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HEALTH AND ENERGY POVERTY IN SUB-SAHARAN AFRICA

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INTRODUCTION

For the Western world, it may seem almost impossible to imagine a reality where there is no constant access to electricity as it is needed for the majority of daily activities and the development of our countries. In Sub-Saharan Africa, this reality is all too common, where the lack of clean energy strongly furthers health disparities and presents a formidable challenge to sustainable development. The electricity market is one of the most impactful worldwide due to its political, economic and humanitarian implications shaping nations' trajectory and citizens' well-being. Although the discussion around energy, particularly renewable energy, is ever-present, less research and political prioritization is given to the energy poverty issue despite it affecting millions of people worldwide. Modern energy industries have encountered significant challenges in the past years. Despite the intrinsic difficulties revolving around the management of the energy market and the further complications caused by COVID-19 and the Russian invasion of Ukraine, which have both contributed to an increase in energy prices, almost all countries have witnessed, at different rates, a reduction in energy poverty in the latest years. However, only one area globally is experiencing an opposite trend, suffering from a steady and worsening energy poverty situation: Sub-Saharan Africa. Hence, even though energy poverty is a present issue for low-income families, even among the most developed countries in the world, this research focuses on the Sub-Saharan region.

The thesis follows a structured approach, beginning with the literature review that provides a comprehensive overview of key concepts needed to defy and understand the issue at stake, including energy poverty measurements, consequences, and the broader context of the electricity market and the climate change problem. The elaboration unfolds by giving an economic overview of Sub-Saharan Africa together with the energy situation. Lastly, it presents a rundown of the causes of the challenge of energy poverty and the solutions that have been theorized to be able to contrast them. Four case studies are investigated to comprehend if the projects that are being implemented in the region are, in fact, in line with the literature review and if they are successful. A comparative analysis is then conducted, followed by a discussion of findings and policy recommendations aimed at addressing energy poverty in the region on the basis of the case studies analysis.

As the paper delves into the complexities of this issue, it uncovers the realities faced by communities across the region and the potential for transformative change through innovative solutions and targeted interventions.

1. LITERATURE REVIEW

1.1. ENERGY POVERTY

The modern energy industry is about to be subjected to three main challenges that are going to bring major changes: energy security, climate change, and energy poverty. While extensive analysis has been conducted on the first two, less focus has been given to the third issue, both in terms of research and its consideration on political agendas (González-Eguino, 2015).

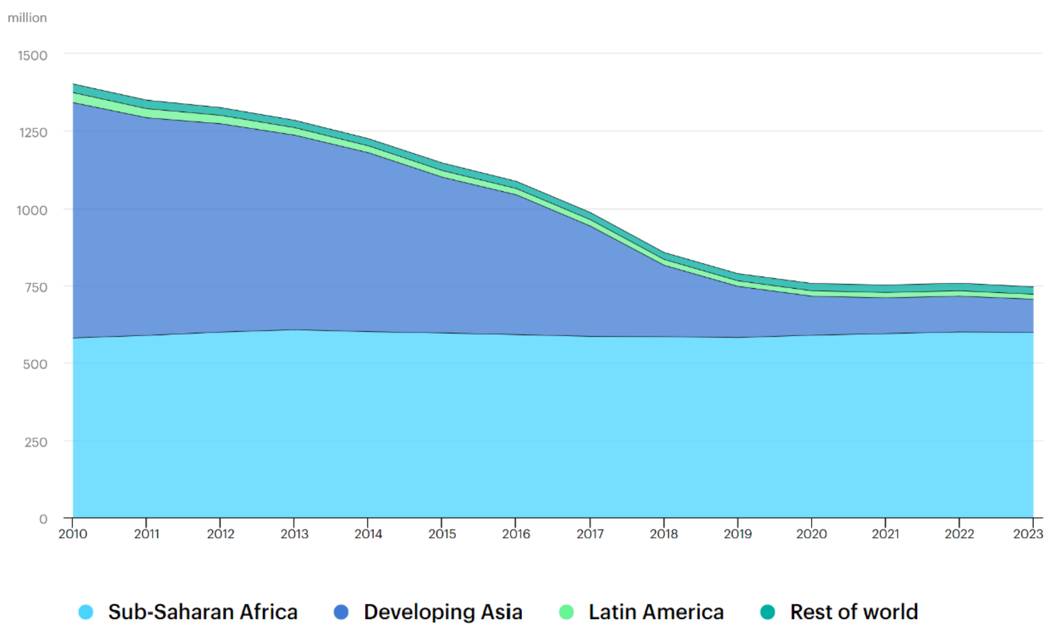
The World Economic Forum describes energy poverty as "*the lack of access to sustainable modern energy services and products*" (World Economic Forum, 2010). Energy poverty entails that a household is forced to reduce the quantity of energy depleted up to a level that affects the health and wellbeing of the residents. The foundations of this phenomenon can be summarized in three main reasons: low household income, low energy performance of building and appliances and energy expenses taking a high share of total expenditure of the household. The private nature of the energy market and its strong relationship to political dynamics, make energy poverty a complicated issue to be addressed (European Commission, 2023). Moreover, the COVID-19 crisis and the following invasion of Ukraine by Russia have had a staggering effect on energy prices, aggravating the conditions for many households worldwide. In 2022 the world saw the number of people that have access to energy decrease for the first time in decades, increasing by 6 million to become a total of 760 million people worldwide. The area that was most impacted was Sub-Saharan Africa where 4 out of 5 people live with no electricity whatsoever. The past year did overthrow this increase by a little bit and the projected number of people that live without electricity is supposed to end up at 745 million by the end of 2023. The number will be similar to the previous year in the Sub-Saharan region for the first time since the rise since 2019. While, developing countries in Asia have experienced a slow increase in accessibility but at a way lower rate compared to the trend that was interrupted with the pandemic (Cozzi et al., 2023).

The bottom graph shows the number of people that have no access to electricity from 2010 to 2023 divided by regions. Overall the down turning trend is apparent until the pandemic crisis and the war had a staggering influence. While Asian countries benefited from the development they went through since 2010, the situation in Sub-Saharan Africa did not upgrade. The amount of individuals suffering from energy poverty in Asia started from 761.6 million in 2010 and in thirteen years it decreased to 106.9, while went from 580,3 million to

598,8 million. Moreover, this graph presents absolute data and does not account for the population size, in fact, Asia is way more densely populated compared to Africa and on top of that underwent a strong population sprout in the last decade.

It is possible to conclude that Sub-Saharan Africa was the only region where energy poverty actually increased over the years showcasing a stark contrast to the rest of the world, and for this specific reason it will be the area of research of this paper.

Figure 1: Number of people without access to electricity by region, 2010-2023



Source: IEA Access to electricity database

Although energy constitutes one of the basic elements for the civilized world, reliable access to energy is not universal, as the sources are not spread out evenly in the world. Economic and social development are the main factors that drive the presence of affordable sources of energy, which entails that poorer countries are the ones that have the worst energy services, additionally playing a part in the mediocre health and living conditions of citizens of the country (Habitat for Humanity, 2023).

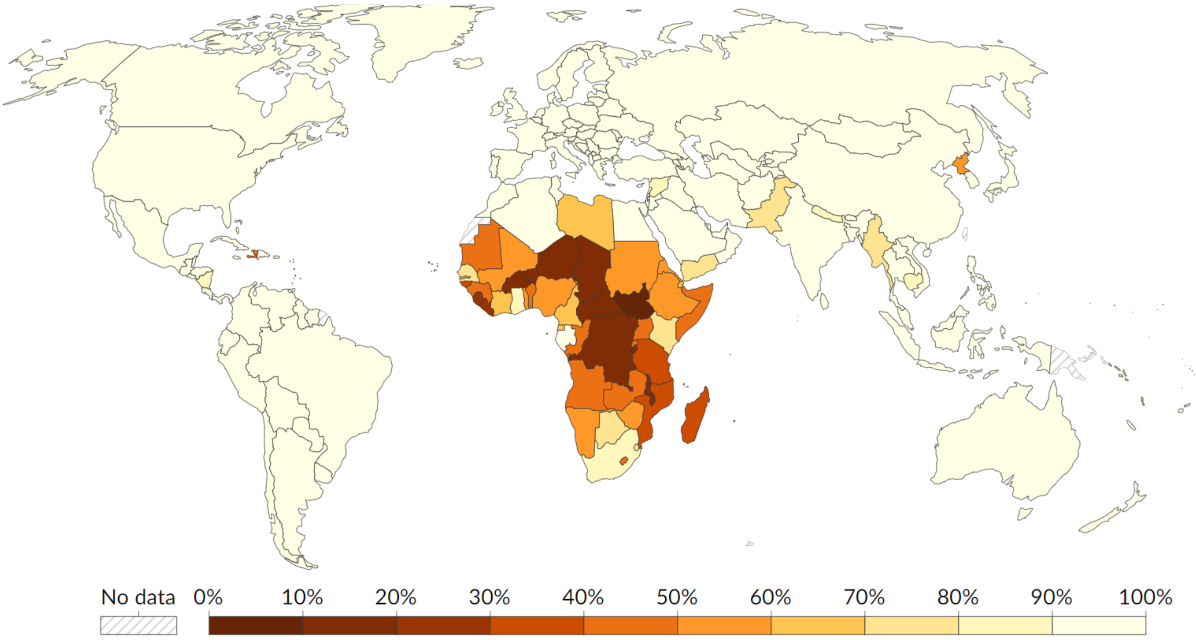
1.1.1. Measurements of Energy Poverty

Typically, energy poverty is defined as the lack of access to and usage of contemporary energy services. However, the interpretation of energy poverty has been a subject of extensive discussion over time, exhibiting substantial variations among scholars, therefore it remains challenging to delineate a distinct boundary and present universally applicable figures. The divergence hinges on whether the absence of access to modern energy directly affects a household's well-being or if there is an indirect, yet associated impact arising from achievements related to energy (Villalobos et al., 2021). Even when discussing an individual perspective there are multiple issues affecting the studies of energy poverty. It is difficult to understand what the amount of energy is accessible that should be considered damaging to one's well-being and thus how to define energy poverty. There are mainly three approaches on how to assess when a household can be defined as energy poor: technological threshold, physical threshold, and economic threshold (Pachauri and Spreng, 2011).

The first way to view energy poverty is through a technological threshold, which entails that an individual is considered energy poor when they do not have access to modern services that allow them to have clean and safe electricity. In this context, the energy poor have no option but to use biomasses for the household tasks that require electricity. Following this method, the process of measuring the amount of people that only have the traditional sources, that have been shown to have negative impact on the household's health (Pachauri and Spreng, 2011). According to the IEA, in 2022 there were 774 million individuals with no access to electricity, and it is set to increase for the first time in a decade (Cozzi et al., 2022). The limitation that this method has is that it does not express the consumption amount (Pachauri and Spreng, 2011).

The threshold considering physical needs is calculated by associating an amount of energy that is to be able to power basic needs and everyone that has lower electricity than the set amount is considered energy poor, which is similar to the way international organizations measure absolute poverty. This method presents a different type of issue, it is in fact, difficult to arbitrary decide what can be considered a basic need, moreover, there is a debate around weather production should be counted (González-Eguino, 2015). In international statistics it is common to consider a minimum of 4 hours of available energy in order to meet basic needs like basic lighting, cooking and charging technological devices. Any household that has no opportunity to meet at least this threshold is regarded as energy poor. The bottom map shows how the world's access to electricity considering this standard in 2020. The map in *figure 2* shows a clear disadvantage for the Sub-Saharan area of Africa, in fact, in the majority of countries in the world outside of the region, nearly 100% of individuals reaches this already low standard. The country in the worst condition is South Sudan, where only 7,24% of the population has access to energy that can power very basic necessities (Ritchie, 2024).

Figure 2: Share of the population with access to 4 hours of electricity for basic needs



Source: Our World in Data; Data compiled by World Bank (2020)

Lastly, the energy poverty threshold can be set through a percentage of income that could be decided to be practical to be spending on energy, similar to the system used usually to measure relative poverty. The UK, which is notorious for studies regarding this topic, has established in 1996 that a maximum of 10% portion of a household income should be going towards funding electricity. The hypothesis is that when a household has a higher share of the revenue is taken by energy costs the people find themselves in an economical vulnerable state, especially among economically disadvantaged communities in developing nations. However, this outlook does not provide for comparison between countries that have different economic situations (González-Eguino, 2015).

