testing. Test results can be easily analyzed by creating clear representations with charts. • The code will act as a safety net, identifying mistakes made during testing and informing of any issues with the instrument or unusual outcomes. • There are more robust solutions such as Python, Excel VBA is more suitable for simpler Excel tests due to its familiarity.
2. [6]	Nurul Dalilah, Hasimah Abdul Rahman	Pre-installation design simulation tool for grid-connected photovoltaic system using iterative methods	PIDG CPV assists in selecting the optimal solar power configuration for your residence or place of business. When recommending the ideal solar panels and inverter, it	• Can construct a solar power system for your Malaysian home with the aid of this software. It considers roof space, energy requirements, and budget.

			takes budget, space, and energy requirements into account.	• To suggest the ideal solution for everyone, it consults a large database of parts and meteorological information. • Can even make a comparison between the recommended system's performance in a simulation and a real system.
3. [7]	Liu Pengpeng, Du Ruiqing	Applications of Excel VBA in Data Calculation and Charts Creation of Mineral Resource Economics	This article demonstrates how to analyze data on mineral resources using Excel VBA. It is useful for: Calculating changes in resource amounts annually. creating charts to display the modifications for every resource. identifying mistakes in the data. comparing modifications made to all resources.	• Consider Excel to have a hidden toolbox full of useful functions. Visual Basic for Applications, or VBA, is comparable to that toolkit. It enables users to accomplish some incredible things with Excel that go beyond its fundamental features. • Users can save time and effort by using VBA to develop custom routines that work as your own unique shortcuts. To eliminate the need for manual labor, repetitive processes like copying and pasting data can also be automated. Even more sophisticated Excel capabilities, like secret tools in a secret room, can be unlocked with VBA. • All things considered, VBA makes working with Excel quicker and more intelligent by automating

				processes, building unique functions, and providing you with access to more robust features.
4. [8]	Birgit Hofer, Dietmar Jannach, Patrick Koch, Konstantin Schekotihin, Franz Wotawa	Product metrics for spreadsheets—A systematic review	creating metrics to assess spreadsheet quality, particularly to identify problems and enhance overall dependability.	• This section delves further into the realm of spreadsheet analysis! It describes the fundamental components of spreadsheets, such as worksheets and cells, as well as how complexity is determined by researchers. • The fascinating element is that spreadsheets may be studied in two ways by academics using these measures. One method is to compare the perceived difficulty of a spreadsheet by users with its calculated real complexity. • Another technique is to forecast prospective issues with spreadsheets, such as inaccuracies or places for improvement, by performing calculations. To put it briefly, this appears to be a manual for academics who wish to gain a completely new understanding of spreadsheets.

5. [9]	Du Ruiqing, Sun Sanjian, Ouyang Longbin	Applications of Excel VBA in Data Processing of Magnetic Survey	Highlighting potentially fictitious or questionable data pieces (anomalous data) adding missing data points in places where measurements were not possible.	• Using dynamic-link libraries (DLLs), VBA provides the ability to create user-defined functions, automate operations, and access low-level functionalities such as the Windows API (Application Programming Interface). • Word's WordBasic and other older application-specific macro programming languages are superseded, and their capabilities expanded upon.
6. [10]	Shi hai-bo	Applying Excel VBA to Implement Comparison among Physical Experiment Data	In addition to automating these processes, the VBA code can handle data with equal or unequal sample sizes, perform various comparison tests not accessible in the built-in ANOVA program, and print the findings in Chinese. can help sports researchers by reducing errors, saving time, and streamlining data processing.	• The variance analysis method is useful for determining whether average grade discrepancies exist, and the comparison method is frequently used in sports education experiments and analysis. • Statistics frequently involves statistical computation, and one of the most frequent errors in statistical work is calculation precision. • The variance analysis method is useful for determining whether average grade discrepancies exist, and the comparison method is frequently used in sports education experiments and analysis.

7. [11]	K.M. Hyde, H.R. Maier	Distance-based and stochastic uncertainty analysis for multi-criteria decision analysis in Excel using Visual Basic for Applications	finds the important data points where even minor adjustments have a big influence on choices. takes into consideration the possibility of various outcomes depending on the uncertainty by using probability distributions.	• An Excel spreadsheet with Visual Basic for Applications coded to test the stability of a result from multi-criteria decision analysis (MCDA). • demonstrates how all available data, including uncertain data, can be included into the analysis simultaneously, giving more information about how resilient the alternatives are to variations in the input parameters and enabling confidence to be placed in the analysis's conclusion. • It can be used to resolve any form of conflict arising from the use of natural resources in opposition to economic growth.
8. [12]	Eduardo DíazEscobar, Dr. Liliana Díaz Olavarrieta	Tlahuilli-ce: a novel solar energy program for the design of photovoltaic systems.	This article presents a new generation of user-friendly solar power design software. It even makes solar power more accessible by considering more variables for a more accurate design and being available in Spanish.	• This software assists users in designing a solar system for their house. It functions with solar panels to provide electricity and heat (hot water). • Users can select a system with a backup generator or one that runs solely on solar power. If necessary, the software even assists users in connecting to the grid and selecting the appropriate pump.

9. [13]	Qingmin Yu	The analysis of several commonly used Excel function in accounting practice	IF function: Determines what to do based on predetermined criteria (grading on scores, for example). Using criteria, the VLOOKUP function locates data in a table (e.g., searching up sales figures for specific goods).	• VLOOKUP functions as a powerful data finder. It searches for users when users tell it what users are looking for and where to seek (for example, a certain column). • LOOKUP is a more straightforward VLOOKUP variant. After assisting you in locating a particular number, it multiplies it by another number—such as an amount. Users won't have to waste time searching through your spreadsheets to find what users need again thanks to these features.
10. [14]	Marvin S. Seppanen	Developing industrial strength simulation models using Visual Basic for Applications (VBA).	This tutorial shows you how to connect Excel spreadsheets with Arena simulation software using VBA. Data exchange is made easier using VBA, which enables you to create intricate models in Arena, edit data in Excel, and move data between the two applications for analysis.	• Consider creating intricate factory or warehouse simulators. Special code, called VBA, is used by this software to set up objects and display results automatically. • To save time and irritation, it also aids in identifying mistakes prior to executing the simulation. • Using a database rather than plain text reports is another awesome feature that makes result analysis much simpler.

11. [15]	S.T.Huseynov	Methodology of Laboratory Workshops on Computer Modeling with Programming in Microsoft Excel Visual Basic for Applications	More user-friendly than other software. Shows them how to operate with simulations. Aids with difficult issues and streamlines Excel chores.	• VBA is comparable to Excel's hidden superpower. It is highly configurable, integrates seamlessly with other Office applications, and is even employed by engineers for intricate jobs. • This useful application may help answer difficult equations, generate charts from your data, and automate repetitive operations. Excel's full potential is unlocked with VBA, making it a more potent tool for all users.
12. [16]	Dr. Azhan Bin Ab Rahman	BELT3843 PV System Design	This course teaches students details about solar and inverters, such as the types of solar, types of inverters, the topology of the inverter, and examples of solar and inverter. But the most important thing is that this subject teaches how to calculate solar and inverter based on budget, based on space, and based on energy requirements.	• Solar PV design is important because it help us use the sun's power to generated electricity • It's good for the planet, solar power is clean energy. So, it helps keep our air clean. • There are a lot of jobs, people who know about solar power can find good jobs. • It saves money, using solar power can help you save money on your electricity bills.
13. [17]	Yingmin Zhang, Shuqin Hao	Development and Application of Financial Analysis	According to this article, a robot can accomplish it far more quickly and effectively. The robot employs	• It might also illustrate a company's performance by contrasting it with that of its rivals.

		Report Robot Based on RPA and VBA Technology	cutting-edge technology to gather information, process it, and compose the report on its own. Time is saved, and accuracy of the reports is ensured.	• The robot might examine data more frequently than annually, providing you with a more comprehensive view of the situation. • It would display all this information in simple-to-read graphs and charts to make things even more plain.
14. [18]	Kenny Channiago, Tanti Octivia	Design a Proposed Scheduling Model in Logistics Company	The goal of the study was to increase the on-time delivery rates for a logistics company that was having problems with scheduling. They created a program using Microsoft Excel and suggested a novel scheduling technique based on due dates (EDD). Results indicated a 15% increase in truck efficiency, indicating that the EDD approach might result in more deliveries being made on schedule.	• Reduced truck malfunctions: To save time, schedule routine truck repairs and devise more efficient routes. Sort deliveries based on urgency and maintained the efficiency of all routes. To track vehicles, automate processes, and improve communication with drivers, use a TMS system. • To optimize your delivery process, never stop measuring it. Operations, and enhance communication. For optimal performance, constantly tracking and refining your delivery procedure.
15. [19]	Alexandre KREBS, Pierre TISSOT	Analyzing and displaying data from a PV system Excel VBA programming and MATLAB data analysis	The study on a solar energy system mounted on a Swedish home is the subject of the article. It investigates the system's overall performance and how much electricity it produces.	• This software functions as a one-stop shop for solar power system monitoring. Its user-friendly interface includes unambiguous graphs and charts that demonstrate

				the amount of power users producing. • It monitors everything, including the number of sunshine users receive and the efficiency of user equipment. • It will notify the user immediately if something goes wrong so the user can correct it. Even better, users may export the data to do additional analysis or observe trends over time. For on-the-go monitoring, there's even a smartphone app.
16. [20]	Ms. Emily Reynods, Dr. Chetan S. Sankar, Dr. P.K. Raju, Mr. Nanda Kumar	Glazing made simple: A decision support system tool using MS Excel VBA	Large windows let in light and have a good appearance, but they can also waste energy. With the help of new window technology, you can enjoy the sunshine without harming the environment because windows are better at keeping heat in.	• There is even more potential power for this window selection tool! Although it now assists in selecting windows for cooler climes, consider the possibility that it may also suggest windows for colder regions to reduce heating expenses. • It might even consider the environmental impact of the windows as well as their cost of purchase and ongoing maintenance. • Use the local weather to provide the most accurate choices, depending on where you build. Additionally, it would display all of this data in

				simple-to-read graphs and charts to make things plain.
17. [21]	Hamed Babanezhaad, Alireza Ghafouri, Mohsen Sedighi	Multi-layer energy management software base VBA for multi microgrid operation planning and cost analysis	Energy needs are growing, while available options are shifting (wind, solar). This article suggests a new design that users can modify to suit their needs and argues that we need better mechanisms to handle this new combination of energy sources (microgrids, software).	• This microgrid software functions as your tiny power plant's extremely intelligent brain. It uses real-time data to make instantaneous adjustments to energy use, such as lowering the volume when there is less power. • It can even cooperate with grid users to modify power consumption during peak hours. It also encourages participation from everyone who produces their own energy and controls the effective distribution of that energy. • The software is a future-proof brain for your microgrid because it communicates with other systems with ease and can be easily updated for new technologies.
18. [22]	Juan D. Aguilar-Pena, P. Perez-Higueras, C.Rus-Casas, F. Munoz-Rodriguez, Pes roM. Rodrigo-Cruz	Tool for the design and energy harvesting of grid-connected photovoltaic power installations: PV Excel Jean 3.0	This article presents a new software program called "PV Excel Jaén V3.0" that is used to design and calculate solar panel energy production. It draws attention to the increasing demand for these	• There is room for improvement in this student-use solar power design program! Consider how it would be useful to create systems that use smaller water generators or wind turbines in addition to solar panels.

			resources in the fields of education and work.	• To add even more realism to the simulations, it might even use actual meteorological data. The program can assist students in weighing the costs of various systems and potential long-term savings. The program could have interactive tasks, tutorials, or quizzes to further enhance learning. • To ensure that more students may use it, the software could also be adapted to function with other spreadsheet programs or even made accessible as a free download.
19. [23]	Yaheya Al Aman, Asim Datta	An Effective Filter Design for Single-Phase Inverters	How to design a filter for a solar inverter is explained in this article. The inverter uses the filter to purify the power it generates from solar panels. While there are several advantages and disadvantages to alternative filter designs, this article concentrates on one that reduces excess current during inverter starting without degrading its performance.	• Consider honing a solar power inverter's filter. This study attempts to address that issue. To determine which approach performs best overall, they are contrasting this novel filter design with current techniques. • They are investigating more sophisticated approaches to electrical current damping than merely enlarging the filter. They are going to construct a prototype and test it against computer simulations to make sure the design functions as intended in real life.

				• They will verify that the filter satisfies safety requirements by examining how it impacts the quality of electricity generated. To put it briefly, the goal of this research is to optimize a filter for solar power converters that operate smoother and more efficiently.
20. [24]	Dasharatha G, Padmanabuni Arun Kumar, N. Rajasekhar varma, Bommakanti Venumadhav, Ageeru Spandana, Boyanapally Prem kumar	Design and Implementation of Three-phase Three Level NPC Inverter	NPC inverters have internal voltage balancing problems and are difficult to extend, but they are excellent for high power devices (low voltage required) and clean power output. This article investigates controlling them with SPWM.	• This work analyzes predictive control for even greater performance, removes minute operational gaps, and investigates enhanced controls for smoother operation. • To test these concepts and evaluate them against current approaches for a more intelligent, effective inverter, they will construct a prototype.

21. [25]	Malar E, Dewanath SK, Ahmed Nadeem M, Divyasree T, Chandrika R	Design of Multi-Level Inverter for Power Electronics Applications	This page describes the function of a power inverter, which converts DC battery power to AC conventional outlet power. It has two types: entirely electronic and a combination of electronics and moving parts. It accomplishes this using sophisticated electronics called transistors. From laptops to air conditioners, they are used in a variety of products.	• This DC electricity is converted into AC electricity, the kind that powers home by inverters. Even though there are different inverters for on-grid and off-grid homes, this conversion loses some energy yet is necessary for solar electricity to function for home. • Everything has an inverter: electric cars, wind turbines, and solar panels. Converts DC power into usable AC power in solar systems. The future is bright: smaller, more effective, and even more intelligent! The next time you turn on a solar-powered light, give thanks to the inverter.

