Cape Peninsula
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TITLE OF THESIS: ASSESSING THE SUSTAINABILITY, COST-EFFECTIVENESS, AND ENVIRONMENTAL IMPACT OF SOLAR PV PANELS IN WESTERN CAPE, SOUTH AFRICA

by

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Faculty of Engineering and the Built Environment

Master of Engineering in Engineering Management

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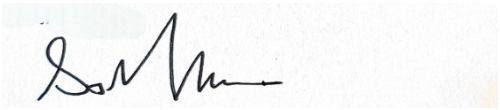
Date submitted: 02 October 2025

DECLARATION

I, Sue-Ann Sharlene, pronounce that the contents of this report embody my own unassisted labour, and the thesis has not formerly been giving in to for academic investigation towards any qualification. Moreover, it represents my own thoughts and not essentially individuals of the Cape Peninsula University of Technology.

Signed	**Date**
S.S. Muller	29 November 2024



LIST OF ABBREVIATIONS

- **PV**: Photovoltaic
- **SDG**: Sustainable Development Goal(s)
- **UN**: United Nations
- **UNMDGs**: United Nation Millennium Development Goals
- **DC**: Direct Current
- **SWHS**: Solar Water Heating System
- **CO_2**: Carbon dioxide
- **SO_2**: Sulphur Dioxide
- **NO_x**: Nitrogen Oxides
- **LIB ESS**: Lithium-ion Energy Storage System
- **USA**: United States of America
- **O&M**: Operation and Maintenance
- **TEU**: Twenty-foot Equivalent Unit
- **SPSS**: Statistical Packages for the Social Sciences
- **Std**: Standard

ABSTRACT

This report focused on evaluating the sustainability, cost-effectiveness, and environmental impact of solar Photovoltaic (PV) panels in Western Cape, South Africa. As the region increasingly turns to renewable source, it is significant to comprehend the complex implications of solar PV development. Therefore, primary objectives were to assess the costs, energy efficiency and environmental benefits of solar photovoltaic systems compared to traditional energy sources. Solar energy is a sustainable and indefinitely renewable energy resource which will never run out in billions of years. A mixed-method approach, merging quantitative analysis of data with qualitative stakeholder interviews in the energy sector was employed for the study. This research is expected to provide constructive insights into the economic feasibility and environmental benefits of solar energy and thereby inform plan decisions and promote sustainable energy practices in the Western Cape. The maximum value of the F-ratio was experiential in Environmental impact, measuring 231.789. The value explains that solar PV panels had an impact on the environment. The second highest F-ratio was observed on sustainability and maintenance being 152.135. Thus, solar PV panels impact on sustainability and maintenance was rated second.

ACKNOWLEDGEMENTS

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DEDICATION

I, Sue-Ann Sharlene Muller announce that this research is my personal effort and is a true replication of study performed by me. This study in full or part thereof has not been succumbed for examination for any degree at any other university/institution.

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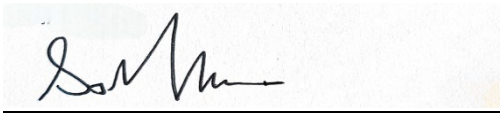
Signature: 

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This section intended to give a summary on the topic of survey, the general contextual on the thesis, which brings out the justification of carrying out the thesis, problem statement, that is the core of this report, research objectives, thesis questions, significance of the study as well as its delimitations.

1.2 Background of the study

In this contemporary era, the utilisation of machines has taken over the globe, whether utilised for need or as a luxury, this has posed an increase on energy consumption since the strategies require energy to complete tasks. Scientific community has been concerned approximately meeting an increasing global energy demand lacking inflicting conservational damage (Mohanty & Filho, 2012; Alejad et al., 2020). The utilisation of scarce conventional energy resources has posed a wreaking havoc on the environment and has resulted in its degradation. The biosphere is now facing different predicaments such as global warming, pollution, acid rain, as well as many other difficulties (Owuse et al., 2016). Therefore, it is essential to produce clean, green energy from renewable sources. One of the most promising environmentally friendly or rather, eco-friendly power sources is solar-powered energy among all as it is plentiful, unrestricted accessible and financial potential (Noorolahi et al., 2020).

The demand for energy will rise by about 56% by 2040, per study by Rahman et al. (2022). Emissions of greenhouse gases will rise in tandem increasing demand for energy if the existing fossil fuel-based policy is maintained. Therefore, in order to prevent these consequences, climate change mitigation is required. Renewable energy sources are crucial for attaining carbon impartiality and dropping global warming also climate change. It is believed that renewable oomph sources are inexpensive, maintainable and free. It is believed that renewable energy sources are cost-effective, sustainable, and free. Therefore, to fight climate change, decarburise the energy

industry, renewable energy must be used. However, weather patterns and upcoming climate changes will determine the availability of solar, hydroelectric, and wind.

The global shift to renewable energy is accelerated through the pressing required to address environment change and achieve sustainable expansion in a period of ecological deterioration (IRENA, 2022). The sustainable energy forthcoming is now conceivable because the growth of green constructions, green energy also power use in manufacturing, green transport, falling renewable energy expenses rising energy efficiency continuous technological advancements and educated legislation. Although this change is beginning to take hold, it has to quicken in order to support sustainable development worldwide. Ali et al., (2023) defines sustainable energy as type of energy that can be exploited repeatedly deprived of a danger of it becoming exhausted, expired or disappeared. Renewable energy use takes a significant positive influence on environment. When energy is reliable, sustainable, and affordable, it meets the number seven, purpose to assurance that everybody has admission to modern, economical, reliable and sustainable energy.

First, solar energy is mostly plentiful renewable energy, and the sun emits it at a very high pace, making it a potential best option for the future of the planet (Kannan & Vakeesan, 2016). Two of the many types of solar energy that the earth has are light and heat. Cloud preoccupation, reproduction and dispersion cause bulk of this energy to be vanished during travel. Due to its abundance in nature and free availability, studies have shown that solar energy force the uses to meet the world's energy requirements (El-Khozondar & El-batta, 2022). Second, compared to other energy sources, it generates solid and rising production efficiency, making it a prospective global energy source. Two important aspects that touch the effectiveness of the solar PV panel sector are dispersion and intensity of solar radiation. These two factors differ greatly between nations.

In addition, solar energy stays that sustainable fresh energy source which is becoming more affordable every day. Transmission won't be feasible unless investment prices decrease by majority to compensate for the high charge of transmission, even if solar power has a lot of potential over much of Africa (Sanoh et al., 2014). An efficient way to generate energy from solar radiation that has no environmental risk and has a low carbon impact is caused solar power. In reality, solar technology might harness the power of sunshine to generate large-scale energy supply (Ramakumar & Hughes, 1981). Diversifying the nation's energy mix using solar energy

technologies would raise living standards and encourage sustainable economic growth. (Timilsina et al., 2012).

Energy and particularly renewable resources, are essential for addressing a number of global issues related to sustainable development, such as poverty, climate change and food insecurity. Even though it was not listed as one technologies for accomplishing MDGs, renewable energy indirectly helped the United Nations achieve its goals, especially in zones like domestic application, well-being, poverty reduction and education in Africa (UN, 2015). As a result, African governments lacked the drive to advance renewable projects. In contrast to the MDGs, one of the seventeen Sustainable Development Goals (SDGs) in the 2030 outline is specifically focused on energy: SDG 7 is to "Ensure access to affordable, reliable, sustainable, and modern energy for all." As a result, the energy sector plays a vital character in reaching the SDGs.

Furthermore, the development of solar energy helps to reduce poverty, manufacturing production, transportation, health services and rural expansion while also encouraging environmental quality and sustainability (Rathore et al., 2018). It has been noted that the ambient temperature in developing countries been unceasingly increasing (Fadhlallah & Benhaji, 2020; Agbo et al., 2021). This highlights how important it is to use clean, renewable energy lowers the temperature. Evolving nations stand fortunate on possess sufficient resources for the production of unsoiled energy, that includes energy derived from sunshine. Therefore, using sunshine to produce electricity is known for example sun-based energy reception (Khalid et al., 2021). In countries that are still under-developed such as most African countries, households still heavily depend on non-renewable sources of energy for cooking purposes which come with health and environmental brushoffs.

Solar PV panels generally utilise heat energy through using the sunlight to produces energy (Mawire, 2009). There is increasing pressure to switch to more sustainable and affordable solar PV panels due to the increased demand on energy resources and the escalating cost of energy. This demand is due to the ever-growing population and scarcity of non-renewable resources. A solar panel or reflectors are typically used to gather and concentrate sunlight, which is then used to create heat for the solar PV sheets. Therefore, the thesis purposes to assess Sustainability, Cost-Effectiveness, and Environmental Impact of Solar PV panels in Developing Countries such as in Western Cape South Africa.

1.3 Problem statement

In underdeveloped nations like South Africa, the adoption and use of solar energy is at its peak due to technological advancement and the depletion of fossil fuels and this has resulted in poor energy supplies within the country. Moreover, population growth exerted more pressure on energy sources thereby depleting non-renewable sources of energy that have negative environmental and health impacts on society. In order for households to function properly, the use of solar PV panels is gaining its momentum. However, there is need to investigate if the use of solar PV panels is cheaper, eco-friendly and sustainable than usage of unrenewable source of energy. Given challenges, it is imperative for this thesis to assess the sustainability, cost-effectiveness also environmental impact of solar PV panels in the Western Cape. We are able to harness the energy through the sun and this is a great chance for developing nations. For more developed nations, which stand to gain from lower electricity costs over time, the market for solar power is growing. It also benefits the environment because it replaces the conventional, and actually detrimental, methods of producing energy. Although there are other renewable energy sources besides solar, solar is particularly useful in sunny regions with limited water and wind resources.

1.4 Objectives of the study

1.4.1 Research

This research purposes to evaluate sustainability, cost-effectiveness and environmental impact of solar PV panels within the context South Africa's status as a developing nation in the Western Cape.

Main objective of the thesis is to evaluate the sustainability, cost-effectiveness and environmental influence of solar PV panels in Western Cape.

1.4.2 Research Objectives

- To investigate environmental impacts of solar PV panels.
- To assess cost-effectiveness of using solar PV panels.
- To examine sustainability and maintenance requirements of solar PV panels.
- To contribute practical recommendations and strategies to develop the sustainability of solar appliance usage in Western Cape regions.

1.5 Research Questions

- What are key environmental impacts linked with usage of solar PV panels in Western Cape?
- How does cost effectiveness of using solar PV panels compare against traditional energy sources over the long-term?
- What sustainability reasons influence the acceptance and maintenance requirements of solar PV panels in Western Cape?
- What practical references can be made to enhance the sustainability and effectiveness of solar PV panels usage in the western cape?

1.6 Research Hypothesis

H_0: There is no positive impact that exist between solar PV panels on the environment, cost effectiveness and sustainability

H_1: There is a positive impact that exist between solar PV panels on the environment, cost effectiveness and sustainability.

1.7 Significance of the study

1.7.1 To organisations

Therefore, an anticipated that the study would investigate sustainability, cost-effectiveness, and environmental effects of solar PV panels. If the investigations point out that solar PV panels are not environmentally friendly, then the study will enable organisations to opt for other machines other than solar gadgets that are eco-friendly. Moreover, if the research outcomes denote that solar PV panels are very expensive and less sustainable, then organisations will look for other alternatives. This contemporary research will contribute largely to helping management through improving an effectiveness of solar PV panels.

1.7.2 To the Researcher:

The research will help the researcher to gain a knowhow on how to conduct research findings. This study may also allow the scholar to gain an in-depth information of sustainable, cost effective and

environmentally friendly are solar gadgets. Therefore, this will enable the researcher to generate solutions to problems associated with solar PV panels and as well as finding recommendations that are useful.