Composite Indicators

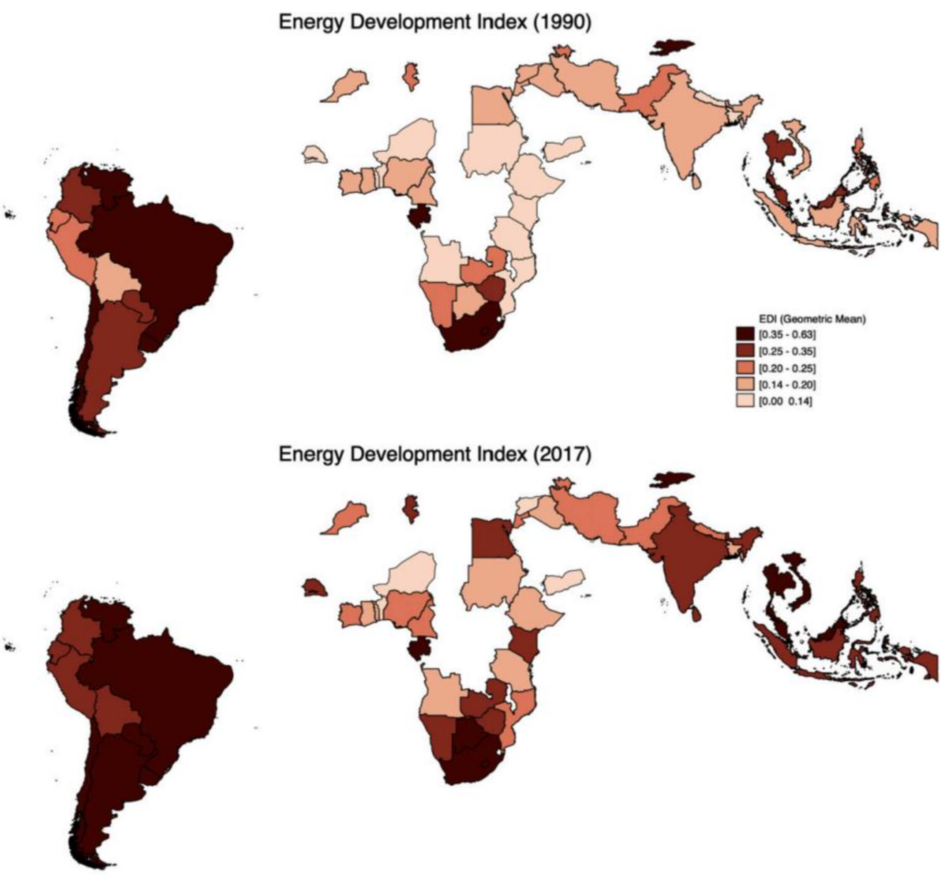
The three methods mentioned above all have their issues, but they also all have a common problem: they could be susceptible to biases in sampling selection, which might result in the potential overestimation or underestimation of energy poverty rates. In contrast, composite indicators are relatively easier to measure and compare across multiple dimensions (Herrero, 2017). A multidimensional indicator, incorporating both objective and subjective measures, is less susceptible to sampling selection bias and survey-related errors. Various international organizations maintain a dataset encompassing the use of traditional fuels and access to electricity, derived from a blend of their independent assessments and nationally reported data. Examples of composite metrics for energy poverty within this dataset include the Multidimensional Energy Poverty Index (MEPI), Energy Development Index (EDI), Energy Poverty Index (EPI), Compound Energy Poverty Indicator (CEPI), and a dashboard comprising individual indicators.

Various studies employ the approach to construct a Multidimensional Energy Poverty Index (MEPI), which can work both for developing and developed countries (Banerjee et al., 2021). The MEPI captures various energy deprivations that individuals may face, consisting of five dimensions that encompass fundamental energy services, each measured by six indicators. It is crucial to choose variables based on their relevance to the issue and their accessibility. A person is deemed energy poor if their experience of these deprivations surpasses a predefined threshold, computed as a product of the percentage of people identified as energy poor and the average intensity of deprivation among the energy poor. The selection and structure of variables should acknowledge the multifaceted aspect of lack of electricity. The index is a number between 0 to 1, where 1 represents the worse a high level of energy poverty (Nussbaumer et al., 2012). This index is designed to approach energy poverty through the lens of energy deprivation, and it offers a thorough evaluation of household energy poverty in a unified index. However, it does not encompass energy usage outside the household or for commercial purposes (Salman et al., 2022).

Herrero and Bouzarovski (2014) developed the Energy Poverty Index (EPI) that examines various aspects of material deprivation, which are then cross-referenced with economic deprivation measures. The study further investigates the correlation between local energy price hikes and energy poverty rates, along with income. It was later modified by introducing two additional energy poverty indicators, resulting in the enhanced Compound Energy Poverty Indicator (CEPI), providing more detailed insights (Salman et al., 2022).

The International Energy Agency (IEA) introduced the Energy Development Index (EDI), a composite index that measures development in terms of energy use calculated through an evenly weighted average of three normalized components: per capita commercial energy consumption and the share of commercial energy in total final energy use. Thus, composite indicators were found to be very comprehensive and robust covering various aspects. The performance of this indicator could be easily compared across dimensions, sectors, and countries (Suganthi, 2020). However, a critique of the EDI is that it primarily reflects the maturity of a national energy system, without adequately capturing the extent of energy deprivation in households (Salman et al., 2022). *Figure 3* is a comparative map showcasing the differences across the three most struggling areas for energy poverty, namely South America, South East Asia and Africa, and how they changed in history. Even though the map does not present data for all countries of interest, it is possible to recognize a trend in how the world has developed. From 1990 to 2017, the area that presented the smallest development was Africa, excluding South Africa. Latin America had better positioning even in the 90's, however, it still improved, the Asian countries were the ones that incurred the biggest positive change and as previously mentioned, it is due to the great industrialization progress they experienced in the last 20 years.

Figure 3: Energy development index (1990; 2017)



Source: World Development Indicators

1.1.2. Consequences of Energy Poverty

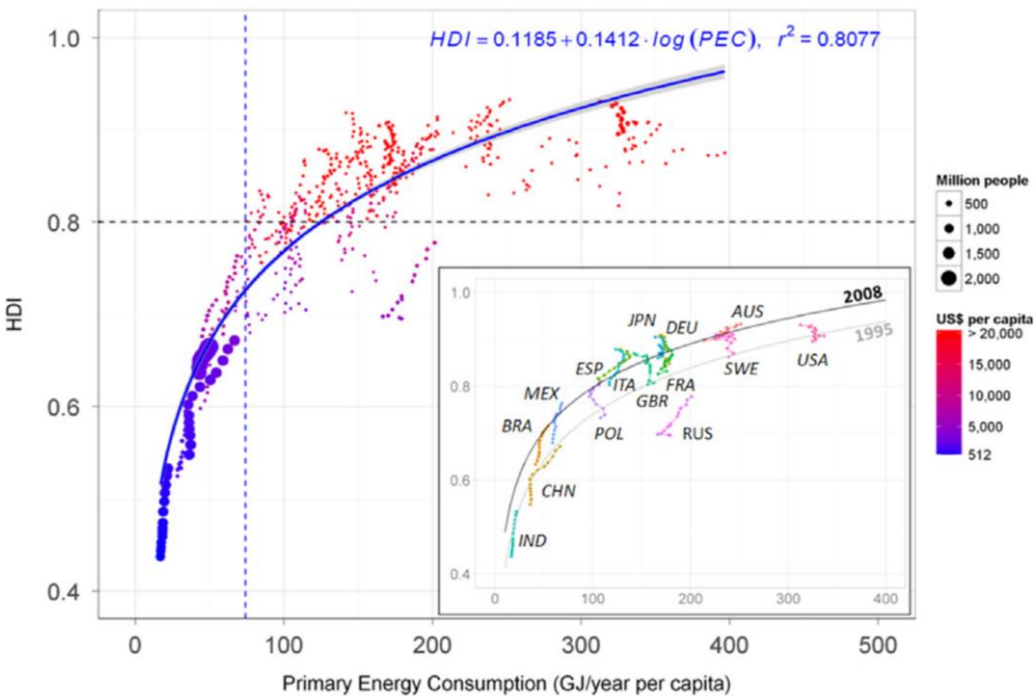
Studies indicate that failing to address energy poverty can lead to significant repercussions, including adverse effects on health, reinforcing poverty, and hindering the achievement of other goals, such as addressing climate change.

The impact that lack of access to energy entails for a country can be outlined in two macro areas, which will be analysed in the following paragraph. First and foremost, the relationship between energy consumption and economic development and secondly but more impactful the health consequences of energy poverty.

Energy is strictly liked to the economic situation of a country, in fact, macro-economic indicators of a country's development comprehend electricity consumption, per-capita CO2 consumption and number of vehicles. The Human Development Index is an indicator for a country' development that takes into consideration citizens' life conditions in key dimensions such as health, longevity, educational level and standard of living (UN Development Program, 2023). While the index only assesses the level of quality of life, understanding the causes of positioning of countries is a more complicated deal and has to give thought to various variables. However, academics have established that there is a strong correlation between the energy consumption and the HDI score of a country all throw-out history as demonstrated by *figure 3* where the primary energy consumption per capita in sample countries around the world is related to the HDI both in 1995 and 2008. The USA and Germany, for example, have almost identical HDIs (0,92) and have respectively 78 and 80 years, consume a pretty high amount of GJ per capita. On the opposite side of the spectrum, India, Nigeria and Ethiopia, have distinctively lower HDI scores and life expectancy below 65 years, present much lower levels of energy consumption (González-Eguino, 2015).

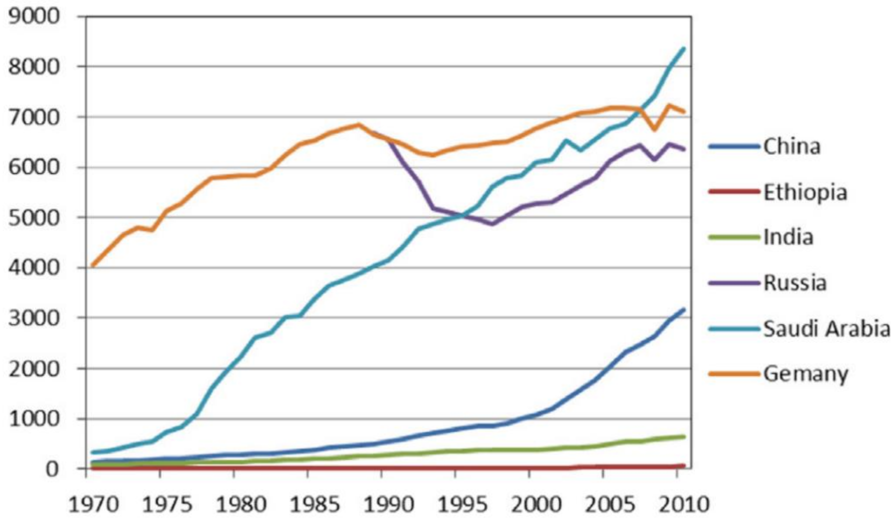
The economic progress of a country leads to an increase in the energy consumption. In *figure 4*, it is represented the energy trends from 1970 to 2010, which is coincidentally the time period in which China underwent a huge economic development and as previously established in this paragraph, the industrialization of a nation has intrinsic growth in the amount of energy consumption. As a matter of fact, China went from 150 Kw per capita in a 1970 to 3000 in 2010. Therefore, China increased its consumption by 20 times in the span of 40 years in order to achieve the extensive economic growth. In contrast, where there was no increment in electricity utilization, in particular some African countries, there was an almost imperceptible difference in economic growth (González-Eguino, 2015).

Figure 3: Human development index and energy consumption, 1995–2008



Source: Source: Arto et al.

Figure 4: Electricity consumption, 1960–2010, kW h per capita



Source: World Bank

The relation between economic growth and energy consumption is clear, however, two other considerations must be made when analysing data. Firstly, the amount of energy per capita can be misrepresented when observing countries that export energy in large quantity. For example, two of the most notable electricity exporting countries are Russia and Saudi Arabia, and they both have a higher level of Kilowatt per capita compared to Germany but their quality of life is lower. Secondly, public policies by governments have a big influence on the consumption quantities, mainly energy and urban policies. The USA energy consumption per capita almost doubles the one in Germany, yet the dissonance cannot be legitimized by a different economic structure nor climate or geographical reasons (Nussbaumer, 2012).

