SELINUS UNIVERSITY
OF SCIENCES AND LITERATURE

THE IMPACT OF RENEWABLE SOLAR ENERGY AS AN ALTERNATIVE SOURCE OF ELECTRICITY IN SUSTAINING SMALL AND MEDIUM SCALE ENTERPRISES TO ENHANCE EMPLOYMENT OPPORTUNITIES IN PORT HARCOURT CITY, NIGERIA.

By

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A DISSERTATION

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Declaration

I hereby that this thesis ‘’ The Impact of Renewable Solar Energy as an Alternative Source of Electricity in Sustaining Small and Medium Scale Enterprises to Enhance Employment Opportunities in Port Harcourt City, Nigeria’’ submitted for the award of Doctor of Philosophy in Renewable Energies has been written by me and it is a report of my research work. It has not been presented in any previous application for a diploma or degree. All quotations are indicated, and sources of information specifically acknowledged by means of references.

Danjuma DOGO

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Abstract

The global drive to combat the effects of climate change by replacing fossil fuels with renewable energy sources for electricity generation also comes with some socio-economic benefits as noted by the International Renewable Energy Agency (IRENA). Nigeria has a challenge with electricity generation and distribution; hence most business enterprises are forced to provide alternative source of electricity from diesel or petrol-powered generators to remain in operation. While the big corporations are able to afford this, small and medium scale enterprises (SMEs) that account for majority of the employment in Nigeria are finding it difficult to cope. The recent increase in the pump price of petrol and diesel in the country has increased the cost of operations for business enterprises, threatening their continued existence. This research was therefore carried out to determine the impact of renewable solar energy as an alternative source of electricity in sustaining small and medium scale enterprises to enhance employment opportunities in Port Harcourt city, Nigeria.

A cross sectional survey research design was employed. The research covered 5873 operators of SMEs located within Port Harcourt city. The sample size used was 588 operators of SMEs which represents 10% of the population. Data collection was achieved using questionnaires containing both structured and semi structured open-ended questions. For qualitative data analysis, non-parametric simple percentages were used while results were presented using simple tables, pie charts and bar charts. The hypotheses were tested using Z-test for simple proportions, while responses derived from the open-ended questions were analysed and presented using descriptive qualitative method. In conclusion, the research shows that the adoption of solar as an alternative source of electricity to fossil fuel powered electricity from generators will lead to cost savings and operational efficiency, and consequently provide employment opportunities within SMEs in Port Harcourt City. In order to achieve this goal, SMEs operators in the commercial category who use petrol-powered generator will be the best target category. The research also revealed that although SME operators in Port Harcourt are aware of solar as an alternative source of electricity, they are reluctant to adopt this alternative mainly due to the cost implication despite its benefits. It is recommended that policies should be put in place to lower the cost of solar PV components.

Dedication

To my wife for her support and encouragement, and my children for their understanding.

Acknowledgement

I thank God almighty for His grace, help, strength, wisdom, and speed all through this research.

I am also thankful to Prof. Salvatore Fava my supervisor for his very helpful guidance all through this research. Also, to other team members of Selinus University of Science and Literature for their support and timely responses to enquiries.

Finally, I would like to express my appreciation to the Rivers State Ministry of Commerce and Industry, and the Unit Head Rivers State COVID-19 Action Recovery and Economic Stimulus for their assistance in the provision of relevant SMEs data.

Nomenclature

AC	Alternating Current: a type of electrical current, in which the direction of the flow of electrons switches back and forth at regular intervals or cycles.
DC	Direct Current: a type of electrical current in which the flow of electrons is one-directional.
PV	Photovoltaic, usually used to describe the ability of solar panels to generate electricity from sunlight.
W	Watt, the SI unit of power, equivalent to one joule per second, corresponding to the rate of consumption of energy in an electric circuit where the potential difference is one volt and the current one ampere.
kW	Kilowatt, one thousand watts.
kWh	1,000 watts generated or used for one hour.
MW	Megawatt, one million watts, especially as a measure of the output of a power station.
MWh	1,000,000 watts of electricity generated or used per hour.
GW	Gigawatt, one billion watts.
GWh	1,000,000,000 watts of electricity generated or used per hour.
TW	Terawatt, one trillion watts.
TWh	1,000,000,000,000 watts of electricity generated or used per hour.

Chapter 1

1. Introduction

1.1 Background of Study

The global drive to combat the effects of climate change has led to more countries embracing renewable energy as an alternative source of energy to fossil fuel to reduce CO2 emissions. On a large scale, hydro, wind, liquid biofuels, and solar sources of renewable energy have been employed. The International Renewable Energy Agency (IRENA) notes that energy also plays a key role in socio - economic development, therefore various countries are approaching the issue of climate change with a view of also harnessing the socio-economic benefits of renewable energy. This thesis will focus on the use of solar energy in boosting the economy by providing more employment opportunities.

Job creation within the solar energy industry can fall into any of these categories: manufacturing of solar photovoltaic panels and associated components, transport and logistics, installation of solar PV plants (projects), management of solar PV plants and utilization of solar PV systems by end users as an alternative source of electricity to boost sustainable commercial activities that create jobs. The IRENA, in its 2021 Renewable Energy and Jobs Annual Review, noted that solar energy created about 4 million jobs. In terms of job creation, the scope of this thesis will be narrowed down to the end users.

Nigeria depends on electricity as her major form of energy but only 51.2% of the total electricity demand is generated through the national grid with 39.2% and 11.7% of this produced from gas and hydroelectric power plants respectively. To compensate

for this short fall, end users employ fossil fuel powered generators to meet 48.6% of the electricity demand while only 0.1% of the electricity demand is generated by off-grid renewables (NBS,2021). Although the country has an installed capacity of 16,384 MW, only about 4,000 MW is generated on the average with more of the supply focused on the urban areas with an access rate of 60% of the nation's population (NSAID,2022). Also, 93% of the electricity generated is channelled to household use while only 4% is made available for industrial activities (IRENA,2018). This suggests that there is a low supply of electricity for industrial and commercial activities. Consequently, businesses employ alternative sources of power to remain in operation.

The industrial setting in Nigeria comprises on one hand of big corporations usually having foreign partners that help to form strong conglomerates. They usually require large start-up capital, and they create employment opportunities mostly for the well trained and educated. On the other hand, there are small, and medium scale enterprises (SMEs) which require less start-up capital and are owned by individuals or families. They create jobs for mostly uneducated workers because they are usually engaged in labour intensive activities. In 2017, SMEs provided a total of 59,647,954 employment in Nigeria. SMEs therefore play a major role in national economic development (NBS,2017).

Inconsistent electricity supply has been identified as one of the challenges faced by business enterprises in Nigeria (Agwu and Emeti, 2014). The Nigerian National Bureau of Statistics estimated that in 2017, about 44.6% of small to medium business enterprises reported between 1-5 hours of alternative electricity usage daily while 26.2% and 5.1% reported 6-10 and more than 20 hours daily usage

respectively. The main source of this alternative electricity are generators powered by either petrol or diesel. Generators account for 48.6% of alternative electricity generated by end users. The high cost of fuel and generator maintenance due to long - running hours suggest a high operational cost with considerable impact on business. Any intervention that provides a renewable source of alternative electricity at the level of the end user is likely to improve the operational cost-effectiveness, competitiveness, and sustainability of the business enterprise. It is proposed that solar energy will be most suitable for such an intervention because it is generated from sunlight.

1.2 Problem Statement

Nigeria is a signatory to the 2015 Paris Agreement on Climate Change and therefore has an obligation to take steps in combating climate change. However, business enterprises who are end users of electricity, still depend on generators that use fossil fuel to generate electricity because the electricity provided by the national grid is not adequate. The utilization of fossil fuel dependent alternative electricity leads to more CO_2 emissions, and this negates the efforts made towards the reduction of CO_2 emissions.

The constant spend on generator purchase, maintenance and fossil fuel with the consequent cost implications also threatens the growth of business enterprises and their potential to strive and provide employment opportunities. Majority of the end users are small, and medium enterprises (SMEs) and they are involved in creating employment opportunities (SMEDAN, 2022). In 2017, 23.1% of SMEs temporarily shut down due to inadequate power supply. (NBS,2017). The level of awareness

about renewable energy may also be an issue among SMEs owners as only 0.1% of the electricity demand deficit is met by off-grid renewables (NBS,2021).

1.3 Objectives

1 To determine the level of awareness of SMEs operators about solar energy as an alternative source of electricity in Port Harcourt city

2. To determine the degree of willingness of SMEs operators to adopt solar energy as an alternative source of electricity in Port Harcourt city
3. To determine whether the introduction of solar energy as an alternative source of electricity directly to SMEs will enhance operational cost-effectiveness/ cost savings in Port Harcourt city.
4. To determine whether the introduction of solar energy as an alternative source of electricity directly to SMEs will result in creation of more employment opportunities in Port Harcourt city.

1.4 Research Questions

1 Are SMEs operators aware of solar as an alternative source of electricity in Port Harcourt city?

2. Are SMEs operators willing to adopt solar as an alternative source of electricity in Port Harcourt city?
3. Does the introduction of solar energy as an alternative source of electricity directly to SMEs result in operational cost-effectiveness/cost savings in Port Harcourt city?
4. Does the introduction of solar energy as an alternative source of electricity directly to SMEs result in creation of more employment opportunities in Port Harcourt city?

1.5 Research Hypotheses

In order to answer the above research questions, the following null hypotheses were formulated.

1. **H_o:** SMEs operators are not aware of solar as an alternative source of electricity in Port Harcourt city.
2. **H_o:** SMEs operators are not willing to adopt solar as an alternative source of electricity in Port Harcourt city
3. **H_o:** The introduction of solar energy as an alternative source of electricity directly to SMEs does not result in operational cost-effectiveness/cost savings in Port Harcourt city
4. **H_o:** The introduction of solar energy as an alternative source of electricity directly to SMEs does not result in creation of more employment opportunities in Port Harcourt city

In addition to the null hypotheses above, corresponding alternative hypotheses have also been formulated.

1. **H_1:** SMEs operators are aware of solar as an alternative source of electricity in Port Harcourt city.
2. **H_1:** SMEs operators are willing to adopt solar as an alternative source of electricity in Port Harcourt city
3. **H_1:** The introduction of solar energy as an alternative source of electricity directly to SMEs does result in operational cost-effectiveness/cost savings in Port Harcourt city

4. **H_1:** The introduction of solar energy as an alternative source of electricity directly to SMEs does result in creation of more employment opportunities in Port Harcourt city

1.6 Study Area

Port Harcourt is the capital city of Rivers State in the Niger Delta region of Southern Nigeria. It has a land mass of 369 km², located at latitude 4.8472° N and longitude 6.9746° E. Figure 1 shows the location of Port Harcourt city within the Niger Delta region. The city experiences a prolonged rainy season with mostly cloudy days. The cloudiest part of the year last between February to November. The dry season is short and less cloudy, usually between November and February as shown in figure 2 (weather Spark, 2022).

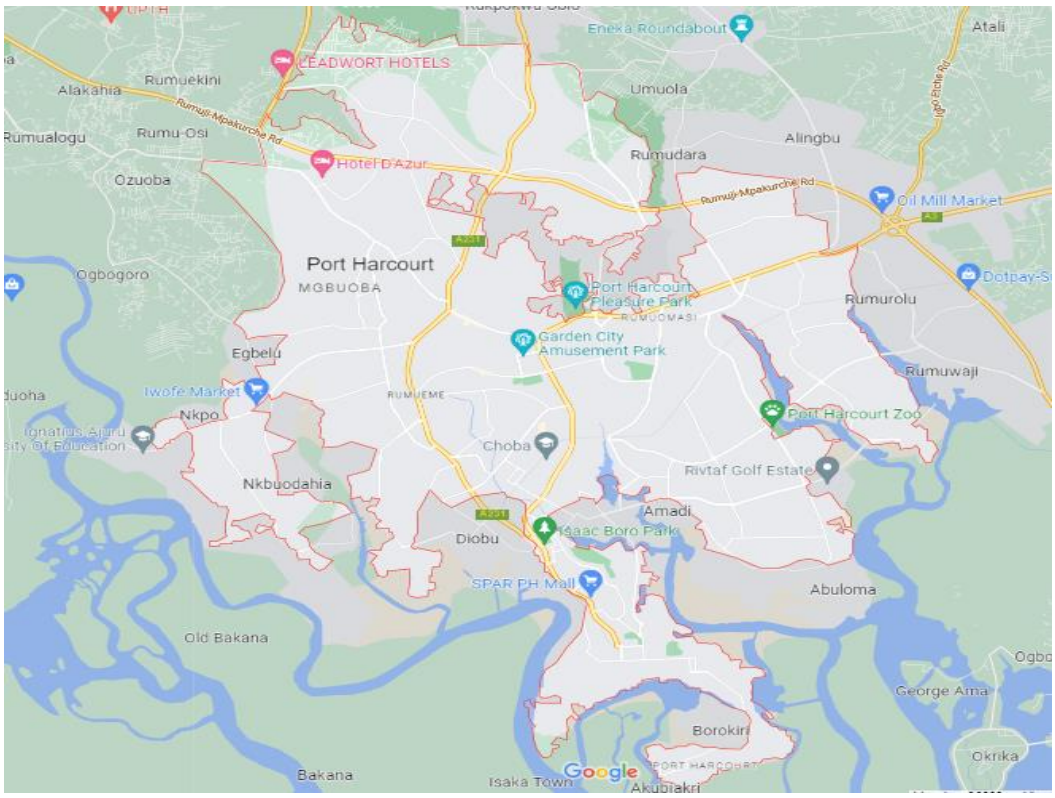


Figure1. Map of Port Harcourt,

Courtesy Google Map.

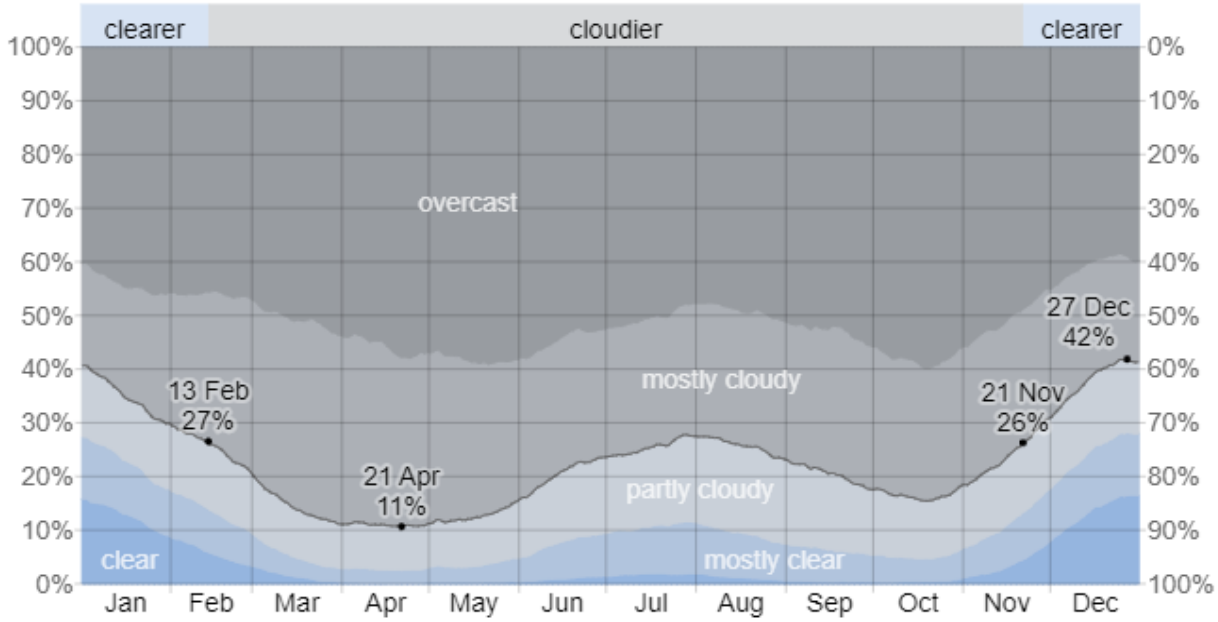


Figure 2. Cloud cover categories in Port Harcourt.