1.7.3 To Academic field

Since few studies have been conducted on economic viability, environmental and sustainability impact of solar photovoltaic panels in underdeveloped nations, the thesis resolves a significant influence on the academic community. Therefore, this current research will be a locus point or guiding principle to future researchers when conducting related research or studying the environmental stability of solar PV panels.

1.8 Assumptions of the study

The following are the assumptions of the thesis:

- **i)** The co-operation of company administration to allow access to company sensitive data sources for academic purposes; and
- **ii)** The wider research atmosphere remains stable and unmoved throughout the period of thesis study.

1.9 Delimitations of the study

The thesis is restricted to Cost effectiveness, sustainability and environmental factors posed by solar PV panels in countries such as South Africa. The study is centred only some households and companies situated in Cape Town Information and findings obtained may be related to other organisations and households throughout the cape region. This research study looked at the period from 2023 up to May 2024.

1.10 Limitations of the study

Confidentiality of information – Roughly of the evidence required by the investigator was considered highly private by organisations and households under study. Therefore, the researcher was limited to the information only available to the public.

Respondent non-cooperation: Because some respondents were unwilling to comply, the study could only use data from willing participants.

Travelling constrains – The researcher faced challenges in meeting targeted population due to high travelling costs.

1.11 Definition of key terms

Cost effectiveness describes how productive or effective something is in comparison to its cost. When a device is affordable, it offers good value for the money spent on it. Cost-effectiveness also refers to achieving quality outcomes at a reasonable price.

Sustainability is capacity to sustain a procedure over a lengthy period of time. Sustainability is frequently divided into three main ideas which are social, environmental and economic. Sustainable goals, such minimising their environmental impact and preservative resources. Sustainability means meeting present demands without sacrificing those of future generations while maintaining equilibrium between social well-being, environmental preservation, and economic progress.

Environmental impact is any change that a facility's operations, goods, or services have on the environment, whether that change be positive or negative.

To put it another way, it's the effect that human actions have on the environment. Most culture depend on significantly on energy, our energy use is often the primary source of concern.

Solar PV, solar photovoltaic based panels produce electricity to power Direct Current (DC) type of electrical devices.

1.12 Chapter outline

Chapter 1: Introduction

An introduction section highlights the background of the thesis, problem statement, study question, as well as research aims.

Chapter 2: Literature review

The chapter reviews what other literature states about cost effectiveness, sustainability and environmental impact of solar PV panels.

Chapter 3: Research Methodology

Through the discussion of research objectives, data collecting, target population, sample procedures, questionnaire design, methods of reliability, and data analysis methodologies, the chapter aims to quantify the cost-effectiveness, sustainability, and environmental impact of solar PV panels.

Chapter 4: Data presentation, Interpretation and analysis

Both questionnaire findings and the statistical analysis of the data are included in this chapter.

Chapter 5: Summary, Conclusion and Recommendations

This chapter summaries research results, recommendations and conclusions drawn as well. It also consists of several suggestions for future research opportunities.

1.13 Chapter summary

This chapter provided an overall introduction of the whole research project. This includes background of the study, research problem, objectives of research as well as research questions. It also covered significant of the study, limitations as well as delimitations of the study. There is also explanation of some key terms relevant uring the course of the study. The succeeding section relates to literature written by other authors pertaining the subject matter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The chapter highlighted local, international and regional literature on sustainability, cost-effectiveness and environmental impact of solar PV panels in the Western Cape. This chapter of thesis focuses on introduction of solar PV panels, concept of sustainability cost- effectiveness and environmental impact of solar PV panels.

2.2 Theoretical framework of the study

2.2.1 Concept of Sustainability

Sustainability is an encompassing ecological, social and economic innovations that uphold social justice and protect and enhance the environment Little et all (2016). Sustainable development starts to gain popularity after the 1987 journal of the World Commission on Environment and Development's (Holden et al., 2014). Sustainable development meets present and also requests without endangering the ability of forthcoming compeers to meet their own. Unsustainable outlines of industrial development were amongst the social and ecological issues that our joint forthcoming identified as demanding a worldwide solution.

The relationships between the social, economic, and environmental are characterised by three interrelated realms of sustainability. These realms are an assembly of linked ideas that, when joint, may deliver a durable foundation upon which important choices and actions can be made. Land use forecasting, surface water administration, building design and construction, and even regulation are a few examples of this type of activity of sustainability (Little et al., 2016). Three areas of sustainability illustrate the connections among the social, economic, and environmental aspects of our world. When taken as a whole, these areas offer a reasonable set of concepts that may guide important decisions and activities. Little et al (2016) goes on to say that construction design and building, surface water management, land use planning, and even legislation are a few examples of sustainability.

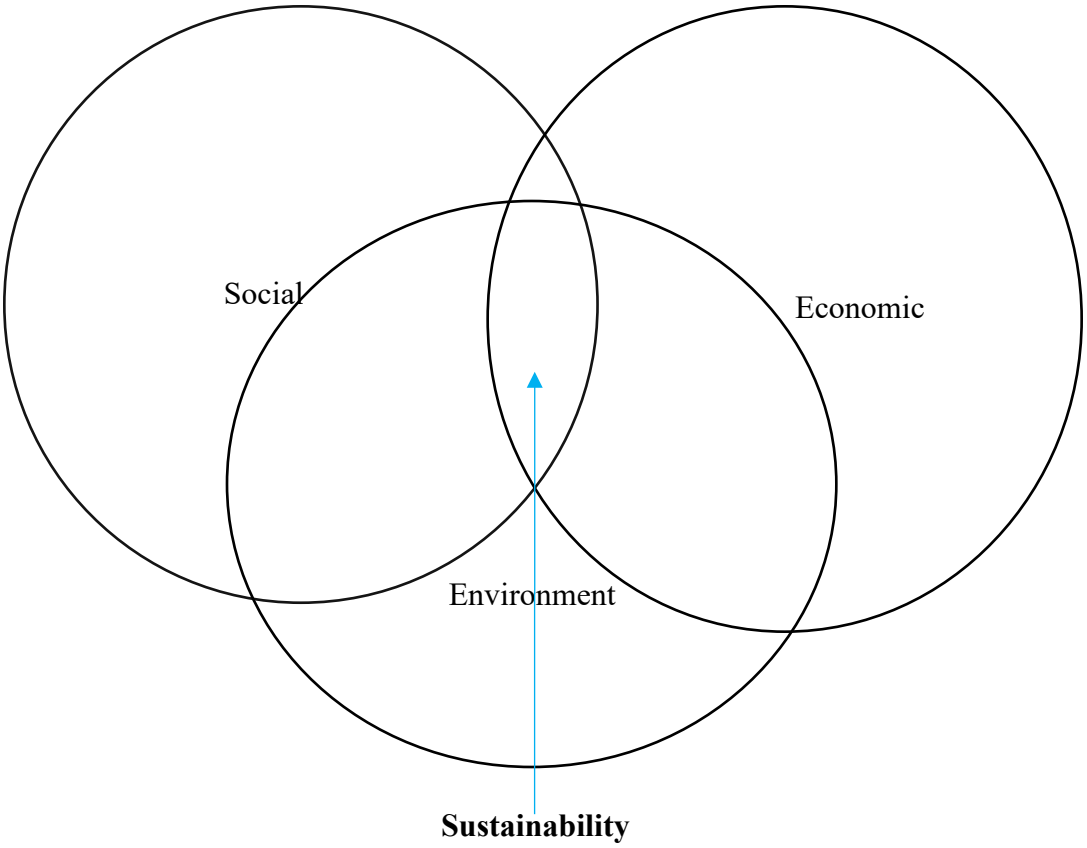


Figure 2.1: The pillars of sustainability.

Source: Primary data (modified from Little et al., 2016)

2.2.2 Environment Sustainability

In a completely sustainable environment, an ecosystem would maintain populations, biodiversity, and overall performance over time. According to Little et al. (2016), decisions should ideally aim to foster positive growth and equilibrium within our natural systems. Every effort should be made to prevent needless environmental disruptions. If there is a disturbance, it should be as small as possible. When making decisions, it is always important to consider how the proposed conclusion or outcome will affect the environment.

A number of things have a direct connection to environmental sustainability. The appropriate management of our natural resources is one of the most crucial ideas. Our environmental effect may be reduced by using solar photovoltaic panels. In certain situations, we may even advocate for habitat preservation and restoration as a way to work out a viable resolution to issues like

deforestation, which ideally results from people in underdeveloped nations chopping down trees for electricity (Adenle, 2020).

2.2.3 Economic Sustainability

Economic sustainability is the creation of economic value from any plan or choice being made, much like environmental sustainability. Considering the other facets of sustainability, economic sustainability entails making judgments in the most objective and financially responsible manner feasible (Little et al., 2016). Long-term advantages must ultimately be taken into account while making choices and working on initiatives, not only the short-term ones. However, something might not really support true sustainability if only its economic components are taken into account. Economic sustainability is the primary focus of the corporate sector, yet on a wide scale, either locally or globally, this limited perspective can ultimately produce unsatisfying results. Nonetheless, beneficial outcomes that benefit society as a whole may be achieved when ethical business practices are coupled with the social and environmental facets of sustainability (Ali et al., 2023).

2.2.4 Social Sustainability

The notion that a decision or action promotes societal betterment is the cornerstone of social sustainability. In general, future generations should benefit from the advantages of the current generation's quality of life. Public participation, human rights, and environmental legislation are just a few of the many subjects that are covered by this concept. If the social aspect of choices or activities is not given priority, the sustainability and social spheres may eventually disintegrate (El-Khozonder & El-batta, 2022).

Good examples of social sustainability are the Safe Drinking Water Act of 1974, the Clean Water Act of 1972 and its amendments in 1977. According to Little et al. (2016), these statutes were excellent pieces of legislation that established minimum criteria for drinking and surface water quality. Everyone in America benefited from this in terms of their health and well-being. The Clean Water Act also safeguarded our nation's water supply by essentially prohibiting the flow of contaminants into neighbouring rivers, lakes, and streams. During this period, many further advancements were made to our nation's environmental laws.

2.3 Advantages of Solar Energy

Solar energy an energy resource that is not sustainable for energy consumption, but also is indefinitely renewable which will never run out in billions of years. Solar power can be used to produce electricity; it is also used in relatively simple technology heat water, for instance solar water heaters. Solar panels also require very little maintenance and repair. After installation and optimization, they are very consistent because they actively create electricity just a few millimetres and do not require any type of mechanical parts that can fail.

Additionally, they generate energy silently which is necessary when interacting with picky neighbours. Solar energy is a clean, reliable, renewable and unpolluting source of electricity is solar energy. It doesn't emit harmful gases into the atmosphere, such as Sulphur oxide, nitrogen oxide, and carbon dioxide. Solar energy circumvents the problems of fuel transportation and the storage of radioactive waste since it doesn't require fuel. Solar cells are long-lasting since they don't produce any noise and don't have any moving parts. When there is no electricity available, solar energy might provide an affordable answer to energy-related issues. In general, solar cells are maintenance-free and have a long enough lifespan.

2.4 Disadvantages of solar PV panels

Solar water heating systems (SWHS), for instance, take a few drawbacks that impair their efficacy contempt the circumstance that solar PV panels have several benefits. First of all, even though SWHS can eventually recoup its costs, the initial investment and installation costs are high. However, the performance of solar PV panels is highly dependent on the weather. Therefore, its efficiency greatly decreases, or even it may not operate during cloudy rainy days.