In short, energy consumption is one of the main factors that contributes to the development of a nation, nonetheless, the economic aspect is not the only aspect of a high life quality. Policies can have a positive impact on welfare without needing additional consumption of energy, and therefore, the choice of policies is significant to the well-being of a country. The importance of energy consumption can more evidently be comprehended through the ramifications of energy poverty (González-Eguino, 2015).

Poverty Aggravation

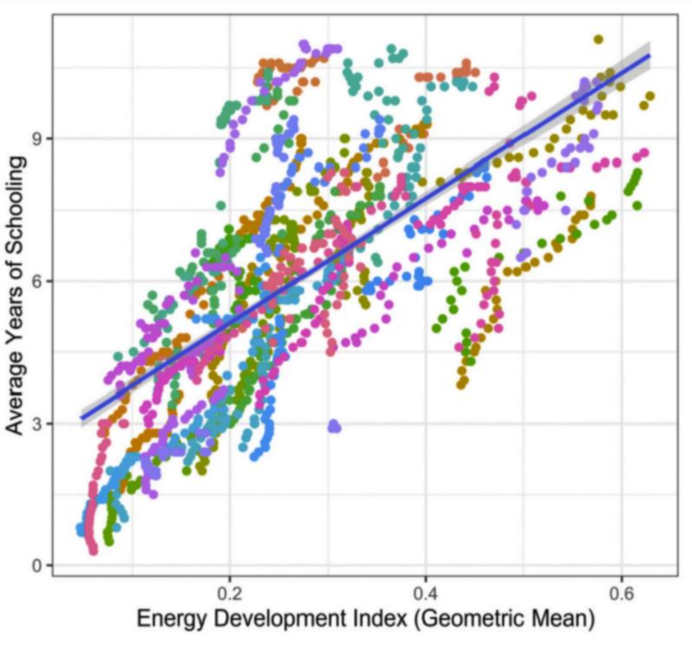
While the previous paragraph discusses how energy consumption is strictly connected to the economic development of a nation, this one will take on a closer look at how it impacts the individuals within a country and their relation to poverty. A big issue for energy poverty is that it exacerbates socio-economic inequalities, meaning that it affects the poorest in society even in poor countries and it aggravates the situation of already poor people or at least, prevents them from getting out of poverty.

In the first place, energy poverty has an impact on how much education individuals are able to achieve (Banerjee et al., 2021), which has shown to affect income, happiness, health, life expectancy explains the reason why education is a huge aspect of an individual and is very relevant when discussing poverty and health (Zajacova & Lawrence, 2018). For instance, the lack of energy affects the lighting and heating or cooling power of a country's institutes which entails an effect on the education systems. Schools are not able to be open when there is no natural light if there is no access to energy and temperature regulation is also necessary for educational services. This results in lower educational attainment, especially for young people in poor families that are often forced to work themselves to support the family and therefore have no time during the day to obtain an education that would potentially allow them to earn more and take the family out of poverty (Lee & Yuan, 2024). Moreover, in the case of extreme poverty, it is common for young kids, especially girls, to dedicate significant time to gathering firewood and traditional cooking fuels instead of attending schools (Banerjee et al., 2021).

Even the quality of teaching changes thanks to the utilization of electricity, educators can have access to electronic tools that improve the educational experience for students, such as computers, photocopiers, televisions and projectors or even use more intricate gadgets for laboratory based teaching. It has been shown that even these changes, that might seem superficial, have an impact on the performance and enjoyment of students and the result is that students spend more time studying, in particular for girls (Banerjee et al., 2021).

The study by Banerjee et al. (2021) that was comparing countries around the world between the Energy Development Index and well-being of individuals to understand if there was a correlation. The results from the scatter plot graph below (*figure 5*) are a clear positive correlation, one of the strongest in the study. The general rule that can be taken away from the study is that countries that have progressed relatively well education outcomes since 1990 have also experienced a progression on energy consumption.

Figure 5: Scatter plot showing the relationship between education outcomes with energy development index



Source: Rajabrata Banerjee, Vinod Mishra & Admasu Asfaw Maruta (2021)

Energy poverty has been accepted as a fundamental element in human development, especially in alleviating overall poverty levels. There is a robust correlation between the multidimensional energy poverty index and household income levels in developing countries (Mendoza et al., 2019).

Inadequate energy usually signifies the impossibility to develop agricultural and manufacturing sectors. Agriculture is particularly conditioned because modern machinery, improved farm equipment and irrigation systems are introduced when energy is available. The growth in agricultural productivity allows valuable resources to be redirected to other sectors like industries and services, thereby reducing overall poverty levels and boosting income. Beyond the agricultural sector, lowering energy poverty barriers has broader benefits, fostering affordable energy services for all, supporting non-farm businesses, and generating higher income, employment, as well as improved health and education outcomes (Banerjee et al., 2021).

The paradox is that energy poverty makes it impossible for individuals in the poorest countries of the world to break free from the vicious cycle of poverty.

Health Consequences

While energy poverty has consequences for various economic sectors and obstructs endeavours in environmental protection, its most significant, yet often overlooked, ramification is its influence on health (González-Eguino, 2015). The European Commission (2023) declares energy as fundamental for the maintenance of our health, functioning as the source of heating and cooling, lighting, safe cooking conditions and many of the everyday tasks executed in a household. To understand how energy poverty affects health, it is important to look at the issue through a multifaceted lens. Energy is needed for various productive uses that impact the well-being of a household, the high household demand of energy comes from the desire to have lighting, cooking, television, refrigeration, drinking water, hot water, and other home appliances (Banerjee et al., 2021).

Firstly, the scarcity of energy frequently leads to a limited availability of clean and dependable energy sources. The poorer countries of the world are the ones equipped with the worst energy services and therefore need to resort to lower quality electricity which as causes diseases, contribute to malnourishment and restrained access to education and employment (Habitat for Humanity, 2020). Poor countries consequently fall back on kerosene, coal and traditional biomasses, including wood, dung, and waste materials, for cooking and heating. These fuels are usually used and burned directly in homes using clay, brick, or metal cookers. Lighting needs are primarily met with candles and, to a lesser extent, kerosene lamps. This energy usage has significant health implications due to elevated pollution levels caused by inefficient combustion and inadequate home ventilation. Indoor air pollution is characterized by higher-than-recommended levels of carbon monoxide, aromatic compounds, and suspended particles (Manisalidis et al., 2020). These particles consist of fine ash, soot, and metal elements and are detrimental to health because of their size. Particles with diameters less than 10 μm are referred to as PM10, and those less than 2.5 μm as PM2.5. Inhaling PM10 can easily penetrate the respiratory system, causing health damage, especially if toxic elements like heavy metals are involved. Additionally, PM2.5 can be deposited in the deepest parts of the respiratory system, potentially leading to more severe health effects. The consequence is an environment where the insides of the homes end up being more polluted and therefore even more damaging even compared to the outside of the most polluted cities (WHO, 2006). Medical research has dedicated decades to examining the health impacts of prolonged and elevated exposure to indoor pollution. It is currently understood that respiratory and cardiovascular diseases, as well as instances of lung cancer, and various other negative health outcomes can be attributed to fine particles (Brusseau et al., 2019). According to the World Health Organization (WHO, 2009), indoor air pollution is believed to double the risk of pneumonia and other respiratory infections in children under five and also increases risks of developing cataracts. Women face a three times higher likelihood of experiencing obstructive pulmonary diseases like chronic bronchitis and emphysema, as well as double the risk of developing lung cancer. The pollution in households also worsens the well-being of unborn babies, contributing to an increased incidence of natural miscarriages and stillbirths (Roser, 2023).

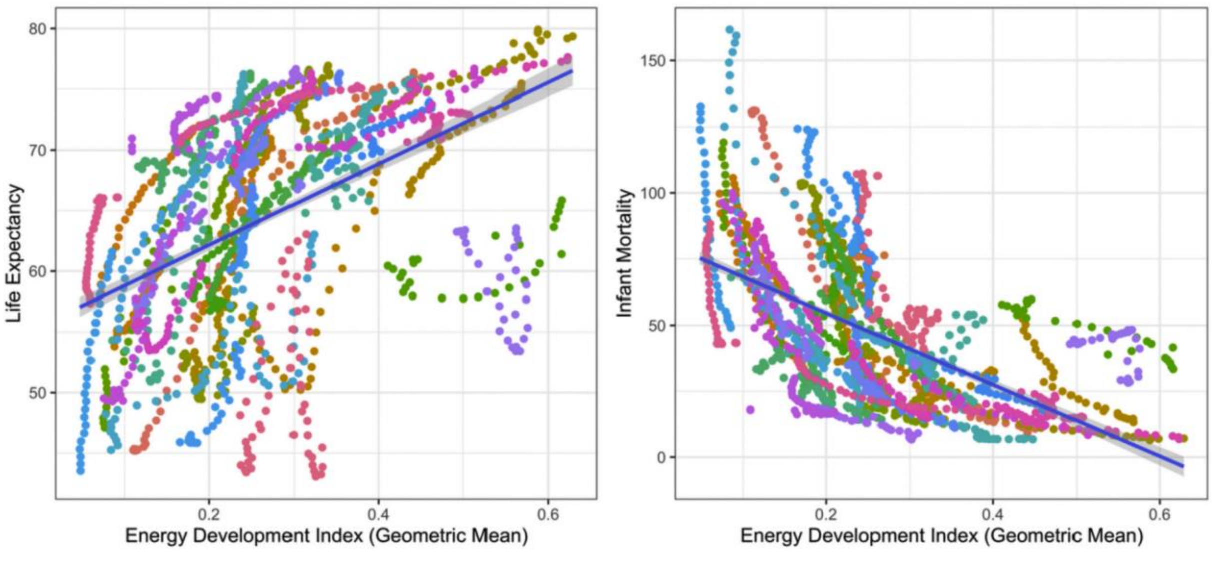
The World Health Organization (2023) estimated that indoor air pollution was the cause of death for 3.2 million people in the year 2020, out of which more than 237000 were children under the age of 5. Moreover, cooking on an open fire or bad quality stoves is the leading risk factor of burns, in particular affecting women and children in low-income countries (WHO, 2023).

Secondly, as the energy resources are lacking, heating or cooling systems are inadequate, creating living environments that do not allow good living conditions. Extreme temperatures, whether too cold or too hot, have adverse effects on health. During colder seasons, the absence of heating increases the chances of hypothermia, respiratory issues, and cardiovascular strain. While in the hotter months, cooling systems are necessary in order to avoid heat-related illnesses, particularly among vulnerable groups like the elderly and children (Longden et al., 2022). Additionally, when families that experience scarcity of energy are forced to reduce the types of food that they cook in order to uses up the smallest amount of energy they can by reducing the time in the kitchen, this inevitably led to uneven diets other malnutrition issues (Moreno, 2023). Access to clean energy is also relevant across the food supply chain, since it directly impacts the quality of food because of the refrigeration needed in the conservation and heat for the preparation (Candelise et al., 2021).

Furthermore, energy poverty negatively affects the operational capacity of medical facilities, starting from the equipment to refrigerators for vaccines and medications. The lack of energy affects the quality of the health services and creates a harming environment for individuals that are already weak and therefore more likely to develop diseases (Ouedraogo & Schimanski, 2018).

The two scatter plots below (*figure* 6) present the results of the study by Banerjee et al. (2021) on how energy poverty affects education and health. The dots represent numerous different countries at different level of energy development. It is visible in the graphs that there is a clear connection between the Energy Development Index and Life expectancy, as well as with infant mortality that. Therefore, countries that have improved their energy systems have had positive repercussion on the health of individuals.

Figure 6: Scatter plot showing the relationship between life expectancy and infant mortality education outcomes with energy development index



Source: Rajabrata Banerjee, Vinod Mishra & Admasu Asfaw Maruta (2021)

In a broader perspective, health is not limited to the physical conditions of individuals but includes the behavioural and psychological welfare as well. In the context of the situation described by this thesis, these factors are very much negatively impacted. For instance, lighting systems are necessary for furthering education. Individuals in poor conditions often need to resort to attending school at night because of working obligations during the day, however, without proper lighting it is impossible to have schooling at night. The lack of opportunity for education and economic possibilities, explained in the previous paragraph about poverty aggravation, can have serious negative outcomes on the mental health and well-being in people living in energy poor countries.