2.5 Summary

Comprehensive Excel-based photovoltaic (PV) design applications by energy requirements are covered in this chapter. The background information, other people's earlier works, and a comparison of earlier works make up its three primary elements. History of solar PV systems and photovoltaic (PV) systems. The background study portion covers generation, PV system components, web-based PV design software and apps, and Microsoft Excel. The primary goals of this investigation are examined in the first section. The development of these tools was impacted by studies that are examined in the second part. The research is contextualized by highlighting features, development processes, techniques, applications, and user interfaces. The uses and features of earlier publications are examined in the comparison section. The current research's significance and originality are emphasized and contextualized through comparison. To sum up, this chapter highlights possible shortcomings and areas for development in the existing Excel-based PV design tools, which enables this article to suggest new fixes and improvements.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter explains the project's objectives and the "Development of solar PV system design by energy requirement using Excel-based VBA" system that will be used. An outline of the system's approach to this project will be provided in this chapter. This chapter provides a thorough and visual account of the project's evolution. The best plan of action for reaching the intended outcome is also covered in this chapter.

3.2 Methodology

To do this, the project will employ several strategies, such as reading information and creating software with VBA in Excel. The process of creating the system's services involves several steps: first, locating the project title; then, an introduction that includes the problem statement, project goals, and scope; next, a search of literature and software; and lastly, data collection. This section describes every piece of software utilized in this project's production process. Figure 3.1 displays the development flowchart for the entire project.

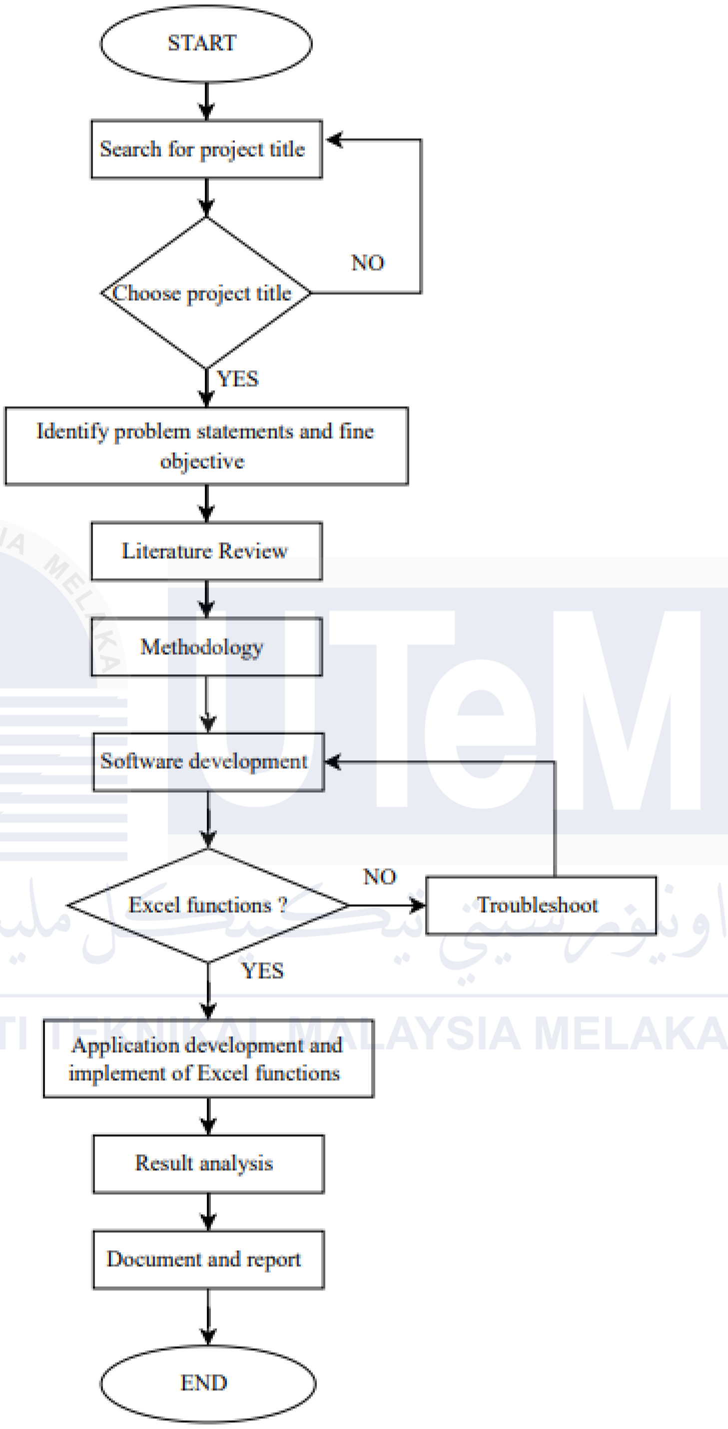


Figure 3.1 Flowchart of the overall project.

3.3 Project system flowchart

The process for designing a solar power system is depicted in the flowchart. The user is prompted by the program to enter the amount of energy they require at the beginning of the process. Next, the user enters how many solar panels and inverters they intend to use. After that, the application asks the user to select a particular model of inverter and solar panel from a pre-made selection. The application computes all the requirements and shows them on the screen after these choices are made. This covers the system's overall cost, maximum capacity, ideal generation, number of solar panels, number of inverters, and power consumption.

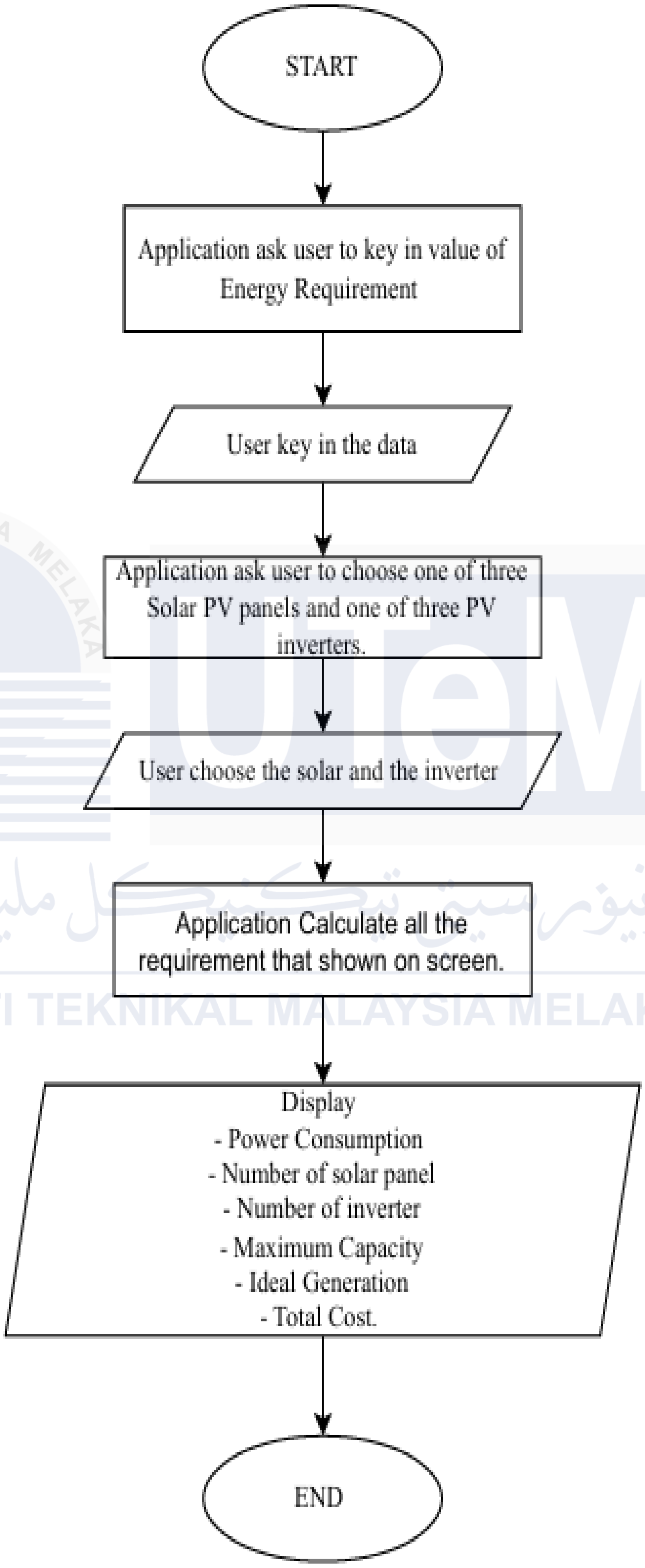


Figure 3.2 Project System Flowchart

3.4 Project architecture

The system prompts users for their desired energy consumption first, then guides them in creating their own solar energy (PV) system using an easy-to-use design procedure (as in Figure 3.2). After using this data, the system determines exactly how many solar panels and inverters are needed to meet those energy needs. It then displays the proposed equipment for PV solutions that are specifically tailored to the needs of the user. As well as the costs that will be required by the user in this solar PV installation process.

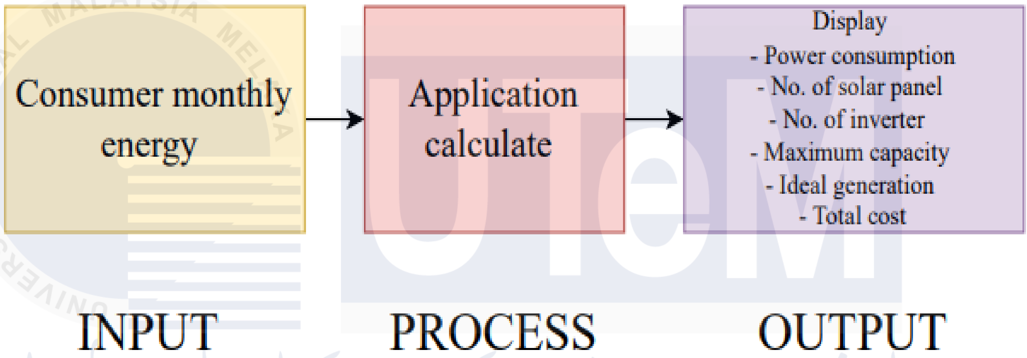


Figure 3.3 Block diagram of the project

3.5 Software of the project

Excel's HLOOKUP function is an effective tool for finding values in tables by scanning horizontally across the top row and returning values from that same column in each row. "H" stands for "horizontal" in HLOOKUP. HLOOKUP is the function of choice when you have a table with comparison values arranged in a row across the top and you need to get data from the rows below. For example, you may use HLOOKUP to discover and retrieve details for a certain product in a dataset where multiple goods are listed in the first row and their relevant details, such as price, quantity, and supplier, are in the rows beneath.

The value the user is looking for (lookup_value), the range of cells containing the data (table_array), the row number from which to retrieve the value (row_index_num), and an optional range_lookup argument to indicate whether the user wants an exact match, or an approximate match are the four pieces of information needed to use the HLOOKUP function. HLOOKUP will locate the closest match that is less than or equal to the lookup_value if the user sets range_lookup to TRUE or leaves it empty. HLOOKUP will only discover an exact match if the user sets it to FALSE; if not, it will return an error. When working with huge datasets where it is impractical to manually search for data, this method is quite helpful. HLOOKUP improves data retrieval activities' accuracy and efficiency [28].

Excel's VLOOKUP function is an effective tool that lets users look for a certain value in a column and then get the value from the matching row. Consider a scenario where a user has a lengthy list of workers, each with their names and ID numbers listed in separate columns. VLOOKUP must be used if the user wishes to locate the name of the employee associated with a certain ID. The value you're seeking, the range in which the data is situated, the column number from which to extract the value, and whether the user wants an exact match, or an approximate match are the four components that make up the function's operation. Thus, VLOOKUP (lookup_value, table_array, col_index_num, [range_lookup]) is the essential formula. When [range_lookup] is set to false, VLOOKUP searches for a precise match to lookup_value.

A user searching for ID number 123 in a database with names in the second column and ID numbers in the first would use the formula =VLOOKUP (123, A2:B100, 2, FALSE). This instructs Excel to search the range A2:B100 for 123 and to return the value from the range's second column when it does. The value from B10 will be returned if row 10 has the number 123. Excel will presume you want an approximate match if you use TRUE for [range_lookup] or ignore it. In this case, sorting the first column in ascending order is necessary. Instead of obtaining precise figures, this is helpful for locating ranges or categories, such as tax brackets or shipping prices [29].

The computer language known as VBA, or Visual Basic for programs, is used to automate activities in Microsoft Office programs. A function in VBA is a kind of procedure that does a certain job and then returns a result. A function can be used to carry out computations, operate with dates and times, or modify strings; in contrast to a subroutine, which carries out operations without returning a value, a function can provide results that can be utilized elsewhere in the code.

In VBA, the function keyword should be used first, followed by the function name and parenthesis to define a function. The user can specify parameters, or inputs, that the function will utilize to carry out its job, inside parenthesis. The user must write the code that comprises the function's body, ending with End Function once the function has been defined. The function runs and returns a value when the user calls it from another location in the VBA code, providing any required parameters. The function named Add Numbers in this example takes two inputs, number 1 and number 2, and returns the total of these two numbers. The user may then use this function in code in the same way that they would utilize Excel's built-in functions. Because they let users write reusable code, functions in VBA are useful tools that improve program efficiency and ease of maintenance. The function named Add Numbers in this example takes two inputs, number 1 and number 2, and returns the total of these two numbers. After that, users may include this function in their code in the same way that they would with native Excel functions. VBA functions are useful tools because they let you construct reusable code, which improves the effectiveness and maintainability of your projects.

3.6 Project interface

This section will explain the project interface (as shown in figure 3.3). In the display, the user must key in the energy consumption for the month used. Then they must choose one of three types of solar PV that are set up on the display. They also must choose one of four types of inverters. Lastly, they must click the calculation box to display all the data, such as power consumption, number. of solar panels, total cost, etc.