Courtesy,© WeatherSpark.com

Port Harcourt has a population of 3,324,694 with annual growth rate of 4.84%. This growth rate has gradually decreased since 2016 (WPR, 2022). It is a host to many different manufacturing companies which are supported by one of Nigeria's leading seaports, the Onne Port, which plays a key role in offshore oil and gas activities in Nigeria. It also boasts a refinery and a petrochemical complex. Most of the oil producing and service companies have their offices in Port Harcourt and like many other metropolitan cities, this has a direct effect on the cost of living. Only a small proportion of the population are directly employed by these oil companies while others work in the civil service or MSMEs. There are about 5,873 registered MSMEs in Port Harcourt offering agricultural, commercial, and industrial goods and services. These enterprises provide a wide range of employment opportunities due to their low start-up capital.

Electricity distribution in Port Harcourt is managed by the Port Harcourt Electricity Distribution Company PHED, while power is generated by various electricity companies. The main source of electricity is gas turbines which are fed with natural gas from some oil and gas producing companies. Some of the gas turbine power plants around Port Harcourt include the Trans Amadi Plant, Omoku Plant and Afam Plant with installed capacities of 136MW, 150MW and 180MW respectively (FIPL, 2022). However, the problem of epileptic electricity supply is common across the nation and Port Harcourt is no exception.

1.7 Significance of Study

Previous studies have focused on the provision of adequate electricity from renewable sources but through the Nigerian national grid as part of government's infrastructure to enhance economic activities and employment opportunities. Others have also covered the employment of solar energy technology and the associated supply chain as a source of employment opportunities. There is however a gap in the role solar energy technology plays in small business enterprises when directly employed at the level of the end user thereby minimizing the grid related power interruptions.

1.8 Scope of Study

This study is confined to the utilization of solar energy as an alternative source of electricity in SMEs to supply the short fall from the national grid. It also focuses on the provision of this alternative at the premises of the SMEs as an end user solution.

The cost savings on fossil fuel will then be considered to determine its impact on operational cost-effectiveness and its likelihood to generate employment opportunities within the SMEs.

Chapter 2

2.0 Literature Review

2.1 Concept of Energy

2.1.1. Energy

Energy is defined as the capacity for doing work while work is the transfer of energy from one form or body to another. The earth's continued existence and the support for all forms of life require energy in the right form. The sun is the primary source of Earth's energy. The sun produces more than 10,000 times the energy needs of the world. It produces the world’s energy need for one year in one hour (MIT, 2011, National Geographic,2022).

Energy exists in various forms, but the earliest adopted form of energy was wood, followed by other fossil fuels made up of coal, oil, and gas, collectively called hydrocarbons. The earliest use of energy was for lighting, heat generation, and rotary motion required for mills and mobility. While the use of wood was mainly limited to meeting domestic needs, hydrocarbons have found application in various fields (Britannia, 2022)

Coal played a major role in the industrial revolution of the mid-eighteenth century as both fuel and coke for the efficient conversion of iron ore to iron which was eventually used for building bridges and large industrial machines. James Watt invented the steam engine in 1769 and this promoted the use of coal in steam-powered trains and commercial boats. Little application was found for oil until after the invention of the internal combustion engine which necessitated the use of oil for fuel (Pirani, 2018)

In 1859, the first oil well was successful drilling by Edwin Drake in north-western Pennsylvania and this made oil commercially available. The gas associated with oil production was either left in the reservoir or flared as it had no immediate use then. The establishment of more oil companies following this discovery made more oil available and affordable. Also, towards the end of the 19th century, various advancements in the development of engines powered by gasoline, a derivative of crude oil, helped boost the transportation industry, The gasoline engines were used in cars and aircrafts and also replaced steam-powered engines in boats. This trend gradually phased out the dependence on coal (Devold, 2006).

The delayed utilization of gas as a source of energy was due to the constraints associated with its transportation from the point where it is generated to the point where it is used. Advancements in welding techniques and the construction of reliable pipelines boosted the distribution of gas across regions. Also, the introduction of gas liquefaction made it possible to transport liquified natural gas (LNG) in large tankers, promoting international sales of gas. Gas is used today mainly for heating, cooking, and the generation of electricity (Devold, 2006).

2.1.2. Energy and Global Climate Change

The use of hydrocarbons as an energy source has increased over the years. The invention of the steam engine and the gasoline engine contributed to the use of hydrocarbon, but it was the discovery of electromagnetic induction in 1831 by

Michael Faraday and the subsequent use of fossil fuels to generate electricity that played a major role in the increased demand for fossil fuels (Caineng et al., 2016).

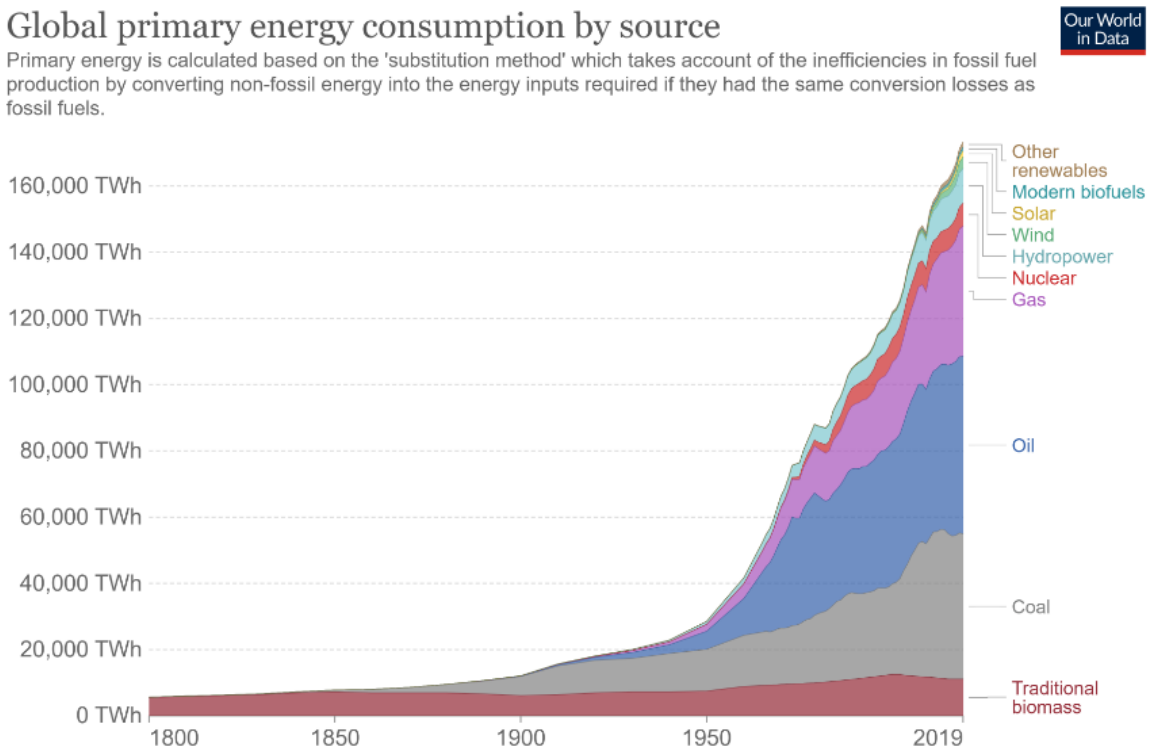


Figure 3. Global primary energy consumption by source

Source: Vaclav Smil (2017) & BP Statistical Review of World Energy *OurWorldInData.org/energy • CC BY*

Figure 3 above shows that fossil fuels are currently used to meet about 80% of the world's energy demand. There is, therefore, a drive for alternative sources of energy because fossil fuels are not renewable and have over the years given rise to a negative impact on the environment and human health (Moodley,2021).

The main environmental impact attributed to fossil fuel is the emission of greenhouse gases and carbon dioxide (CO_2) responsible for the current global climate change resulting in global warming. Fossil fuels account for about 90% of CO_2 emissions and over 75% of greenhouse gas emissions. Figure 4 shows a steady increase in emissions

from 15,461 metric tonnes of CO_2 in 1973 to 33,633 metric tonnes of CO_2 in 2019. To curb this trend, The Paris Agreement was established in 2015 to reduce CO_2 emissions and consequently reduce global warming. Currently, 192 countries, including the European Union are signatories to the Paris Agreement (UN, 2022).

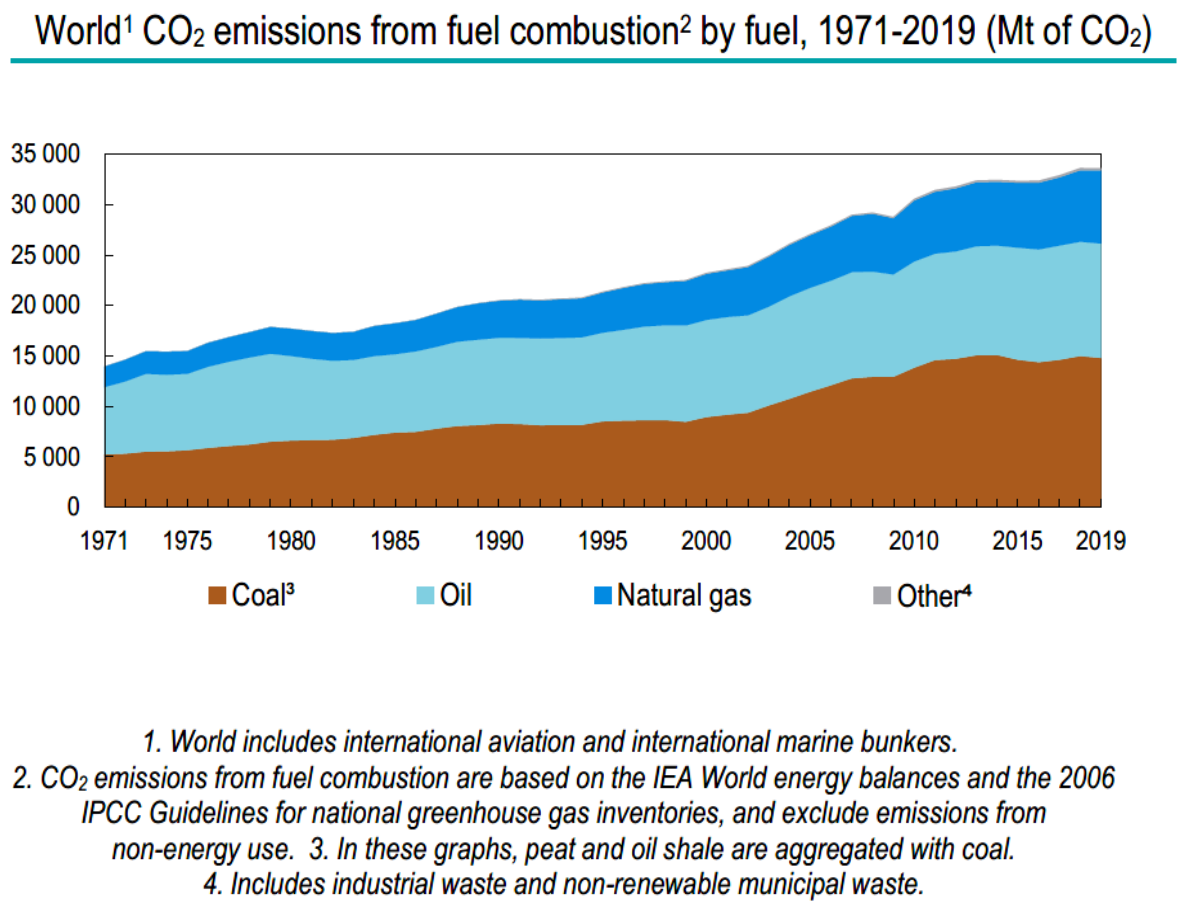


Figure 4. World CO2 emissions from fuel combustion by fuel, 1971-2019 (Mt of CO2)

Source: IEA, CO2 Emissions from Fuel Combustion, 2021/Statistics Report, Key World Energy Statistics 2021

2.1.3. Evolution of Energy Sources

A series of discoveries in the field of electricity were made in the nineteenth century which changed the trajectory of energy generation. One notable discovery was the dynamo, invented by Frenchman Hippolyte Pixii in 1832. It was a simple device that

converted mechanical energy to electricity. Several improvements by other scientists helped modify the dynamo to produce a steady direct current. Also, the invention of the incandescent lamp in 1879 by Thomas Edison increased the demand for electricity because the lamp was required for lighting the streets and homes. Edison later went ahead to build a power generation station in Lower Manhattan. He also made electricity commercially available by employing wire conductors to distribute the electricity generated to clients. Thereafter, several more advancements were made that improved power generation, and by the early twentieth century, power stations were producing about 1 MW to 10 MW (Power,2022).

In 1834, another important device, the electric motor was invented by Thomas Davenport and used in a printing press. The electric motor unlike the dynamo converts electrical energy to mechanical energy. It relied on electricity supplied to the end user, so it afforded the user the possibility of its use in a location away from the point of generation of electricity as depicted in Figure 5.

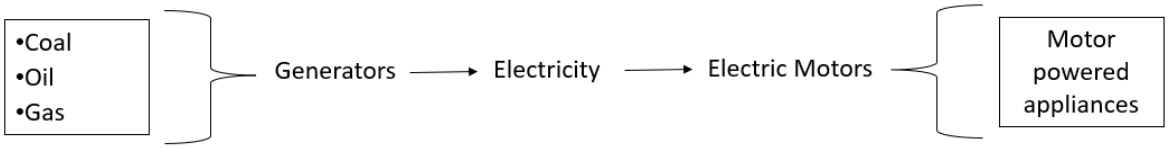


Figure 5. Electricity generation

The electric motor has gone through several improvements which have produced motors run by alternating current (AC) or direct current (Parvalux, 2022). These options increased the utilization of electric motors in a variety of appliances used in industries, homes, and the transport sector. Some of these appliances include compressors, blowers, fans, crushers, HVAC, lathe machines, drills, power tools

conveyors, elevators, escalator printers, winches, washing machines, robots, electric vehicles, and several others that require rotary motion. Following this wide range of applications, the energy trend has gradually tilted toward the use of electricity. This conversion of machines and systems to adapt to the use of electric power is called electrification.

Although the invention of the electric generator and electric motor has increased the dependence on electricity as a major source of energy, the primary source of powering the generators has remained fossil fuels. Consequently, the increased demand for electricity has led to a corresponding increase in the use of fossil fuels which still accounts for about 60% as shown in Figure 6 below.