It is important to notice that the consequences on health vary also from country to country based on institutional, economic, and social differences. It is especially relevant the level of urbanization. In countries that present a low level of urbanization, the rural areas resort to using the biomass fuels that are extremely damaging to public health (Zhang et al., 2023). The countries with a moderate urbanization level there are some improvements even though the effects of energy poverty are generally pretty visible as well. In the urbanization process there is more accessible clean energy which reduces the possibility of indoor pollution that happens in the rural areas. Nonetheless, other problem come up with the urbanization process: the quality of water and sanitation is undoubtedly worse. Moreover, there is a prominent issue with waste management that affects the water flows of cities. These issues may not seem related to energy but are closely linked to it since some technologies that could help with the sanitization issues cannot even be implemented. On top of that, urban areas have weighty population density and deficient housing establishments which are another cause of disease spreading across civilians (Tiwari et al., 2023). In nations experiencing significant urbanization, more modern energy infrastructure and service delivery are present. Energy supply tends to be more consistent and cleaner in such settings, which diminishes the influence of energy poverty on health (Tiwari et al., 2023). The more enhanced services contribute to improved indoor air quality, lowering the risks associated with respiratory illnesses. Additionally, urbanization frequently results in the availability of superior medical facilities and healthcare services, which prove advantageous for disease prevention, control, and treatment.

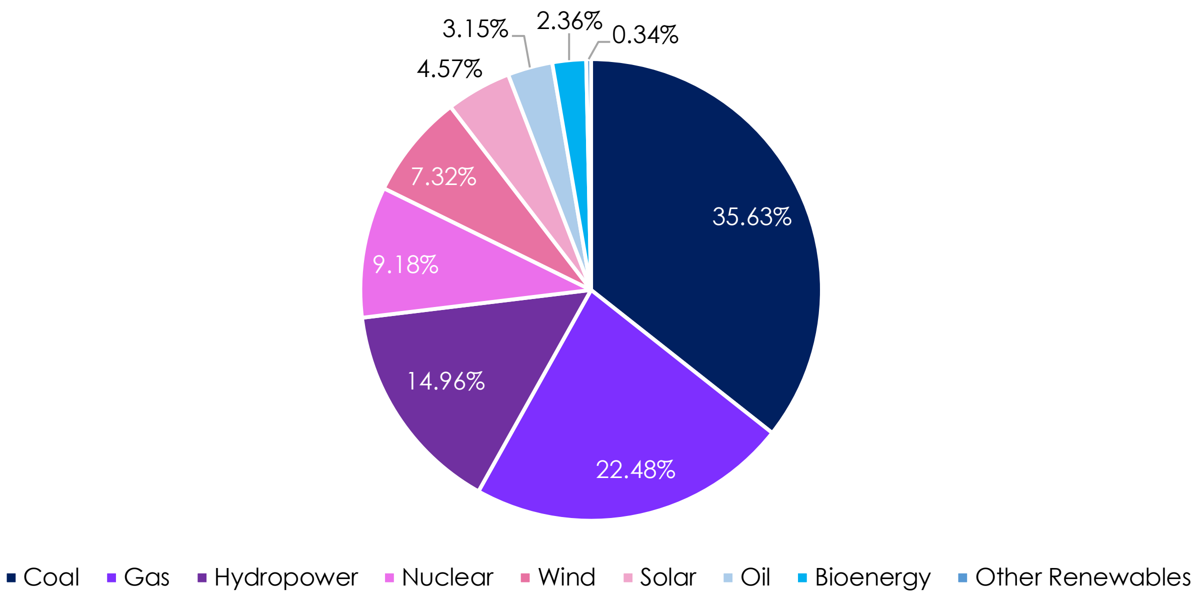
Therefore, it is possible to conclude that urbanization can improve the disadvantageous effects of energy poverty on health specifically even though it may bring some other challenges (Lee & Yuan, 2024).

1.1.3. The Electricity Market

The energy market fundamentally involves the trading and distribution of energy, encompassing both electrical energy and other energy resources. Recognized for its rapid growth and complexity, the energy market plays a crucial role in global economies, serving as a vital component in power and gas supply, while also addressing financial considerations within the energy sector (Mousavi et al., 2021). The type of service provided by the electricity industry has undergone many changes over the years. This industry is one of the most important factors influencing economic, political, social, cultural, and welfare conditions as thoroughly discussed in this thesis. As a result, the electricity industry has been monopolized for years. However, the processes are changing. The electricity industry around the world has seen significant structural changes over the past two decades. These structural changes, which were made to create a competitive and nonexclusive environment to ensure social welfare and increase the reliability of the power system, also greatly affected the type of market service (Mousavi et al., 2021). Understanding the market is fundamental for the comprehension of the energy poverty issue causes and furthermore for understanding the systemic holes that need to be offset by policies potentially contributing to the alleviation of the problem discussed in this paper.

Energy can be obtained through various method. To understand better where the resources come from and who has the political power that is connected with them, it is necessary to look at the different types of energy sources in detail and what countries are involved in the trading. This includes fossil fuels such as coal, oil, natural gas and renewable energy, namely solar, wind, hydro, geothermal and lastly nuclear power. As of 2022, the composition of electricity production can be attributed mainly to coal and gas, making up more than half of the electricity worldwide. The pie chart in *figure 6* below shows the full breakdown of the most relevant sources for the electricity by the proportion of the total. It is important to consider that some sources might present a lower consumption level than expected because the data discussed in this thesis is how these materials are used to create electricity. For instance, oil production and consumption are way higher than the data exhibited below since crude oil and other liquids derived from fossil fuels undergo refining processes to create petroleum products utilized for various purposes. Petroleum products are used to propel vehicles and are also commonly used as raw materials to manufacture products like plastics, polyurethane, solvents, and numerous other intermediate and end-user goods (U.S. Energy Information Administration, 2023).

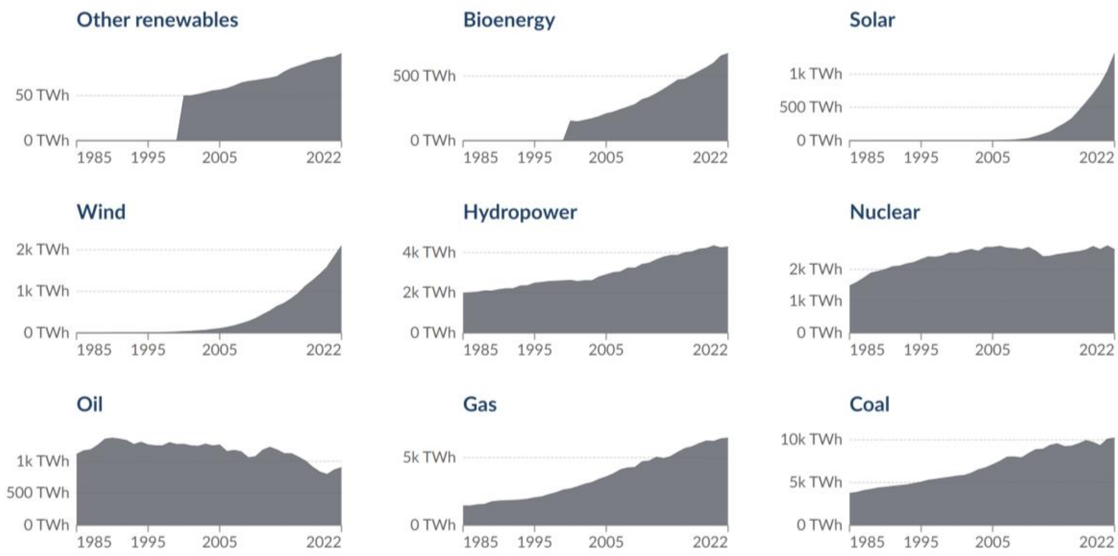
Figure 6: Share of electricity production in 2022



Source: Own elaboration based on data from Yearly Electricity Data (Ember, 2023)

The objective of the analysis on this section is to understand how the sources of electricity creation. On a global scale, coal, followed by gas, stands as the predominant source of electricity production. Among low-carbon sources, hydropower and nuclear contribute the most, with wind and solar, which have been experiencing rapid growth in the market. The *figure 7* presents the production amount in Terawatts threw out history of the different sources since 1985, showing how the energy market has changed. The other renewables mentioned in both graphs are newer technologies that have been introduced as a consequence of the environmental crisis but have not yet been explored as thoroughly as others and they include waste, geothermal, wave and tidal (Ritchie & Rosado, 2024). The composition of the sources changes between countries because of geographical, economic and political reasons. Therefore, examining the electricity composition of specific countries reveals notable shifts. When going over the markets of the different sources this chapter will present insight on the major players both of production and consumption as well as the many challenges presented by the mediums.

Figure 7: Electricity production by source (1985 – 2022)



Source: OurWorldinData.org; data: Yearly electricity Data (Ember, 2023)

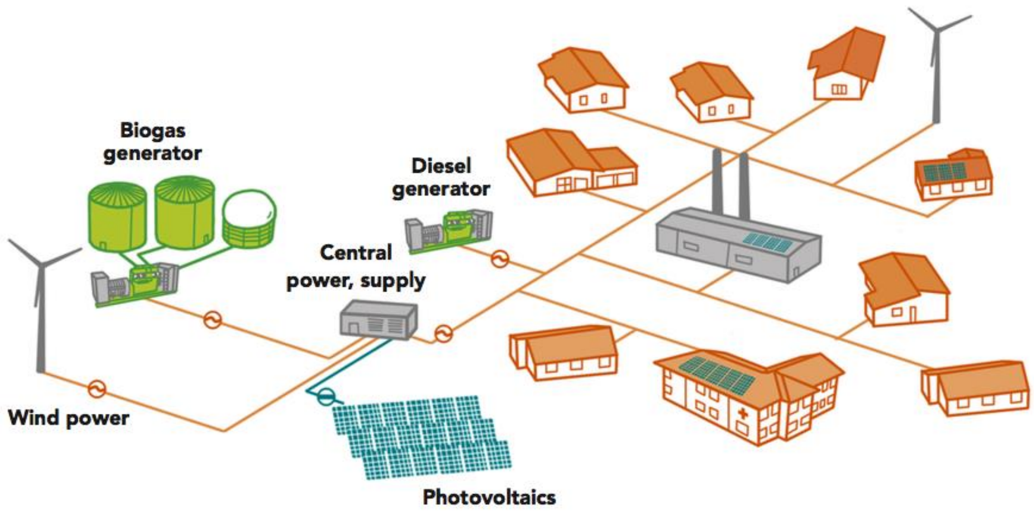
When discussing fossil fuels production, it is crucial to denote the difference between resources and reserves to comprehend if the lack of energy source in an area has a geological or economic explanation. A mineral fuel resource is an aggregation of a substance that have been certified to be present in an area and estimated in quantity. The assessment can be more or less reliable, however, what makes them a resource, is the lack of economic possibility to extract the material and refine it. On the other hand, the confirmed reserves refer to parts or resources that geological and engineering data reasonably indicate can be recovered in the future from known deposits under existing economic and operational conditions. There is more stringent qualification for a resource to be classified as a reserve that are economic and legal in nature (Statista, 2023).

The electrical grid infrastructure

For the understanding of this paper, it is relevant to define what an electric grid is and make a quick excursus on the global electricity generation, transmission and distribution system that powers houses and companies around the world. The grid consists of various components, including power plants that generate electricity using through one of the diverse energy sources. Transmission lines are made of conducting electricity over long distances from power plants to substations, which play the role of transforming voltage levels and redistributing electricity to different regions through distribution lines. The distribution lines are usually suspended on utility poles or placed underground and deliver power to homes, businesses, and other consumers. Additionally, the grid incorporates monitoring and control systems, such as switches, relays, and sensors, to ensure the efficient and reliable operation of the entire network. Transformers are essential electrical devices that enable the efficient transmission of electricity over long distances and the adjustment of voltage levels to match the requirements of various end consumers (Majcher, 2023).

There are several categories that the distribution network might fall into. Networks are typically categorized based on their design and their size. One aspect to understand is the difference between on-grid and off-grid distribution. On-grid systems rely on centralized generation and distribution networks, connecting consumers through a centralized grid infrastructure. In contrast, off-grid systems operate independently, typically utilizing local renewable energy sources and energy storage solutions. Additionally, mini-grids are smaller networks that are independent from the main grid, often localized in remote areas, providing a solution that combines the benefits of both on-grid and off-grid systems. The *figure 8* below presents a simplified example of a hybrid mini-grid system, which entails the presence of multiple sources of energy (Meier, 2019). The distinction in connection to a centralized grid infrastructure is fundamental to the understanding of the diverse approaches to energy distribution.