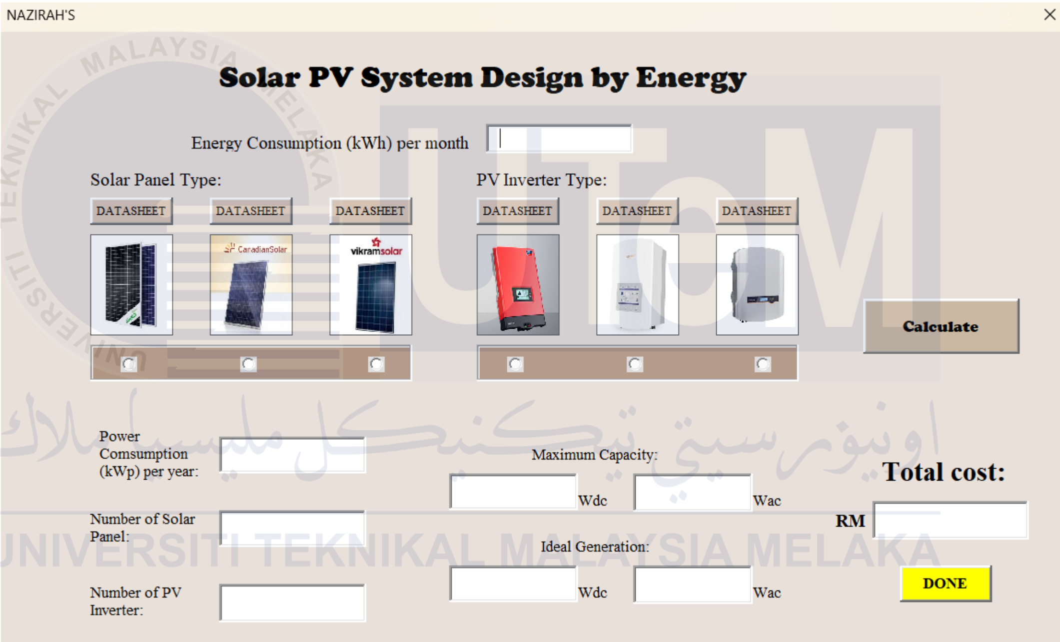


Figure 3.4 Project interface

3.7 Setup of Project

The procedures used to construct the project's application will be covered in this part. Launching Microsoft Excel is the initial step in setting up the project. The Microsoft Excel spreadsheet's layout is displayed in figure 3.4.

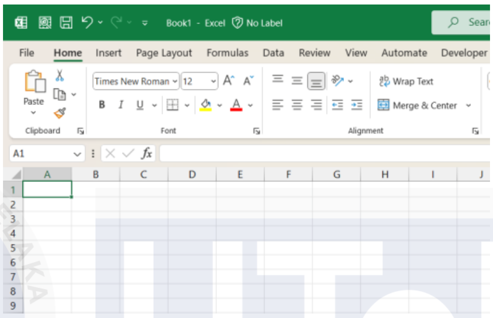


Figure 3.5 Step 1

Next, insert all the datails required on the spreadsheet as shown in fegure 3.6. As mentioned, details are based on the datasheet of three specific models of solar panels anf PV inverters.

JINKO SOLAR 78HL4-BDL 635 Watt		SUNNY BOY 3000HF	
Power Output STC (Pnom) [Wp]	635	Rated Output power [W]	3000
Temperature Coefficients of Pmax [%/°C]	-0.29	Max Efficiency [%]	96.3
Voltage at Pmax [V]	47.86	Recommanded max PV power [Wp]	3150
Current at Pmax [A]	13.27	Max. Input Voltage [V]	700
Open Circuit Voltage (Voc) [V]	57.21	Rated Input Voltage [V]	530
Short Circuit Current (Isc) [A]	13.92	Max. input current per MPPT [A]	15
Efficiency [%]	22.72	Max. short circuit current [A]	15
VIKRAM SOLAR SOMERA VSM.385 Watt		SOLIS RHI-4.6K-48ES-5G	
Power Output STC (Pnom) [Wp]	385	Rated Output power [W]	4600
Temperature Coefficients of Pmax [%/°C]	-0.39	Max Efficiency [%]	97.5
Voltage at Pmax [V]	40.3	Recommanded max PV power [Wp]	8000
Current at Pmax [A]	9.56	Max. Input Voltage [V]	600
Open Circuit Voltage (Voc) [V]	48.9	Rated Input Voltage [V]	330
Short Circuit Current (Isc) [A]	10.14	Max. input current per MPPT [A]	11
Efficiency [%]	19.84	Max. short circuit current [A]	17.2
CANADIAN SOLAR HiDM CS1U-420MS		SUNGROW SG5K-D	
Power Output STC (Pnom) [Wp]	420	Rated Output power [W]	5000
Temperature Coefficients of Pmax [%/°C]	-0.37	Max Efficiency [%]	98.4
Voltage at Pmax [V]	44.9	Recommanded max PV power [Wp]	5000
Current at Pmax [A]	9.37	Max. Input Voltage [V]	600
Open Circuit Voltage (Voc) [V]	53.8	Rated Input Voltage [V]	360
Short Circuit Current (Isc) [A]	9.8	Max. input current per MPPT [A]	20
Efficiency [%]	20.4	Max. short circuit current [A]	24

Figure 3.6 Step 2

In Microsoft Excel, select the "Development" tab from the Visual Basic extension located at the upper right corner. The creation of the project dashboard requires Visual Basic.

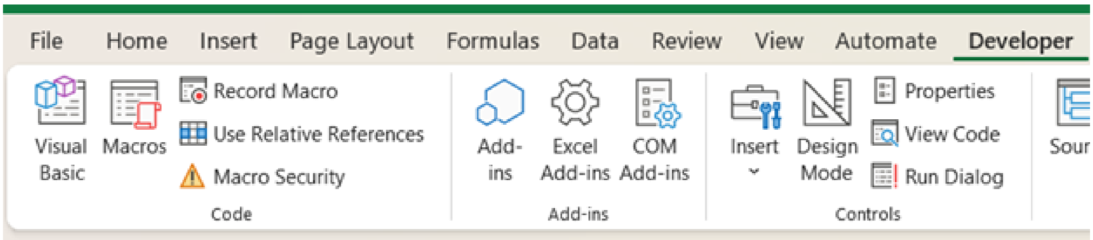


Figure 3.7 Step 3

Next, the Microsoft Visual Basic program layout that appears in figure 3.6 when the "Visual Basic" option from the "Development" taskbar is selected. The "canvas" for creating the dashboard will be displayed (as shown in figure 3.8).

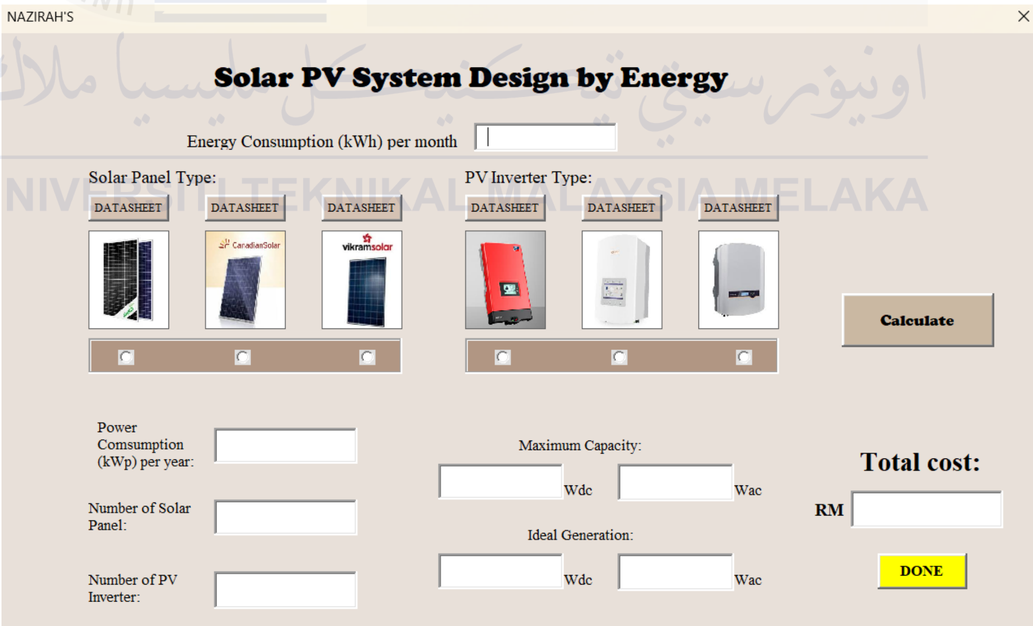


Figure 3.8 Step 4

Subsequently, after launching and creating a project in Visual Basic, select the "Userform" icon located in the second row of the program (as shown in figure 3.9).

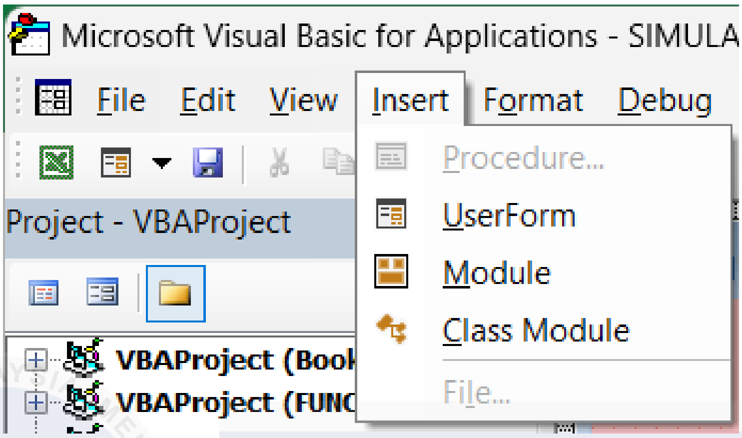


Figure 3.9 Step 5

The user form will then appear, as shown in figure 3.10. The user form serves as an empty canvas for creating dashboards.

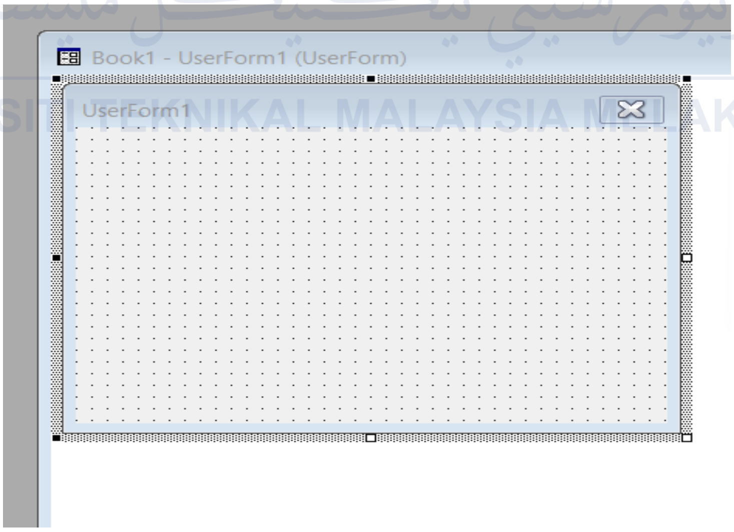


Figure 3.10 Step 6

Next, as seen in Figure 3.11, a toolbox pop-up is displayed to alter the userform. There are numerous choices in this toolbox to modify the Userform dashboard.

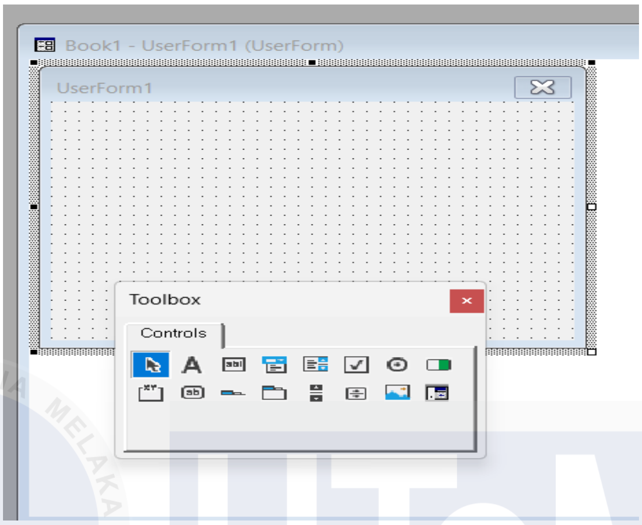


Figure 3.11 Step 7

Subsequently, the "Label" option is chosen to be included in the Userform (see figure 3.12). The type of data that needs to be entered and displayed is "Label.".

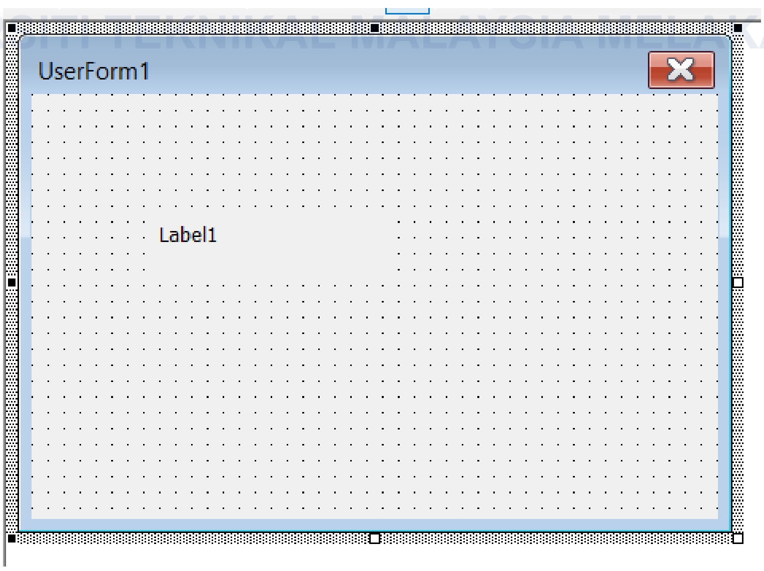


Figure 3.12 Step 8

Next, "Textbox" is inserted beside "Label," and a further set of "Label" and "Textbox" is added beneath the initial set. (as seen in picture 3.113) "Textbox" is where the result of the computation is shown.

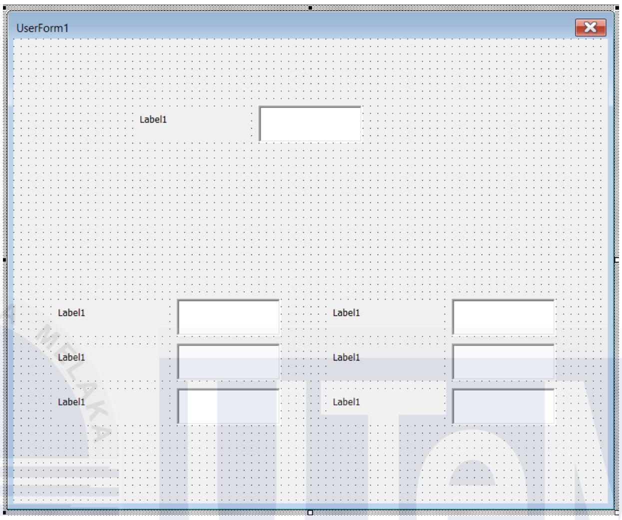


Figure 3.13 Step 9

Subsequently, "CommandButton" is placed in figure 3.14 to indicate that the value to be added in the two "Textboxes" should begin to be calculated. To perform the computation, code will be added to the "CommandButton.".