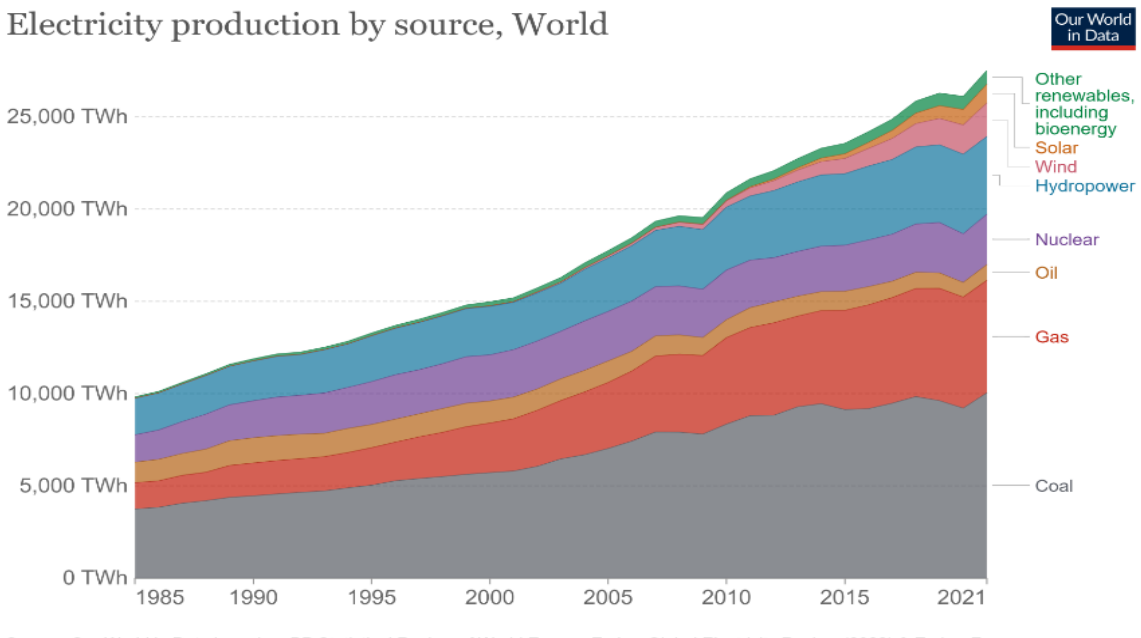


Figure 6. Electricity production by source, World

Source: Our World in Data based on BP Statistical Review of World Energy, Ember Global Electricity Review (2022) & Ember European Electricity Review (2022) OurWorldInData.org/energy • CC BY

2.1.4. Energy Transformation

Globally, steps are being taken by countries and various agencies to reduce the dependence on fossil fuels for the generation of electricity. This concept is called energy transformation, and it involves the move from fossil fuels – coal, gas, and oil to renewable energy sources – wind, solar and storage batteries. The adoption of electrification from clean electricity as a power source and recent changes in energy production and consumption trends have given a boost to energy transformation. These changes include the reduced cost of renewables, digitalization, and efficient energy use (IRENA, 2019). The journey so far is highlighted in Figure 7.

Energy transformation comes with a lot of advantages across various areas of society besides the reduction in CO_2 emission. More job opportunities will be created leading to economic growth in addition to reduced impact on human health. These improvements will lead to savings of between three to seven times the amount invested in a year in energy transformation. Besides energy security, it is estimated that global employment will increase by 0.2% with a corresponding 2.5% improvement in GDP (IRENA 2019). However, countries will need to come up with firm policies to actualize these projections. The key policy areas to be focussed on include social protection, macroeconomic and growth policies, active labour market policies, industrial and sectoral policies, skills development, enterprise policies, occupational safety and health, rights, and social dialogue and tripartism (ILO,2015)

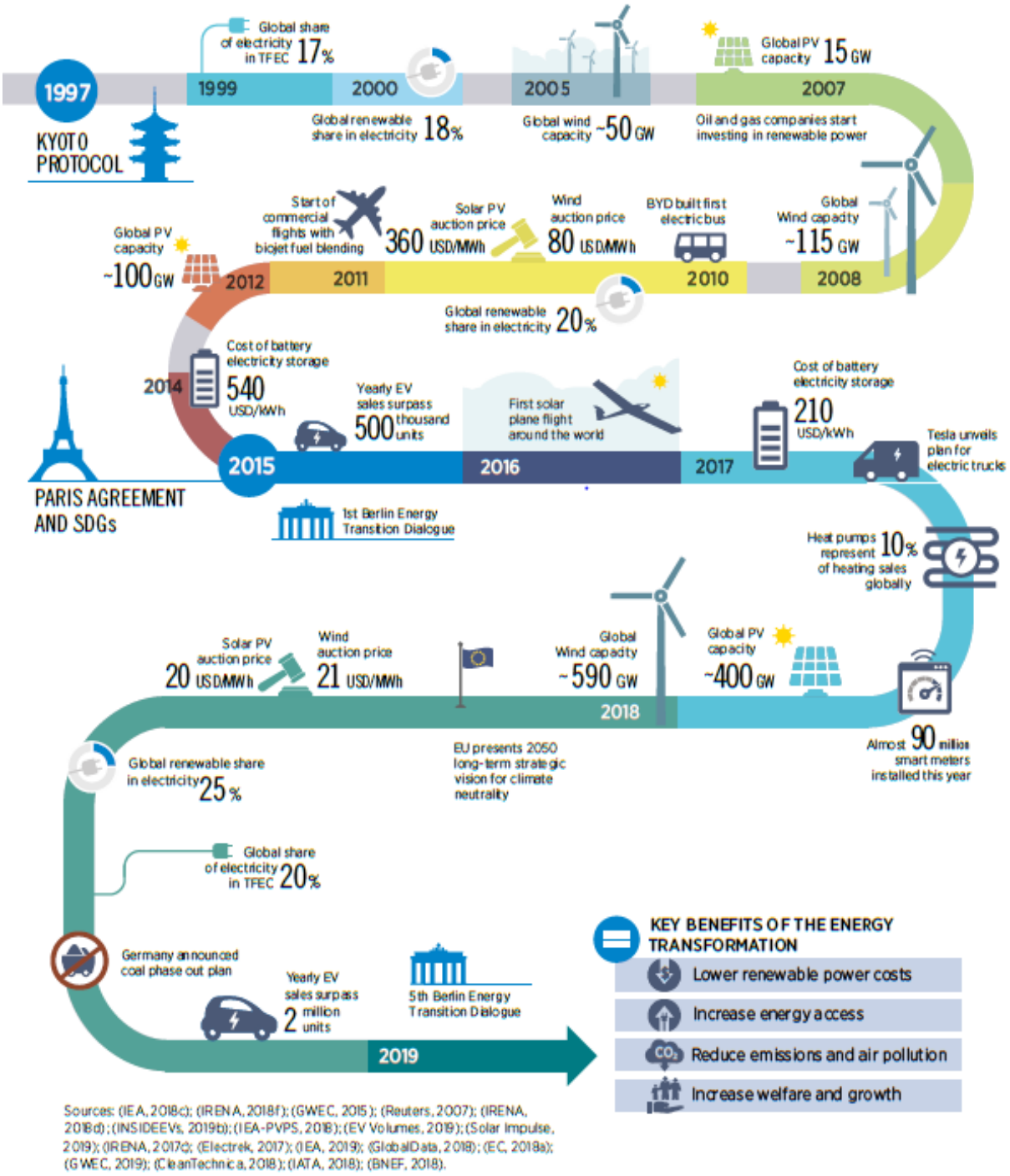


Figure 7. Recent progress of the energy transformation: key milestones over the past 20 years in renewables and digitalization

Source: IRENA,2019

2.1.5 Renewable Energy

Renewable energy as defined by The United Nations is ‘energy derived from natural sources that are replenished at a higher rate than they are consumed’. Renewable energy sources include wind, solar, hydropower, bioenergy, geothermal, and ocean (IRENA,2022). As a result of an increase in the demand for energy and the consequences associated with the use of fossil fuels, renewables are gradually becoming the energy source of choice. The demand for electricity is projected to continue to increase while renewables will provide 25% and 34% of the electricity demand in 2023 and 2025 respectively (figure 8). This will be driven by the introduction of more electric vehicles in the transport sector, industrial-scale electrification, and the need for space cooling as a direct consequence of a higher standard of living among highly populated non – Organization for Economic Cooperation and Development (OECD) countries. The cost of wind turbines, solar panels, and the associated components are also predicted to continue to drop, thus becoming cheaper than traditional fossil fuels due to technological advancements (McKinsey,2019).

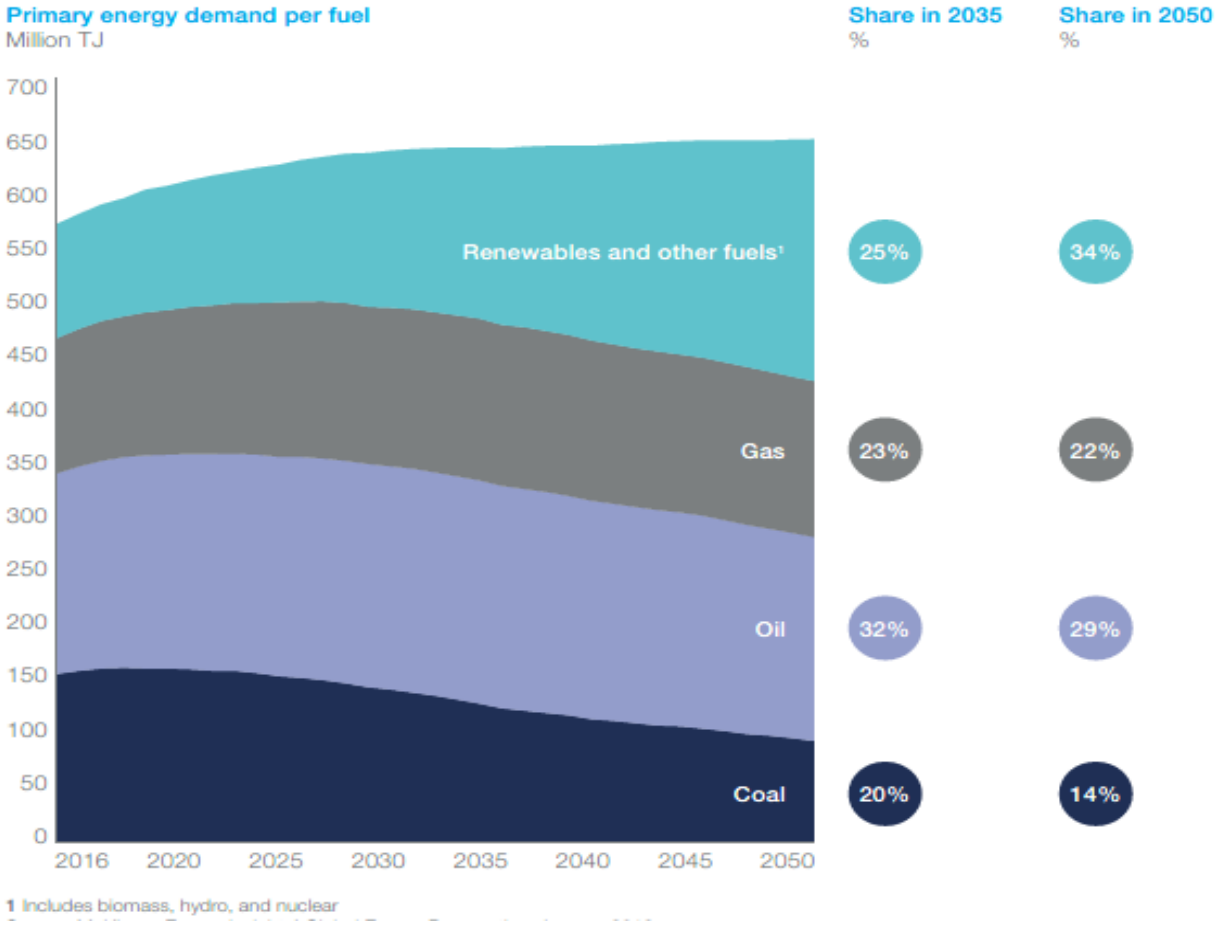


Figure 8; Primary energy demand per fuel 2016 - 2050

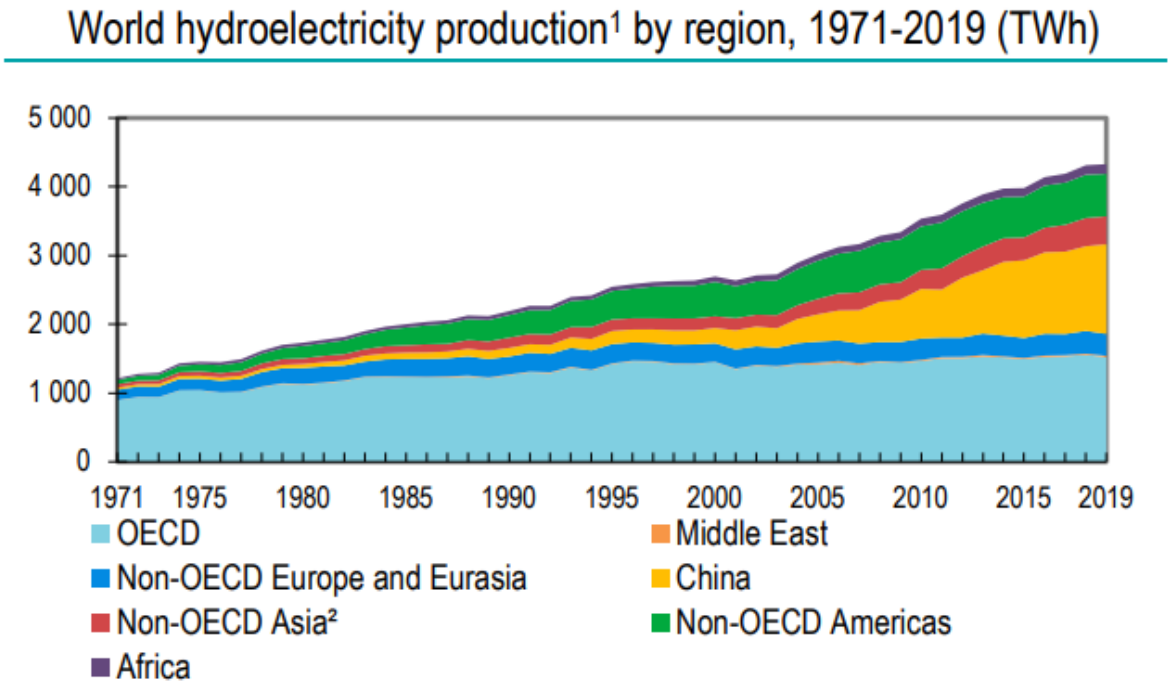
Source: McKinsey Energy Insight's Global Energy Perspective. January 2019

2.1.6 Electricity from renewable energy

Hydroelectricity Production

The commonest source of electricity from renewable is hydroelectricity. The principle is hinged on converting the potential energy of water at a height, usually in a dam to mechanical energy. The force of the falling water is used to turn turbines which are connected to generators, and this produces electricity. The use of hydroelectricity varies from region to region and the level of dependence differs. Norway produces 99% of its electricity from hydroelectricity while China produces 22.5 gigawatts of

energy from its Three Gorges Dam, the world's largest which serves up to 80 million households (IRENA,2022). Figure 9 shows that the generation of hydroelectricity has steadily grown over the years with a marked increase in China followed by Non-OECD Americas (IEA, 2021).