2.5 Ecological Impacts of Solar PV panels

2.5.1 Carbon footprint

Humanity has easy admission to renewable energy sources. The decrease of greenhouse gas productions, environmental pollution, is main advantage of using renewable energy sources. This is achieved through replacing traditional fuels and fossil-based electricity, which lowers atmospheric emissions (Ali et al., 2023). The limitless, pollution-free energy source that is

essential to the sustainable provision of energy service is the solar energy. Unlike traditional fuels solar energy does not yield destructive pollutants into the atmosphere such as CO2, SO2, and NOx. Countless nations have previously selected solar energy as a safety option on counteract the negative ecological consequences for conventional fuels. One of the primary solutions for dependable, reasonably priced, useful, and ecologically sustainable energy supply for both small and large-scale needs is solar energy technology (El-Khozondar & El-batta, 2022).

Despite their high level of maturity and dependability among renewable technologies, solar systems have a number of drawbacks. Some restrictions are country- or region-specific, while others are unique to solar technologies. In0order to determine the0obstacles to the Western Cape's use of solar energy, several research were conducted. There are certain drawbacks to installing the solar system in terms of reaching the SDGs. One of the many well-known0advantages of lithium-ion energy storage systems (LIB ESS) is their capability to decrease greenhouse gas emissions and cut energy waste by storing excess energy. It is necessary to recognize, nonetheless, that this technology does have some disadvantages. Three phases of negative consequences can be distinguished: manufacturing, manufacturing, and mining.

However, gallons of water are necessary for producing one-ton of lithium, potentially harming surrounding ecosystema and water bodies (Lakatos et al., 2011). Moreover, the waste generated from the manufacturing of solar batteries as well as solar PV panels are recycled, and the rest is then dumped. Because they include chemicals and other hazardous items that endanger the environment and natural ecosystems, the discarded waste materials cause significant environmental harm and have a direct detrimental effect on Sustainable Development Goals 13, 14, and 15.

2.5.2 Resource depletion

Solar energy fluctuates greatly during the day creating it an extremely discrete energy source. This property of solar energy enables it not to be depleted by any means (Keisang et al., 2021; Stevanovic et al., 2022. Therefore, huge, spacious equipment are required for the concentration of this energy and its transformation into electricity. The development and upkeep of such devices simultaneously consume a significant quantity of traditional energy.

The entire roof must be used for the installation of solar PV panels if homeowners wish to generate electricity using them (Ahmad et al., 2017). Furthermore, large businesses or industries that wish to use solar energy give up a large area in order to install solar panels. For optimal energy output, the place used for solar PV panels needs to expose to direct sunlight for at least three hours each day. In India, a sizable portion of land has been set aside for solar energy, and many homes are powered by this energy (White-Hawk, 2016).

2.5.3 Ecological aspect

Solar power is renewable and clean. When in use, it doesn't release carbon dioxide. Silicon is the main component of the most widely used solar panel nowadays. Silicon is plentiful and safe for the atmosphere. Ali et al. (2023), goes on to say solar energy is a limitless, environmentally benign, and safe energy source.

However, there are a number of situations in which using solar energy technologies can be risky. Despite being a renewable energy source, the manufacture of solar panels is significant bad environmental impact. These include usage of hazardous items that are not properly disposed of, habitat loss, and contamination of the land and water. Among the resources used in the mass production of solar photovoltaic panels are cadmium lead gallium arsenide copper-indium-gallium-di-selenide sulfuric acid, nitric acid, hydrogen fluoride tri-chloro-ethane and acetone. In many countries, including the USA, solar panel manufacturers are required to reuse rather than dispose of their components; nevertheless, in the Philippines, Malaysia, China, and Taiwan, these materials end up in landfills, contaminating the air, water, and land (IRENA, 2019). Before choosing solar PV panels, one should consider this, since it may be one of the biggest drawbacks of solar energy.

2.6 Cost-effectiveness of Using Solar PV panels

2.6.1 Upfront costs

Long-term economic merits of investing solar PV panels include lower electricity expenses, while the initial expenses of the panels notoriously high. An important investment will be necessary to fully power solar PV panels and cost of these panels can differ dependent on the supplier (Ali et

al., 2023). The charges of installing panels and necessary equipment are too high in the Western Cape that most households, particularly those from lower socioeconomic classes, cannot afford it. The money you save on electricity bills is a significant factor in your verdict to use solar energy. Whole residences will be powered through solar panels, halving their electricity costs. In addition to saving, you a lot of money on bills, they may be used to power electrical items like air conditioners and heaters that need a lot of electricity.

The charge of photovoltaic electricity is prejudiced by location for instance larger systems are required in fewer bright areas to generate the same quantity of electricity as smaller systems in sunny areas; larger transmission lines are vital to attach the generated power to a grid in farther-flung locations; the type of technology used and system complexity also have an impact.

2.6.2 Operation and Maintenance Costs

Due to their vulnerability to deterioration, solar PV panels will eventually need to be replaced, which will cost more than half of their original cost. Utility-scale solar PV panels' operation maintenance (O&M) costs have decreased recently (Stevanovic et al., 2022). However, because capital costs have decreased more quickly than O&M expenses, the share of O&M costs has increased in some markets. Improvements in module efficiency have decreased the surface area needed, which has led to a decrease in O&M costs. Simultaneously, pressure from competition and technological advancements has led to system projects targeted lowers O&M expenses and better O&M tactics which leverage a variety of breakthroughs, from robotic cleaning to big data to identify issues and preventative interventions ahead of failures to drive down O&M costs and reduce downtime data analysis of performance (Sampaio &Gonzalez, 2017).

2.7 Long Term Financial Benefits of Solar

By 2050, people will get between 20 and 25 percent of sunlight’s energy (IRENA, 2019). An international energy expert, highlighted that through the help of up-to-date technology will produce 9,000 TEUs in 40 years, or 25 percent of power every hour, that will save CO2 emissions by almost 6 billion tons (IRENA, 2019). These days, solar energy is used to generate a large amount of power.

According to Nassar et al. (2019), rocket launchers in Egypt will cut carbon dioxide emissions to tons by the end of 2022 renewable source employed as an everlasting energy source, which would result in a price of $433,427.6× 103 would result in 19,066 kilotons of fuel savings and a verified emission reduction return. If more people were already utilizing solar PV panels than was previously thought, these advantages would grow much faster.

The Economics of Solar Power without government subsidy, solar energy is not a viable alternative. Many sources concur that solar cells now often lose when directly competing with fossil fuel-generated power. For solar energy growth to be effective, governments must be clearly committed to providing subsidies. Although such subsidies are anticipated to be short-lived, proponents of solar energy contend that as economies of scale and technology advance, solar will become significantly more economically competitive than fossil fuels (Ali et al., 2023). Proponents of solar energy also point out that government subsidies for fossil fuels. For example, oil and gas industries received significant government support in their early years and still receive favourable terms for drilling leases on government land, tax breaks for exploration, and other benefits.

Economically, solar energy is not currently a competitive energy source without government subsidies. Many sources concur that solar cells now typically lose when directly competing with fossil fuel-generated electricity. For solar energy expansion to be effective, governments must be clearly committed to providing subsidies. Although such subsidies are anticipated to be short-lived, proponents of solar energy contend that as economies of scale and technology advance, solar will become significantly more economically competitive than fossil fuels (Ali et al., 2023). Additionally, proponents of solar energy point out that fossil fuels have traditionally benefited from government subsidies, including the oil and natural gas sectors, which had significant government support in their early years and still enjoy favourable tax incentives for development.

2.8 Sustainability and Maintenance Requirements of Solar PV panels

No machine will ever operate at 100% efficiency in accordance with the second law of thermodynamics (Keisang et al., 2021). It is expected that solar PV panels with motors and reflectors that follow the sun would have a maximum energy production of 85% (Keisang et al., 2021). But that doesn't mean a system isn't working hard or producing enough just because it's not 100% efficient. Efficiency is more about how much room the panel needs to generate electricity.

A 250-watt solar panel with 15% efficiency will generate the same amount of electricity as one with 20% efficiency. The more efficient solar panel will be smaller, which is the only difference (Keisang et al., 2021).

Because efficient panels take up less space, higher efficiency is a crucial consideration for solar PV panels. Efficiency might not be a problem for you if your roof has enough space to accommodate a significant number of panels. However, in confined spaces, space conservation is crucial. The costlier nature of efficient solar PV panels is the only disadvantage. According to industry standards, solar panels should last between 25 and 30 years on average (Stevanovic et al., 2022). In contrast, the solar PV panels' power output will be drastically reduced after this period of time, but they won't completely stop operating (Stevanovic et al., 2022). However, the precise lifespan of solar panels varies according on manufacturer, model, and added factors.

An amount of sunlight and environmental diversity both affect how well a solar energy system performs. Single effect of the atmosphere is the build-up of dirt on the sides of the solar panels which avoids sun's rays from reaching solar PV panels and causes power outages. The volume of sunshine and environmental range both affect how effectively a solar energy system performs. EI-Khozondar & EI-batta (2022) goes on to say effects of environmental factors is to build of dirt on the surfaces of solar panels, that prevents sunlight to reach the panels and creates power outages.

Keisang, Bader, and Samikannu (2021) highlighted that better particles do affect concert more than coarser ones. The term used to describe the collection of dust is called hard shading. The study also gives recommend on how to minimize power loss, through cleaning of solar panel every week during the dry season and more often in locations with high levels of dust accumulation. Therefore, research was done to find out how well-informed the communities were about the cause of dust build up on system performance and if they followed cleaning instructions for the panels. The outcome of the research is that majority of the participants in that research reported never cleaning their solar panels, while some reported cleaning them more than four times each year.

Another research done by Gebreslassie (2020), outlays that people with solar home systems have lengthy lamented the difficulty of finding repair specialists when their equipment breaks down. An investigation is needed to determine how frequently their technology’s fault and who they naturally contact when they require maintenance specialists. The majority of cities stated that their systems have not ever broken since they installed the technology, and less than a year of use, they

have not yet met this issue, are results highlighted by the study results. Nevertheless, an important portion of households have had system failures ranging from once a year to more frequently.

Villarini et al. (2017) during their study highlighted that many issues, hiccups, and failure mechanisms that solar PV panel connections encounter in the workplace. The research proposals the finest (cost-effective) outline for maintaining solar PV panel micro grids over the sequence of their project lifecycle and meeting maintenance and replacement necessities. A comprehensive analysis of the flaws is the next phase that, requires a professional view, and then incorporating the optional fixes and maintenance actions into a timeline. Ugli (2019) stated that solar PV panels needs check and maintained through undertaking monotonous examinations to detect any potential issues with your solar energy system. The regular checks include checks for loose connections, damaged wiring, or signs of wear and ensure that all components are securely secure and operative properly.

A thorough examination of the different issues, hiccups and mechanisms failure encountered through solar appliance connections in the workplace was conducted by Villarini et al. (2017). The thesis done by Villarini et al (2017) provided the providing maintenance replacement needs, it also proposes an ideal framework (cost-effective and efficient) for upholding solar appliance micro grids over the course of their intended lifespan. Prior to the study organisations suggested fixes and maintenance activities into a timeline, and the next steps include a critical analysis of the flaws, which needs an expert opinion. Therefore, in order to recognise any likely difficulties with your solar energy system, regular check-ups are essential for the examination and maintenance of solar equipment (Ugli, 2019). Checking of all parts are firmly attached and working as proposed, and look for any slack connections, broken wiring, or wear. Then if you have noted any noticeable abnormalities, contact a trained solar technician for assistance. Furthermore, schedule regular maintenance visits with an expert to conduct more examinations that are thorough and address any maintenance requirements.

Moreover, there is need for battery maintenance especially for solar energy systems with battery storage, proper maintenance is crucial for maximizing their lifespan and performance. Checking the battery connections regularly and ensure they are clean and secure. Monitoring the battery's charge levels and avoid fully discharging them, as it can shorten their lifespan. Sometimes the

manufacturer's guidelines for battery maintenance may require activities such as equalizing or topping up the electrolyte levels (Lakatos et al., 2011; Keisang el al., 2021).