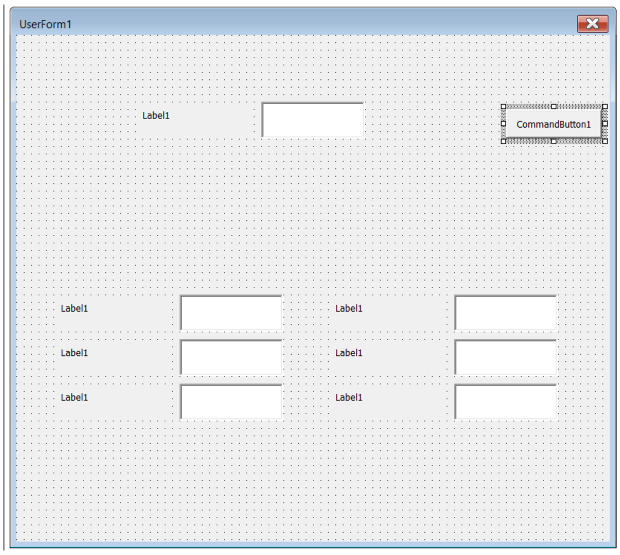


Figure 3.14 Step 10

The last "Label" is then inserted, and it will show the outcome at the end (as seen in figure 3.15). The outcome that is shown will include all the user-input data as well as monthly energy consumption calculations.

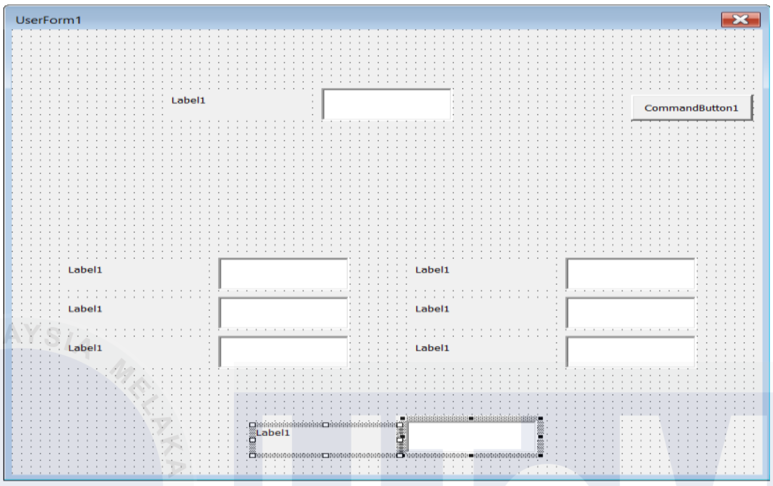


Figure 3.15 Step 11

The "CommandButton" is double-clicked in figure 3.14 to access the VBA coding. This is to ensure there are no coding errors before performing any calculations. There will be a comparison between the generated and manual computations.

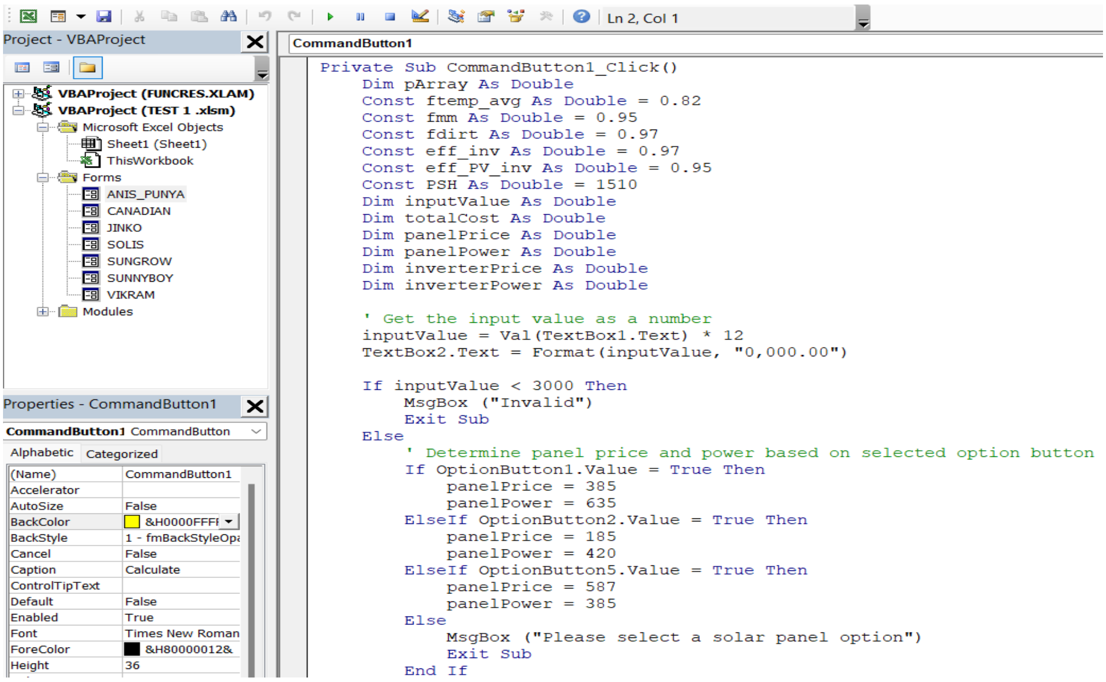


Figure 3.16 Step 12

Next, all the "Lable," "Textbox," and "CommandButton" are renamed appropriately in figure 3.17. This is to ensure that the text is readable and clear.

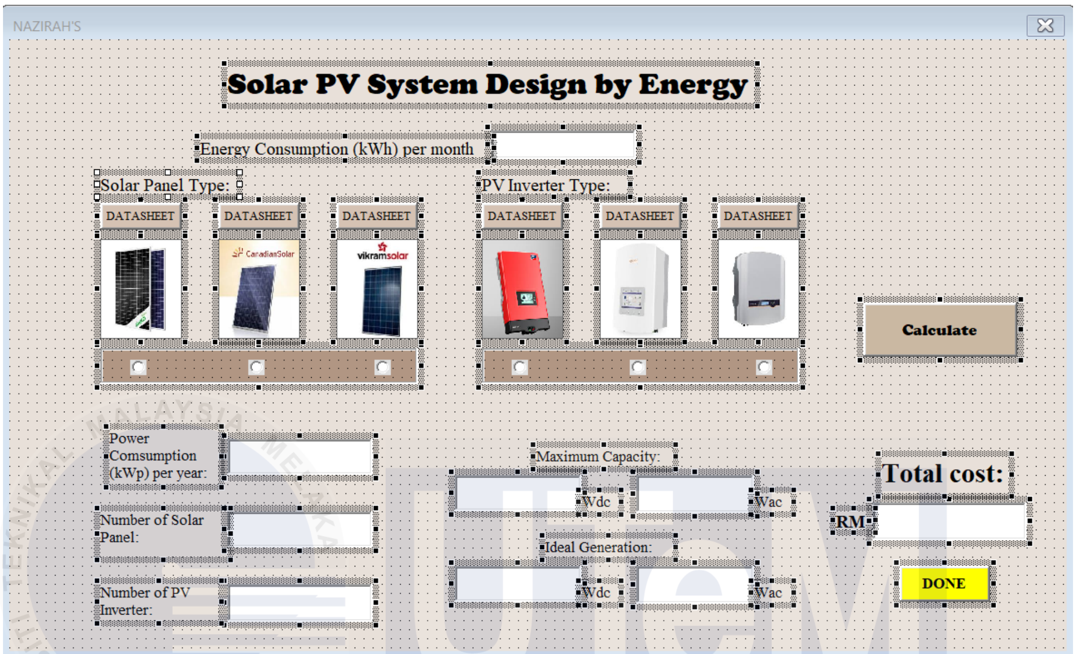
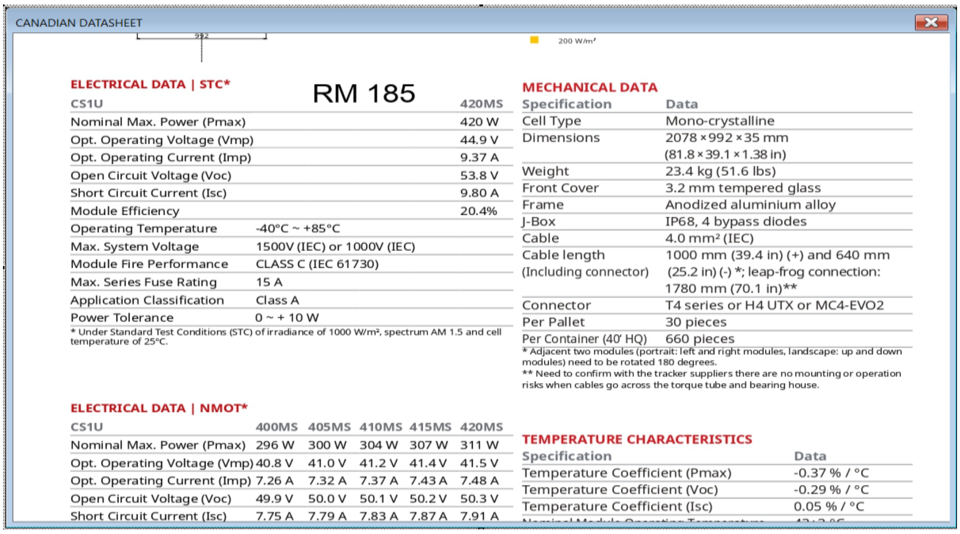


Figure 3.17 Step 13

Next, in Figure 3.18 another userform is created to insert the datasheet of solar panel. To insert the datasheet image, click on "Picture" and ulpoad the datasheet image. Datasheets are important to be displayed to make sure that the details entered in Excel spreadsheet are the same.


CANADIAN DATASHEET

200 W/m²

ELECTRICAL DATA | STC*

RM 185

CS1U		420MS
Nominal Max. Power (Pmax)		420 W
Opt. Operating Voltage (Vmp)		44.9 V
Opt. Operating Current (Imp)		9.37 A
Open Circuit Voltage (Voc)		53.8 V
Short Circuit Current (Isc)		9.80 A
Module Efficiency		20.4%
Operating Temperature	-40°C ~ +85°C	
Max. System Voltage	1500V (IEC) or 1000V (IEC)	
Module Fire Performance	CLASS C (IEC 61730)	
Max. Series Fuse Rating	15 A	
Application Classification	Class A	
Power Tolerance	0 ~ + 10 W	

* Under Standard Test Conditions (STC) of irradiance of 1000 W/m², spectrum AM 1.5 and cell temperature of 25°C.

ELECTRICAL DATA | NMOT*

CS1U	400MS	405MS	410MS	415MS	420MS
Nominal Max. Power (Pmax)	296 W	300 W	304 W	307 W	311 W
Opt. Operating Voltage (Vmp)	40.8 V	41.0 V	41.2 V	41.4 V	41.5 V
Opt. Operating Current (Imp)	7.26 A	7.32 A	7.37 A	7.43 A	7.48 A
Open Circuit Voltage (Voc)	49.9 V	50.0 V	50.1 V	50.2 V	50.3 V
Short Circuit Current (Isc)	7.75 A	7.79 A	7.83 A	7.87 A	7.91 A

MECHANICAL DATA

Specification	Data
Cell Type	Mono-crystalline
Dimensions	2078 × 992 × 35 mm (81.8 × 39.1 × 1.38 in)
Weight	23.4 kg (51.6 lbs)
Front Cover	3.2 mm tempered glass
Frame	Anodized aluminium alloy
J-Box	IP68, 4 bypass diodes
Cable	4.0 mm² (IEC)
Cable length (Including connector)	1000 mm (39.4 in) (+) and 640 mm (25.2 in) (-) *; leap-frog connection: 1780 mm (70.1 in)**
Connector	T4 series or H4 UTX or MC4-EVO2
Per Pallet	30 pieces
Per Container (40' HQ)	660 pieces

* Adjacent two modules (portrait: left and right modules, landscape: up and down modules) need to be rotated 180 degrees.
** Need to confirm with the tracker suppliers there are no mounting or operation risks when cables go across the torque tube and bearing house.

TEMPERATURE CHARACTERISTICS

Specification	Data
Temperature Coefficient (Pmax)	-0.37 % / °C
Temperature Coefficient (Voc)	-0.29 % / °C
Temperature Coefficient (Isc)	0.05 % / °C

Figure 3.18 Step 14

Next, figure 3.19, a coding is made under the button of “DATASHEET” be on top the solar panel and PV inveter image. This makes sure that the datasheet can only be viewed whrn clicking on the buttom and will display in another userform.

```
Private Sub CommandButton2_Click()
Me.Hide

Dim frmTwo As New JINKO
frmTwo.Show


End Sub
```

Figure 3.19 Step 15

The project taskbar is displayed in figure 3.20, with the "play" button on the top of the Visual Basic software pressed. This is to ensure that the Excel Spreadsheet can display the dashboard.

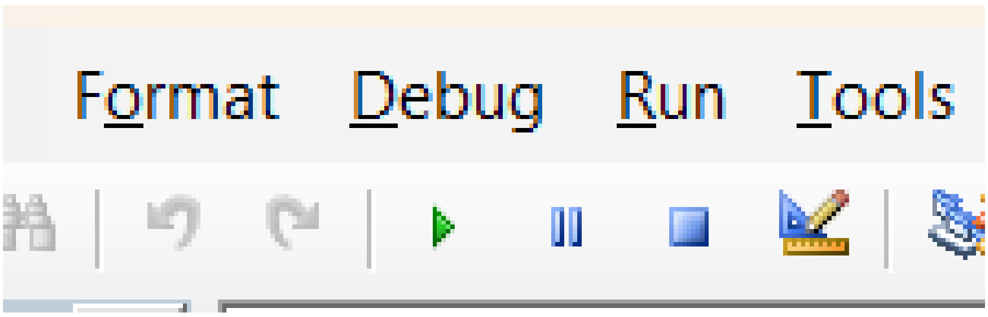


Figure 3.20 Step 16

Next, as shown in Figure 3.21, an Excel spreadsheet, and a pop-up Userform are presented by the application's dashboard. An execution is deemed successful when the dashboard is visible.