1. Includes electricity production from pumped storage.
2. non-OECD Asia excludes China.

Figure 9. World hydroelectricity production by region, 1971-2019 (TWh)

Source: IEA, CO2 Emissions from Fuel Combustion, 2021/Statistics Report, Key World Energy Statistics 2021

Wind Electricity Production

Wind-generated electricity dates to the 1800s in both the United States and the United Kingdom while modern wind turbines began in Denmark. In a wind turbine, the wind transfers its kinetic energy to the blades of the wind turbine. This causes the blades to rotate and turn the turbine thus changing the kinetic energy to rotational energy. The shaft from the turbine is connected to a generator which

converts the rotational energy to electricity. The use of wind turbines has continued to grow both in capacity and demand mainly because the cost of the associated components is becoming lower by the day. In 1997 produced capacity was 7.7 GW, this has increased to about 564 GW over 20 years. Figure 10 shows that more than half of the world wind electricity generated in 2019 was from OECD countries. China has steadily increased its share of world wind electricity generation accounting for one-third in 2019 (IRENA,2022, IEA, 2021)

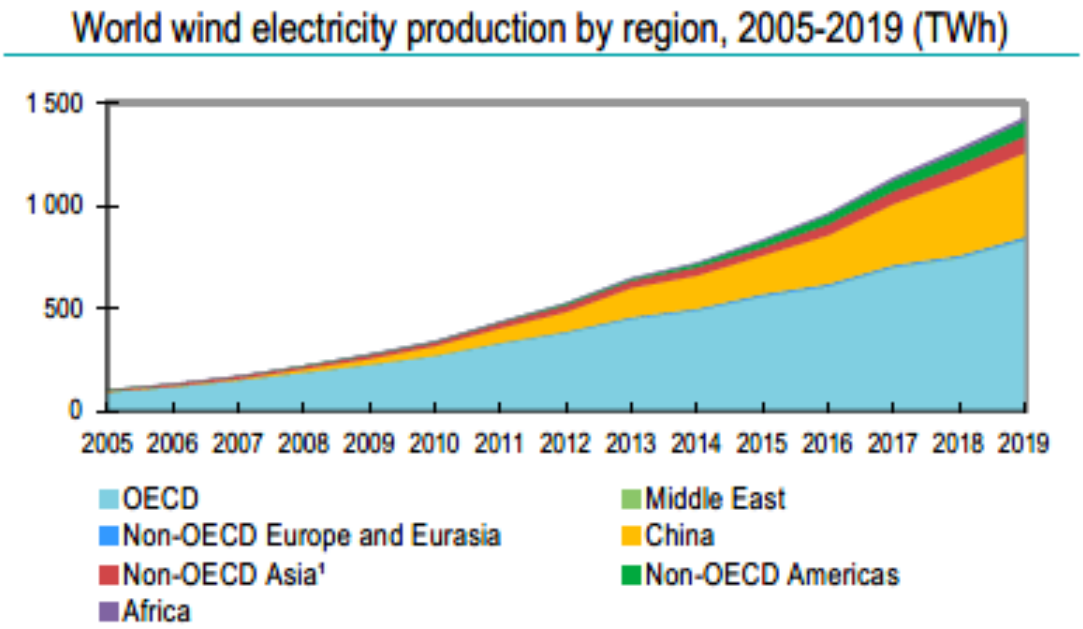


Figure 10. World wind electricity production by region, 1971-2019 (TWh)

Source: IEA, CO2 Emissions from Fuel Combustion, 2021/Statistics Report, Key World Energy Statistics 2021

Solar PV Electricity Production

Electricity production from solar PV worldwide has steadily increased from 2006 to date. The US Office of Energy Efficiency and Renewable Energy estimates that 97.2 gigawatts which represent 3% of the electricity generated in the US come from solar

energy (EERE, 2022). Figure 11 shows that Asia has continued to increase its contribution with China accounting for more than one-third of electricity produced from solar in 2019. Similarly, there has also been a corresponding increase in PV production in Asia by China and Japan due to falling production costs (IRENA, 2017).

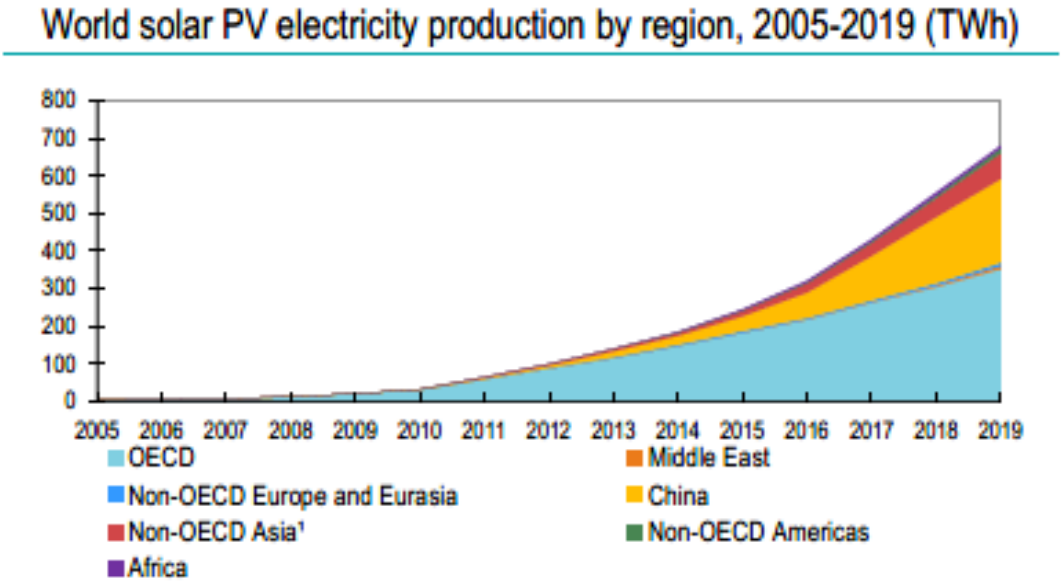


Figure 11. World Solar PV production by region, 1971-2019 (TWh)

Source: IEA, CO2 Emissions from Fuel Combustion, 2021/Statistics Report, Key World Energy Statistics 2021

The solar energy category has recorded a significant fall in prices across all the associated components (figure 12) and this has increased its adoption for both small and large projects (IRENA, 2016).

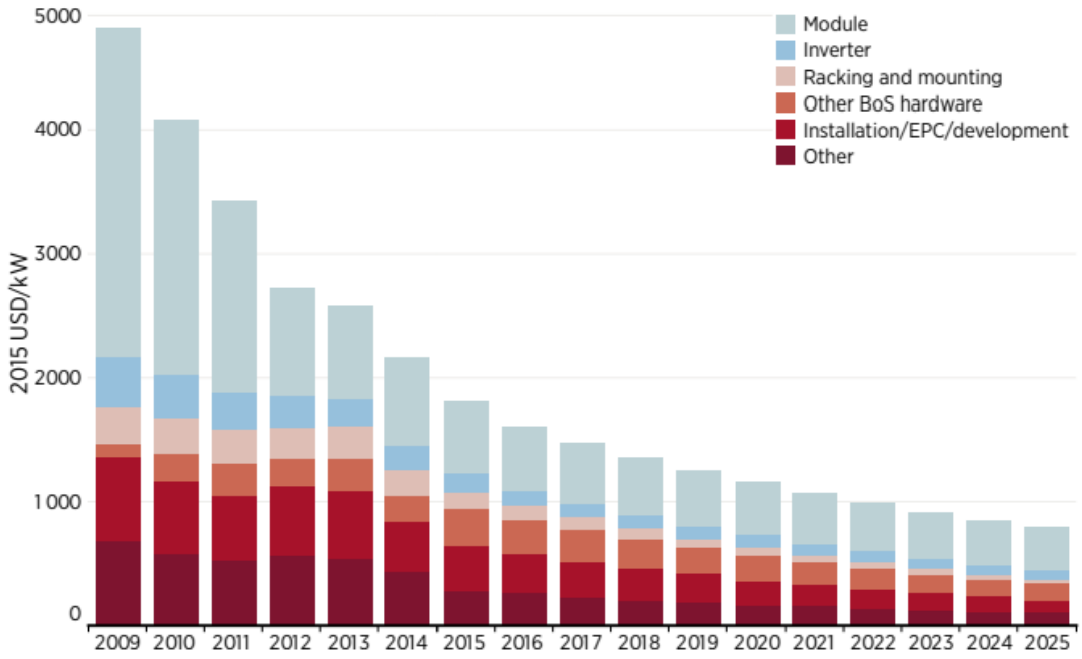


Figure 12: Global weighted average utility-scale solar PV total installed costs, 2009-2025

Source: The Power to Change: Solar and Wind Cost Reduction Potential to 2025 (irena.org)

Energy Storage for Renewables

One of the early challenges of the use of renewables was the lack of continuous generation of electricity. Wind turbines for example rely on a minimum amount of wind speed to produce electricity and consequently became inefficient when wind speed is inadequate. Solar PV systems also need sunlight to produce electricity hence they do not produce electricity in the absence of sunlight. Energy storage batteries are therefore utilized to store excess electricity when produced and released for use in the absence of renewables providing cheaper electricity. Energy storage also has the advantage of delivering energy at the rate it is required, over the entire period of an operation. The type of battery used also plays a key role. Lithium-ion batteries are preferred because they are more efficient. New technologies have led to a gradual fall in the cost of lithium–ion batteries by 97%

between 1991 and 2020 (MIT,2022), and an increase in capacity for energy storage. Batteries are sometimes used on a small scale in homes, or as utility-scale battery systems, where they are used in complementing renewable energy sources to serve large populations. Australia has a large capacity Tesla 100 MW/ 129 MWh Li-ion battery storage installation at the Hornsdale Wind Farm (figure 13) and it provides power for more than 30,000 homes (Tesla, 2017). Large-capacity battery storage systems are being installed in several other countries and it is estimated that by the end of 2030, the global cumulative energy storage will be 358 gigawatts/1,028 gigawatt-hours (BloombergNEF,2021)

Figure 13. Tesla 100 MW/ 129 MWh Li-ion battery storage installation at the Hornsdale wind farm, Australia.

Source: Tesla

2.1.7 Solar PV System

The energy generated from the sun is referred to as solar energy. It reaches the earth through radiation, arriving as heat, and light. Although some of this energy is lost in transit and on entering the earth's atmosphere, the amount that reaches the earth is still useful. Special devices are used to harness the heat from the sun to produce thermal energy to provide heating solutions. The heat is also used in concentrated solar power plants (CSP) by utilizing mirrors that concentrate solar rays to heat a fluid. The steam produced by the heated fluid is channelled to drive turbines which then produce electricity. One advantage of CSP is that the fluid can be replaced with molten salt which retains heat that can be stored to produce electricity in the absence of heat from the sun.

The light from the sun is also converted to electricity using photovoltaic solar panels. The amount of electricity produced increases with the intensity of light from the sun and the absence of shading effects by clouds. Consequently, various regions of the world have varied potentials to generate electricity from sunlight. Figure 14 shows the photovoltaic power potential across various regions. Generally, tropical regions have higher photovoltaic power potentials than temperate regions (Britania,2022).

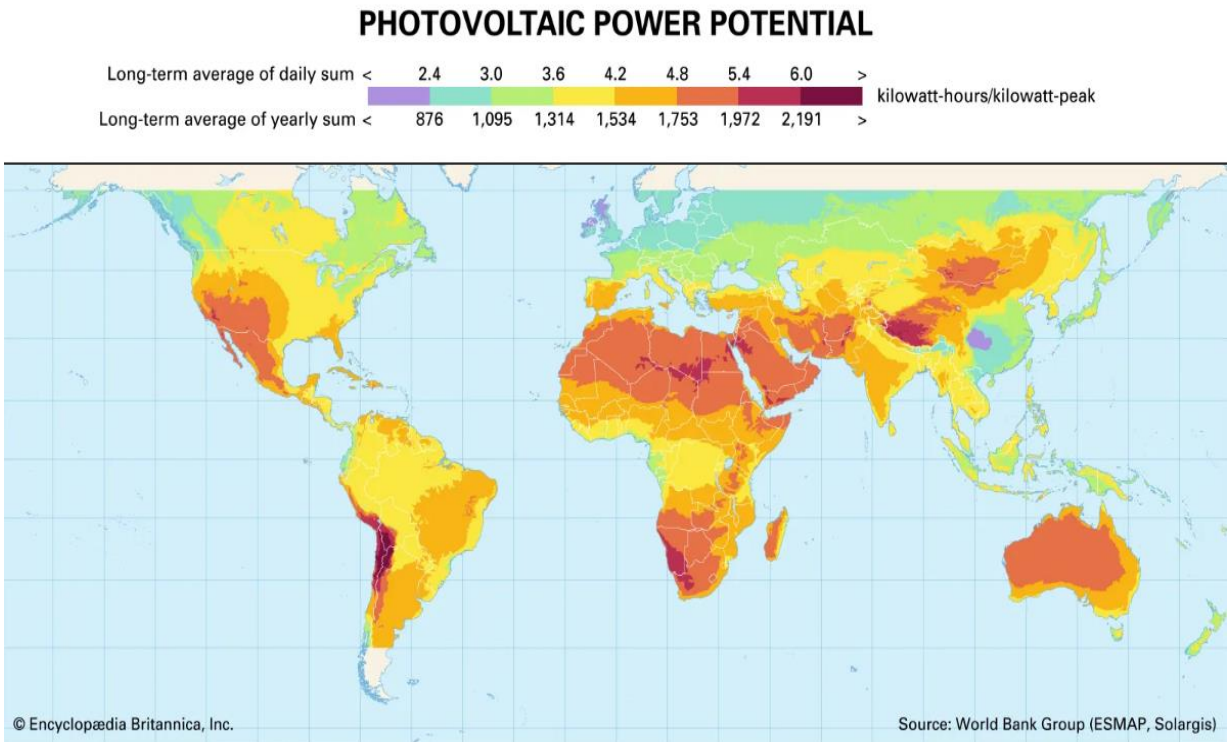


Figure 14. Earth's photovoltaic power potential

Source: Encyclopædia Britannica, Inc./Kenny Chmielewski

General Principle

The simplest arrangement of solar photovoltaic (PV) system starts with PV panels which convert the energy of the sun to electricity. Direct current (DC) is generated by the PV panels and fed into an inverter that converts DC to alternating current (AC). The AC is then used to power electrical appliances. This arrangement can be more complex where energy storage or connection to the grid is required. The solar PV system can also be on a small scale for application to homes and offices (end-user solutions), or a large scale in the case of solar PV plants or farms.

Solar PV End User Solutions

End-user solutions are installed at the point where the power will be used. The PV panels are often mounted on the roof or the ground where space is available. They can also be used to replace building parts such as windows roofing sheets or walls. They are therefore called building integrated PV (BIPV). The other associated electrical components that make up the solar PV system are normally installed in a dedicated area within the building with short wiring.

Off-Grid Solar PV System

This solution is particularly useful in remote areas where there is no source of electricity. It can be used to power small appliances, an off-grid house, or even an isolated community. An important feature of this solution is the incorporation of batteries for power storage, thus making power available at night when there is no sunlight. The power storage capacity plays a key role in the effectiveness of this solution, and it is cost-effective if energy demand is low.

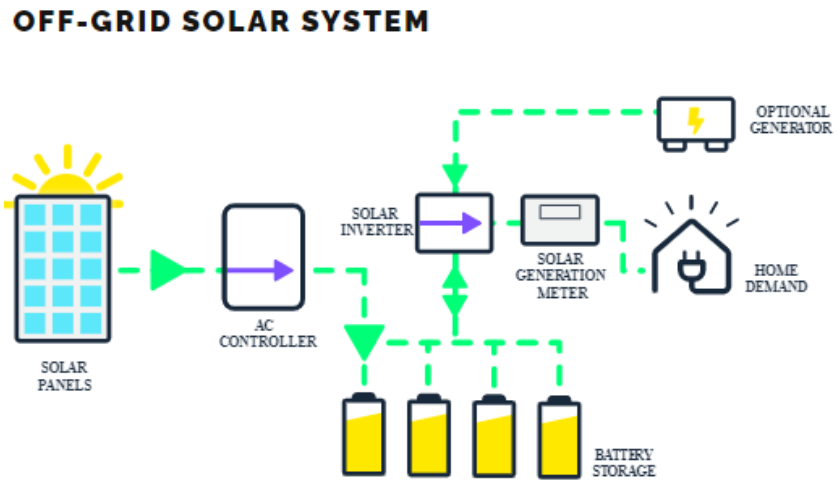


Figure 15. Off-grid Solar PV system

Source: Deege Solar, UK

Grid-Tied or On-Grid Solar PV System

In a grid-tied solution, the electricity generated from the solar PV system is utilized by the user while the excess power generated (above the consumption of the user) is sent to the grid. This way, the user can make some savings on energy bills and also sell excess power to the grid. However, when the solar PV system generates less power (below the demand of the user), power is taken from the grid to satisfy the user's demand. The same is the case at night when there is no sunlight. There is usually no storage system as the power supply from the PV system is augmented with power from the grid. One disadvantage of this solution is that the solar PV system will cease to function if there is a power cut from the grid.