2.9 Chapter Summary

This section gave literature review of the study project. The background of sustainability, cost effectiveness and environmental impact of solar Pv panels in Western Cape South Africa. The chapter also highlighted benefits of sustainability to the community as a whole of Western Cape. It also covered the research gap of the study. The succeeding chapter is the methodology of study.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

Methodology subdivision presents methods that was used in directive to meet the goals of the thesis in which a researcher aims to assessing the sustainability, cost-effectiveness, and environmental impact of using solar PV panel in Western Cape South Africa**.** Therefore, the section focuses on the study techniques and data collection that was employed. The section will cover research design, population and sampling events, variable quantity, method of reliability, research instrument that were used in assembly data and data analysis methods.

3.2 Research Design

The academic had to come up with a study design with the purpose of study in link with the study objectives. Research design is an idea, structure and strategy for research providing the overall agenda for gathering data (Marczyk et al., 2010). Case study technique was used for purpose of the current research; this enabled the problem to be studied in its normal settings. The Western Cape consists of households, schools and organisations that are now employing solar PV panels as their source of energy and as well as companies that are manufacturing solar gadgets. Therefore, case study focus was on such organisations that have adopted the use of solar PV panels. A researcher to divides population being studied into manageable segments. The research used a survey approach to get data from respondents since case study gives information that the actor in circumstances under investigation was aware of. In addition, the research design included a case study, which accepted questionnaire as a prime data collection instrument. A questionnaire survey is the gathering of data from the sample using a formally intended schedule of questions called a questionnaire (Singh & Masuku,2013).

3.3 Population and Sampling

3.3.1 Target Population

Population refers to total group for elements, personalities, entities or organisations exhibiting more or less similar features from which research wishes to work a representative sample,

(Mweshi, 2020). The study population must be precisely and completely specified, outlining what is and is not included. The researcher targeted specialist in the field of solar technology such as companies that are manufacturing solar PV panels, households both solar users and none- solar users, schools and a financial company. Purposive sampling was utilized to collect the necessary data for the selection process, which is used to select professional settings or clusters in a certain field of research. Purposive sampling, a method used to choose professional settings or groups in a certain field of research, was employed to collect the necessary data. Participants are chosen on purpose not randomly and therefore it is also called judgmental sampling. The use of purposive sampling is cheaper and time effective method. However, is susceptible to errors in judgement by the researcher and there is low level of reliability.

3.3.2 Sample size

The central limit hypothesis states that even if populace is non normal sampling distribution of sample means will be provided the sample size is sufficiently high. This means that the sample size needs to be at least thirty or more before the sampling distribution of the mean becomes normal (Marczyk et al., 2010; Mweshi, 2020). The sample size for this contemporary research consisted of 100 respondents from the companies that are manufacturing solar PV panels, households of both solar users and none- solar users, schools and a financial company.

3.4 Sampling procedures

A sample is subdivision of whole populace that takes part in the study. The method of sampling is mostly used to pick some aspects of the population in order to make inferences about the complete population (Mweshi, 2020). It would have been too expensive and time-consuming to conduct research on the entire population. In this current study, the researcher employed purposive sampling. A non-probability sampling method which eliminates need for estimation is called purposive sampling. This method was employed because the researcher deliberately chose participants who were knowledgeable about the environmental impact, cost-effectiveness, and sustainability of solar PV panels.

3.5 Research instruments

3.5.1 Questionnaire

The contemporary research adopted a questionnaire method which is a transparent research procedure. Questions were developed to address the goals of the study. Questionnaire was given to the respondents electronically, via email wats app and other social media platforms Distribution of the questionnaire through electronic mail ensured that a large sample of the dispersed population could be reached. The questions were designed in closed questions that have guided answers and open-ended questions. Therefore, some questions, Likert scale was used in which the responded have to indicate agreement level and disagreement factors such as maintenance and sustainability of solar PV panels. The questionnaire comprised of two sections in which section. A was about socio-demographic data and section B focused on the research.

3.6 Data collection procedures

Marczyk et al. (2010) stated that secondary data comes from sources that have previously been published, while primary data is gathered from primary sources. This contemporary study included both secondary and primary data sources.

3.6.1 Primary data

Academic researcher collected primary information relating to the topic under study using questionnaires. This entailed field research which was carried out to get first-hand information regarding sustainability, cost-effectiveness, and environmental impact of solar appliance in developing countries. Questionnaires were sent out to companies that are manufacturing solar PV panels, households both solar users and none- solar users, schools and a financial company. Respondents were willing to provide information generously, although they took time to return questionnaires.

3.6.2 Secondary data

The data was gathered from textbooks then published papers by other authors who addressed the sustainability, cost-effectiveness, and environmental impact of solar photovoltaic panels in underdeveloped countries. These resources, which were accessible both online and at the library,

assisted the author in gathering secondary data. The Google search engine was quite helpful in supplying pertinent links to websites that included study-related information.

3.7 Data analysis

The scrutiny of information through scrutinized with Statistical Packages for the Social Sciences (SPSS) version 29 and presentation of graphs was done using Microsoft excel. The data was analysed with the aim to provide description of the sample. The analyses and present obtained information were done through the use of tables and graphs. Graphic presentation was also utilised to further elaborate results. For qualitative data thematic analysis were be utilised in recognise and interpret recurring patterns.

3.8 Validity and Reliability

3.8.1 Validity

It denotes to the level on which any measuring instrument measures what is intended to be measured (Myers et al., 2013). In endeavour to integrate validity, the researcher ensured that each question in the questionnaire was related to the problem as well as the objectives. A questionnaire was pre-tested through discussion and review done by the research supervisor to safeguard that it measures it is supposed to measure.

3.8.2 Reliability

When carrying out a survey there is need to for research reliability. Therefore, reliability takes into account of the consistency sand accuracy of the research instrument (Singh & Masuku, 2013). Parallel forms are forms of reliability that are used to evaluate the consistence of the results of two tests constructed in the same way from the similar content. Test retest is a reliability for, two or more individuals agree that is used to assess the consistency of a measure as of one time to another, and that is, the similar test is given to the same test respondents on two separate occasions. Inter rater reliability addresses the uniformity of the execution of a rating, that is the extent to which two or more individuals agree.

The researcher developed questions that addressed the topic of each purpose in order to safeguard validity of the study tool. To eliminate any doubt or uncertainty, the researcher employed good

questions. This ensure the smooth flow thoughts, terms were defined and related questions were presented on the questionnaire in a certain order.

3.9 Ethical Considerations

Research ethics are crucial for ensuring rights, dignity, and comfort of contributors throughout a study. This study adhered ethical principles to establish trustworthiness and credibility, ensuring that participants felt protected and respected. These ethical considerations included obtaining informed consent, guaranteeing that no harm would come to participants, safeguarding confidentiality and anonymity, and securing permission from both the individuals and organizations involved (Bank & Miller 2018).

3.9.1 Informed consent

The investigator informed the respondents of study's goal via a permission form before beginning any research. The decision to continue the research or not was entirely up to the participants (Dankar 2019). The respondents voluntarily choose to participate in the research project.

3.9.2 No harm to participants

The researcher made it very clear that any data gathered during the study process would be utilized in scholarly drives. Therefore, a consent form guaranteed that participants in the research study would not suffer any harm.

3.9.3 Anonymity and Confidentiality

The researcher-maintained privacy throughout study by entering into a non-disclosure of information agreement with the subjects. Hoft 2021 urges that the study in addition excluded names of participants but used numbers instead to reflect the respondents.

3.9.4 Permission

Authorisation to conduct the research was approved by organisations under investigation and the respondents also agreed to partake in the study and decent authorisation was attained from Cape

Peninsula University of Technology. Prior to starting the research, the academic obtained consent from appropriate authorities, includes organization's management, as well as the participants (Hoft 2021). Respondents agreed to engage in the research project by signing a permission form before to their participation.

3.10 Chapter summary

In this chapter, the study technique used for the research has been discussed and supported. The target population, research instrument, research design, and research methodologies were described in this chapter. This survey was case study and qualitative methodology was approved in the use of a questionnaire. In this survey, the population embraced individuals from companies that are manufacturing solar PV panels, households both solar users and none- solar users, schools and a financial company. Non-probability selection techniques were employed in the survey which is purposive selection in particular. The model size for this study consisted of 100 respondent's different platforms. The SPSS version 29 was employed to analysed data in this survey. The next chapter is going0to present and analyse data collected.

CHAPTER 4

DATA PRESENTATION, ANALYSIS AND DISCUSSIONS

4.1 Introduction

The section concentrated on researcher's information-gathering methodology. Presenting and analysing the research's interactions was its main goal. One interpretive method for providing data rationale and aiding in decision-making is data analysis. SPSS Version 29 was used to present and analysing of data, Hence, graphs and tables are used when appropriate in helping study better understand the information provided by the participants.

4.2 Response Rate

The scholar pursued to first recognise the availability respondents and following information on figure 4.1 was noted.

The response rate in the research study was calculated following the formula;

$$Response\ rate\ = \frac{Absolute\ Frequency}{Targeted\ frequency}\ X100\% = \frac{80}{100}\ X100\% = 80\%$$

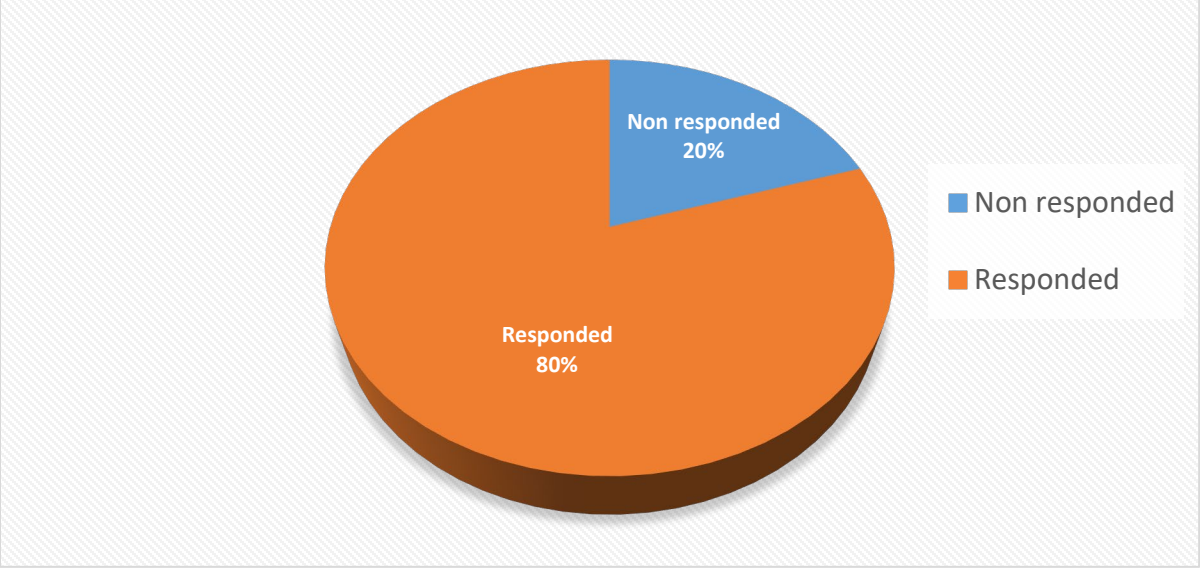


Figure 4.1: Response rate

The researcher had targeted 100 participants which included, 84 households' members, 8 participants were chosen from one of the solar manufacturing companies known as 1Energy solar

manufacturing company, the researcher also selected 4 school officials, and another 4 people were selected from one of the local financial companies. However, only 80 participants were available for the study. These included 66 residents, 4 officials from 1Energy solar company, 5 school officials, and lastly 5 people were selected from a financial investment company which invest on energy products. The response rate was considered 80%. The survey was competent the response rate as it is above the minimal expected rate of 50% (Mweshi, 2020).