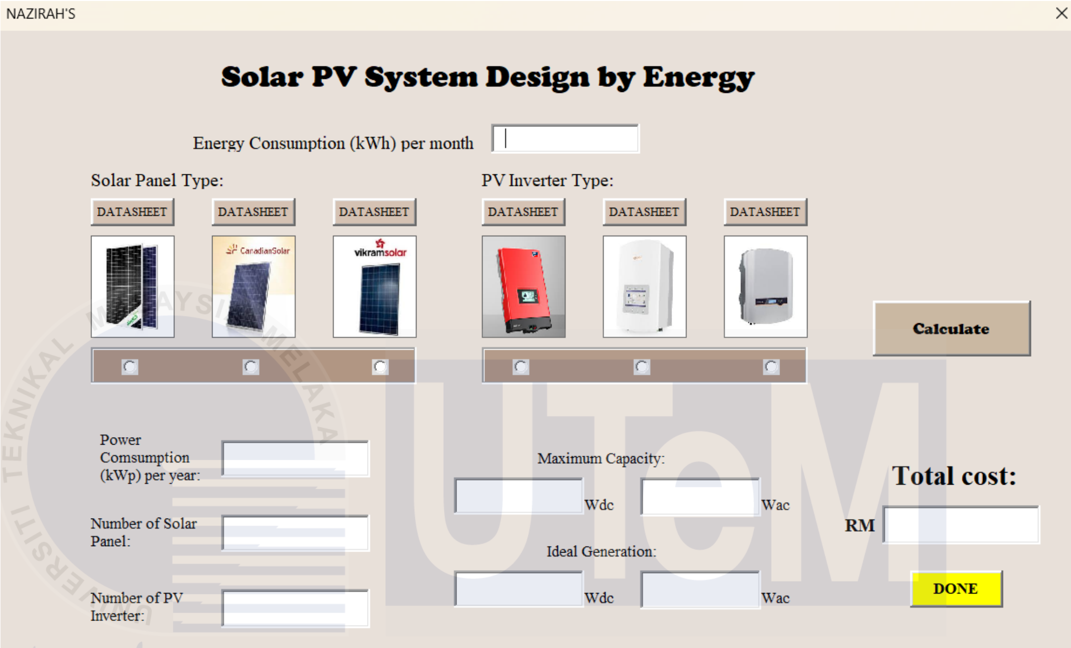


Figure 3.21 Step 17

Click the Form Control button next to the Visual Basic icon, then place the button on the Excel sheet to extract the Visual Basic Dashboard into Microsoft Excel. The application is prepared for testing after the step above. Finally, the Excel spreadsheet is used to produce the dashboard. To verify that the output produced matches the numbers in the spreadsheet, as illustrated in Figure 3.22, the values are input in accordance with the spreadsheet.

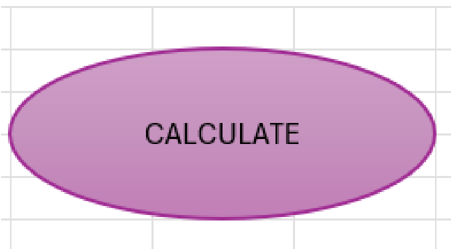


Figure 3.22 Step 18

Finally, the Excel Spreadsheet is used to produce the dashboard. To test it, enter the values, and the result appears as Figure 3.23 illustrates. The values are derived via human computations and VBA coding.

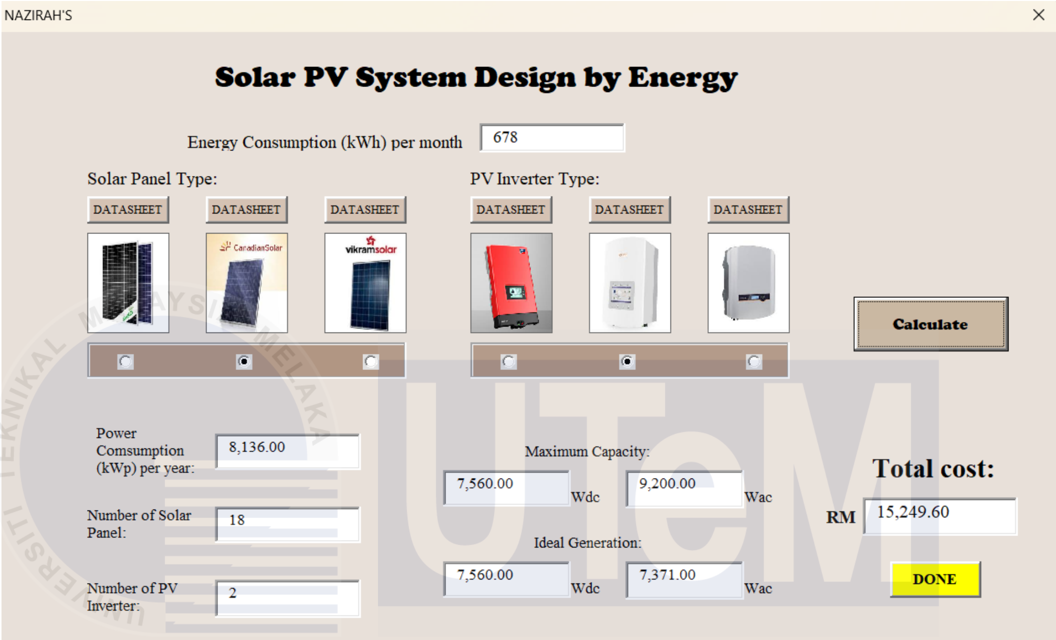


Figure 3.23 Step 19

3.8 Gantt Chart

The Gantt chart ensures that the project stays on track by accurately showing the progress of the project schedule in terms of tasks and weeks. When time management is planned, it is more beneficial and efficient.

Table 3.1 Shows the tasks or activities and duration to completed BDP 1

No.	Task	PSM1														PSM2													
	Weeks	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
1	Briefing for PSM 1 by JK PSM, FTKEE																												
2	Project Title Conformation and Registration																												
3	Briefing with Supervisor																												
4	Study the Project Background																												
5	Drafting Chapter 1: Introduction																												
6	Task progress evaluation 1																												
7	Drafting Chapter 2: Literature Review																												
8	Table of Summary Literature Review																												
9	Drafting Chapter 3: Methodology																												
10	Work on the Software/Hardware																												
11	First Draft submission to Supervisor																												
12	Task progress evaluation 2																												
13	Submission Report to the Panel																												
14	Presentation of BDP1																												
15	Drafting Chapter 4: Analyze Data and Result																												
16	Data Analyze and Result																												
17	Record the Result																												
18	Drafting Chapter 5: Conclusion and Recommendation																												
19	Compiling Chapter 4 and Chapter 5																												
20	Submit Latest Report to Supervisor																												
21	Finalize the Report																												
22	Presentation of BDP2																												

3.9 Summary

This chapter was used to develop the solar PV system design application, focusing on creating a user-friendly and efficient tool using Excel-based VBA. The process began with defining objectives, gathering data on solar panels and inverters, and reviewing relevant literature. The system workflow involves users inputting their energy consumption and selecting from pre-defined solar panel and inverter options. The application then calculates and displays results, including system requirements and costs, using Excel’s VLOOKUP function for accurate data retrieval. The interface is designed for simplicity, featuring textboxes, labels, and command buttons, with a secondary form for datasheet verification. Extensive testing with various inputs confirmed the system's accuracy, reliability, and error-handling capabilities. A Gantt chart outlines the project timeline, ensuring efficient task management. This methodology integrates automation, data accuracy, and user-focused design, achieving the project’s goal of simplifying solar PV adoption and promoting renewable energy use.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter will outline the project's development and showcase its outcomes. The entire system, including the yearly power consumption and the consumption range, will be covered in this chapter. The anticipated results and constraints will also be covered in this chapter. This chapter shows how to test and analyze applications, as well as how to use variations in input parameters to show the application's influence and the output result.

4.2 Results and Analysis for difference input.

The designed program makes it easier to calculate the amount of power used each month. The user chooses "calculate" after entering the monthly energy usage of electrical equipment. The power use for the rest of year will be shown on the dashboard. To get accurate results, a user who wants to manually calculate the entire system must follow the right steps. The project was likewise subjected to the formula. It saves time to use this program rather than manual techniques. But the monthly power usage needs to be more than or equivalent to <1000 Wp. The factors that need to be considered when manually calculating the steps are all displayed in the calculations below. Although all these steps can be omitted when using the built-in program, certain settings are necessary.

4.2.1 Condition 1: Invalid Input (alphabet and symbol)

This area contains the entry of numerical values. anytime a user type of any character or any other symbol that is not a number in any text box whether it be text one, text two, or all of it. An "Invalid: Please enter a valid numeric value" pop-up will therefore show up. Figures 4.1 and 4.2 show the results for entering the numbers.

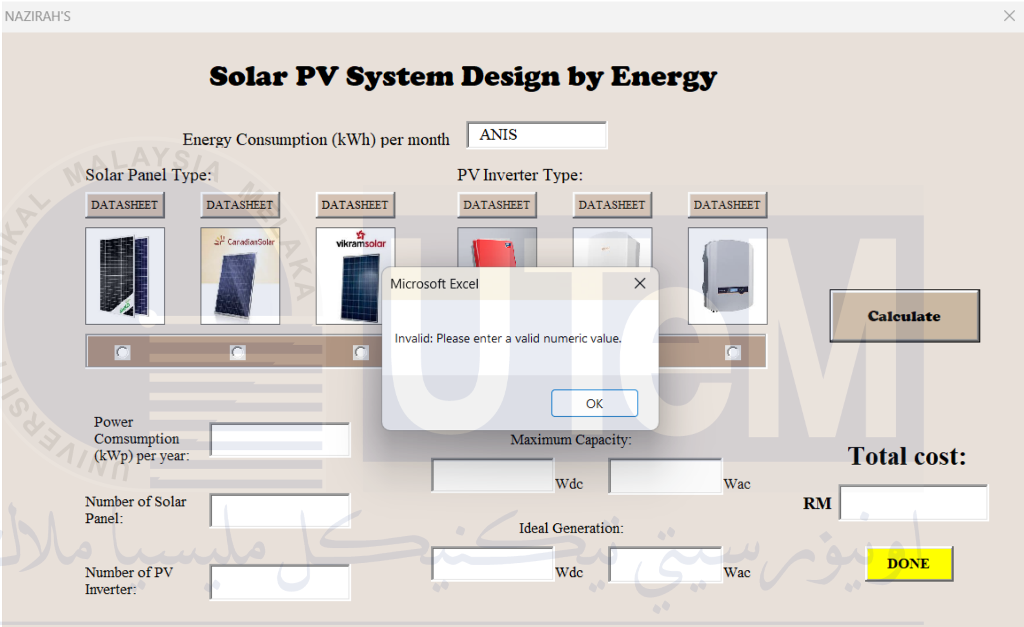


Figure 4.1 Shows the example of invalid message 1

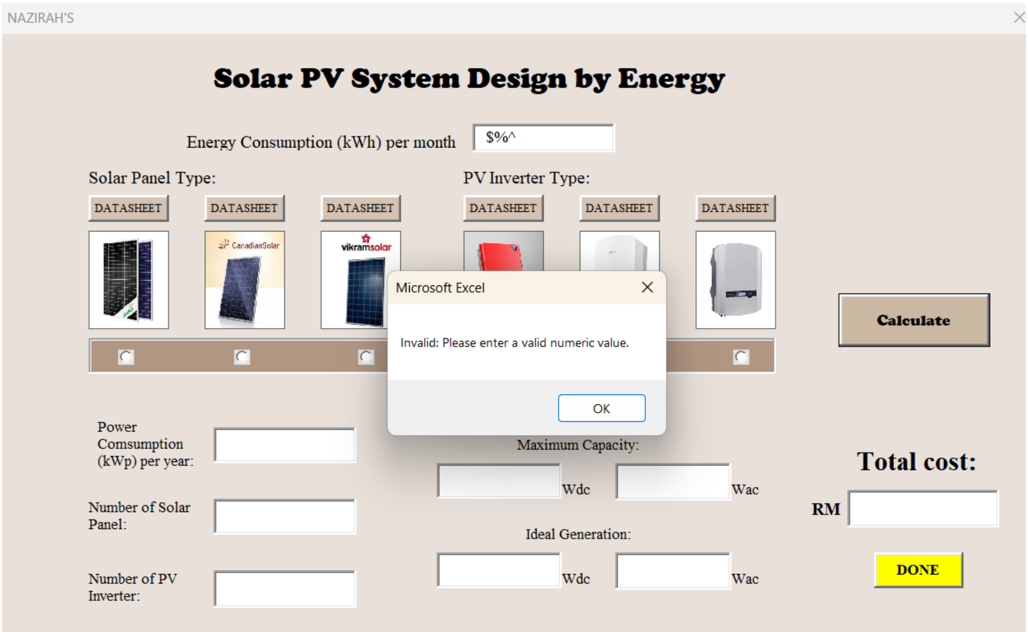


Figure 4.2 Shows the example of invalid message 2

4.2.2 Condition 2: Less than allowable capacity

Values are entered and calculated in this subsection. It will display the year energy use of the user along with a tiny range. Able to protect the system. The outcomes of entering these values are displayed in Figures 4.3 and 4.4.

$$\textit{Power consumption per year} = \textit{Energy consumption per month} \times 12 \quad (4.1)$$

Customers include 67 Wh in their monthly energy use, as shown in Figure 4.3. The user then enters their usage. Finally, the user enters the electronic device's 30 days of use. As a result, the application power consumption (kWp) per year will be displayed as 804Wp. This is the result from the application's verification of accurate calculations.