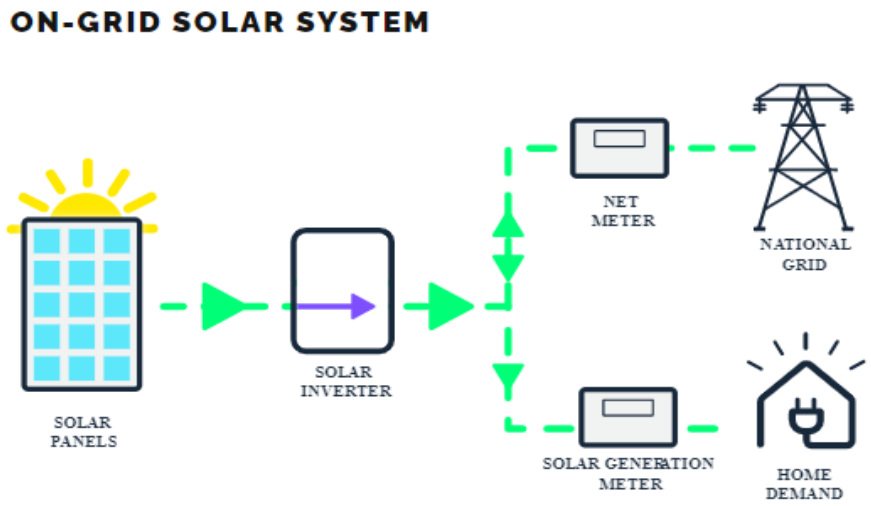


Figure 16. On-grid Solar PV system

Source: Deege Solar, UK

Grid-Interactive or Hybrid Solar PV System

This solution combines the principles of a grid-tied solar PV system with batteries for power storage. Consequently, the stored power is made available even when there is no sunlight. The power supply from the batteries can also be supplemented by power from the grid. The batteries will still supply power even if there is a power cut from the grid. However, the stored power provided by the battery cannot be sustained for long, so it is important to make an alternative source of electricity e.g., a generator available if the power cut will last for long in the absence of sunlight.

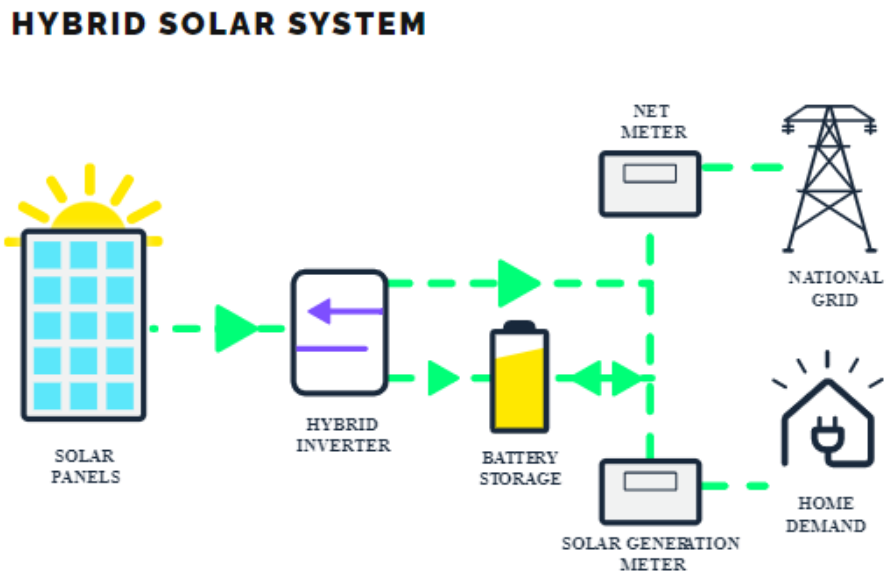


Figure 17. Hybrid Solar PV system

Source: Deege Solar, UK

Solar PV plant

Large-scale solar plants are usually located far away from the end user and are grid-connected. They have been developed in various countries to provide electricity for many homes. The Bhadla Solar Park located in India is the largest solar PV farm in

the world covering 5700 hectares with a total capacity of 2245 megawatts enough to power about 1.3 million homes (Black Bridge, 2022)

Figure 18. Bhadla Solar Park, India

Source: NASA Earth Observatory image

2.2 Theoretical Framework

The theoretical framework provides the basis for establishing the relationship between the statement of the problem and the study objectives. The study is based on the deadweight loss theory which postulates that when external factors restrict output, there is also a loss in producer and consumer surplus (Hayes and Porter-Hudak, 1987 in Iliyasu and Zakari, 2021). These external factors include the adequacy of infrastructure that supports production input such as electricity. Electricity plays a key role in production and economic growth. Access to electricity,

and its supply quality are factors considered in determining the global competitiveness of nations. Countries with better electricity infrastructure have a better ranking (World Economic Forum, 2019).

The availability and cost of electricity differ from region to region. An increase in the cost of providing electricity, either in the cost per unit or the cost of providing an alternative source, will directly impact the cost of production. Business enterprises are therefore forced to adjust in other to remain in operation through any of the following steps. Firstly, they may decide to curb the expansion of their activities or relocate to areas where there is an adequate supply of affordable electricity. In extreme cases, a decision may be taken to shut down operations if they are in deficit. Secondly, business enterprises may decide to reduce the salaries of workers or the number of workers to remain in business, consequently leading to unemployment (World Bank, 2018). Several studies have established the fact that an increase in the cost of providing electricity, leads to lower employment in firms (Deschenes, 2010, Cox et al, 2014 and Bijnens, Konings and Vanormelingen, 2018, in Byström 2019).

2.3 The Burden of Alternative Electricity Generation in Nigeria.

Due to the many challenges associated with the generation and distribution of electricity in Nigeria, business enterprises are forced to provide alternative sources of electricity to power their operations. The most common alternative is the use of generators fuelled by either petrol or diesel. Large enterprises and factories however use diesel-powered generators due to their large capacity. Consequently, the country's economy has been described as diesel-dependent (Business Day, 2022).

The use of generators is usually associated with the initial cost of purchase, maintenance, and fuelling. The costs of fuelling and maintenance account most for the impact on business enterprises' operations. Most spare parts for these generators are expensive because they are imported, and their prices are forex dependent. The price per litre of diesel has continued to increase astronomically. In July 2022, the average price of diesel across the country was ₦774.38 (about $1.83) per litre, representing an increase of 208.74% compared to the ₦250.82 ($ 0.58) per litre for the same month in 2021. There was also a 5.53% increase between June and July 2022. In December 2022 the average retail price rose to ₦817.86 per litre, which represents an increase of 182.64% from ₦289.37 per litre recorded in December 2021 (NBS,22).

The cost of diesel also has a direct impact on the distribution of consumer products because the trucks used for haulage require diesel. In September 2022, the distribution cost was ₦209 billion which was an increase of 35% compared to the ₦154.4 billion recorded in September 2021.

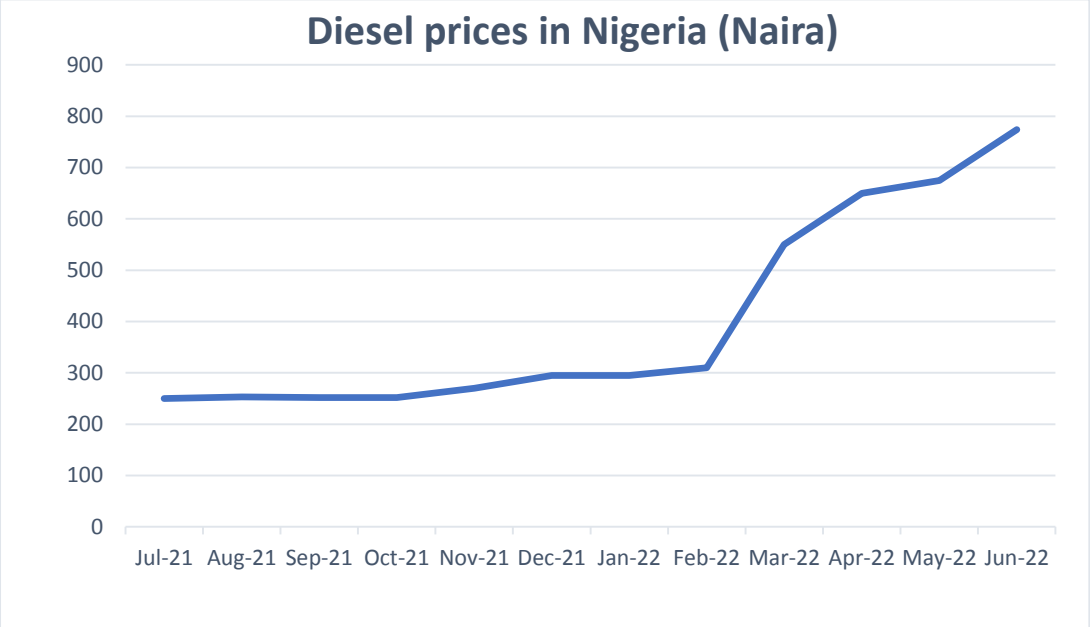


Fig 19. Diesel prices in Nigeria

Source: National Bureau of Statics

The Manufacturers Association of Nigeria affirm that the continued increase in the price of diesel for electricity generation may ultimately lead to an increase in unemployment as more manufacturers are shutting down their operations due to inadequate electricity supply and the rising cost of diesel (Punch, 2022).

Most SMEs who provide mainly services opt for generators that use petrol instead of diesel because petrol is cheaper. Over the years the pump price of petrol too has steadily increased from as low as ₦87 per litre in December 2015. The recent removal of oil subsidy in Nigeria has led to a sudden increase in the pump price of petrol. The pump price rose from ₦165.00 per litre at the beginning of 2023 to ₦557.00 per litre after the subsidy removal in the second quarter of 2023. This sudden increase is predicted to have an impact on the operations of SMEs that rely on petrol to run their generators, consequently leading to unemployment.

This observed trend is in line with the results of studies carried out on the effect of the availability of electricity on unemployment in Nigeria (George and Oseni, 2012, Iliyasu and Zakari, 2021)

2.4 Renewable Solar Electricity Initiatives in Nigeria

Generation of electricity from renewable energy is not new in Nigeria with hydropower from various dams being the main source of electricity. Steps have however been taken to ensure the generation of electricity from other renewable energy sources. One of such steps is the formulation of the National Renewable Energy and Energy Efficiency Policy by the Nigerian government. This policy provides the framework for the increase in the generation of electricity from the following renewable sources, Hydropower, geothermal, biomass, solar, wave and tidal energy power plants, wind, and co-generation plants for energy production and energy efficiency. About 6,831 MW of electricity is expected to be generated from solar alone by 2030 corresponding to a 6% solar contribution to the total energy mix after this policy is implemented (NREEEP,2015).

The Nigerian government has also launched some programmes to promote the generation of electricity from solar. For example, following COVID-19, a programme, Solar Power Naija, championed by the Rural Electrification Agency was launched as part of the Economic Sustainability Plan (ESP). The focus was to provide communities with about 5 million off-grid electricity connections from solar sources. It is also expected to increase annual tax revenues by ₦7 billion and reduce importation to generate $10 million annually from increased demand for locally produced goods. The programme also provides an opportunity for the expansion of

solar components manufacturing facilities, promotion of research and development, enhance the off-grid solar value chain by increasing local content thereby facilitating the growth of the local manufacturing industry, and the potential creation of about 250,000 jobs in the energy sector (REA, 2022).

Chapter 3

3 Methodology

3.1 Method Employed

This research was carried out to determine the impact of renewable solar energy as an alternative source of electricity in sustaining, small and medium scale enterprises (SMEs) to enhance employment opportunities in Port Harcourt City, Nigeria. In order to adequately capture the opinions of SMEs business operators, a cross sectional survey research design was employed. A cross sectional survey research design is employed for analysing information usually derived from responses about a population within a locality at a specific point in time. In this instance, the focus is on the period of increase in fuel price within Nigeria.

The research covers 5873 operators of SMEs located within Port Harcourt city. The sample size used was 588 operators of SMEs which represents 10% of the population. Data collection was achieved using questionnaires containing both structured and semi structured open-ended questions. The structured questions were accompanied by scaled-response options to measure the intensity of the responses of the respondents. For qualitative data analysis, non-parametric simple percentages were used while results were presented using simple tables, pie charts and bar charts. The hypotheses were tested using Z-test for simple proportions. The responses derived from the open-ended questions were analysed and presented using descriptive qualitative method.

3.2 Questionnaire Administration

SME businesses were categories into commercial, industrial, and agricultural sub-groups.

- The commercial category covers businesses engaged in the sales of goods and provision of services. These include but not limited to supermarkets, business offices, schools, restaurants etc.
- The industrial category covers businesses involved in small scale production of goods. These include bakeries, bottled water production plants, food processing plant and small-scale manufacturing.
- The agricultural category covers businesses that carry out cultivation of crops or animal husbandry for commercial purposes. These include poultry farms, piggeries, fisheries, and crop farming.

Business premises were randomly selected across Port Harcourt city for the research. The process of questionnaire development, administration and collation of results ran from March 2023 to October 2023. Due to the fact that most SMEs are low scaled businesses with little IT capabilities, hard copies of the questionnaires were administered to respondents in their various business premises. During the visit, the procedure for filling the questionnaire was explained to respondents. Personal interviews were also conducted to cover the additional open-ended questions. Peculiar responses given to open ended questions were noted on the questionnaire where necessary. Discussions were held with respondents who were either the business owners or supervisors in the best position to give informed responses. Due to the fact that there was no previous research on the adoption of

solar as an alternative source of electricity among SMEs business operators in Port Harcourt city, the questionnaire administration continued till the target of 588 operators was met.

3.3 Limitations

The administration of the questionnaires was based on randomly selected SME business premisses that fall within the predefined categories. However, not all business owners accepted to take part in the research. Therefore, the results obtained were derived from the responses of business operators who voluntarily participated in the research.

Chapter 4

4. Results and Discussions

4.1 Distribution of responses on research questions

4.1.1 Question number 1

- Are SME operators aware of solar as an alternative source of electricity in Port Harcourt city?

Table1 shows that a total of 266 i.e., 45.24% of the respondents are to a large extent aware of solar as an alternative source of electricity in Port Harcourt city, 212 i.e., 36.05% expressed a mild extent of awareness while 110 i.e., 18.71% of the respondents expressed a poor extent of awareness of solar as an alternative source of electricity in Port Harcourt city. It can therefore be inferred that SME operators are aware of solar as an alternative source of electricity in Port Harcourt as evidenced by the 45.24% large extent response of the sample of respondents.