Figure 8: Scheme of a hybrid mini-grid



Source: Meier (2019)

1.1.4. Climate Change and Net Zero Emissions

Climate change is a critical global challenge highly linked to our energy consumption patterns, as three quarters of greenhouse emissions are direct result of the unsustainable practices of the energy market (World Economic Forum, 2022). The negative results are evident in the escalating impacts of climate change, ranging from rising global temperatures and sea levels to increased frequency and intensity of extreme weather events. These environmental changes have disastrous implications for ecosystems, biodiversity, and human societies worldwide. As nations grapple with the urgency of mitigating climate change, there is a growing recognition of the need to transition towards sustainable energy sources. Data reveals alarming trends in greenhouse gas emissions, primarily stemming from the combustion of fossil fuels and industrial processes (European Commission, 2024).

In response to the urgent need for action, the global community has set ambitious targets. In 2015 the United Nations Development Programme has set the global project of the Sustainable Development Goals (SDGs) in order to ensure a promising future universally, which is one of the programs that has most universal consensus. The goals include tackling by 2030 social, economic and environmental problems such as poverty alleviation and protection of health, education and sustainability worldwide. There are 17 main goals that interconnected with each other, out of which, SDG7 regards global accessibility to clean energy (UNDP, 2015). Nonetheless, the Sustainable Development Goal 7 is not even close to reaching its 2030 target in terms of progress. The current global objective is a decarbonisation progression that should culminate in achieving net zero greenhouse emissions by 2050 in order to restrict the world's temperature increase to 1.5°C (World Economic Forum, 2022). In the 2022 report "*Net Zero by 2050: A Roadmap for the Global Energy Sector*", the International Energy Agency emphasizes how the climate change issue necessitates to be addressed conjointly with the promotion of universal access to energy. For this reason, a wide range of energy and economic realities need to be taken into consideration. Indeed, the increase of power consumption that is needed to reach the objective of universal energy access combined with the goal of ultimately eliminating carbon dioxide emissions, entails a transition away from fossil fuels towards renewable energy sources. Embracing energy efficiency measures, adopting innovative technologies, and promoting sustainable practices across sectors are crucial components of the strategy needed to combat climate change (IAE, 2022).

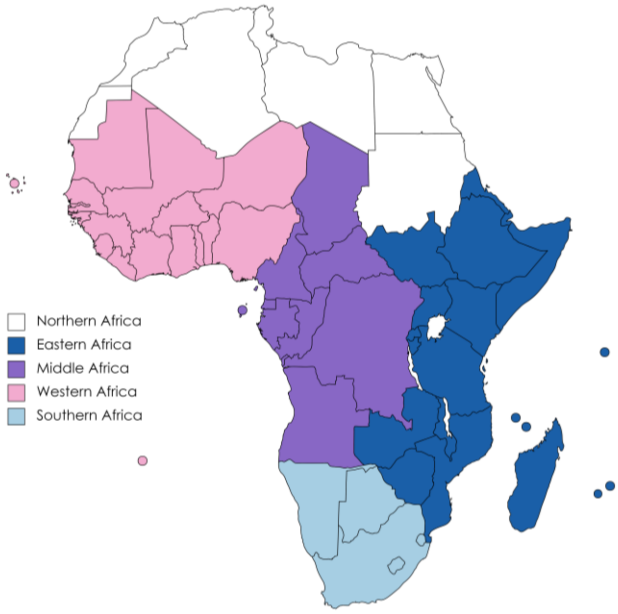
Furthermore, the climate change issue is extremely relevant for the area subject to the analysis of this thesis because, as declared by the IPPC, Sub-Saharan Africa will suffer from very extreme consequences from climate change following the path of the current policies in place. The objective of maintaining a maximum increase of 1.5°C is fundamental for limiting damages that African countries will experience both to the environment and subsequently to their economy. Even half a degree more than this threshold could have extremely damaging turnouts such as decreased food production, higher mortality and reduced biodiversity (Ramalope, et al., 2023). Even though energy consumption is highly linked with development that the area desperately needs (Banerjee et al., 2021), Sub-Saharan Africa would still benefit more from implementing low emissions technologies rather than the energy sources that the developed countries had the opportunity of using in the past.

For these reasons, this paper will only focus on transformative policies that rely on implementation of renewable solutions for the eradication of the energy poverty problem.

1.2. SUB-SAHARAN AFRICA

Sub-Saharan Africa is a geographical region of the African continent located under the Sahara Desert that comprehends the Eastern, Middle, Western and Southern parts of Africa, in the map below it is expressed by all the coloured countries. Essentially, according to the United Nations (2024), Sub-Saharan Africa includes all the countries and territories in Africa except Northern African ones, namely Algeria, Egypt, Libya, Morocco, Tunisia, Western Sahara and Sudan. Even though in other entities the latter country is considered to be part of Eastern Africa and therefore Sub-Saharan Africa as well. Nonetheless Sudan is a relevant country because of its severe decline, due to the conflict that began in April 2023. The conflict has forced over 5 million people to be displaced, out of which 4 million internally and the rest are seeking refuge in neighboring countries (Beaumont, 2023). The crisis is not only humanitarian but has also inflicted substantial economic damage on the country. Sudan's real GDP has, in fact, experienced a decrease of -18.6%, significantly affecting the whole region (IMF, 2023).

Figure 9: The geographical sub regions of Africa



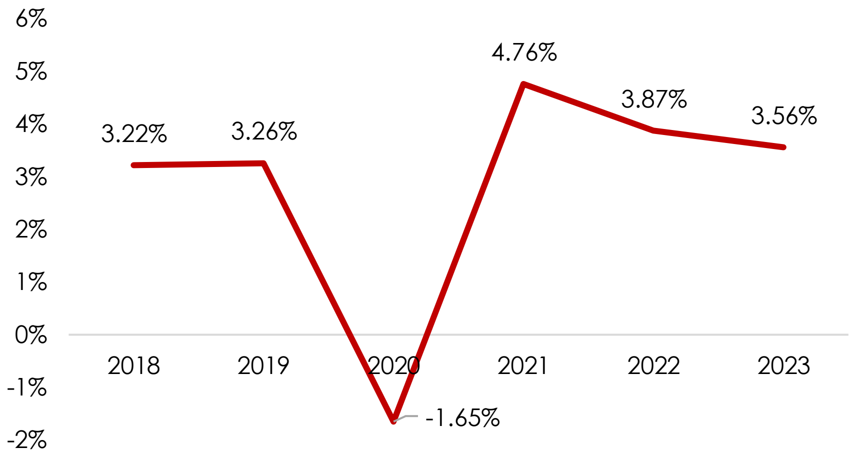
Source: Own elaboration; data from UN Statistics Division

Some of the countries part of Sub-Saharan Africa have partial areas converging with the Desert, however, the region has been subdivided as such because of socio-economic reasons. Even though the size of the area prompts the possibility of having very different societies with differing economic environments that are in fact present, Sub-Saharan Africa still departs from the rest of the world for the overall economic growth. The development of the areas is, in fact, not robust enough to eradicate extreme poverty, promote inclusive prosperity, and facilitate job creation, underscoring the multifaceted predicaments faced by the region.

1.2.1. Economy of Sub-Saharan Africa

Sub-Saharan Africa comprehends variating countries, as mentioned above, from low to lower-middle, upper-middle and high income. There are indeed various common trends that associate the countries of the region. For example, 22 countries are involved in serious conflicts that affects the welfare of the population and the political stability. Additionally, there are 13 micro countries that have limited resources due to their size and extremely low population, which entails a smaller human capital. Nonetheless, the area offers great opportunities thanks to the natural resources and the presence of the world's largest free trade area by size, population and number of countries involved known as the African Continental Free Trade Area (AfCFTA). As a matter of fact, the AfCFTA connects 55 countries, with a combined population of 1,3 billion and an estimated GDP of approximately 3,4 trillion US$ (AfCFTA, 2023). Despite the promising outlook, the many challenges that are entrenched in the history of the region, such as the rising conflicts, the climate and the Covid-19 crises, hinder the development of the area. Growth in Sub-Saharan Africa has actually seen a downturn and, as of 2023, around 462 million people are still living in extreme poverty (World Bank, 2023). The graph below in *figure 10* shows the change in real GDP in the recent years.

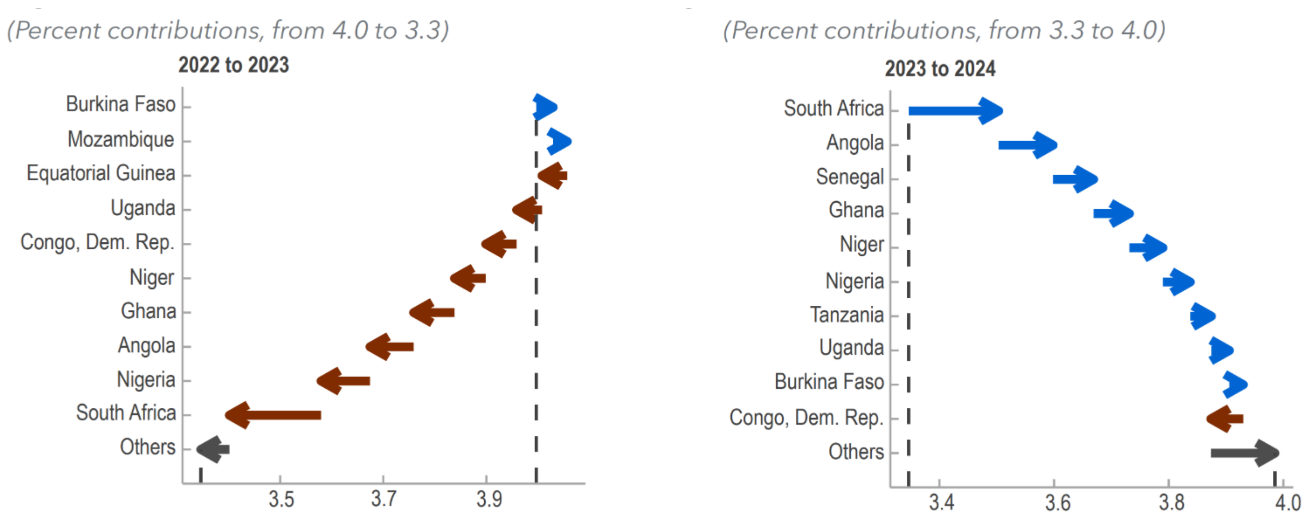
Figure 10: Real GDP growth compared to the previous year in SSA (2018-2023)



Source: Own elaboration; data from Statista (2023)

The year 2020 had negative effects on the global economy and was reflected especially in Sub-Saharan Africa. The major issue with the region relies on the down turning trend that the real GDP of the region endured right after coming back to 4,76% in 2021 after the Covid-19 crisis. While the rest of the world was able to get back on track by experiencing a bigger growth in 2021, Sub-Saharan Africa, that was indeed already struggling, has had a hard time to redeem itself and it is currently still suffering from another economic decline (Statista, 2023). The ongoing decline in economic indicators highlights the enduring fragility and challenges confronting Sub-Saharan Africa, raising concerns about the sustainability of its growth path. The average can be explained by in the fact that 28 out of the 48 countries in the Sub-Saharan Africa region have witnessed a decrease. This data is concerning considering that the number of countries that have had negative trajectories are more than half out of the total in the region, and the ones that did experience growth, did not have a sufficiently high enough yield to offset the regional average. Niger experienced the most substantial decline with a drop of 4,6% attributed to the economic consequences of a military coup. Additionally, countries such as the Central African Republic, Guinea-Bissau, Angola, and Zambia share a down turning in their growth forecasts, since each nation demonstrates an economic growth rate below 2% (The World Bank, 2023).