4.3 Reliability Test

The researcher utilised the SPSS version 29 to test the internal consistency of the research instrument as shown in the table below.

Table 4.1; Cronbach Alpha's reliability test results.

Solar PV Panels Impact	**Cronbach's alpha**	**Comments**
	0.920	Reliable
Average	0.920	Reliable

Sustainability, cost-effectiveness, and environmental impact of solar PV panels in the Western Cape

Reliability test results in table 4.2 shows these variables, 0.920 was the average Cronbach's alpha coefficient. Based on results attained and put on SPSS after an extensive analysis the results showed that solar PV panels are sustainable, cost effective, and environmentally friendly. As a result, the Cronbach test findings were deemed positive and approved because they exceeded the anticipated value of 0.7 (Conwell, 2021). According to the research by Mallik et al. (2020), a common rule of the Cronbach's is that a reliability level of 0.7 to 0.9 is considered acceptable. Accordingly, the study's stated average value suggests that the subject matter was accurately demonstrated to be reliable and consistent.

4.4 Demographic Information

Research collected respondents' demographic data starting with Gender on table 4.2. the following data was captured on the people that participated in the study.

Table 4.2		Gender			
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	54	67.5	67.5	67.5
	Female	26	32.5	32.5	100.0
	Total	80	100.0	100.0	

Gender distribution illustrations that 54 people (67.5%) were represented by males, whilst 26 people (32.5%) were females. Population analysis by gender showed that males were highly represented as compared to females. This is because the majority of the participants who understood solar PV panels were male participants. This.gender distribution gives good represent ratio of the views of male and female respondents into the overall findings provide for the purpose of achieving the research objectives. The representation by gender has shown a balanced study, thus the study conducted by Muller, (2019) has pointed out that gender in research plays a essential role proving the research balanced and equally shares and interpreters the views of both women and men. With this assumption it is therefore justified to note that gender highly influenced the research.

4.4.1 Age

The research also sought to collect data through Age and the following data was retrieved.

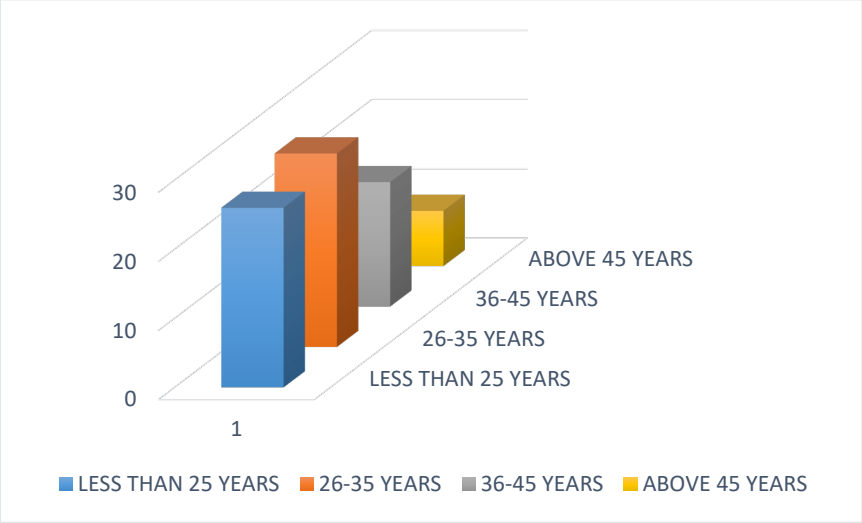


Figure 4.2: Age of the respondent

The results obtained that the participants, it must be noted that 26 people were less than 25 years, whilst 28 people were ranging between the ages of 25-35. Additional, group of 18 people were between the ages of 36-45 and lastly 8 people were above 45 years. Age in research has also been identified as an important feature in research as it helps ensure that the research represents all the age groups. In relation to the study, age was considered important as it help determine most active age groups in solar technology. The survey conducted by Sahu (2021) showed that the management of age diversity in solar management, and installation allows the researcher to understand his/her targeted participants, and this helps determine if answers collected are reliable.

4.4.2 Education

Table 4.3: Education Level

The following table summarizes the education qualification attained by general participants.

Table 4.3		Education			
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Diploma	30	37.5	37.5	37.5
	Degree	36	45.0	45.0	82.5
	Masters	12	15.0	15.0	97.5
	Doctorate	2	2.5	2.5	100.0
	Total	80	100.0	100.0	

The table above expressions participants' educational attainment. 30 people had diplomas, whereas 36 people had degrees, whilst 12 people from the participants were holders of master's degrees, and final two person was a holder of doctorate degree. Education qualification played an significant role through defining quality of the research as the majority of respondents had a minimum expected qualification to interpret questions directed to them during data collection period. The research conducted by Agyekum et al., (2020) shows education qualification makes it easier for the researcher to collect a compactable information, this therefore improves the quality of research.

4.4.3 Number of years using solar PV panels.

Table 4.4: Number of Years using Solar PV panels

How long have you been using solar PV panels?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	less than 2 years	10	12.5	12.5	12.5
	2-3 Years	28	35.0	35.0	47.5
	3-4 Years	22	27.5	27.5	75.0
	4-6	14	17.5	17.5	92.5
	Above 6 Years	6	7.5	7.5	100.0
	Total	80	100.0	100.0	

The scholar also asked contributors how long there have used solar PV panels from the information collected 10 people revealed that there have used it for less than 2 years, and the majority of the people (28) have used it for 2-3 years. Another group of 22 people indicated that there used solar PV panels for about 3-4 years, whilst 14 people used it for 4-6 years and finally 6 people used it for more than 6 years.

4.3.4 Occupation

The researcher also sought to analyse and determine participants' occupation, so that the researcher may determine the affordability rate of the participants.

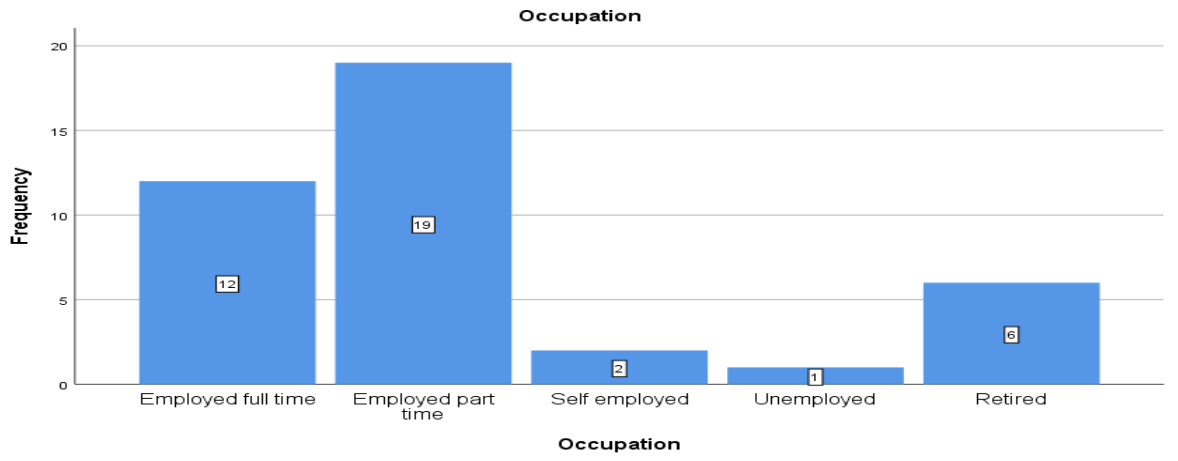


Figure 4.3: Occupation

On occupation the researcher identified that 24 people were full time employees, whereas the majority of the participants (38) were employed part-time, and (4) people were self-employed. Only two people was unemployed and finally 12 people indicated that they had retired from their job. Occupation in this study played an important role socioeconomic analysis. Occupation is a significant predictor of socioeconomic level, which might influence the research, according to Ahmad et al. (2017). Furthermore, occupation is critical as it influence exposure to environmental factors like chemicals, noise, pollution and other factors related to the environment.

4.3.5 Monthly Household Income

The researcher also collected information based on participants' income level and there are summarized below

Table 4.5: Monthly Household Income

Monthly Household Income

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than ZAR5000	18	22.5	22.5	22.5
	ZAR5000-15000	20	25.0	25.0	47.5
	ZAR15000-20000	16	20.0	20.0	67.5
	ZAR20000-25000	10	12.5	12.5	80.0
	ZAR25000-30000	10	12.5	12.5	92.5
	Above ZAR30000	6	7.5	7.5	100.0
	Total	80	100.0	100.0	

18 people from the participants disclosed that they get less than ZAR5000, and 20 people which is the majority get approximately ZAR5000-15000, whereas 16 people indicated that there received a monthly income of ZAR15000-20000. Another group of 10 people showed that there received a monthly income of about ZAR20000-25000 and another group of 10 people ranged between ZAR25000-30000. Lastly only 6 people received a monthly stipend of more than 30000. The research done by Khalid et al. (2021) showed income is a critical factor in determining access to energy, particularly in off-grid communities. Therefore, income levels can influence demand for solar products and services, driving market growth and industry a development.

4.3.6 Location

The research also determined to use location of participants to help determine where solar PV panels are mostly used.

Table 4.6: Location

Location

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Suburb	46	57.5	57.5	57.5
	Urban	14	17.5	17.5	75.0
	Rural	20	25.0	25.0	100.0
	Total	40	100.0	100.0	

The table above showed that people in suburbs (46) mostly used solar PV panels, and 14 people were from urban areas and final 20 people were from rural areas.

4.3.7 Experience with solar PV panels

Table 4.7: Experience with solar PV panels

Previous Experience with Solar PV panels

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	60	75.0	75.0	75.0
	No	20	25.0	25.0	100.0
	Total	80	100.0	100.0	

The investigator also wanted to determine if whether majority of participants have knowledge with solar PV panels and majority of respondents (60 people) indicated that there have previously used solar PV panels, whilst only 20 people did not have any experience with solar PV panels. This section helped improve the excellence of the study as the majority of participants understood the topic under study.

4.5 The environmental impacts of solar PV panels

The student was resolves looking at the environmental effects of solar PV panels over the first aim. The researcher initially tried to find out how knowledgeable the participants were of environmental concerns and the following fig 4.3 summarized the answers as follows.