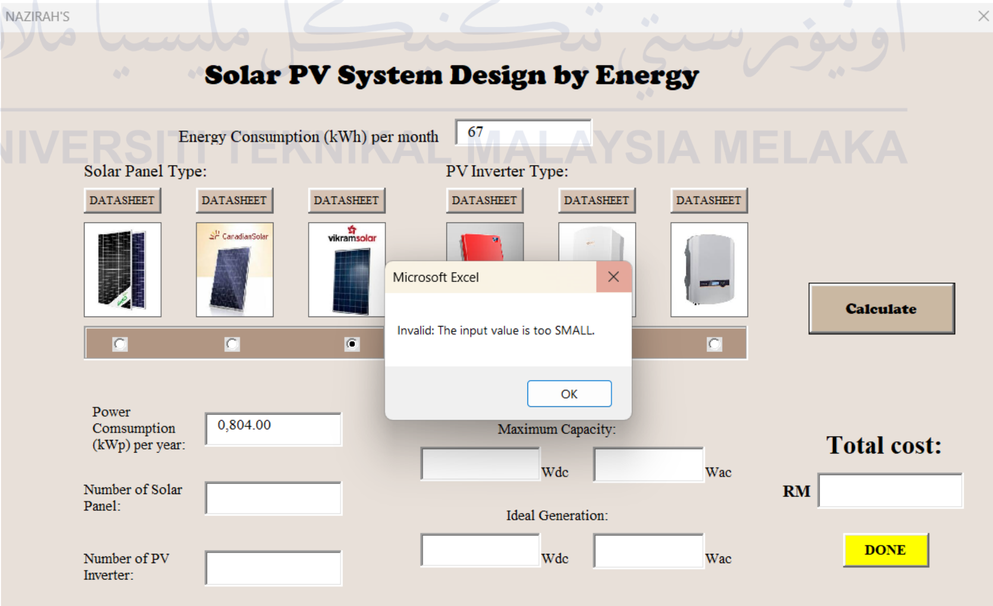


Figure 4.3 Show the result

$$67kWh \times 12 = 804Wp \quad (4.2)$$

Figure 4.4 illustrates how 167 watts are used by the user monthly. This means that 2004 kWp will be displayed as the application year power use (kWp). These results confirm the accuracy of the application's calculations.

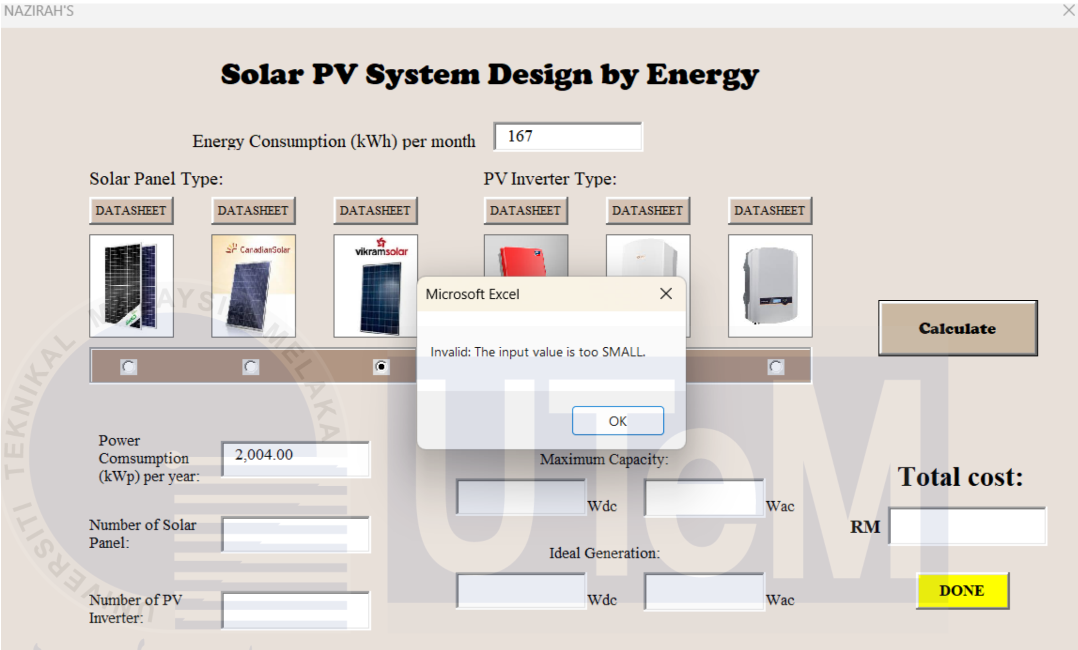


Figure 4.4 Show the result

$$167kWh \times 12 = 2004Wp \tag{4.3}$$

4.2.3 Condition 3: Selection of one solar PV and one inverter

The essential computations for developing a solar energy system are outlined by the presented formula. To estimate yearly usage, the monthly energy use is multiplied by twelve. The yearly energy usage is then divided by several efficiency factors and the peak sun hours (PSH) to get the array size (Parray). By dividing the array size by the power of a single solar panel, the number of solar panels is determined. Similarly, dividing the array size by the power of a single inverter yields the number of PV inverters needed. The number of units multiplied by the power rating of each solar panel and inverter yields the maximum capacity of each. The same formula is used to determine the optimal generating capabilities for the inverters and solar panels. The cost of the panels and inverters is added, and a 20% markup is then used to determine the system's overall cost. These equations offer a methodical way to plan a solar system that can supply a home's energy requirements.

$$\textit{Power consumption per year} = \textit{Energy consumption per month} \times 12 \tag{4.4}$$

$$Parray = \frac{Power\ Consumption\ per\ year}{ftemp\_avg \times fmm \times fdirt \times eff\_inv \times eff\_PV\_inv \times PSH} \tag{4.5}$$

$$Number\ of\ solar\ panel = \frac{Parray}{solar\ panel\ power} \tag{4.6}$$

$$Number\ of\ PV\ inverter = \frac{Parray}{PV\ inverteer\ power} \tag{4.7}$$

$$\textit{Maximum capacity of solar panel, Wdc} = \textit{number of solar panel} \times \textit{solar panel power} \tag{4.8}$$

$$\text{Maximum capacity of PV inverter, } W_{ac} = \text{number of PV inverter} \times \text{PV inverter power} \tag{4.9}$$

$$\text{Ideal generation for solar panel, } W_{dc} = \text{number of solar panels} \times \text{solar panel power} \tag{4.10}$$

$$\text{Ideal generation of PV inverter, } W_{ac} = (\text{number of solar panels} \times \text{solar panel power}) \times \text{efficiency} \tag{4.11}$$

$$\text{Total cost} = ((\text{number of solar panel} \times \text{solar panel price}) + (\text{number Of PV inverter} \times \text{PV inverter price})) \times 1.2 \tag{4.12}$$

4.2.3.1 Select one of three solar panel (635W) and PV inverter (4600W)

Values are input and computed in this subsection. It will show the optimal generation's value, which can span the whole system. The results for entering these numbers are displayed in Figures 4.5

$$\textit{Power consumption per year} = \textit{Energy consumption per month} \times 12 \quad (4.13)$$

$$Parray = \frac{Power\ Consumption\ per\ year}{ftemp\_avg \times fmm \times fdirt \times eff\_inv \times eff\_PV\_inv \times PSH} \quad (4.14)$$

$$Number\ of\ solar\ panel = \frac{Parray}{Power\ Output\ (W)} \quad (4.15)$$

$$Number\ of\ PV\ inverter = \frac{Parray}{Rated\ Output\ Power\ (W)} \quad (4.16)$$

$$\textit{Maximum capacity of solar panel, Wdc} = \textit{number of solar panels} \times \textit{Power Output (W)} \quad (4.17)$$

$$\textit{Maximum capacity of PV inverter, Wac} = \textit{number of PV inverter} \times \textit{Rated Output Power (W)} \quad (4.18)$$

$$\textit{Ideal generation for solar panel, Wdc} = \textit{number of solar panels} \times \textit{Power Output (W)} \quad (4.19)$$

$$\textit{Ideal generation of PV inverter, Wac} = (\textit{number of solar panels} \times \textit{Power Output (W)}) \times \textit{efficiency} \quad (4.20)$$

$$\textit{Total cost} = ((\textit{number. of solar panel} \times RM^{***}) + (1\times\ RM^{****})) \times 1.2 \tag{4.21}$$

From Figure 4.5, the user inserts 497kWh as their monthly energy consumption. Therefore, it will display 5964kWp as the power consumption (kWp) per year. From the yearly power consumption, the application generates a calculation of 8 solar panels, 2 inverters, maximum capacity of 5080Wdc and 9200Wac, and ideal generation of 5080Wdc and 4953.00Wac and the total cost for the system is RM 14,949.60. This is the outcome of the application's correct calculation verification.

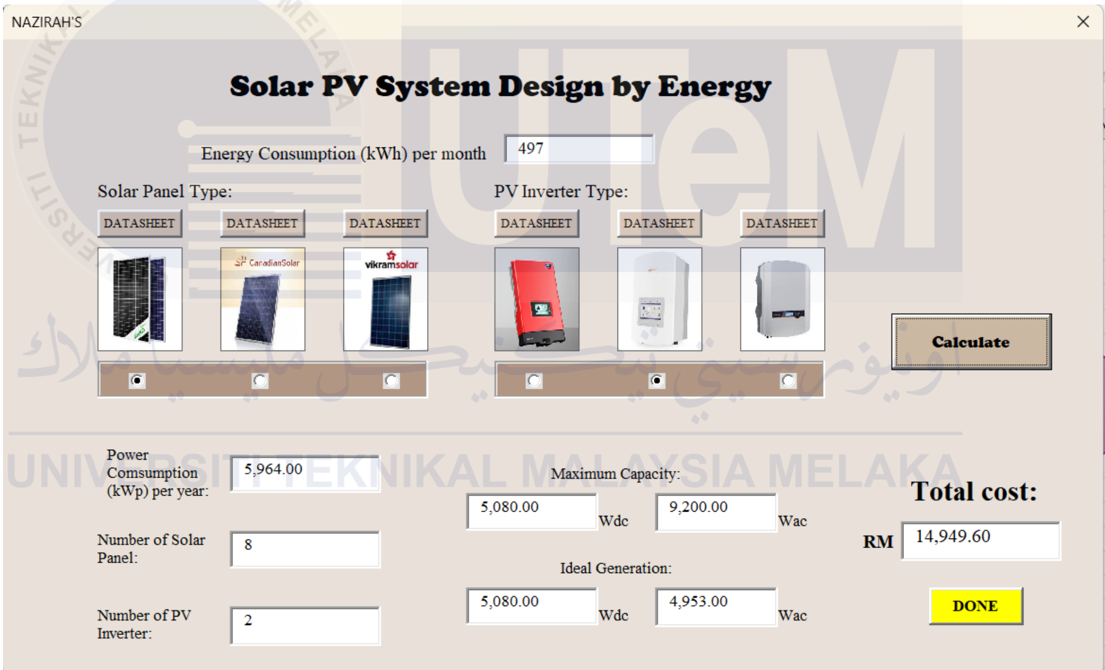


Figure 4.5 shows the result of ideal generation value lower than yearly power consumption.

$$497kWh \times 12 = 5964kWp \tag{4.22}$$

$$Parray = \frac{5964kWp}{0.82 \times 0.95 \times 0.97 \times 0.97 \times 0.95 \times 1510} = 5.6722kW \approx 5.672kW \tag{4.23}$$

Number of solar panels needed:

$$\frac{5.672kW}{635W} = 8.93$$
$$\approx 8\ modules \tag{4.24}$$

Number of PV inverter needed:

$$\frac{5.672kW}{4600W} = 1.23$$
$$\approx 2\ inverter \tag{4.25}$$

Maximum capacity for solar panels:

$$8 \times 635W = 5080.00Wdc \tag{4.26}$$

Maximum capacity for PV inverter:

$$2 \times 4600W = 9200.00Wac \tag{4.27}$$

Ideal generation for solar panel:

$$8 \times 635W = 5080.00Wdc \tag{4.28}$$

Ideal generation of PV inverter:

$$(8 \times 635W) \times 0.975 = 4953.00Wac \tag{4.29}$$

Total cost:

$$((8 \times RM385) + (2 \times RM4689)) \times 1.2 = RM14,949.60 \tag{4.30}$$

4.2.3.2 Select one of three solar panel (420W) and PV inverter (5000W)

The user enters 845kWh as their monthly energy usage from Figure 4.6. As a result, 10,140kWp will be shown as the annual power usage (kWp). The program calculates 22 solar panels, 2 inverters, a maximum capacity of 9240 Wdc and 5000 Wac, and an ideal generation of 9240 Wdc and 9092.16 Wac based on the annual power demand. The total cost of the system is RM 17,061.60. This is the outcome of proper computations being verified by the application.