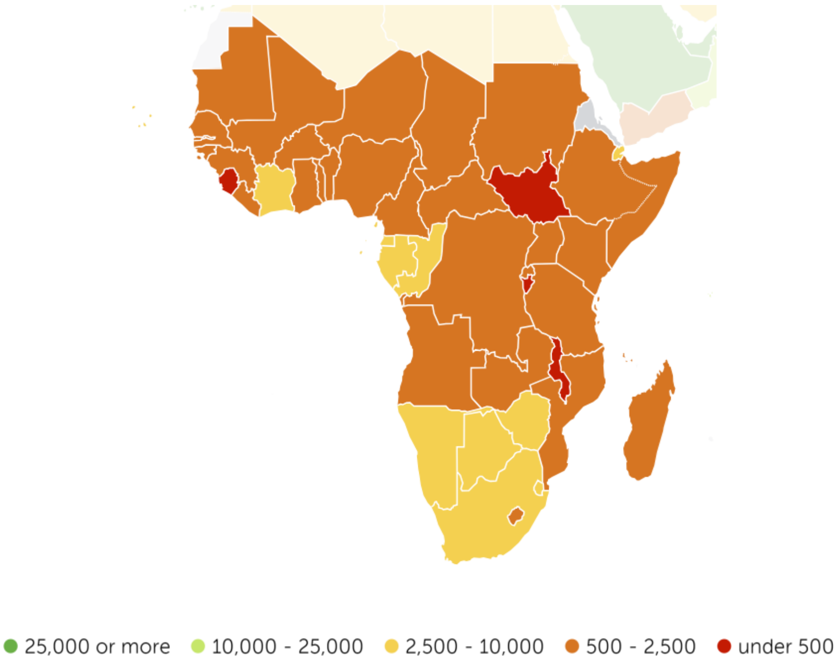
Figure 11: Countries' contributions to change in expected GDP Growth in SSA (2022-2024)



Source: IMF; data from World Economic Outlook database

As per the Regional Economic Outlook for Sub-Saharan Africa (IMF, 2023), it is projected that GDP growth will decrease for the second consecutive year, dropping to 3.3% from the previous year's 4%. Nonetheless, various issues are persisting: inflation remains high, borrowing costs continue to be elevated, exchange-rate pressures continue, and ongoing political instability remains one of the biggest problems. The two graphs above explain how some sample countries are contributing to the GDP growth of Sub-Saharan Africa in the projections made by the International Monetary Fund.

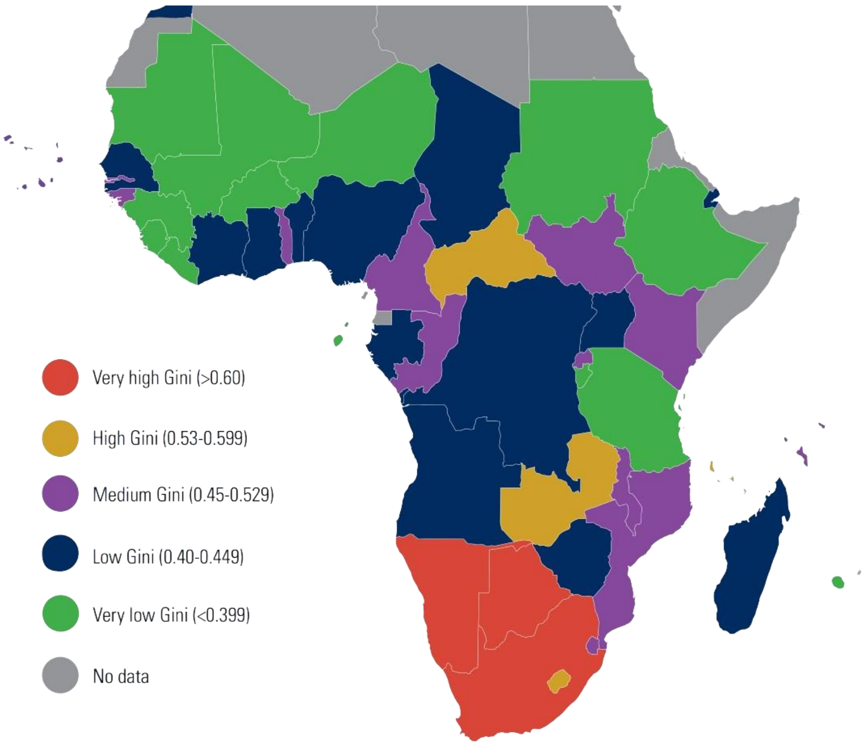
Figure 12: GDP per capita in SSA (2023) in US$



Source: International Monetary Fund (2023)

The map above (*figure 12*) represents the current situation of the Gross Domestic Product divided by the population across the different countries in Sub-Saharan Africa in 2023. According to the World Bank Group (2023), growth per capita in the region has not increased since 2015. It seems that the only difference Sub-Saharan Africa has increased over the decade from 2015 to 2025 is only by 0,1% yearly, which is why the World Bank denominates it “the lost decade”. The country with the most strikingly low condition is Burundi with an annual GDP per capita of 228.82 US$, while the countries best positioned are Gabon, Botswana and South Africa with respectively 8.97, 8.07 and 6.43 thousand US$. The average of the region is 1.79 thousand US$, which is a strikingly low amount compared to the world average that amounts to 13.87 thousand US$ (IMF,2023). The GDP per capita is a well-established indicator for a country’s development and one of the most used. However, it is not exhaustive since it does not stipulate how evenly the wealth of a nation is divided. Indeed, Sub-Saharan Africa presents high inequality and conglomeration of wealth. Therefore, an analysis of the GINI coefficient and the poverty share of the population in the area could explain better how equal the region is. The map in *figure 13* shows how much the countries change from one another, in fact, the GINI coefficient spans between its extremes (from 0 to 1). Southern Africa is the most equal region, having the highest numbers. The coefficient gives the opportunity of better analysing the inequality in Sub-Saharan Africa. For example, Gabon has a relative higher GDP per capita but the GINI indicates a higher inequality. The conclusion is that in the country there is a strong economic disparity among the population even though it possesses more wealth compared to other Sub-Saharan nations.

Figure 13: GINI index in Sub-Saharan Africa

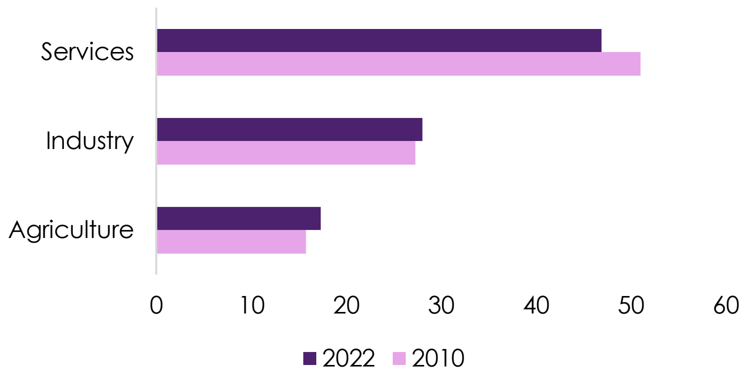


Source: United Nations Development Programme; data from World Bank (2016)

Sub-Saharan Africa by Sectors

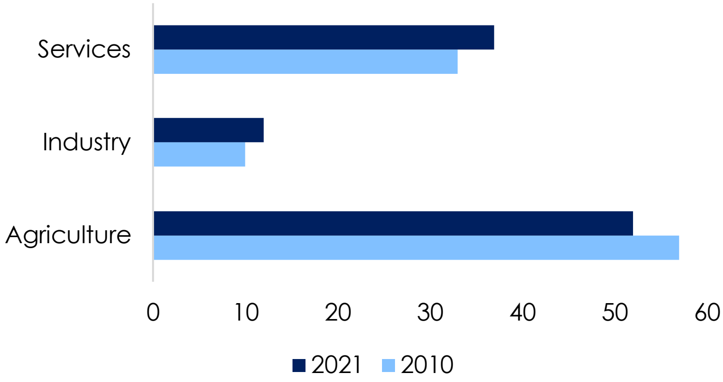
In 2022, the primary driver of Sub-Saharan Africa's economy was the services sector, making up nearly 47% of the GDP. Following closely, industries constituted the second-largest sector, contributing around 28% to the GDP. Lastly, agricultural activities accounted for over 17% of the region's economic output as presented in *figure 14* where the data is compared to the situation in 2010. (Statista, 2023). The service industry in Sub-Saharan Africa has expanded its value in recent times, the structure of the economy remains pretty stagnant compared to the previous decade. The global data expresses a clear connection between development and the expansion of the service industry. Consequently, the world average in 2021 for the share of GDP attributed to services is 63,9%. Indeed, considering the aggregates of low-income and high-income countries it is possible to notice a stark distinction, the added value attributed to services in fact is respectively 33,8% and 70% of GDP for the two groups. Additionally, the Sub-Saharan area has the lowest share compared to the rest of geographical regions of the world, confirming itself once again as the least developed of the world (World Development Indicators WB, 2022). The global shift toward innovation and technological progress contrasts with the relatively restricted industrialization in Sub-Saharan African nations. The role of governments should be to ensure that economic development is extensive and creates sufficient employment opportunities by addressing specific needs of the population (World Bank Group, 2021). When the objective is to understand household poverty, it can be relevant to inspect the employment industry and the sectors that are most responsible for the welfare of the population. The employment in services sector only 37% of the people employed, in the industry the share is only 12%, and lastly, agriculture is the sector that employs more than half of the working population by a great amount (52%). Some countries such as Burundi, Madagascar, and Malawi present an even bigger share of the workforce employed in the agricultural sector, exceeding 80%.

Figure 14: GDP by sector in SSA (in % of total GDP)



Source: Own elaboration; data from Statista (2023)

Figure 15: Employment by sector in SSA (in % of total employment)



Source: Own elaboration; data from (World Bank Open Data, 2021)

Poverty in Sub-Saharan Africa

Similar to the change in energy poverty worldwide since the 90's, the amount of people living in extreme poverty in different regions has changed in contrasting ways. In essence, while the other areas of the world that were struggling decades ago like South and East Asia and the Pacific, Sub-Saharan Africa has remained constant. Extreme absolute poverty is measured through an established threshold of daily income that supposedly allows a person to have their most basic needs satisfied and it amounts to 2,15$ for low-income countries. Thirty years ago, nearly half of the Sub-Saharan population was earning below this threshold, while in the other three areas mentioned above it was about 2/3. Regardless, the modern scenario is oppositional since people living in extreme poverty are 9% in south Asia, 1% in East Asia and the Pacific, but in Sub-Saharan Africa it reaches 35%. The Democratic Republic of Congo, Burundi, the Central African Republic, and Liberia are operating under heavy conflicts continuously since 1998, the consequence is that the extreme poverty rate average between the countries is 73%. Today, they still hold the baggage from the warfare and the rate of 58%, which doubles the ones from other countries that are currently undergoing internal conflicts (Baah & Lakner, 2023). These circumstances are so extreme only in Sub-Saharan Africa, as a matter of fact, the area is responsible for 60% of the global extreme poor. Despite the fact that in 2015 the Millennium Development Goals established the objective of reducing global extreme poverty under 3%, recent conflicts and the struggle that was experienced by Africa since the covid-19 crisis is actually inducing a growth in poverty. At the current rate the area is expected to host up to 90% of the poor worldwide (ISPI, 2023).

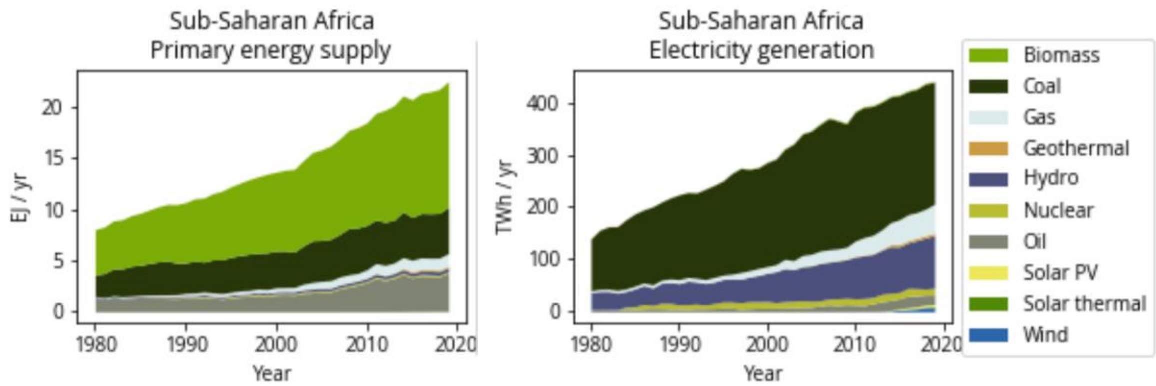
Anti-poverty policies can differ in nature from one another depending on the country in question. For instance, a big component to poverty in Sub-Saharan Africa can be related to the conflicts affecting the area, the lack of employment opportunities, education, and fostering the economic development of the country. Furthermore, with the expansion of industry and commerce, particularly in the agriculture sector, there will be an increased demand for energy (Ramalope et al., 2023). The common issue with implementing these investments is the need for energy that is necessary. Therefore, energy attainment is highly relevant to the most aggravating problems of Sub-Saharan Africa (The World Bank, 2023).