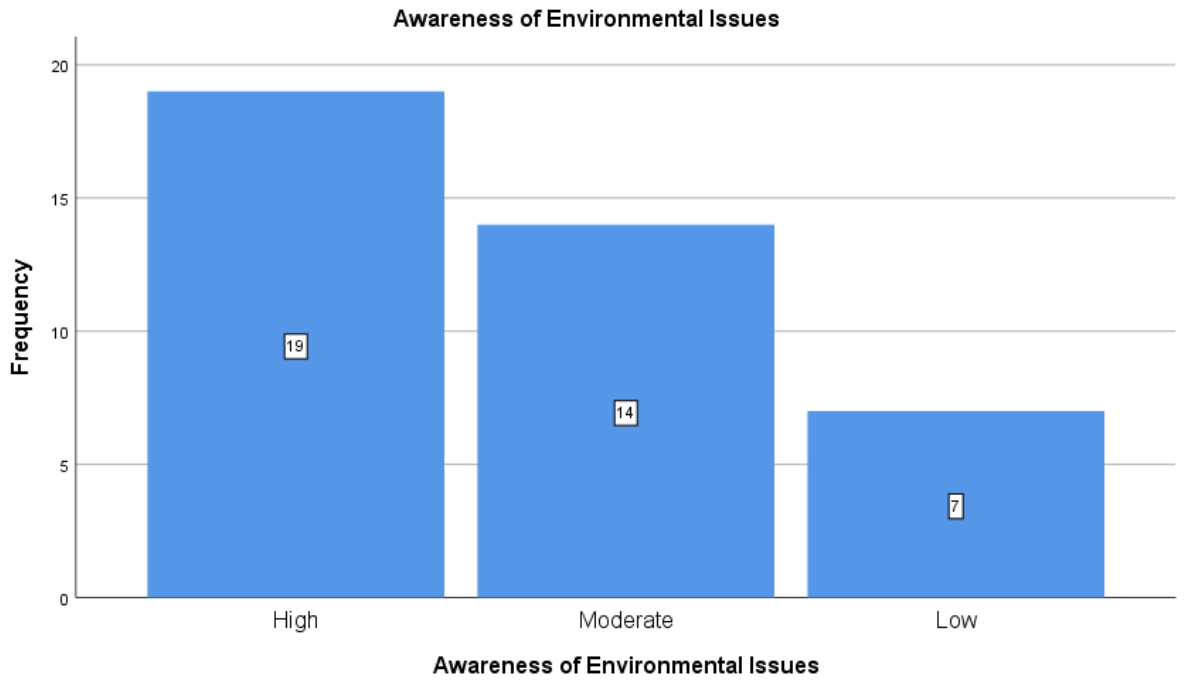


Figure 4.4: Awareness of environments Issues

From the respondents 38 people indicated that their level of awareness of solar on environmental issues was considered high, whereas 28 people had a moderate perception and 14 people indicated that they had a low rate on the awareness of environmental issues. The results portrayed that the majority of the participants had the knowledge of environmental impacts and issues related to solar matters. In justifying the above figure, the researcher also asked participants to rate the environmental impacts allied with the use of solar PV panels in the Western Cape. The following responses were expressed in the following table using Mean and Std Deviation. According Mutatkar (2017) in his study "sustainability assessment of decentralised solar projects in Kenya" stated that in Kenya before the solar services were offered, a normal household spent 0.5L of kerosene every day with a monthly spending of KES 450 (USD 4.4). According to the standard base tariff, families now pay KES 450 (USD 4.44), which interprets to a monthly saving of 47%.

Table 4.8: Descriptive Statistics

Descriptive Statistics

	N	Mean	Std. Deviation
Please rate the environmental impacts associated with the use of solar PV panels in the Western Cape, South Africa	80	1.83	1.130
Valid N (listwise)	80		

Analysis above confirms that the statement "please rate the environmental impacts associated with the use of solar PV panels in the Western Cape, South Africa" had a highest Mean of 1.83, this highest Mean value shows that the respondents were all agreeing that solar PV panels had an impact on the atmosphere. The Standard deviation was 1.130. The std deviation indicated there was less dispersal from the general responses by the respondents. In support of the above findings the research conducted Kannan and Nakeesan (2016) is of the view that solar installation especially at a commercial level usually impacts land use and disrupting habitats thus it affects the environment. However, for White-Hawk (2016) solar PV panels are significantly positive as there highly influence a clean source of energy which may positively impact the environment.

The researcher also compared the impact of using traditional energy sources and using solar PV panels, the following rate was given.

Compared to traditional energy sources in the same context, how would you rate the environmental impacts of solar PV panels?

Table 4.9: Environmental impacts of solar panels

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Much Lower	42	52.5	52.5	52.5
	Slightly Lower	20	25.0	25.0	77.5
	Similar	2	2.5	2.5	80.0
	Slightly Higher	6	7.5	7.5	87.5
	Much Higher	10	12.5	12.5	100.0
	Total	80	100.0	100.0	

The majority of the participants (42) were of the view that environmental impact of solar PV panels was much lower, and 20 people indicated that the impact was slightly lower. However, only 1 person pointed that the impact was similar to traditional sources, whereas 6 people indicated that the difference was slightly higher, and final 10 people showed that it was much higher. This

significantly poses a view that solar PV panels are more environmentally friendly as compared to traditional method. Boscario et al., (2024) pointed out that as compared to traditional sources of energy solar has been considered one of the cleanest sources of energy within the environment. This research also tallied with the results by Janik et al. (2020) who argues solar energy is renewable and sustainable source, and it has zero greenhouse gas emissions as it generates electricity without emitting greenhouse gases. It is therefore justified to note that solar PV panels offer a cleanser, more sustainable and renewable source of energy contributing to a healthier environment and a more sustainable future as compared to traditional source.

4.6 The cost-effectiveness of using solar PV panels.

The researcher also sought to evaluate the cost effectiveness of using solar PV panels in Western Cape. Through objective researcher sought to ask the participants to rate the operational charges of solar PV panels. The following responses were given.

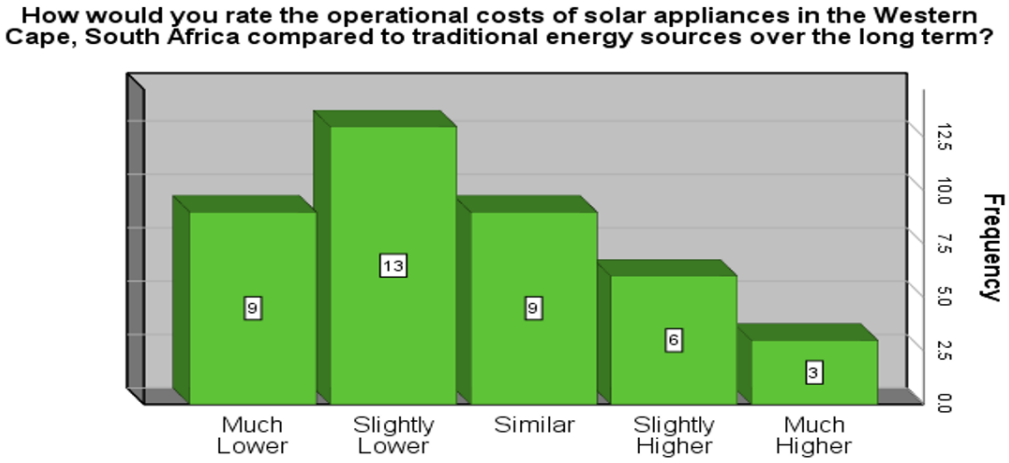


Figure 4.5: Cost effectiveness of using solar PV panels

The popular of the respondents (26) highlighted that the cost was slightly lower, whereas 18 people pointed out that the cost was much lower. Another group of 18 people showed that the operational cost was neutral whereas 12 people reported that the maintenance and operational cost was slightly high and the last group of 6 people pointed out that the operational cost was much higher.

To further validate the researcher further asked respondents to estimate upfront cost of implementing solar PV panes in the Western Cape and therefore, the majority of the participants stated out the cost was between ZAR60000-250000, another participant further highlighted that

"The size of your project will determine the value of your upfront cost, then you still need to consider maintenance and also the cost due to the Municipality".

Another participant rated the cost as R30 – R75000, whilst showed that the cost was determined by various factors which included the operational place, and the size of solar PV panels. The research findings tallied with Stevanonic et al. (2022), who argued that the operational and maintenance cost has been determined by various factors, which include place, size, location and the number of people with a given environmental place. Sampaio and Gonzalo (2017) claim that technological advancements and competitive pressures have resulted in system projects that are optimized to decrease O&M costs. They have also made improvements to O&M strategies that use a range of revolutions, such as robotic cleaning and big data analysis of presentation data to identify problems and preventive interventions before disappointments to further reduce downtime and O&M costs. This supports the idea that a variety of factors influence cost and maintenance factors.

4.7 The sustainability and maintenance requirements of solar PV panels.

The researcher also determined examine the sustainability then maintenance requirements of solar PV panels. Thus, the investigator asked the respondent to rate the durability characteristics of solar PV panels in the Western Cape and the following rating was received.

Table 4.10: Sustainability and maintenance requirements of solar PV panels

Please rate the durability characteristics of solar PV panels in the Western Cape, South Africa

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not durable at all	6	7.5	7.5	7.5
	Less durable	8	10.0	10.0	17.5
	Similar	10	12.5	12.5	30.0
	Durable	28	35.0	35.0	65.0
	High Durable	28	35.0	35.0	100.0
	Total	80	100.0	100.0	

The majority of the respondents (28) pointed out that solar PV panels had high durability, and the other group of 28 people also rated characteristics of solar PV panels as durable, and 10 people viewed is as similar of other energy sources, whilst 8 people pointed it as less durable whereas the

last group pointed out that there were not durable at all. From the above results it was clear that the majority of the people in this study appreciated durability of solar PV panels. This therefore contributed to the researcher concluding that solar PV panels were more durable, cost effective and sustainable as compared to other sources of energy. The conclusion is supported by research by El-Khozondar and El-Batta (2022), which demonstrated that the act of solar energy systems depends on the amount of sunlight and the variety of the atmosphere. As a result, they are considered sustainable, but the cost of maintenance is largely determined by a number of factors.

4.8 Inferential data analysis

Additionally, the scholar was able apply inferential data to the study data. Regression analysis, chi-square tests, and analysis of variance for the variables were performed using SPSS version 29 in instruction to establish the topic under study. This research goals to assess the sustainability, cost-effectiveness also environmental impact of solar PV panels within the context of South Africa's status as a developing nation in the Western Cape. Thus, SPSS will be used to determine and analyses variances and variables using questionnaires and responses collected from the participants.

4.8.1 Pearson Correlation Test

The academic succeeded to found the correlation between environmental impact, sustainability, and maintenance and cost effectiveness of solar PV panels of in Western Cape.

Table 4.11: Correlation Coefficient Testing

Solar PV panels		**Human-Wildlife Conflict Impact**		
		Environmental Impact	Cost-Effectiveness	Sustainability and Maintenance
Environmental Impact of Solar PV panels	Pearson Correlation	.961	.958**	.916**
	Sig. (2-tailed)		.000	.000
	N	80	80	80
**. Correlation is significant at the 0.01 level (2-tailed).				

The scrutiny of results in the table overhead, it is revealed that there is a stronger relation that exist between solar PV panels and environmental impact as much of these impacts are considered positive especially when comparing with traditional energy sources, the regression is at (r= .961, p<.000). solar PV panels' impact on environment have also been considered cost effective with a regression rate of (r= .958, p<.000), whilst between their ratio in sustainability and maintenance is at (r=.916, p<.000).

4.8.2 Analysis of correlations

To establish the above correlation the ANOVA analysis was considered as described below.

Table 4.12 Analysis of Variance

		Sum of Squares	Mean Square	F	Sig.
Environmental Impact	Between Groups	78.383	19.596	231.789	.000
	Within Groups	5.833	.085		
	Total	84.216			
Cost Effectiveness	Between Groups	52.680	13.170	123.918	.000
	Within Groups	7.333	.106		
	Total	60.014			
Sustainability and Maintenance	Between Groups	84.913	21.228	152.135	.000
	Within Groups	9.628	.140		
	Total	94.541			
	Within Groups	.000	.000		
	Total	73.149			

Test: One-way ANOVA

H_0: There is no positive impact that exist between solar PV panels on the environment, cost effectiveness and sustainability

H_1: There is a positive impact that exist between solar PV panels on the environment, cost effectiveness and sustainability

Significance Level: 95% Confidence Level, thus 0.05 significance

Rejection Criteria: Accept H_0 if $p>0.05$ Reject H_0 if ≤ 0.05

Decision: The findings presented in the above table indicate that, because all of the hypotheses' p-values were found to be less than 0.05, we reject the null hypotheses and come to the alternative conclusion that, at a 95% confidence level, there is sufficient evidence to support the idea that solar PV panels improve sustainability, cost-effectiveness, and the environment. Therefore, solar PV panels have a positive impact on the environment, cost-effectiveness, and sustainability.