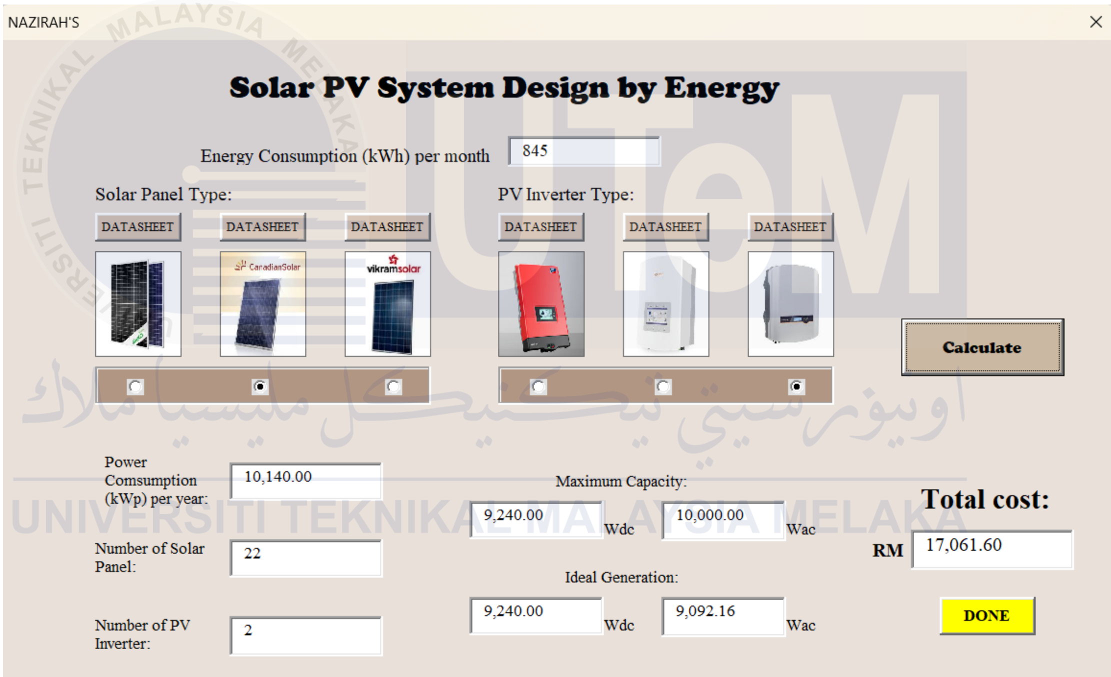


Figure 4.6 shows the result of ideal generation value lower than yearly power consumption.

$$845kWh \times 12 = 10140kWp \tag{4.31}$$

$$Parray = \frac{10140kWp}{0.82 \times 0.95 \times 0.97 \times 0.97 \times 0.95 \times 1510} = 9.6439kW \approx 9.644kW \tag{4.32}$$

Number of solar panels needed:

$$\frac{9.644kW}{420W} = 22.95$$
$$\approx 22\ modules \tag{4.33}$$

Number of PV inverter needed:

$$\frac{9.644kW}{5000W} = 1.92$$
$$\approx 2\ inverters \tag{4.34}$$

Maximum capacity for solar panels:

$$22 \times 420W = 9240.00Wdc \tag{4.35}$$

Maximum capacity for PV inverter:

$$2 \times 5000W = 10{,}000.00Wac \tag{4.36}$$

Ideal generation for solar panel:

$$22 \times 420W = 9240.00Wdc \tag{4.37}$$

Ideal generation of PV inverter:

$$(22 \times 420W) \times 0.984 = 9{,}0920.16Wac \tag{4.38}$$

Total cost:

$$((22 \times RM185) + (2 \times RM5074)) \times 1.2 = RM17{,}061.60 \tag{4.39}$$

4.2.3.3 Select one of three solar panel (385W) and PV inverter (3000W)

Based on Figure 4.7, the customer inputs 9876kWh as their monthly energy use. Consequently, 118512kWp will be displayed as the yearly power consumption (kWp). Based on the yearly power requirement, the software determines the optimal generation of 112420Wdc and 108,260.46Wac, 292 solar panels, 38 inverters, and a maximum capacity of 112420Wdc and 114,000Wac. The system would set you back RM 583,891.20 in total. The application's verification of precise computations produced this outcome.

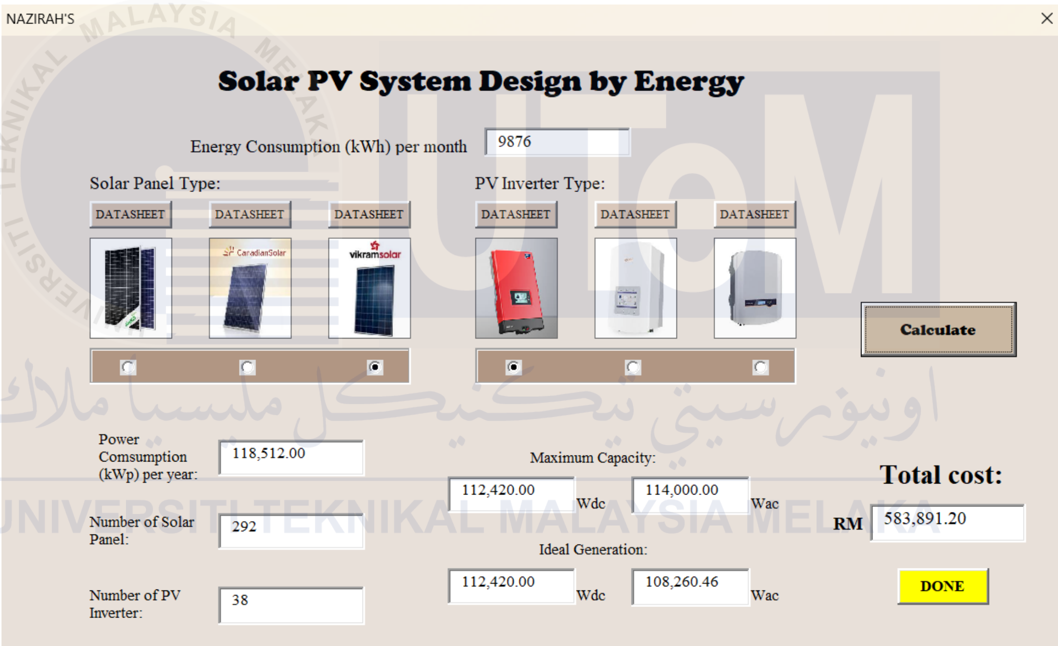


Figure 4.7 shows the result of ideal generation value lower than yearly power consumption.

$$9876kWh \times 12 = 118512kWp \qquad (4.40)$$

$$Parray = \frac{118512kWp}{0.82 \times 0.95 \times 0.97 \times 0.97 \times 0.95 \times 1510} = 112.7147kW \approx 112.715kW \qquad (4.41)$$

Number of solar panels needed:

$$\frac{112.715kW}{385W} = 292.77 \approx 292\ modules \tag{4.42}$$

Number of PV inverter needed:

$$\frac{112.715kW}{3000W} = 37.57 \approx 38\ inverters \tag{4.43}$$

Maximum capacity for solar panels:

$$292 \times 385W = 112420Wdc \tag{4.44}$$

Maximum capacity for PV inverter:

$$38 \times 3000W = 114000Wac \tag{4.45}$$

Ideal generation for solar panel:

$$292 \times 385W = 112420Wdc \tag{4.46}$$

Ideal generation of PV inverter:

$$(292 \times 385W) \times 0.963 = 108{,}260.46Wac \tag{4.47}$$

Total cost:

$$((292 \times RM587) + (38 \times RM8294)) \times 1.2 = RM583{,}891.20 \tag{4.48}$$

4.2.4 Condition 4: Small range to big range energy consumption

Values are input and computed in this subsection, including the optimal generating capacity, which might not be enough to meet the energy needs of the entire system. One of the main challenges in this process is coding the annual power usage range, which is not constant and might vary. Another issue is that, because of inverter losses and monthly energy usage estimates, the optimal generation for a PV inverter may not be able to fulfill the annual energy demand. One way to overcome these constraints and create the best PV system possible is to enter the greatest monthly energy usage figure for more precise computations. To give a thorough financial evaluation, this part also computes the overall system cost, including for components, installation, and maintenance.

4.2.4.1 Low Power Consumption

The monthly energy use of 329 kWh is derived from Figure 4.8 and is taken as monthly average. It may be less than 329kWh in some months. The annual power usage is 3948 kWp, and 3175 watts is the optimal generation for a photovoltaic inverter. Consequently, 3175Wac is enough and capable of covering the entire system. Errors within the acceptable range are those that are 10% or less. The error percentage in this instance is 19.57%.

Power consumption per year – ideal generation for PV inverter = Difference

$$= 3948 - 3175.00 \qquad (4.49)$$
$$= 773$$

$$\frac{Difference}{Power\ consumption\ per\ year} \times 100 = \frac{868.25}{3948} \times 100 \qquad (4.50)$$

$$= 19.57\ \%$$

Based on Figure 4.8, the customer inputs 329kWh as their monthly energy use. 3948 kWh will thus be shown as the yearly power use. Based on the yearly power use, the software determines the ideal generation of 3175Wdc and 3124.20Wac, five solar panels, one inverter, and a maximum capacity of 3175Wdc and 5000Wac. The system would set you back RM8398.80 in total. In this setup, a Jinko Solar brand solar panel, one of the three available has been chosen, and a Sungrow brand PV inverter has been picked.

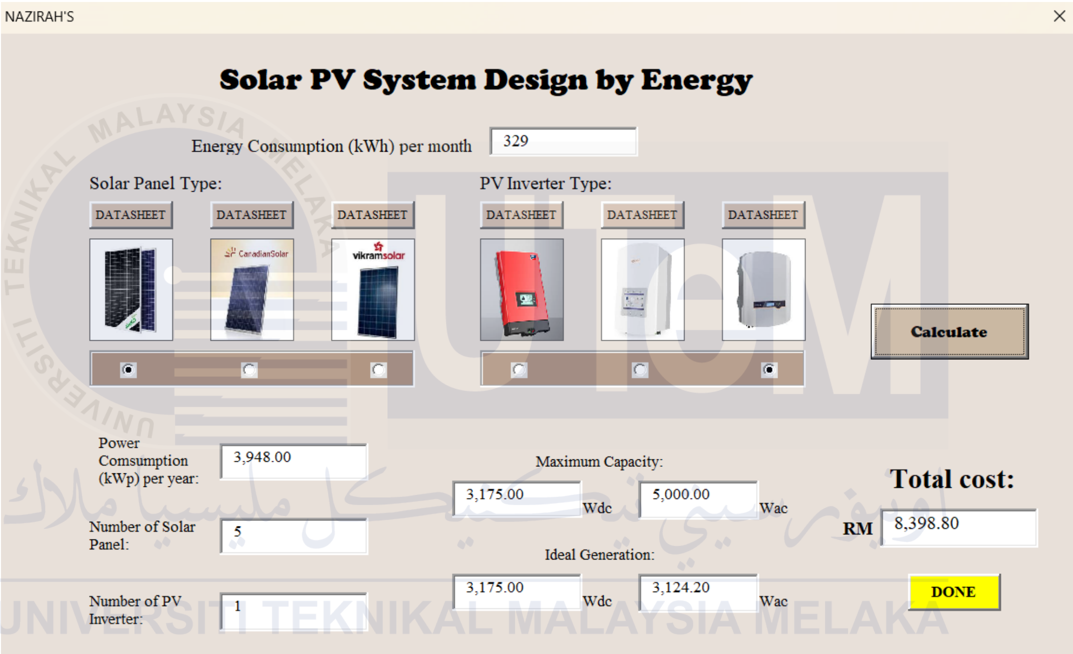


Figure 4.8 shows the result of ideal generation lower than yearly power consumption

$$329kWh \times 12 = 3948kWp \tag{4.51}$$

$$Parray = \frac{3948kWp}{0.82 \times 0.95 \times 0.97 \times 0.97 \times 0.95 \times 1510} = 3.7548kW \approx 3.755kW \tag{4.52}$$

Number of solar panels needed:

$$\frac{3.755kW}{635W} = 5.91 \approx 5\ modules \tag{4.53}$$

Number of PV inverter needed:

$$\frac{3.755kW}{5000W} = 0.75 \approx 1\ inverter \tag{4.54}$$

Maximum capacity for solar panels:

$$5 \times 635W = 3175Wdc \tag{4.55}$$

Maximum capacity for PV inverter:

$$1 \times 5000W = 5000Wac \tag{4.56}$$

Ideal generation for solar panel:

$$5 \times 635W = 3175Wdc \tag{4.57}$$

Ideal generation of PV inverter:

$$(5 \times 635W) \times 0.984 = 3124.20Wac \tag{4.58}$$

Total cost:

$$((5 \times RM385) + (1 \times RM5074)) \times 1.2 = RM8398.80 \tag{4.59}$$

4.2.4.2 Medium Power Consumption

Figure 4.8 shows that the customer's monthly energy usage is 572 kWh. The annual electricity usage will thus be shown as 6864kWh. The program calculates the maximum capacity of 6300 Wdc and 4600 Wac, 15 solar panels, 2 inverters, and the optimal generation of 6300 Wdc and 6142.50 Wac based on the annual power usage. Your total expenditure using the system would be RM14,583.60.80. One of the three available solar panels, from the Canadian Solar brand, has been selected for this arrangement, together with a PV inverter from the Solis brand. This is what happens after the application confirms that the calculations are correct.

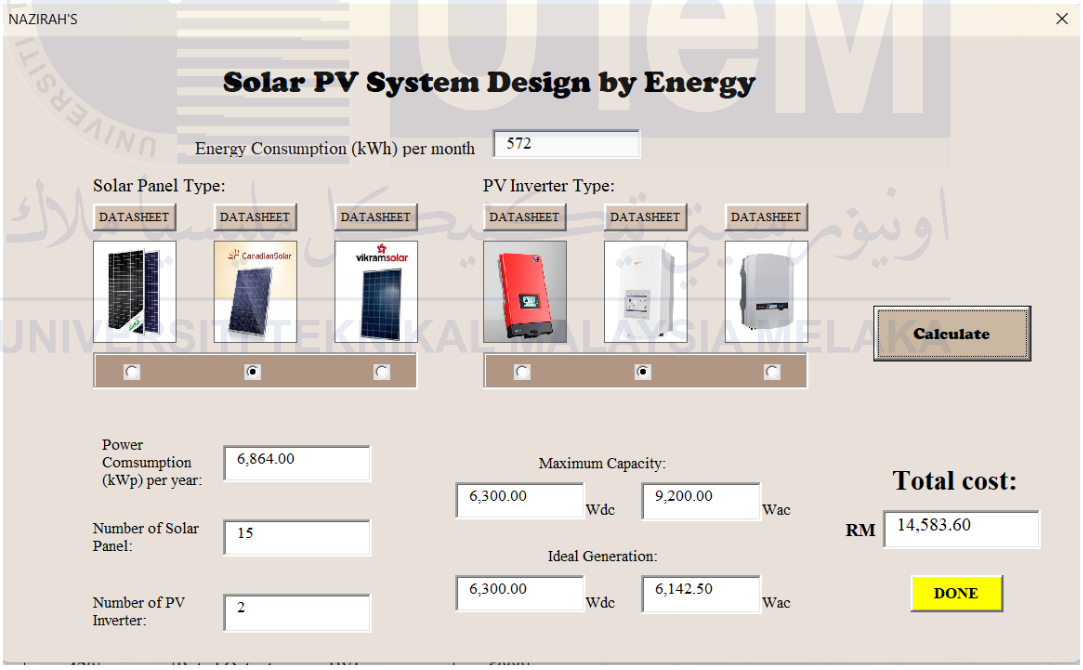


Figure 4.9 shows the result of ideal generation lower than yearly power consumption

Power consumption per year – ideal generation fot PV inverter = Difference

$$= 6864 - 6300$$
$$= 564 \quad (4.60)$$

$$\frac{Difference}{Power\ consumption\ per\ year} \times 100 = \frac{564}{6864} \times 100 \tag{4.61}$$

= *8.22 %*

Power consumption per year = Energy consumption per month × 12

$$572kWh \times 12 = 6864kWp \tag{4.62}$$

$$Parray = \frac{6864kWp}{0.82 \times 0.95 \times 0.97 \times 0.97 \times 0.95 \times 1510} = 6.5282kW \approx 6.528kW \tag{4.63}$$

Number of solar panels needed:

$$\frac{6..528kW}{420W} = 15.54 \approx 15\ modules \tag{4.64}$$

Number of PV inverter needed:

$$\frac{6.528kW}{4600W} = 1.42 \approx 2\ inverters \tag{4.65}$$

Maximum capacity for solar panels:

$$15 \times 420W = 6300Wdc \tag{4.66}$$

Maximum capacity for PV inverter:

$$2 \times 4600W = 9200Wac \tag{4.67}$$

Ideal generation for solar panel:

$$15 \times 420W = 6300Wdc \tag{4.68}$$

Ideal generation of PV inverter:

$$(15 \times 420W) \times 0.975 = 6142.50Wac \tag{4.69}$$

Total cost:

$$((15 \times RM185) + (2 \times RM4689)) \times 1.2 = RM14{,}583.60 \tag{4.70}$$

4.2.4.3 High-Power Consumption

According to Figure 4.10, the client uses 742 kWh of electricity per month. As a result, the annual power use will be shown as 8904kWh. Based on the yearly power demand, the software determines the ideal generation of 8085 Wdc and 7785.86 Wac, as well as the maximum capacity of 9000 Wac and 8085 Wdc, 21 solar panels, and 3 inverters. The entire amount you would have to pay to use the system is RM44,650.80. For this setup, a PV inverter from the SMA and one of the three solar panels from the Vikram Solar brand have been chosen.