Table1. Response pattern on whether SME business operators are aware of solar as an alternative source of electricity in Port Harcourt City

Responses Provided	Number of Respondents	Percentage of Respondents
Large Extent	266	45.24%
Mild Extent	212	36.05%
Poor Extent	110	18.71%
Total	588	100%

Source: Field survey 2023

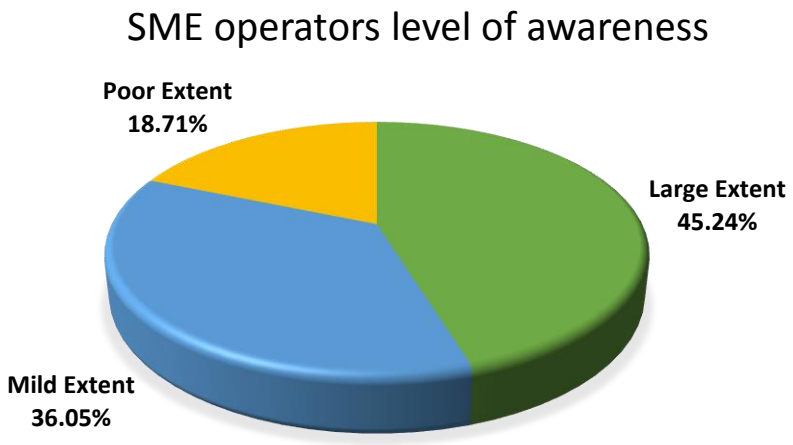


Chart 1. Response pattern on whether SME business operators are aware of solar as an alternative source of electricity in Port Harcourt city

4.1.2 Question number 2

- Are SME operators willing to adopt solar as an alternative source of electricity in Port Harcourt city?

Table 2 shows that a total of 311 i.e., 52.89% of the respondents are to a large extent willing to adopt solar as an alternative source of electricity in Port Harcourt, 148 i.e., 25.17% expressed a mild extent of willingness, while 127 i.e., 21.94% of the respondents expressed a poor extent of willingness to adopt solar as an alternative source of electricity in Port Harcourt. It can therefore be inferred that SME operators are willing to adopt solar as an alternative source of electricity in Port Harcourt as evidenced by the 52.89% large extent response of the sample of respondents

Table 2. Response pattern on whether SME business operators are willing to adopt solar as an alternative source of electricity in Port Harcourt city

Responses Provided	Number of Respondents	Percentage of Respondents
Large Extent	311	52.89%
Mild Extent	148	25.17%
Poor Extent	129	21.94%
Total	588	100%

Source: Field survey 2023

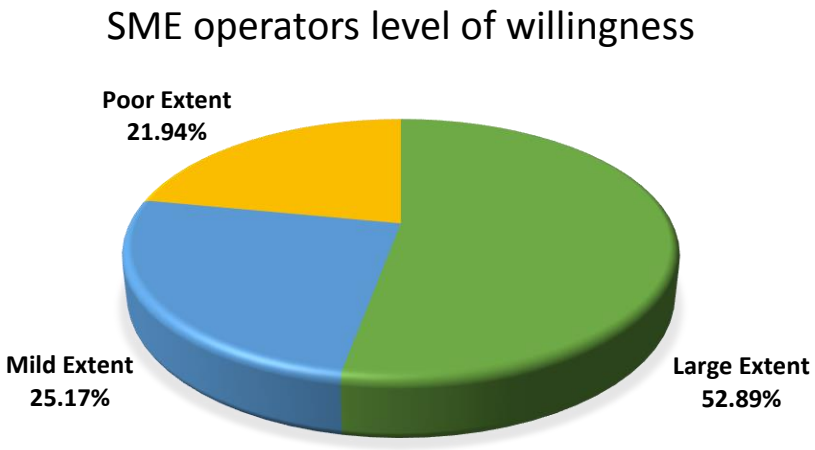


Chart 2. *Response pattern on whether SME business operators are willing to adopt solar as an alternative source of electricity in Port Harcourt city*

4.1.3 Question number 3

- Does the introduction of solar energy as an alternative source of electricity directly to SMEs result in operational cost-effectiveness/cost savings in Port Harcourt city?

Table 3 shows that a total of 314 i.e., 53.40% of the respondents to a large extent agree that the introduction of solar energy as an alternative source of electricity directly to SMEs will result in operational cost-effectiveness/cost savings in Port Harcourt city, 128 i.e., 21.77% agreed to a mild extent, while 146 i.e., 24.83% of the respondents agreed to a poor extent that the introduction of solar energy as an alternative source of electricity directly to SMEs will result in operational cost-effectiveness/cost savings in Port Harcourt city. It can therefore be inferred that the introduction of solar energy as an alternative source of electricity directly to SMEs will result in operational cost-effectiveness/cost savings in Port Harcourt city as evidenced by the 53.40% large extent response of the sample of respondents.

Table 3. Response pattern on whether the introduction of solar energy as an alternative source of electricity directly to SME business enterprises will result in operational cost-effectiveness/cost savings in Port Harcourt city

Responses Provided	Number of Respondents	Percentage of Respondents
Large Extent	314	53.40%
Mild Extent	128	21.77%
Poor Extent	146	24.83%
Total	588	100%

Source: Field survey 2023

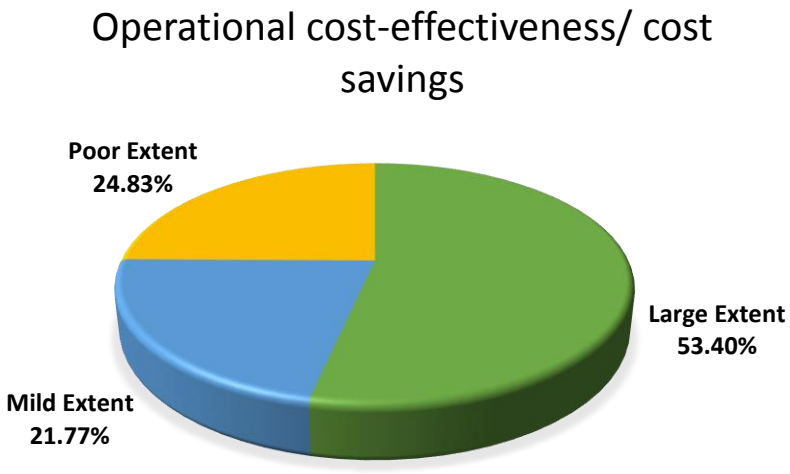


Chart 3. Response pattern on whether the introduction of solar energy as an alternative source of electricity directly to SME business enterprises will result in operational cost-effectiveness/cost savings in Port Harcourt city

4.1.4 Question number 4

- Does the introduction of solar energy as an alternative source of electricity directly to SMEs result in creation of more employment opportunities in Port Harcourt city?

Table 4 shows that a total of 264 i.e., 44.90% of the respondents to a large extent agree that the introduction of solar energy as an alternative source of electricity directly to SMEs will result in creation of more employment opportunities in Port Harcourt city, 99 i.e., 16.84% agreed to a mild extent, while 225 i.e., 38.27% of the respondents agreed to a poor extent that the introduction of solar energy as an alternative source of electricity directly to SMEs will result in creation of more employment opportunities in Port Harcourt city. It can therefore be inferred that the introduction of solar energy as an alternative source of electricity directly to SMEs

will result in creation of more employment opportunities in Port Harcourt city as evidenced by the 44.90% large extent response of the sample of respondents.

Table 4. Response pattern on whether the introduction of solar energy as an alternative source of electricity directly to SMEs will result in creation of more employment opportunities.

Responses Provided	Number of Respondents	Percentage of Respondents
Large Extent	264	44.90%
Mild Extent	99	16.84%
Poor Extent	225	38.27%
Total	588	100%

Source: Field survey 2023

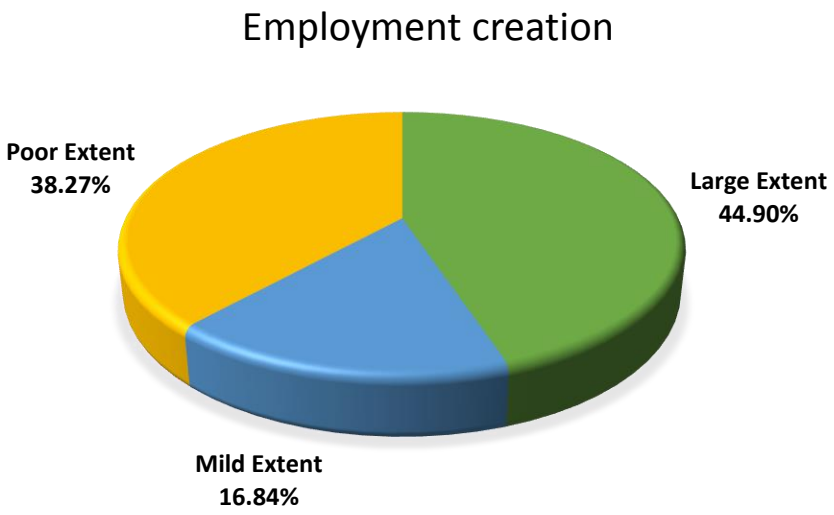


Chart 4. Response pattern on whether the introduction of solar energy as an alternative source of electricity directly to SMEs will result in creation of more employment opportunities.

4.2 Other findings

4.2.0 Respondents by category of SME operators

Table 5 shows that a total of 394 i.e., 67.01% of the respondents were from commercial SMEs, 124 i.e., 21.09% were from Industrial SMEs, 60 i.e., 10.20% were from Agricultural SMEs, while 10 respondents i.e., 1.70% were from SMEs that do not belong to any of the above categories It can therefore be concluded that majority of the SMEs are in the commercial category.

Table 5. Respondents by category of SME operators

Category	Number	Percentage
Commercial	394	67.01%
Industrial	124	21.09%
Agricultural	60	10.20%
Others	10	1.70%
Total	588	100%

Source: Field survey 2023

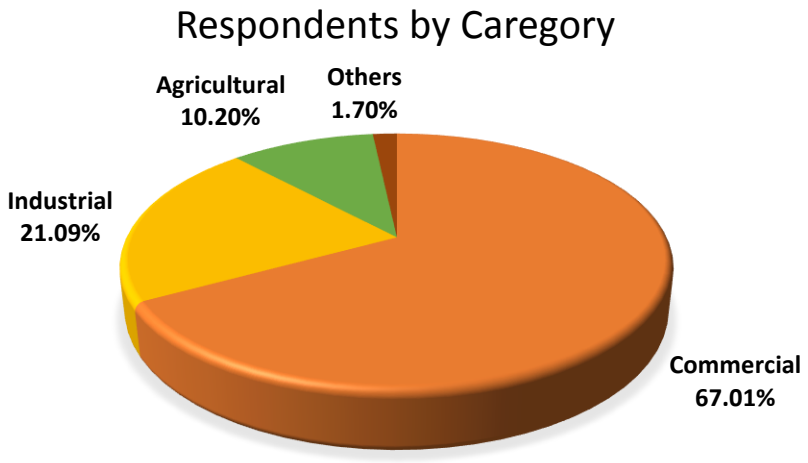


Chart 5. Respondents by category of SME operators

4.2.1 Source of Electricity for Operators of SMEs

Table 6 shows that out of the 588 SME operators,440 i.e., 74.83% of the respondents were connected to the grid, 483 ie. 82.14% use generators to provide electricity, 337 of them were connected to the grid and also have generators, 1 (one) respondent representing 1.70% of the population had solar PV installed. Therefore, it can be concluded that the major source of electricity for SME operators in Port Harcourt is generators as evidenced by its use by 82.14% of SME operators.

Table 6. Source of electricity for 588 operators of SMEs in Port Harcourt

Source of electricity	Number	Percentage
Grid connected	440	74.83%
Generator	483	82.14%
Grid and Generator	337	57.31%
Solar PV installation	1	1.70%

Source: Field survey 2023

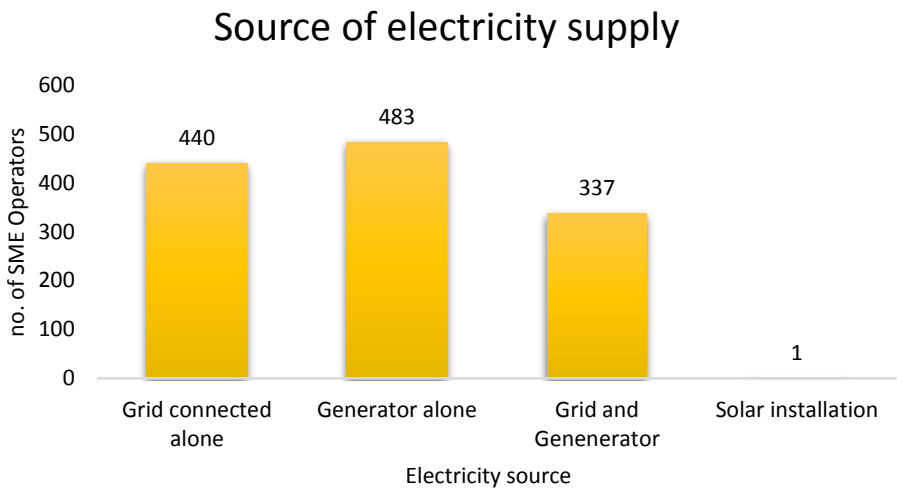


Figure 20. Sources of electricity for 588 operators of SMEs in Port Harcourt

4.2.2 Grid availability

Table 7 shows that out of the 588 SMEs surveyed, only 84 i.e., 14.29%% have regular electricity supply from the grid, 356 i.e. 60.54% have irregular electricity supply from the grid while 148 i.e., 25.17% are not connected to the grid. Therefore, it can be concluded that electricity supply from the grid to SMEs in Port Harcourt city is irregular evidenced by the 60.54% response from respondents describing electricity from the grid as on irregular.

Table 7. Grid availability for 588 operators of SMEs connected to the grid in Port Harcourt city

Total Connected to Grid	**Number of Respondents**	**Percentage**
Regular Power Supply	84	14.29%
Irregular Power Supply	356	60.54%
No grid connection	148	25.17%
Total	588	100.00%

Source: Field survey 2023

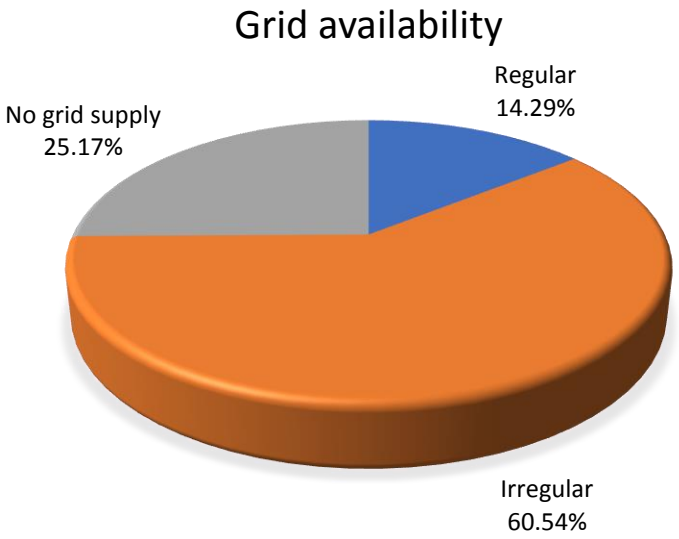


Chart 6. Grid availability for 588 operators of SMEs connected to the grid in Port Harcourt city

4.2.3 Type of fuel used by SMEs Operators

Table 8 shows that out of the 479 operators of SMEs who use generators, 350 i.e. 72.46% purchase petrol as source of fuel, while 136 i.e. 28.16% purchase diesel to run their generators. Therefore, it can be concluded that the major type of fuel used by operators of SMEs in Port Harcourt city is petrol evidenced by the 72.46% response from respondents on the type of fuel used.