1.2.2. Energy in Sub-Saharan Africa

This paper has established that Sub-Saharan Africa has the lowest accessibility to energy globally and why his is an issue for the development of the country and, even more essentially, on the welfare of the poorest people in the world. This following section will try to understand where this problem resides by inspecting the resources available, the sources of electricity mainly utilized the region and the causes of lack of accessibility of clean energy. As acknowledged, Sub-Saharan Africa is globally the least electrified area: merely 48% have access to electricity for cooking, and only 17% uses clean energy to cook as traditional biomass continues to constitute nearly half of the primary energy mix in Sub-Saharan Africa. Even though, some minimal progress before 2020 was achieved, the rise in population growth and need for economic development force additional challenges on the already very present issue of lack of electricity access (IEA, 2022). The International Energy Agency claims that Sub-Saharan Africa would have to nearly triple its power supply by 2030 to accommodate for the energy demand, comprised of household power generation, electrification industry and increased transportation systems (IEA, 2022).

The bottom graphs show the share on energy supply and electricity generation in the area and how it changed up to 2020.

Figure 16: Primary energy supply and electricity generation by source in SSA (1980-2020)

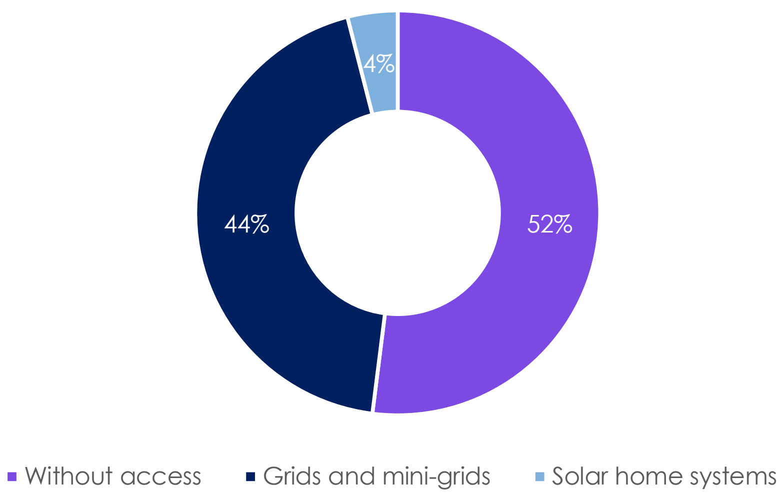


Source: Ramalope et al.; data from IEA, 2021

The majority of the energy sources in the region are derived from fossil fuels, with significant contributions from oil and coal, particularly in South Africa, along with an increasing presence of natural gas. The share of renewable energy, excluding traditional biomass, is close to 20% of total primary energy. Although they only account for a small portion (about 1%), solar, wind, and geothermal energy are becoming more and more significant. Furthermore, hydropower is the most present green electricity source and makes up for 1,7% of the total primary energy supply (IEA, 2021).

The graph in *figure 17* helps understand the distribution of electricity technologies across the population in Sub-Saharan Africa and reveals that excluding the 52% of people that lack access, 44% relies on grids, including mini-grids, and 4% utilizes solar home systems. The assessment of recent improvements is that the population with electricity access through solar home systems has increased since 2019 by approximately 25 million, reaching 45 million in 2022. This translates to 4% of African households now having electricity access through these systems. In contrast, mini-grids offer access to 2% of the sub-Saharan African population, while main grids extend access to over 40% (IEA, 2023).

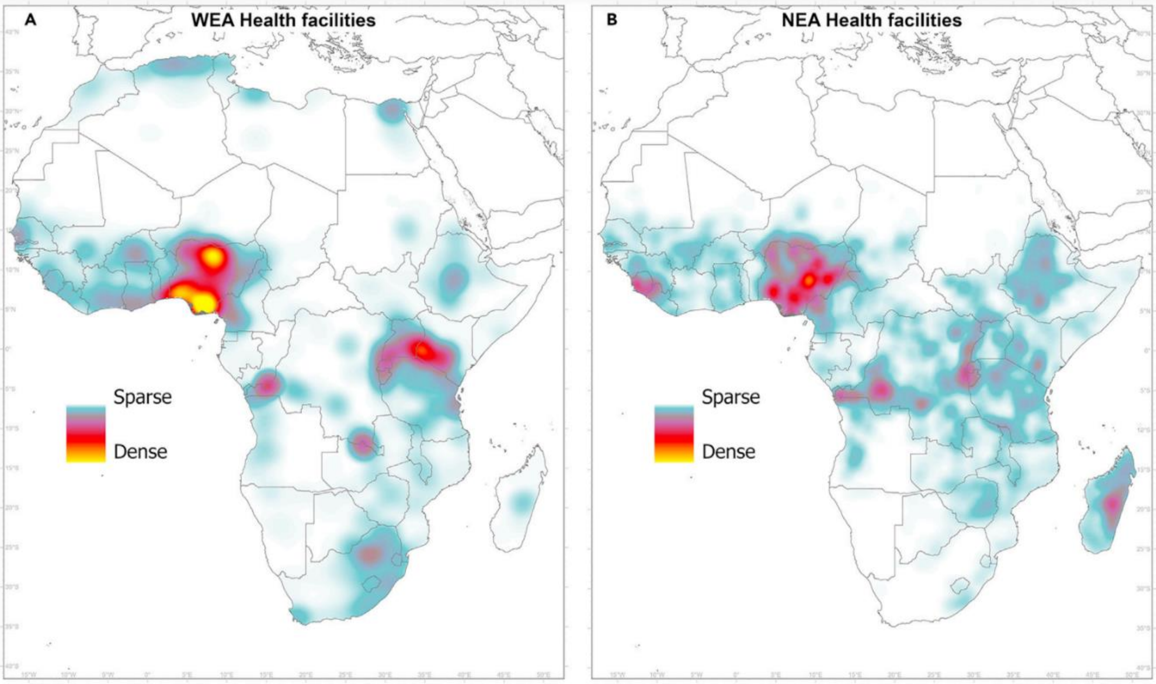
Figure 17: Population access to electricity share by technology in SSA (2022)



Source: Own elaboration; data from International Energy Agency (2023)

The issue of absence of energy extends to social infrastructures, although, in recent times governments have favoured to different extents the electrification to these facilities compared to expanding access to inhabitants. For instance, in Gambia all healthcare facilities are electrified, while in Uganda the electrification rate is about 42%. Although this data does not account for the reliability of the electric systems in the area, and it is very limited to the countries that have been subject to the studies in question. The rural areas are the ones that are least supplied areas, as presented in *figure 18*, where the total number of establishments included is 122 899. The two pictures represented are heatmaps of presence of healthcare facilities divided in the ones with detected power supply (*A*) and the ones without (*B*). Out of the total of rural health facilities, more than 56 000 (*B*) healthcare infrastructures experience electricity supply deficiency (Moner-Girona et al., 2021).

Figure 18: Healthcare facilities according to their electricity access status



Source: Moner-Girona et al. (2021)

As far as resources go, the continent hosts about 30% of the world's total natural resources but has never been able to make a good use out of them for economic development. The area withholds plenty of minerals that are needed for the production of renewable energy, and as the worldwide undergoes an increasingly strong pressure to transition to clean energy, the need for minerals creates a significant chance for African nations to stimulate economic and social progress. Indeed, governments are responsible for establishing effective national plans for the transition towards renewable energy and if handles correctly Sub-Saharan Africa could be able to provide universal electricity access in the region. The exploitation of the resources present in the area could be a great opportunity to both alleviate the energy access problem and further economic and social development (Natural Resource Governance Institute, 2023). The more present resources that could be harnessed for a cleaner energy transition in Sub-Saharan Africa comprise of solar, wind, hydro, geothermal and biomass resources. As a matter of fact, 17 African countries are among the major 35 countries that are dominant in solar, wind, hydro and geothermal resources (Longe et al., 2013). According to the Regional Economic Outlook by the International Monetary Fund, the resources are not evenly spread out threw out Sub-

Saharan Africa, entailing in heterogeneous rates for future growth. Countries that are lacking resources will benefit later on from the increased consumption that will derive from the neighbouring nations. As of right now, it is possible to observe the beginning of the process in the area since there are a few upcoming national projects, hydrocarbon implementation in Niger and Senegal and mining projects that are getting underway in the Democratic Republic of the Congo, Liberia, Mali, Sierra Leone (IMF, 2023). When discussing mining in lower income countries it is impossible to deny the apparent mistreatment of workers that occurs in the extraction process of materials such as cobalt and copper. People living the areas of mining interest are forcedly displaced and the workers are subject to various human rights violation including sexual harassment (Jazeera, 2023).

The outlook for the future offers a positive perspective due to the resources available and the recent growth experienced in power generation. Nonetheless, the increment of solar panel production is a very small improvement, but it is promising. Additionally, some modern technologies have been appearing the area, namely solar lanterns and multi-light systems. These compact off-grid solar photovoltaic systems represent the beginning of a new era for the attainment of electricity services for essential needs. Although they still fall below the International Energy Agency's threshold for defining electricity access, these electricity generation methods have heled a big percentage (around 18%) of the population that is energy poor to improve their starting conditions. Additionally, solar lanterns, multi-light systems, and solar home systems have another fundamental purpose of substitution in areas where there are weak grid conditions resulting in frequent load shedding. The consequence is a reduction of reliance on petrol and diesel generators that can even be substantial, as in some countries like Nigeria, backup usage can account for up to 70% of sales (IAE, 2023). Although eradicating energy poverty can be considered a long process, the opportunities are present; if it is possible to acquire funds to finance effective national policies, there are many possibilities for Sub-Saharan countries to highly increase the welfare of the population and, as a consequence, the economic development.

1.3. ENERGY POVERTY ALLEVIATION

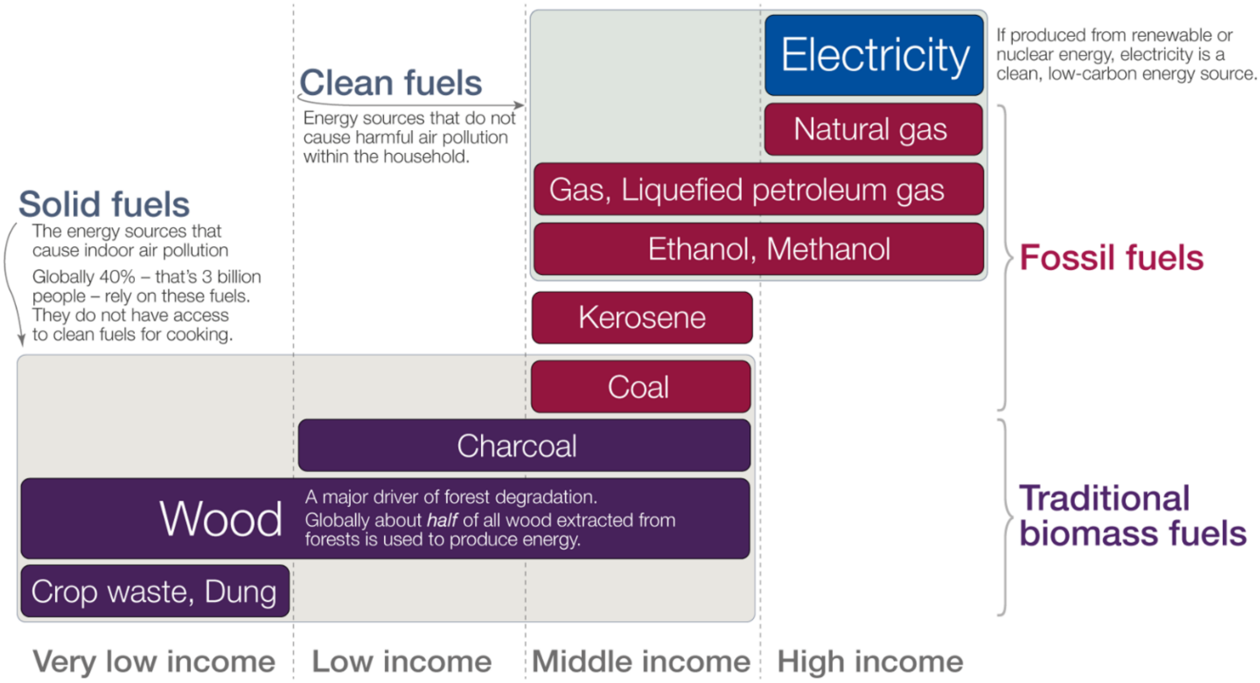
The following chapter discusses the factors that contribute to the energy situation, specifically in Sub-Saharan Africa, and then explains the theories on how these issues could be resolved in order to have a framework to better examine the projects of the case studies.