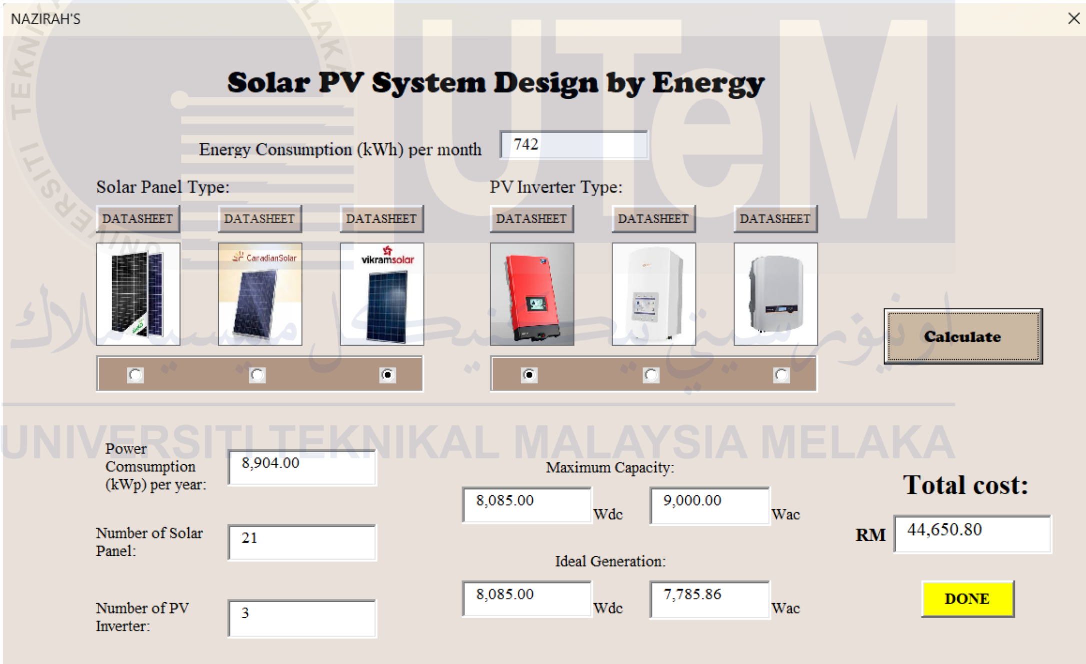


Figure 4.10 shows the result of ideal generation lower than yearly power consumption

Power consumption per year – ideal generation for PV inverter = Difference

$$= 8904 - 8085 = 819 \quad (4.71)$$

$$\frac{Difference}{Power\ consumption\ per\ year} \times 100 = \frac{819}{8904} \times 100 \quad (4.72)$$

$$= 9.19\ \%$$

$$\textit{Power consumption per year} = \textit{Energy consumption per month} \times 12$$

$$742kWh \times 12 = 8904kWp \tag{4.73}$$

$$Parray = \frac{8904kWp}{0.82 \times 0.95 \times 0.97 \times 0.97 \times 0.95 \times 1510} = 8.4684kW \approx 8.468kW \tag{4.74}$$

Number of solar panels needed:

$$\frac{8.468kW}{385W} = 21.99 \approx 21\ modules \tag{4.75}$$

Number of PV inverter needed:

$$\frac{8.468kW}{3000W} = 2.82 \approx 3\ inverters \tag{4.76}$$

Maximum capacity for solar panels:

$$21 \times 385W = 8085Wdc \tag{4.77}$$

Maximum capacity for PV inverter:

$$3 \times 3000W = 9000Wac \tag{4.78}$$

Ideal generation for solar panel:

$$21 \times 385W = 8085Wdc \tag{4.79}$$

Ideal generation of PV inverter:

$$(21 \times 385W) \times 0.963 = 7785.86Wac \tag{4.80}$$

Total cost:

$$((21 \times RM587) + (3 \times RM8294)) \times 1.2 = RM44{,}650.80. \tag{4.81}$$

4.3 Summary

This chapter focuses on the results and analysis of the solar PV system design application, showing how it performs with different user inputs. The program simplifies monthly power consumption calculations by allowing users to input their energy usage, which is then processed to display results like yearly power usage, the number of solar panels and inverters needed, system capacity, and costs. It handles various scenarios, such as invalid inputs, low consumption values, and high consumption needs, ensuring accurate calculations and error handling. The program also calculates the optimal generation of solar panels and inverters, factoring in efficiency, environmental conditions, and power requirements. Through different case studies, it verifies the accuracy of the calculations, comparing results with manual formulas. The results demonstrate how the application helps users choose the right solar PV and inverter combinations, showing clear outputs for each consumption level, from small to high power needs. Overall, this chapter highlights the system's reliability, efficiency, and ability to simplify complex solar energy system design, providing accurate and practical solutions for various energy requirements.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter will give an overview of the project, covering its history, research on earlier journal publications, development methods, and project outcomes. This chapter also outlines the project's potential and future work that can be carried out.

5.2 Conclusion

This chapter 1 explains the background which in the background talks about the history of solar PV installations in Malaysia and why VBA is part of this project. in the same chapter, The Problem Statement of why the project was started is also stated in this chapter by giving some questions along with 3 Sustainable Development Goals which are very closely related to the problems found in this project. The third item contained in this chapter is the objective of the project. only three objectives are listed to achieve the goals of the project to be produced. The last thing in this chapter is a sketch. There are several scopes that have been listed according to the advice given by the project supervisor.

In chapter 2, the first thing listed is about the introduction that will be in the rest of this chapter. the second point is about the background study of the project which contains the history of the solar PV system created, the necessary components, a summary of the types of solar used, examples of data sheets used, how to connect inversion type funds, types of solar PV connections, some good structures for solar installation, cable sizes used for solar installation and inversion, types of batteries that are suitable for solar use, solar structures carefully explained in this chapter and the percentage of solar energy that will be produced in the future. next, there are several Web-based PV designs and applications also recounted in this chapter. This is because there are many types of web sites that exist but are less explored by users. This chapter also explains a little bit about the use of VBA. most in this chapter lists a list of previous work by other individuals. There are 12 lists closest to the resulting project. Finally, there are 20 comparative lists of works by individuals dating to different times and years that are relatively close to the project.

This chapter 3 outlines the systematic approach used in developing the project, "Development of Solar PV System Design by Energy Requirement Using Excel-Based VBA." The methodology begins with identifying the project objectives and establishing a workflow to achieve the desired outcomes efficiently. The chapter explains the steps involved in designing the solar PV system application, from data collection to software development, testing, and evaluation. The development process starts with creating a conceptual framework for the application. This includes defining the problem, setting project goals, reviewing relevant literature, and gathering data on solar panels and inverter models. Data collection involves obtaining technical specifications for three models of solar panels and three inverters, which are essential inputs for the system. The process flow begins with the user inputting their monthly energy consumption. The application prompts the user to select a solar PV panel and inverter model from pre-defined options. Using these inputs, the system performs calculations to determine the required number of panels and inverters, system capacity, and associated costs. The results are displayed in a user-friendly interface, allowing users to make informed decisions. The system architecture integrates Excel's VBA capabilities with VLOOKUP functions for efficient data retrieval and calculations. The VBA scripting automates repetitive tasks, reduces errors, and ensures precise outputs. The application interface includes textboxes for user inputs, labels for data descriptions, and command buttons for performing calculations. The HLOOKUP function is used to find values in horizontal data arrays, while VLOOKUP handles vertical searches for data matching specific criteria. These functions enable the system to process large datasets quickly and accurately, ensuring reliable outputs. VBA functions are also utilized to simplify and organize the code, enhancing maintainability and performance. The interface is designed to be intuitive and user-friendly. It guides users through each step, from entering energy consumption data to selecting system components. Visual elements like dashboards and datasheets provide clarity and allow users to verify data. A secondary user form is included to display datasheet images, ensuring accuracy in input details. The application was tested using four types of input small, medium, large, and invalid to validate its accuracy, reliability, and error-handling capabilities. The testing process ensured that the application produces consistent results that align with manual calculations, verifying its precision and usability. The chapter also includes a Gantt chart to highlight the project's timeline and progress. Each task is scheduled to ensure efficient completion, from data collection to software testing and finalization. By combining Excel's computational functions with VBA automation, this methodology ensures that the project meets its objectives of providing an accessible, reliable, and accurate tool for solar PV system design. The systematic approach detailed in this chapter underpins the project's success and supports its goal of promoting renewable energy adoption.

In this chapter 4, presents the outcomes of the solar PV system design application and discusses its performance under various conditions and inputs. The program streamlines the calculation of monthly and annual energy consumption, allowing users to input daily energy usage and receive accurate results, including the number of solar panels and inverters required, the system's maximum and ideal capacity, and the overall cost. The system's functionality is tested across four main conditions. First, it effectively handles invalid inputs (e.g., letters or symbols) by displaying error messages that prompt users to enter valid numeric values. Second, the application verifies calculations for low power consumption scenarios, ensuring the results align with energy needs while minimizing errors. Third, for medium and high-power consumption, it calculates the necessary components and costs based on user inputs, factoring in environmental and efficiency variables. Finally, the system is tested with a variety of pre-defined solar PV panels and inverters, showcasing its ability to recommend optimal configurations for specific energy demands. The application utilizes formulas to determine the total power requirement, array size, number of solar panels and inverters, and total cost, including a 20% markup for installation and maintenance. For example, it calculates energy consumption per year by multiplying monthly usage by 12, then determines the array size using factors like peak sun hours and system efficiency. The results include the maximum and ideal generation capacities of solar panels and inverters, ensuring that the system can meet energy requirements accurately. Testing scenarios demonstrate the program's reliability and accuracy. For small consumption cases, the system verifies low-cost solutions, while for medium and high consumption, it calculates detailed configurations, showing the scalability of the program. The application simplifies decision-making by providing clear recommendations, allowing users to compare configurations and costs effectively. Overall, this chapter demonstrates that the program is a reliable and user-friendly tool for designing solar PV systems, offering accurate calculations, robust error handling, and practical solutions for different energy needs. It highlights how the program saves time, reduces manual calculation errors, and enables users to transition to solar energy confidently.

This project, which involves creating a VBA system to handle interactions between two UserForms, offers several advantages. It allows seamless navigation between forms, ensuring a smooth user experience by enabling image display and interactivity. The project also provides flexibility in customizing the forms, making it easy to adapt for various purposes such as showcasing data or visuals. However, there are some disadvantages, including the potential for errors like the "Run-time error '400'" if forms are not managed properly, leading to issues when trying to display multiple forms simultaneously. Additionally, handling multiple UserForms requires careful attention to avoid complications such as form visibility conflicts or incorrect closing procedures, which could affect the overall functionality.

5.3 Future Works

Future work, building on this project, might turn the dashboard into a data visualization powerhouse that reveals intricate patterns of energy usage. The program may also be extended to forecast the best energy production based on surface area, letting users input the measurements of their spaces and get suggestions for optimizing things like solar panel arrangement. Additionally, the tool could allow users to explore options for adding more solar panels and inverters, enabling them to choose from a variety of photovoltaic (PV) systems to scale their energy setup. These developments set this project up for success in becoming a valuable resource for individuals and businesses aiming to maximize energy consumption, enhance scalability, and make informed decisions.

5.4 Project Potential

This project focuses on creating an innovative application tailored for solar PV installers to optimize customer engagement by accurately determining the required system size based on their annual energy usage. This tool not only simplifies decision-making for customers but also opens opportunities for collaboration with companies registered under the Sustainable Energy Development Authority (SEDA), making it a scalable and marketable solution in the renewable energy sector.

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APPENDICES

Appendix A Example of Appendix A

```
Private Sub CommandButton1_Click()
    Dim pArray As Double
    Const ftemp_avg As Double = 0.82
    Const fmm As Double = 0.95
    Const fdirt As Double = 0.97
    Const eff_inv As Double = 0.97
    Const eff_PV_inv As Double = 0.95
    Const PSH As Double = 1510
    Dim inputValue As Double
    Dim totalCost As Double
    Dim panelPrice As Double
    Dim panelPower As Double
    Dim inverterPrice As Double
    Dim inverterPower As Double
    Dim inverterCount As Double
    Dim efficiencyFactor As Double


    On Error GoTo ErrorHandler


    If IsNumeric(TextBox1.Text) Then
        inputValue = Val(TextBox1.Text) * 12
        TextBox2.Text = Format(inputValue, "0,000.00")

        If inputValue < 3000 Then
            MsgBox "Invalid: The input value is too SMALL."
            TextBox2.Text = ""
            Exit Sub
        Else
            TextBox2.Text = Format(inputValue, "0,000.00")
        End If
    Else
        MsgBox "Invalid: Please enter a valid numeric value."
        TextBox2.Text = ""
        Exit Sub
```

Appendix B Example of Appendix B