In view of the F-ratios from the directly above table, the superior the magnitude implied the greater the degree of influence of solar PV panels. The greatest scale of the F-ration was understood on environmental impact whose value was 231.789. The value enlightens that solar PV panels had an impact on the environment. The second highest F-ratio was observed on sustainability and maintenance being 152.135. Thus, solar PV panels impact on sustainability and maintenance was rated second. Also, from table solar PV panels were considered cost effective with the F-ratio of 123.918.

In conclusion all the exhibited aspects were confirmed to have a positive impact on solar PV panels. An order of their impact of solar PV panels is as rated based on the following

1. Environmental
2. Sustainability and maintenance
3. Cost-effectiveness

Based on the above results it must be noted that the influence of solar PV panels is positive on the atmosphere based on the collected and analysed data provided through questionnaires. Solar PV panels have also been considered sustainable and maintenance cost and practice is considered cheaper.

4.9 Chapter Summary

The gathered data was shown, analysed, and discussed in this chapter. The study employed a mixed methodology, and SPSS version 29 was utilized to analyse some of the data. It should be mentioned that the information was presented in tables that were simple to understand. The next subdivision provides a summary of the results, conclusions and suggestions.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter focuses on the summary of the study, as well as the conclusions and recommendations derived from the research findings. Recommendations for potential enhancements will be emphasized based on participant suggestions and the researcher's observations of deficiencies.

5.2 Summary of the study

The determination of this survey was to evaluate the sustainability, environmental impact and cost-effectiveness of solar PV panels in the Western Cape. In an endeavour to do so the research was navigated through four study questions which are, what are the key environmental impacts associated with the use of solar PV panels in the western cape? How does the cost efficiency of using solar PV panels compare against traditional energy sources over the long-term? What sustainability aspects influence the acceptance the maintenance requirements of solar PV panels in the western cape? What practical commendations can be complete to improve the sustainability and efficiency of solar PV panels usage in Western Cape (South Africa)?

In this research the concept of sustainability provided a viewpoint on the topic under investigation. According to one definition, sustainability is the aim of sustainable development, which includes social and economic advancements that preserve and improve social justice and the environment.

In addition, the research design included survey research in which a questionnaire was used to gather information. Purposive sampling was used since information was needed from those with the knowledge of solar PV panels and 100(hundred) questionnaires were administered to the respondents and 80 of them managed to respond.

5.3 Summary of Findings

5.3.1 To examine the sustainability and maintenance requirements of solar PV panels.

This research was assessing the sustainability cost-effectiveness, and environmental impact of solar PV panels in Western Cape. The first objective was to investigate the environmental impacts

of solar PV panels. The researcher found that solar PV panels had a optimistic effect on the environment and much these impacts was determined by various number of factors. The majority of the respondents pointed out that there were aware of the environmental factors, and this enabled them to be in a position to address them in a positive way. Maksimov (2023) stated that there is cost reduction in using of solar PV panels through his study "Energy efficiency mapping: solar power as a source of a sustainable energy", through implementing solar power at a facility such as Meconet can result in a reduction in grid electricity consumption. The projected annual energy generation is 197 MWh, which is distributed throughout the year, with varying efficiency expected during different periods. Data from Meconet's plant in Estonia shows that the maximum amount of electricity is generated between April and August. During the solar panels' peak operating phase, energy consumption decreases proportionally.

5.3.2 To assess the cost-effectiveness of using solar PV panels.

The second objective sought to assess the cost-effectiveness of using solar PV panels. From the stated objective the researcher found out that solar PV panels were considered cost-effective with the popular of the participants agreeing that the charges of solar PV panels were not that much costly, thus there were considered accessible and cheap in terms of maintenance and operational. The research create that the accessibility of solar PV panels was also determined by different number of factors as well. Mustafa et al. (2022) conducted a study where cost-benefit analysis was employed to determine the net financial gain from installing a solar photovoltaic system. This profit is generated through savings on expenses and improved agricultural output due to a more consistent power supply for water pumping. To achieve this, all relevant costs and subsequent profits were calculated and contrasted to establish the cost-effectiveness and benefits of using a PV solar system as an alternative to conventional grid electricity. Table 5.1 presents an itemized list of all costs associated with a grid-electricity-powered water-pumping system, which is required for an average 5.7-acre parcel of land.

Table 5.1: Cost related to grid electricity

Cost Details	Particulars	Cost (in USD)
Initial cost	HT (building) 0 46’	619.40
	LT (building) 30’8’	162.30
	25 KVA11/4 kV Converter	860.70
	Static Energy M 3 phase	19.20
	AAC (1/172) ANT	297.40
	11KV Steel cross arm	215.60
	11KV D/Out C/out insulator	25.70
Connection cable	PVC 7/058 I/core (10mm2)	311.00
Submersible	20HP	1220.00
Pipe	40(20ft)	1377.5
Carriages	N/A	22.60
Yearly O & M	Year	2787.80
Other costs	N/A	109.20
Total		8002.70

Table 5.2 outlines all the costs associated with installing a PV solar system, derived from an analysis of primary data. The figures are based on the average costs reported by 392 participants in the study area who use a PV solar system for water-pumping irrigation (Mutatkar 2017).

Table 5.2 Cost associated to PV solar system

Cost Details	Particulars	Costs (in USD)
Initial Cost	Solar panels 400 W	6144.00
	DC Inverter	959.10
	Connection cable	83.80
	Mounts	1629.30
Submergible	20 hp	1220.00
Pipe	40(20 ft)	1376.50
Carriage	N/A	21.60
Yearly o & M	Yearly	26.60
Other costs	N/A	109.20
Total		11560.30

Therefore, the above table highlighted that the cost of installing PV solar will be cheaper in the long run of the operations against electricity grid for electricity you need annual operations and maintenance cost of USD2797.80 whilst for PV solar is USD26.60, hence PV solar is game changer to Western Cape people.

5.3.3 To examine the sustainability and maintenance requirements of solar PV panels

Under the third base objective, that sought to scrutinise the sustainability maintenance requirements of solar PV panels, the researcher found that, solar PV panels were sustainable. Information collected by the researcher showed that the majority of the people in this study appreciated durability of solar PV panels. This therefore contributed to the researcher concluding that solar PV panels were more durable, cost effective and sustainable as equated to other sources of energy. Routine maintenance is necessary for solar PV power plants to ensure optimal performance and maximize energy generation. Maintenance tasks are generally classified as preventive, corrective, or predictive. The regular maintenance expenses are variable, as they depend on the plant's size, location, and particular maintenance requirements (Maksimov, 2023).

5.4 Conclusions

The study concluded that solar PV panels had an optimistic impact on the atmosphere. The solar PV panels were considered cost-effective and thus there were considered accessible, cheap in terms of maintenance, and operational. Therefore, the study it answered all the study objectives and that the study addressed all the research questions. Research collected data from only Western Cape therefore there is need for future researchers to investigate other areas.

5.5 Commendations of the study

To advance research, the thesis has suggested the following modifications.

- Governments can effectively promote the adoption of solar energy by offering financial incentives. Government policies have a considerable influence on the adoption of solar energy. These policies can either encourage or discourage investment and expansion, and they play a role in cultivating a favourable business environment. According to Akshay (2023), solar energy regulations enacted by the government may include mandates, tax breaks, and subsidies. Therefore, introduction of rebates on importing solar panels, decrease tax breaks and also subsidies solar PV panels will encourage the use of solar in Western Cape. Government of South Africa policies are crucial in inspiring the use of solar energy. Use of solar energy has been fortified through financial inducements, net metering and taxation.
- People should invest in appropriate batteries for back up like lithium batteries. Consider selling back the generated electricity to the grid via the Municipality.
- Installing energy-efficient light fittings such as LED lights Installing rainwater tanks at homes to collect and store rainwater. Installing solar PV panels may be an effective way of maintaining solar
- The government should create well-defined plans for expanding effective financial incentives for building clean energy. In the notion, that the more the government enter into the providing PV panels that will lead into following footsteps of country such as Mexico. Lopez (2021) emphasised that global photovoltaic industry reflects Mexico to one of the top five states to do investments. A general rising consensus that solar power in Mexico, and its associated industrial, has great possible for growing Solar Power Mexico (SPM). A

freshly applied a survey to more than 30 global companies that are promote industrial, distribution, supply and integration in the photovoltaic sector (Lopez 2023). (Grajeada, 2020). The European Association of Solar PV considers the Mexican Republic to be among the most promising nations for solar photovoltaics. This is primarily because of its high solar radiation levels (5.2 kWh/m2). Indeed, the majority of Mexico's territory receives significant solar radiation.

5.6 Contributions and areas of further studies

The thesis's scope was restricted to the Western Cape's solar PV panels' environmental impact, cost-effectiveness, and sustainability. It ignored other aspects like government subsidies for solar PV panel use and the uptake of solar PV panels, mostly in developing nations. Accordingly, this provides ideas for further study. Future studies might look at how individuals in developing nations are using solar photovoltaic panels.

REFERENCES

Abdullahi, D., Renukappa, S., Suresh, S. and Oloke, D., 2022. Barriers for implementing solar energy initiatives in Nigeria: an empirical study. *Smart and Sustainable Built Environment*, 11(3), pp.647-660.

Agbo, E.P., Edet, C.O., Magu, T.O., Njok, A.O., Ekpo, C.M. & Louis, H., 2021. Solar energy: A panacea for the electricity generation crisis in Nigeria. *Heliyon*, *7*(5).

Ahmad, S., Mat Tahar, R.B., Cheng, J.K. & Yao, L., 2017. Public acceptance of residential solar photovoltaic technology in Malaysia. *PSU Research Review*, 1(3), pp.242-254.

Akshay, S., 2024, June. Design and Simulation of 100MW Floating Solar PV System: A Idukki Reservoir Case Study. In *2024 International Conference on Advancements in Power, Communication and Intelligent Systems (APCI)* (pp. 1-6). IEEE.

Ali, S., Yan, Q., Irfan, M., Hussain, M. S., & Arshad, M. 2023. Evaluating the environmental impact and economic practicability of solar home lighting systems: a roadmap towards clean energy for ecological sustainability. *Environmental Science and Pollution Research*, *30*(31), 77668-77688.

Alinejad, T., Yaghoubi, M. & Vadiee, A., 2020. Thermo-environomic assessment of an integrated greenhouse with an adjustable solar photovoltaic blind system. *Renewable energy*, 156, pp.1-13.

Amoah, S.T., 2019. Determinants of household's choice of cooking energy in a global south city. *Energy and Buildings*, 196, pp.103-111.

Aramesh, M., Ghalebani, M., Kasaeian, A., Zamani, H., Lorenzini, G., Mahian, O. & Wongwises, S., 2019. A review of recent advances in solar cooking technology. *Renewable Energy*, 140, pp.419-435.

Asmelash, E. and Gorini, R., 2021. International oil companies and the energy transition,

Awais, M., Fatima, T. & Awan, T.M., 2022. Assessing behavioral intentions of solar energy usage through value-belief-norm theory. *Management of Environmental Quality: An International Journal*, 33(6), pp.1329-1343.

Battocchio, C., Bruni, F., Nicola, G., Gasperi, T., Lucci, G., Tofani, D., Varesano, A. & Venditti, L. 2021. Solar cookers and dryers: Environmental sustainability and nutraceutical content in food processing. Foods, 10(10), pp 2326.

Cousse, J., 2021. Still in love with solar energy? Installation size, affect, and the social acceptance of renewable energy technologies. *Renewable and Sustainable Energy Reviews*, *145*, p.111107.

Cuce, E. and Cuce, P.M. 2013. A comprehensive review on Solar Cookers, *Applied Energy*, 102, pp. 1399–1421. Available at: https://doi.org/10.1016/j.apenergy.2012.09.002.

Dankar, F.K., Gergely, M. and Dankar, S.K., 2019. Informed consent in biomedical research. *Computational and structural biotechnology journal*, *17*, pp.463-474.