Table 8. Type of fuel used by 486 operators of SMEs who use generators in Port Harcourt city

Fuel type	Number of respondents	Percentage
Petrol	350	72.46%
Diesel	136	28.16%
Total	486	100.00%

Source: Field survey 2023

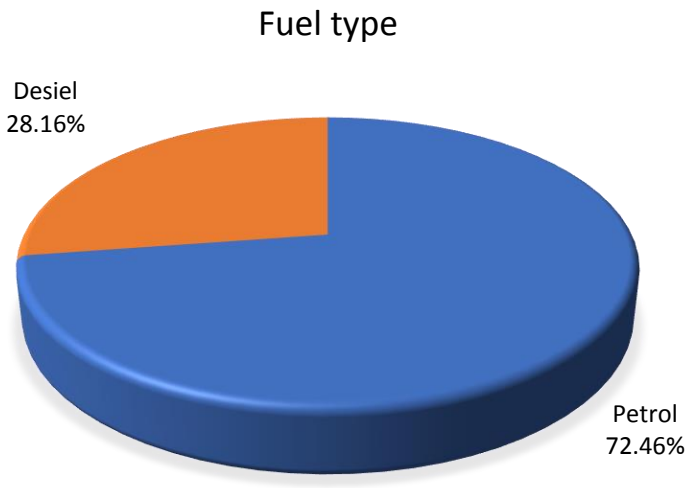


Chart 7. Type of fuel used by 479 operators of SMEs who use generators in Port Harcourt city

4.2.4 Type of fuel used by Operators of SMEs by Category

Table 9 shows that out of the 359 SMEs operators in the commercial category, 296 use petrol while 63 use diesel. In the industrial category, 104 SMEs operators have generators out of which 37 use petrol while 67 use diesel. In the agricultural category, 14 SME operators have generators out of which 12 use petrol while 2 use diesel. The Others category is made up of 9 SME operators that use generator out of which 5 use petrol while 4 use diesel. Therefore, it can be concluded that the commercial category of SME operators accounts for the most use of petrol fuel for generators while the industrial category account for the most use of diesel fuel for generators.

Table 9 Type of fuel used by SME operators by category

Category	Number of Generator	Diesel	Petrol
Commercial	359	63	296
Industrial	104	67	37
Agricultural	14	2	12
Others	9	4	5
Total	486	136	350

Source: Field survey 2023

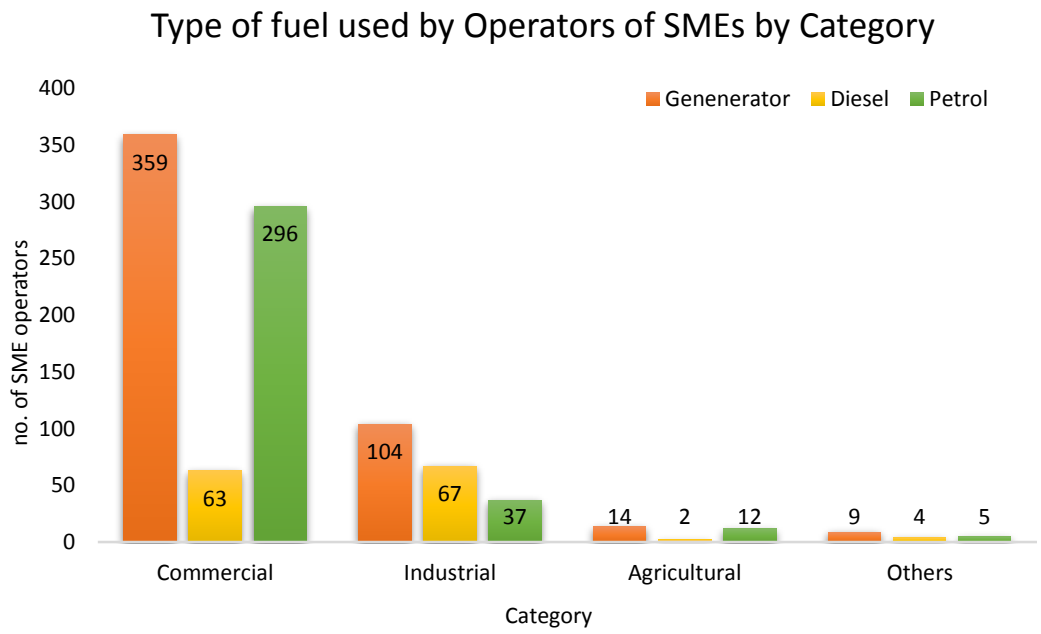


Figure 21. Type of fuel used by SME operators by category

4.2.5 Willingness to adopt Solar Power Source vs Grid Power Availability

Table 10 Shows that out of the 359 SMEs operators in the commercial category, 256 i.e. 64.97% are willing to a large extent to adopt solar as an alternative source of electricity. However, only 31 SME operators representing 7.87% of this category have regular grid power availability. Also, out of the 124 SME operators in the industrial category, 43 SME operators i.e. 34.68% are willing to a large extent to adopt solar as an alternative source of electricity. However, only 35 SME operators representing 28.23% of this category have regular grid power availability. Likewise, out of the 60 SME operators in the Agricultural category, 7 SME operators i.e., 11.67% are willing to a large extent to adopt solar as an alternative source of electricity. However, only 8 SME operators representing 13.33% of this category have regular grid power availability. Out of the 10 SME operators in the category designated Others, 5 SME operators i.e., 50.00% are willing to a large extent to

adopt solar as an alternative source of electricity. However, only 1 SME operator representing 10.00% of this category had regular grid power availability. Therefore, it can be concluded that categories (commercial and Others) that have low availability of grid supply are more willing to adopt solar as an alternative source of electricity.

Despite the various figures from the field survey, some of the respondent gave some reasons besides grid availability, why they may not consider adopting solar as an alternative source of electricity. For example, some SMEs operators within the industrial category explained that most of their equipment require a lot of power that cannot be provided the solar PV system at a reasonable cost. It was therefore more economical to use diesel powered generators in the absence of electricity from the grid. In the agricultural category, only 13.33% of the SMEs operators have regular electricity while even a lesser proportion (11.67%) are willing to a large extent to adopt solar as an alternative source of electricity. The reason given for this trend by some of the SMEs operators in this category is that some agricultural activities do not require constant electricity and they are able to schedule their operation to maximize the availability of electricity. Besides the issue of cost, other reasons provided by some SMEs operators for not willing to adopt solar as an alternative source of electricity include lack of space for the installation of the solar PV panels, additional operating and maintenance cost, and security of the externally mounted panels.

Table 10 Willingness to adopt solar power source vs grid availability according to various SMEs operators' categories

Category		Willing to adopt solar as an alternative source of electricity (Large Extent)		Regular availability of grid supply	
Type	Class Total	Count	%	Count	%
Commercial	394	256	64.97 %	31	7.87 %
Industrial	124	43	34.68 %	35	28.23 %
Agricultural	60	7	11.67 %	8	13.33 %
Others	10	5	50.00 %	1	10.00 %

Source: Field survey 2023

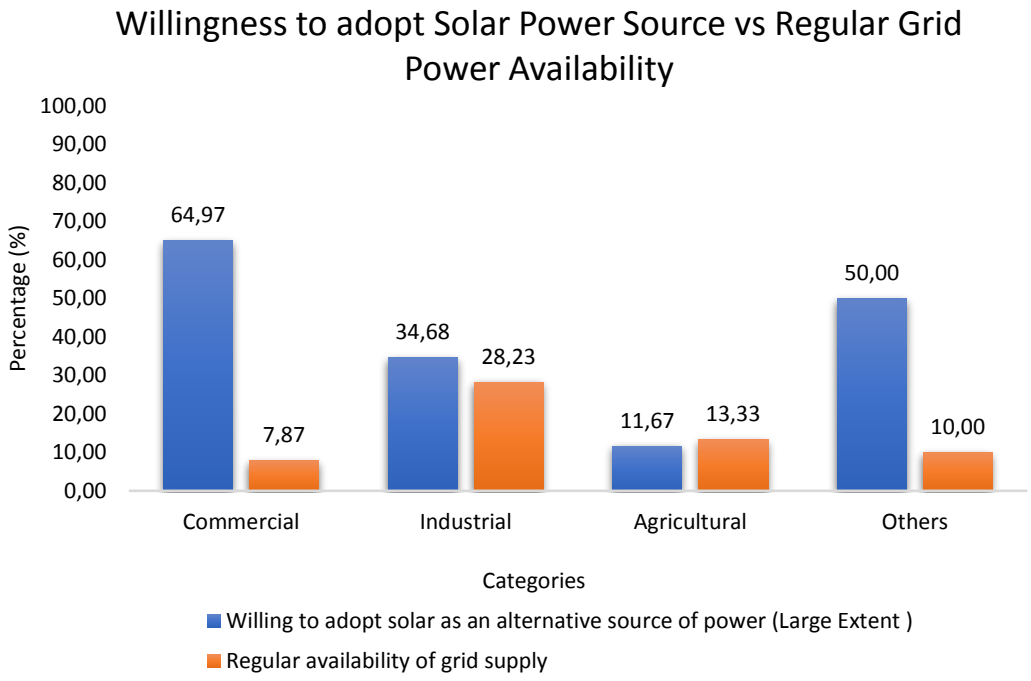


Figure 22. Type of fuel used by SME operators by category

4.2.6 Fuel Usage Vs Cost Savings

Table 11 shows that categories that have a high dependence on fuel usage e.g., commercial category will also have a higher number of savings from adopting solar as an alternative source of electricity especially in the use of petrol for their

generators. Also, categories that have a low dependence on fuel usage e.g., agricultural category, will have the lease number of savings from adopting solar as an alternative source of electricity. The preference for the use of different fuel types is evident from the table among the various categories. For example, 75.13% of SMEs in the commercial category prefer to use petrol powered generator compared to 15.99 % who use diesel powered generators in the same category. This reason for this trend is due to the fact that most of the equipment used by those in the commercial category are computers, printers and other office equipment easily powered by petrol generators which are considered light duty. On the other hand, 54.03% of SMEs operators in the manufacturing category prefer diesel powered generators compared to 29.84% of those who use petrol powered generators within the same category. The reason for a higher preference for diesel powered generators is due to the heavy equipment used within the manufacturing industry. Most of the equipment used have rotary functions that require the use of several electric motors. Some other equipment used are for heating in the manufacturing process and they therefore require adequate and reliable source of electricity. Heavy-duty diesel-powered generators with high rating are therefore the best option.

Table 11 Fuel usage vs cost savings from adoption of solar according to various SMEs operators' categories

Category		Diesel		Petrol		Cost savings on adopting solar (Large Extent)	
Type	Class Total	count	%	count	%	count	%
Commercial	394	63	15.99 %	394	75.13 %	258	65.48%
Industrial	124	67	54.03 %	124	29.84 %	47	37.90%
Agricultural	60	2	3.33 %	12	20.00 %	5	8.33%
Others	10	4	40.00 %	10	50.00 %	4	40.00%

Source: Field survey 2023

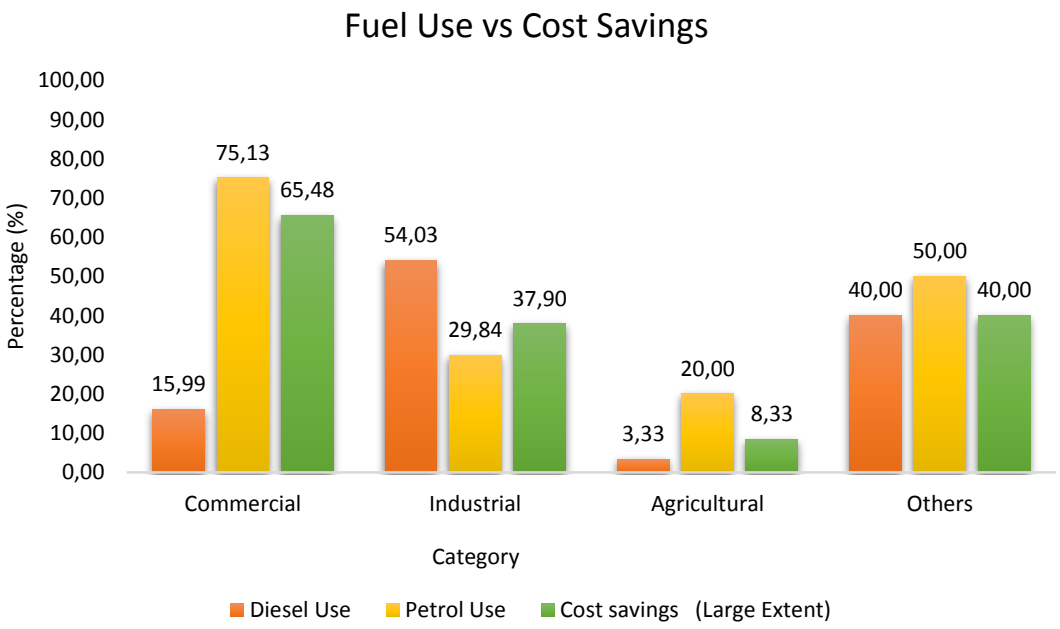


Figure 23 Fuel usage vs cost savings from adoption of solar according to various SMEs operators' categories

4.2.7 Cost Savings Vs Employment Opportunities

Table 12 shows that there is a direct relationship between the cost savings from the adoption of solar as an alternative source of energy and employment opportunities. The higher the cost savings envisaged, the higher the employment opportunity.

However, for each SME category, the percentage of respondents who agree that there will be cost savings to a large extent are slightly higher than the percentage of those who agree that there will be employment opportunity to a large extent. This suggests that there are some SME operators who will not employ more worker even if they save cost on electricity. Various reasons were given by SMEs operators from the various categories for this observed trend and these include the following.

- Some SMEs have reached their saturation point in terms of staff employment where an increase in staff strength will not improve the operations of the business but rather increase overhead cost. These SMEs prefer to channel the savings to improving the welfare of the current staff and improving operations.
- Some other SMEs plan to invest the savings in their corporate social responsibility (CSR) programmes where they train young graduates in skill that make them either self-employed or employable by other organizations thereby creating indirect employment.

Table 12 Cost savings vs employment opportunities according to various SMEs operators' categories

Category		Cost savings from adoption of solar (Large Extent)		Employment Opportunities (Large Extent)	
Type	Class Total	count	%	count	%
Commercial	394	258	65.48	220	55.84
Industrial	124	47	37.90	37	29.84
Agricultural	60	5	8.33	4	6.67
Others	10	4	40.00	3	30.00

Source: Field survey 2023

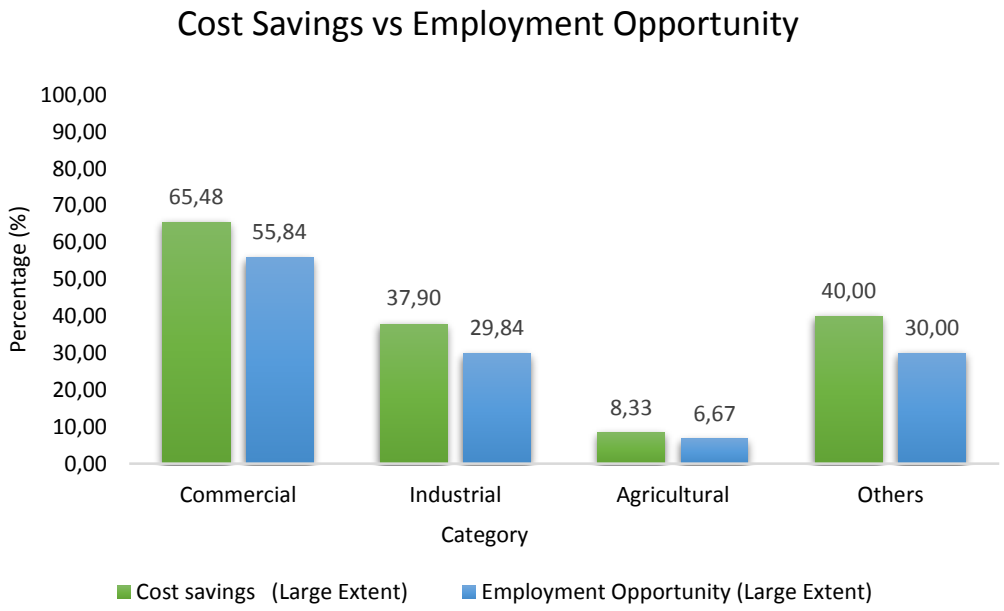


Figure 24 Cost savings vs employment opportunities according to various SMEs operators' categories

4.3 Testing of Hypotheses

4.3.1 Testing of First Hypothesis

H_0: SME operators are not aware of solar as an alternative source of electricity in Port Harcourt city.

H_1: SME operators are aware of solar as an alternative source of electricity in Port Harcourt city.

Using the figures from Table 1

Sample proportion p = 45.24% = 0.4524

Population Proportion Po = 50% = 0.5

Sample size N = 588,

Significance level α = 0.05, confidence level = 0.95, critical z = - 1.645 (left tailed)

$$Z = \frac{p - Po}{\sqrt{\frac{Po\,(1 - Po)}{N}}} = \frac{0.4524 - 0.5}{\sqrt{\frac{0.5\,(1 - 0.5)}{588}}} = \frac{-0.0476}{\sqrt{\frac{0.25}{588}}} = \frac{-0.0476}{0.0206} = -2.311$$

Calculated Z = - 2.311, this means $Z < -1.645$, so the null hypothesis Ho is rejected. Therefore, SME operators are aware of solar as an alternative source of electricity in Port Harcourt city.

4.3.2 Testing of Second Hypothesis

H_o: SME operators are not willing to adopt solar as an alternative source of electricity in Port Harcourt city

H_1: SME operators are willing to adopt solar as an alternative source of electricity in Port Harcourt city

Using the figures from Table 2

Sample proportion p = 52.89% = 0.5289

Population Proportion Po = 50% = 0.5

Sample size N = 588,

Significance level α = 0.05, confidence level = 0.95, critical z = 1.645 (right tailed)

$$Z = \frac{p - Po}{\sqrt{\frac{Po\,(1 - Po)}{N}}} = \frac{0.5289 - 0.5}{\sqrt{\frac{0.5\,(1 - 0.5)}{588}}} = \frac{0.0282}{\sqrt{\frac{0.25}{588}}} = \frac{0.0282}{0.0206} = 1.367$$

Calculated Z = 1.367, this means Z < 1.645, so the null hypothesis Ho is accepted. Therefore, SME operators are not willing to adopt solar as an alternative source of electricity in Port Harcourt city. Some SME operators in the course of the research noted that cost of Solar PV systems, insufficient space for installation, maintenance and operating cost, and the security of the externally mounted solar PV panels were some of the reasons why they were reluctant to adopt solar as an alternative source of electricity despite the benefits.

4.3.3 Testing of Third Hypothesis

H_o: The introduction of solar energy as an alternative source of electricity directly to SMEs does not result in operational cost-effectiveness in Port Harcourt city.

H_1: The introduction of solar energy as an alternative source of electricity directly to SMEs does result in operational cost-effectiveness in Port Harcourt city.

Using the figures from Table 3

Sample proportion p = 53.40% = 0.5340

Population Proportion Po = 50% = 0.5

Sample size N = 588,

Significance level α = 0.05, confidence level = 0.95, critical z = 1.645 (right tailed)

$$Z = \frac{p - Po}{\sqrt{\frac{Po\,(1 - Po)}{N}}} = \frac{0.5340 - 0.5}{\sqrt{\frac{0.5\,(1 - 0.5)}{588}}} = \frac{0.034}{\sqrt{\frac{0.25}{588}}} = \frac{0.034}{0.0206} = 1.651$$

Calculated Z = 1.651, this means Z > 1.645, so the null hypothesis Ho is rejected.

Therefore, the introduction of solar energy as an alternative source of electricity directly to SMEs does result in operational cost-effectiveness in Port Harcourt city.

4.3.4 Testing of Forth Hypothesis

H_o: The introduction of solar energy as an alternative source of electricity directly to SMEs does not result in creation of more employment opportunities in Port Harcourt city.

H_1: The introduction of solar energy as an alternative source of electricity directly to SMEs does result in creation of more employment opportunities in Port Harcourt city.

Using the figures from Table 4

Sample proportion p = 44.90% = 0.4490

Population Proportion Po = 50% = 0.5

Sample size N = 588,

Significance level α = 0.05, confidence level = 0.95, critical z = - 1.645 (left tailed)

$$Z = \frac{p - Po}{\sqrt{\frac{Po\,(1 - Po)}{N}}} = \frac{0.4490 - 0.5}{\sqrt{\frac{0.5\,(1 - 0.5)}{588}}} = \frac{-0.051}{\sqrt{\frac{0.25}{588}}} = \frac{-0.051}{0.0206} = -2.476$$

Calculated Z = -2.476, this means Z < -1.645, so the null hypothesis Ho is rejected.

Therefore, the introduction of solar energy as an alternative source of electricity directly to SMEs does result in creation of more employment opportunities in Port Harcourt city.

Chapter 5

5.0 Conclusion and Recommendations

5.1 Summary

Currently, there is a global effort to combat climate change and one of the key strategies is the reduction of the amount of carbon dioxide (CO_2) released into the atmosphere from man's activities. The burning of fossil fuel to meet various needs, including electricity generation, accounts for a large percentage of CO_2 emissions. One common approach to reducing CO2 emissions is the use of renewable source of electricity to replace fossil fuels. In addition to reducing CO_2 emissions, various countries have tried harnessing the added economic advantage of job creation while adopting renewables. These job opportunities arise either from the value chain of producing and providing these renewable solutions or the operational savings made by various business enterprises who adopt renewables as an alternative source of electricity.

The supply of cheap and consistent grid electricity has remained a challenge in Nigeria over the years. This situation has forced business owners to provide alternative source of electricity using petrol or diesel-powered generators adding to the cost of running their business. Consequently, this has led to the poor growth of business enterprises while others have shut down in extreme cases. Small and medium scale enterprises (SMEs) account for majority of the employment in Nigeria are also affected by the poor electricity supply. This research therefore evaluates the impact of renewable solar energy as an alternative source of electricity in sustaining small and medium scale enterprises to enhance employment opportunities in Port Harcourt city, Nigeria.

5.2 Conclusion

The research results following the z- tests, show that SMEs operators within Port Harcourt city are aware of solar as an alternative source of electricity. One of the hypotheses tests shows that SMEs operators are not willing to adopt solar as an alternative source of electricity in Port Harcourt city. The reason for this reluctance is due to the fact that there is a feeling among SMEs operators in Port Harcourt city that the cost of the solar PV system is high compared to the immediate benefits. Factors such as insufficient space for solar PV panels installation, maintenance and operating cost, and security of the externally mounted solar PV panels were also identified as militating against the adoption of solar as an alternative source of electricity. Out of the 588 SMEs operators surveyed, only 1 SME operator had solar PV panels installed.

The initial increase in the pump price of diesel followed by the recent increase in the pump price of petrol in the absence of an improvement in the grid supply of electricity has led to an increase in the cost of business operations. Cost reduction on fuel purchase was therefore identified as one of the benefits of adopting solar PV system especially for SMEs operators within the commercial category that used petrol-powered generators. There were however few exceptions in some SME categories e.g., industrial category where diesel powered generators are predominantly used. In this category, the prospect of savings was lower because it was deemed that solar PV systems will not efficiently power the heavy equipment used in the manufacturing process. Therefore, the extent to which savings are made on the adoption of solar as an alternative source of electricity depends largely on the type of fuel being replaced and the nature of equipment used by the SMEs category. There will be guaranteed

operational savings if solar is adopted as an alternative source of electricity in SMEs that use petrol powered generators within the commercial categories.

SMEs operators agreed to a large extent in all the categories that operational savings made from the adoption of solar as an alternative source of electricity will create more employment opportunities. It was however observed that not all savings will be channelled towards employing new staff because some of the SMEs are already adequately staffed and an increase in staff strength will result in overhead cost and consequently operational cost. They therefore proposed to channel some of the savings toward improving staff welfare and business operations. Other SMEs operators also prefer to use the savings to execute corporate social responsibility (CSR) programmes. These programmes train young graduates in skills acquisition that will make them either self-employed or employable by other organizations thereby creating indirect employment.

In conclusion, the adoption of solar as an alternative source of electricity to supplement insufficient electricity supply from the grid, and fossil fuel powered electricity from generators will lead to cost savings and operational efficiency, and consequently provide employment opportunities within SMEs in Port Harcourt City. In order to achieve this goal, SMEs operators in the commercial category who use petrol-powered generator generators will be the best target category.

5.3 Recommendations

SMEs operators have identified some reasons why there is a reluctance in adopting solar as an alternative source of electricity in Port Harcourt city despite the level of awareness and benefits. The following recommendations are therefore proposed to stimulate a drive towards the adoption of solar as alternative source of electricity.

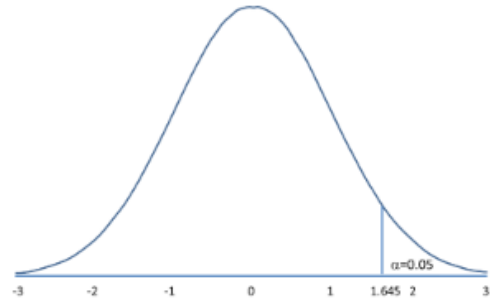
- The main components which make up the solar PV system such as solar PV panels, batteries and inverters are all imported. While the effect of foreign exchange may be difficult to manage, the government can classify these items as import duty free to make them more affordable to the end users. The government can also give incentives to encourage the local manufacturing of these items.
- The government's renewable energy initiative, Solar Power Naija, is currently focused on providing solar electricity to rural dwellers and creating job opportunity only within the energy sector. The scope should be expanded to include provision of solar electricity to SMEs because they play a major role in creating job opportunities. This will enable operators of SMEs access the long-term low credit facilities provided by the government for the installation of solar PV systems without putting any financial pressure on business operations.

The result of this study is only a first step in examining the possibility of creating jobs within SMEs in Port Harcourt city through the adoption of solar as an alternative source of electricity. Further research should focus on the best configuration of solar PV systems that is tailored to each SME business needs. This should include carrying of technical feasibility studies and developing a business case to ensure

that there is a positive return on investment before the adoption of solar as an alternative source of electricity.

Appendix 1 – Z test

Right tailed z test table

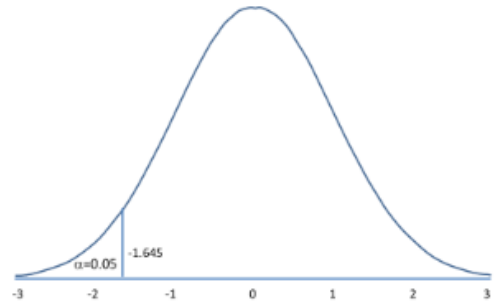


Rejection Region for Upper-Tailed Z Test (H_1: $\mu > \mu_0$) with α=0.05

The decision rule is: Reject H_0 if $Z \geq 1.645$.

Upper-Tailed Test	
α	Z
0.10	1.282
0.05	1.645
0.025	1.960
0.010	2.326
0.005	2.576
0.001	3.090
0.0001	3.719

Left tailed z test table



Rejection Region for Lower-Tailed Z Test (H_1: $\mu < \mu_0$) with α =0.05

The decision rule is: Reject H_0 if $Z \leq 1.645$.

Lower-Tailed Test	
a	Z
0.10	-1.282
0.05	-1.645
0.025	-1.960
0.010	-2.326
0.005	-2.576
0.001	-3.090
0.0001	-3.719

Source : https://sphweb.bumc.bu.edu/

Appendix 2 - Computation of calculated z value for the first hypothesis

- Are SME operators aware of solar as an alternative source of electricity in Port Harcourt city?

Sample proportion p = 45.24% = 0.4524

Population Proportion Po = 50% = 0.5

Sample size N = 588,

Significance level α = 0.05, confidence level = 0.95, critical z = - 1.645 (left tailed)

$$Z = \frac{p - Po}{\sqrt{\frac{Po\,(1 - Po)}{N}}} = \frac{0.4524 - 0.5}{\sqrt{\frac{0.5\,(1 - 0.5)}{588}}} = \frac{-0.0476}{\sqrt{\frac{0.25}{588}}} = \frac{-0.0476}{0.0206} = -2.311$$

Z = - 2.311, this means Z < -1.645, therefore the null hypothesis Ho is rejected.

Appendix 3 - Computation of calculated z value for the second hypothesis

- Are SME operators willing to adopt solar as an alternative source of electricity in Port Harcourt city?

Sample proportion p = 52.89% = 0.5289

Population Proportion Po = 50% = 0.5

Sample size N = 588,

Significance level α = 0.05, confidence level = 0.95, critical z = 1.645 (right tailed)

$$Z = \frac{p - Po}{\sqrt{\frac{Po\,(1 - Po)}{N}}} = \frac{0.5289 - 0.5}{\sqrt{\frac{0.5\,(1 - 0.5)}{588}}} = \frac{0.0282}{\sqrt{\frac{0.25}{588}}} = \frac{0.0282}{0.0206} = 1.367$$

Z = 1.367, this means Z < 1.645, therefore the null hypothesis Ho is accepted.

Appendix 4 - Computation of calculated z value for the third hypothesis

- Does the introduction of solar energy as an alternative source of electricity directly to SMEs result in operational cost-effectiveness/cost savings in Port Harcourt city?

Sample proportion p = 53.40% = 0.5340

Population Proportion Po = 50% = 0.5

Sample size N = 588,

Significance level α = 0.05, confidence level = 0.95, critical z = 1.645 (right tailed)

$$Z = \frac{p - Po}{\sqrt{\frac{Po\,(1 - Po)}{N}}} = \frac{0.5340 - 0.5}{\sqrt{\frac{0.5\,(1 - 0.5)}{588}}} = \frac{0.034}{\sqrt{\frac{0.25}{588}}} = \frac{0.034}{0.0206} = 1.651$$

Z = 1.651, this means Z > 1.645, therefore the null hypothesis Ho is rejected.

Appendix 5 - Computation of calculated z value for the fourth hypothesis

- Does the introduction of solar energy as an alternative source of electricity directly to SMEs result in creation of more employment opportunities in Port Harcourt city?

Sample proportion p = 44.90% = 0.4490

Population Proportion Po = 50% = 0.5

Sample size N = 588,

Significance level α = 0.05, confidence level = 0.95, critical z = - 1.645 (left tailed)

$$Z = \frac{p - Po}{\sqrt{\frac{Po\,(1 - Po)}{N}}} = \frac{0.4490 - 0.5}{\sqrt{\frac{0.5\,(1 - 0.5)}{588}}} = \frac{-0.051}{\sqrt{\frac{0.25}{588}}} = \frac{-0.051}{0.0206} = -2.476$$

Z = -2.476, this means Z < -1.645, therefore the null hypothesis Ho is rejected.

Appendix 6 - Questionnaire

PhD Thesis Questionnaire

The impact of renewable solar energy as an alternative source of electricity in sustaining micro, small and medium scale enterprises to enhance employment opportunities in Port Harcourt City, Nigeria

Category of Business Enterprise

	Commercial
	Supermarket
	Business Office
	Restaurant
	School
	Others -

	Industrial
	Bakery
	Water production
	Food processing
	Manufacturing
	Others-

	Agricultural
	Fishery
	Crop Farming
	Piggery
	Poultry
	Others-

	Generator		Diesel		Petrol

	Grid Power		Regular		Irregular		None

2 Are you as a business operator aware of solar as an alternative source of electricity?

Large extent	Mild Extent	Poor Extent

2. Are you as a business operator willing to adopt solar as an alternative source of electricity?

Large extent	Mild Extent	Poor Extent

3. Will the introduction of solar energy as an alternative source of electricity directly to your business enterprise result in operational cost-effectiveness/cost savings?

Large extent	Mild Extent	Poor Extent

How will this result in cost saving ……

4. Will the introduction of solar energy as an alternative source of electricity directly to your business enterprise result in creation of more employment opportunities?

Large extent	Mild Extent	Poor Extent

How will it create more employment opportunities……

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