El-Khozondar, H. J., & El-batta, F. 2022. Solar energy implementation at the household level: Gaza Strip case study. *Energy, Sustainability and Society*, *12*(1), 17.

Fadlallah, S.O. & Serradj, D.E.B., 2020. Determination of the optimal solar photovoltaic (PV) system for Sudan. *Solar Energy*, *208*, pp.800-813.

Gawali, S. R. & Papade, C. V. 2015. Hybrid Solar Cooker. *International Journal of Engineering Research & Technology (IJERT),* 14(6), pp 173-176.

Gebreslassie, M. G. 2020. Solar home systems in Ethiopia: Sustainability challenges and policy directions. *Sustainable Energy Technologies and Assessments*, *42*, 100880.

Ghazi, S., Sayigh, A., & Ip, K. 2014. Dust effect on flat surfaces–A review paper. *Renewable and Sustainable Energy Reviews*, *33*, 742-751.

Gil, V., Gaertner, M.A., Gutierrez, C. & Losada Doval, T., 2019. Impact of climate change on solar irradiation and variability over the Iberian Peninsula using regional climate models. https://doi. org/10.1002/joc.5916.

Guest, G., 2014. Sampling and selecting participants in field research. *Handbook of methods in cultural anthropology*, 2(1), pp.215-250.

Hoft, J., 2021. Anonymity and confidentiality. *The Encyclopedia of Research Methods in Criminology and Criminal Justice*, *1*, pp.223-227.

International Renewable Energy Agency, Abu Dhabi About IRENA The Internationals

Junejo, F., Saeed, A. and Hameed, S. 2018. Energy management in Ocean Energy Systems, Comprehensive Energy Systems, 5, pp. 778–807. Available at: https://doi.org/10.1016/b978-0-12-809597-3.00539-3.

Keisang, K., Bader, T., & Samikannu, R. 2021. Review of operation and maintenance methodologies for solar photovoltaic microgrids. *Frontiers in Energy Research*, *9*, 730230.

Khalid, B., Urbański, M., Kowalska-Sudyka, M., Wysłocka, E. & Piontek, B., 2021. Evaluating consumers' adoption of renewable energy. *Energies*, *14*(21), p.7138.

Lakatos, L., Hevessy, G., & Kovács, J. J. W. F. 2011. Advantages and disadvantages of solar energy and wind-power utilization. *World Futures*, *67*(6), 395-408.

Lentswe, K., Mawire, A., Owusu, P. & Shobo, A. 2021. A review of parabolic solar cooksers with thermal energy storage. *Heliyon*, 7(10), pp.

Lim, W.M., 2024. What is qualitative research? An overview and guidelines. *Australasian Marketing Journal*, p.14413582241264619.

López-Flores, F.J., Ramírez-Márquez, C., Rubio-Castro, E. and Ponce-Ortega, J.M., 2024. Solar photovoltaic panel production in Mexico: A novel machine learning approach. *Environmental Research*, *246*, p.118047.

Maksimov, D., 2023. Energy efficiency mapping: solar power as a source of a sustainable energy.

Mawire, A. & Taole, S. 2014. Performance comparison of thermal energy storage oils for solar cookers during charging. *Applied thermal engineering*, 73, 1323-1331.

Mawire, A. 2019. Solar Cookers with Thermal Energy Storage: A Sustainable Cooking Solution for Developing Countries, (North-West University Mafikeng Campus South Africa).

Mohanty, M., 2012. New renewable energy sources, green energy development and climate change: Implications to Pacific Island countries. *Management of Environmental Quality: An International Journal*, *23*(3), pp.264-274.

Morse, J.M., 2016. *Mixed method design: Principles and procedures*. Routledge

Mustafa, Z., Iqbal, R., Siraj, M. and Hussain, I., 2022. Cost–Benefit Analysis of Solar Photovoltaic Energy System in Agriculture Sector of Quetta, Pakistan. *Environmental Sciences Proceedings*, *23*(1), p.26.

Muthusivagami, R. M., Velraj, R. & Sethumadhavan, R. 2010. Solar cookers with and without thermalhermal storage. *Renewable and Sustainable Energy Reviews*, 14, 691-701.

Nikolina, S.A.J.N., 2016. International renewable energy agency (IRENA).

Noorollahi, Y., Golshanfard, A., Ansaripour, S., Khaledi, A. & Shadi, M., 2021. Solar energy for sustainable heating and cooling energy system planning in arid climates. *Energy*, *218*, p.119421.

Owusu, P.A., & Asumadu-Sarkodie, S., 2016. A review of renewable energy sources, sustainability issues and climate change mitigation. *Cogent Engineering*, *3*(1), p.1167990.

Owusu-Manu, D.G., Mankata, L.M., Debrah, C., Edwards, D.J. & Martek, I., 2021. Mechanisms and challenges in financing renewable energy projects in sub-Saharan Africa: a Ghanaian perspective. *Journal of Financial Management of Property and Construction*, *26*(3), pp.319-336.

Panwara, N. L., Kaushik, S. C. & Kothari, S. 2012. State of the art of solar cooking: An overview. *Renewable and Sustainable Energy Reviews*, 16(6), pp 3776-3785.

Rathore, P.K.S., Rathore, S., Singh, R.P. & Agnihotri, S., 2018. Solar power utility sector in india: Challenges and opportunities. *Renewable and Sustainable Energy Reviews*, *81*, pp.2703-2713

Salim, A.M. & Alsyouf, I., 2020. Development of renewable energy in the GCC region: status and challenges. *International Journal of Energy Sector Management*, *14*(6), pp.1049-1071.

Sampaio, P. G. V., & González, M. O. A. 2017. Photovoltaic solar energy: Conceptual framework. *Renewable and sustainable energy reviews*, *74*, 590-601.

Sovacool, B.K., D'Agostino, A.L. & Bambawale, M.J., 2011. The socio-technical barriers to Solar Home Systems (SHS) in Papua New Guinea: "Choosing pigs, prostitutes, and poker chips over panels". *Energy Policy*, *39*(3), pp.1532-1542.

Stevanović, S., Stevanović, S., & Živković, R. 2022. Advantages and disadvantages of solar energy production and use. *Journal of Agricultural, Food and Environmental Sciences, JAFES*, *76*(4), 65-70.

Ugli, T. J. T. 2019. The Importance of Alternative Solar Energy Sources and the Advantages and Disadvantages of Using Solar Panels in this Process. *International Journal of Engineering and Information Systems (IJEAIS)* 3 (4):70-78.

United Nations. (n.d.). Goal 7: Ensure access to affordable, reliable, sustainable, and modern energy. United Nations Sustainable Development Goals. Retrieved 24 November 2022,.

Villarini, M., Cesarotti, V., Alfonsi, L., & Introna, V. 2017. Optimization of photovoltaic maintenance plan by means of a FMEA approach based on real data. *Energy Conversion and Management*, *152*, 1-12.

White Hawk, R. M. 2016. Community-Scale Solar: Watt's in It for Indian Country. *Environs: Envtl. L. & Pol'y J.*, *40*, 1.

Wyllie, J.O., Essah, E.A. & Ofetotse, E.L., 2018. Barriers of solar energy uptake and the potential for mitigation solutions in Barbados. *Renewable and Sustainable Energy Reviews*, *91*, pp.935-949.
Yaqoot, M., Diwan, P. & Kandpal, T.C., 2016. Review of barriers to the dissemination of decentralized renewable energy systems. *Renewable and Sustainable Energy Reviews*, *58*, pp.477-490.

APPENDICE

Appendix 1: Letter to the respondent

To: The Respondent

Dear Sir/Madam

My name is Sue-Ann Sharlene Muller, Registration Number 209102365, a final year student at the Cape Peninsula University of Technology and am studying a master's degree engineering management. I am conducting a research study entitled: "***Assessing the sustainability, cost-effectiveness, and environmental impact of solar PV panels in Western Cape, South Africa".***

I therefore kindly request your co-operation in this regard by completing the attached questionnaire for my collection.

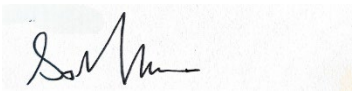
Your response will be treated as grouped data and used for academic purposes therefore there is no need of identifying yourself in any way on the form.

Thank you in advance for your kind co-operation.

Yours faithfully

Sue-Ann Sharlene Muller

Contracts Details: Sueannmuller5@gmail.com



Appendix 2: Questionnaire

Instructions to the respondent

i) Kindly answer the following questions

ii) The questions only have one answer therefore only one tick [✓] maybe placed in response to a question.

iii) Please feel free to provide addition information or expansion of your respondent to question by a way of a comment (s) in the space provide for below. Some of the questions that constitute this questionnaire.

SECTION A (SOCIO-DEMOGRAPHIC DATA)

1) Indicate your gender

Male	
Female	

2) Indicate your age group

Less than 25 Years

25-35 Years

36-45 Years

Above 45 Years

3) Highest Level of Education

High school diploma or equivalent

Bachelor's degree

Master's degree

Doctorate or professional degree

Other (please specify)

4) How long have you been using solar PV panels?

Below 2 years
2-3 years
3-4 years
4-6 years
Above 6 years

5) Occupation:

Student
Employed full-time
Employed part-time
Self-employed
Unemployed
Retired

6) Monthly Household Income:

Less than R5 000
R5001 - R15000
R15001- R20000
R20001- R25000
R25001 – R30000
More than R30001

7) Location:

Urban
Suburban
Rural

8) Household Size:

1-2 members
3-4 members
5 – 6 members
7 or more members

9) Previous Experience with Solar PV panels:

Yes
No

10) Awareness of Environmental Issues:

Low
Moderate
High

SECTION B: FOUR KEY CATEGORIES

1. Environmental Impacts of Solar PV panels:

1a. Please rate the environmental impacts associated with the use of solar PV panels in the Western Cape, South Africa.

Scale	Not Significant	Significant	Neutral	Significant	Very Significant
Rate	1	2	3	4	5

1b. Compared to traditional energy sources in the same context, how would you rate the environmental impacts of solar PV panels?

Scale	Much lower	Slightly lower	Similar	Slightly higher	Much higher
Rate	1	2	3	4	5

2. Assessing Cost-effectiveness:

2a. What is the estimated upfront cost of implementing solar PV panels in the Western Cape, South Africa? [Open-ended response]

……

2b. How would you rate the operational costs of solar PV panels in the Western Cape, South Africa compared to traditional energy sources over the long term?

Scale	Much lower	Slightly lower	Similar	Slightly higher	Much higher
	1	2	3	4	5

3. Examining sustainability, and maintenance requirements:

3a. Please rate the durability characteristics of solar PV panels in the Western Cape, South Africa on a scale of 1 to 5, with 1 being "Not durable" and 5 being "Highly durable."

Scale	Not durable at all	Not durable	Similar	Durable	Highly Durable
Rate	1	2	3	4	5

3b. What sustainability factors do you believe influence the adoption and maintenance of solar PV panels in the Western Cape, South Africa? [Open-ended response]

……

3c. On a scale of 1 to 5, with 1 being "Very low" and 5 being "Very high," please rate the maintenance requirements and associated challenges of using solar PV panels in the Western Cape, South Africa.

Scale	Very low	Low	Similar	High	Very high
Rate	1	2	3	4	5

4. Contributing practical recommendations and strategies [Open-ended response]:

4a. What practical recommendations do you suggest enhancing the sustainability and effectiveness of solar PV panels usage in the Western Cape, South Africa?

……

4b. How can policy frameworks be adjusted to facilitate the widespread adoption of solar PV panels in the Western Cape, South Africa?

……

4c. What strategies do you propose to overcome barriers hindering the successful integration of solar PV panels into the energy mix in the Western Cape, South Africa?

…….

THANK YOU