Although South Africa is geographically located in Sub-Saharan Africa and therefore it will be present in aggregates of data of the region, it will not be included in the analysis of this paper. As, especially from an energetic perspective, South Africa really differentiates itself from the rest of the nations in the Sub-Saharan area. Concretely, South Africa is able to generate 26% of the energy of the continent. Northern Africa holds the energy capacity for 45% of the total, while the remaining 29% is attributable to all the other countries in Sub-Saharan Africa (UNCTAD, 2023). This does not dismiss the presence of energy-poor individuals in the country, however, the causes, and therefore the solutions that have to be implemented, are very different due to political and economic reasons.

1.3.1. Energy Poverty Causes

The factors that lead a family towards energy poverty are various and depend on the location of the area analysed. The general rule is that the causes can be grouped into three main reasons: high energy prices, low household income and energy inefficiency. Additionally, for Sub-Saharan Africa, the inefficiency of energy infrastructure systems has to be taken into consideration. As, explored in the chapter regarding the economy of Sub-Saharan Africa, the people living in extreme poverty represent the majority of the population and it is not an abnormality, which is partly the explanation for why they cannot achieve clean energy (European Parliament, 2017). In *Figure 19,* the "*energy ladder*" explains what is the principal source of energy that can be afforded by a family according to the income level. The poorest individuals use wood and various biomass, including agricultural residue and dried animal waste. The ones that have a little bit more economic flexibility, opt for charcoal or coal for cooking and heating. The financially secure of the world usually cook with gas and the rest of household tasks are powered by electricity. The division between the solid fuels and clean fuels is fundamental since the difference between them is the incredibly damaging effects that solid fuels have on the health when adopted as an energy source. As demonstrated previously, the amount of people relying only on the traditional biomass fuels in Sub-Saharan Africa amounts to more than half of the total population. It is apparent that there is a strong link between the sources exploited and financial capability, in fact, access to clean energy increases the more the household income expands, even within the same country (Roser, 2021).

Figure 19: The dominant energy source for households by income level



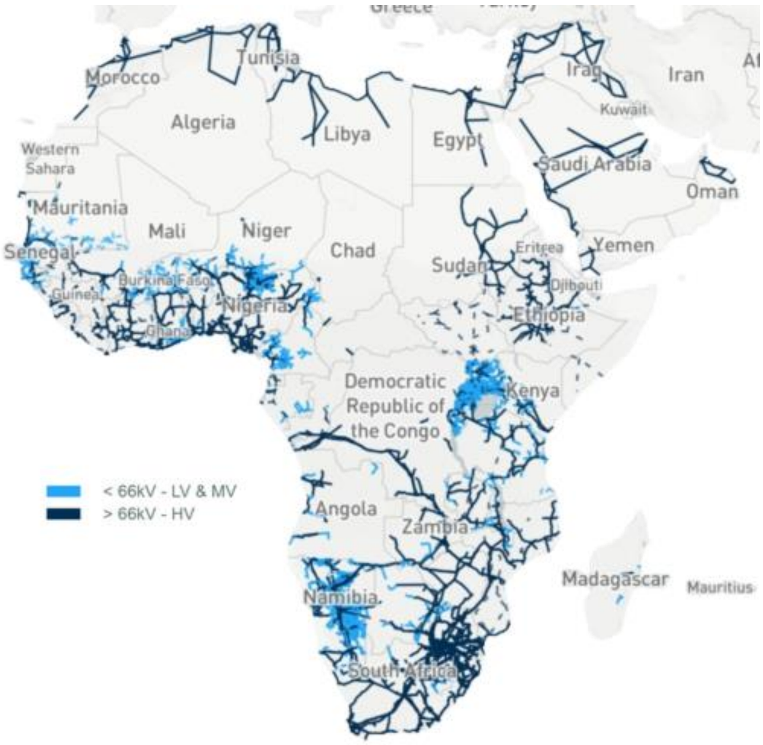
Source: OurworldinData.org (Roser, 2022); Data from WHO

The Covid-19 pandemic and the current global wars have been the reasoning for the price increase of electricity and therefore, the affordability of clean energy has become a relevant issue more and more. The combination of higher prices that are set globally and therefore according to standard of high-income countries and the excessive omnipresence of severe poverty in the Sub-Saharan Africa make it impossible for the poorest people of the world to escape the vicious cycle of poverty (Banerjee et al., 2021), According to Statista (2022), Cape Verde has the highest household electricity prices. In 2022, a kilowatt hour cost roughly 0.32 US$. Close behind, with families paying 0.22 US$ per kilowatt-hour, were Rwanda and Mali. Additionally, Burkina Faso and Gabon have the highest documented electricity prices. Ethiopia, Libya, and Zimbabwe had the lowest electricity prices out of the nations in the Sub-Saharan Area.

Another problem that comes with the energy consumption is the energy inefficiency. It is an important topic when discussing the affordability of energy and the sustainability aspect. According to the IEA (2022), by incrementing energy production only by 30%, the exploitation of a clean energy mixture has the potential to sustain an economy that is twice the current size, and it would be possible to achieve universal access while simultaneously cutting down emissions produced. Older technologies tend to consume more while achieving the same function, therefore, it is less common that households with lower disposable income could swap their equipment for newer counterparts which entails that people who have less money are forced to keep inefficient technologies that make them consume more and therefore are less cost efficient. The same mechanism can be applied for energy infrastructure, the decay of old system has a direct consequence on the effectiveness and therefore price of energy and lower income countries have less possibilities to update them (Shabalov et al., 2021).

Infrastructure systems are another massive component of the energy accessibility especially for lower-bottom income countries. The potential that the African continent has for the development of renewables is auspicious, however, resources are not evenly placed and require adequate infrastructure that can reach every deserted area so that it can open up the possibility for everyone to have access to electricity (La Camera & Bekele-Thomas, 2023). The bottom map presents the estimation of the current electricity grid in Africa, it is clear that South Africa is the most connected, while come countries in Central Africa are almost completely lacking. Moreover, the dotted lines represent planned infrastructure and therefore are not functional at the moment (The world Bank group, 2024).

Figure 20: Electricity grids in Africa



Source: Africa Electricity Grids Explorer (The World Bank Group, 2024)

The infrastructure issue is especially relevant in Africa since it is the least urbanized area of the world. In 2023 the worldwide urbanization level was 57%, which means that more than half of the population lives in cities. in Africa, only 45% of inhabitants are located in urban areas, making the definition of what an urban settlement is can different based on the area in the world, thus it is hard to compare them. Anyhow, there are some common characteristics about life in cities such as the heightened connectivity compared to people living in more rural environments, which also includes more accessibility to energy sources (Statista, 2024). Considering that majority of population in Sub-Saharan Africa equal to 58% in 2022 lives in rural areas (MacroTrends, 2024), inadequate energy infrastructure impedes access to electricity. Moreover, even in the presence of electric grids, the power shouts down frequently, making the coverage of the area less reliable. The World Bank developed a reliability index that can tell the quality of the electricity service if present to better ensure the accessibility of energy (Corfee-Morlot, 2019).

1.3.2. Improving Electricity Access

According to scholars, the three main directions governments should take in order to lower energy poverty are energy poverty reduction policies, encouraging development of renewable energy and increasing awareness. Lowering the rate of energy poverty can be fully done through utilizing the inclusion of green development. The government should actively encourage the growth of the new energy sector and supply household with renewable energy sources, thus improving the accessibility to electricity while also facilitating the shift to a carbon-free environment. Energy poverty in developing nations can be alleviated by technological, economic, and cultural factors, with kitchen equipment upgrades being the most successful (Sesan, 2012). The objective of focusing on awareness is to teach the population how to better use energy avoiding excess waste, however, the efficiency issue in extremely poor contexts is more connected with malfunctioning infrastructure and therefore is less relevant to the area discussed in this thesis. However, according to Chapman et al. (2019), low-income households have a lower awareness of environmental pollution and how it affects their own health. Therefore, government agencies should improve their communication with individuals' desire for a renewable transition, because having a population that cooperates with the objectives of governance can better impact the clean energy development (Lin et al., 2023). The research on household energy poverty governance primarily provides recommendations for these three areas, although it avoids discussing important factors. The literature mentions that the government should formulate relevant policies to increase investment in the construction of energy infrastructure in rural areas. However, Policies design must take the region's features into account and the implementation must be feasible. The long-term sustainability of policy implementation and strategies is often lacking in the literature. (Lin et al., 2023).

When looking specifically at Sub-Saharan Africa, the two biggest problems to tackle are the subpar infrastructure that prevents energy access and the inability for households to economically afford it. Governments should rapidly revamp the electricity sector and expand the infrastructure and distribution (Han Phoumina et al.,2019). Although, extending the electric grid may seem like the obvious solution for the accessibility issue, it is not always feasible because of geographical reasons, additionally, the Sub-Saharan area of interest is so wide that the implementation would be a massive economic investment. Consequently, it could be more effective to implement an off-grid approach. Rooftop solar panels, small-scale solar farms, and mini-grids powered by biogas or hydropower are the preferred options for the area. There are, in fact, recent projects that are being implemented in Kenya and Nigeria and new initiatives are always being implemented. Nonetheless, enforcing off-grid renewable energy cannot be the solution everywhere: the malfunctioning electricity system is clearly not the only issue since every poverty is a common struggle even within urban settings where electric grids are more developed (Perch Energy, 2023). Moreover, households should not be the only objective of policies since, as previously explained, the low-income individuals experience damaging diseases due to the internal pollution, but hospitals are not equipped to cure them. On top of this, educational facilities lacking electricity are also detrimental to the populations' economic and psychological wellbeing. Hence, governments should have the objective of expanding accessibility to households but also providing better welfare (Lin et al., 2023).

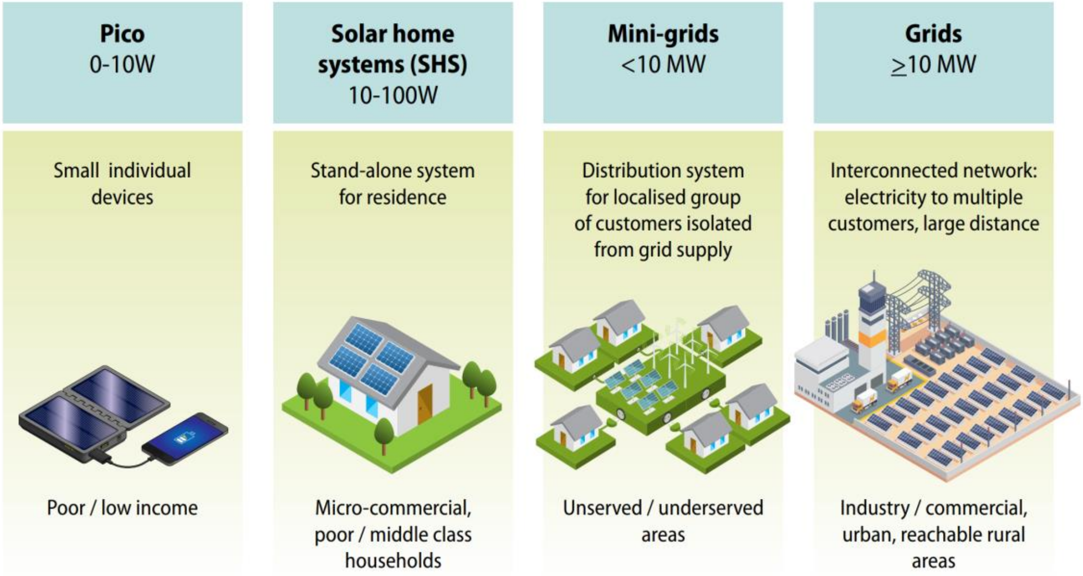
This paper wants to analyse how renewables energy implementation can have an effect on energy poverty. As a matter of fact, investing in fossil fuels might be damaging for Sub-Saharan countries at this point in history. Even if consumption of fossil fuels is still pretty high and it might seem a good investment both for domestic consumption and possibility of increasing exports, the global consensus is the decarbonisation direction. As a consequence, the demand for coal and gas will inevitably slow down, which entails that the industry will not be as remunerative as it may appear (Ramalope et al, 2022). On the other hand, the solar and hydro markets are developing just now, which gives Sub-Saharan nations a way to utilize its resources in order to specialize in these industries (Ember, 2023).

Infrastructure Improvement

Although national electric grid will remain a crucial component of energy access solutions, technology advancements for renewables actually present the biggest opportunity for eradicating energy poverty since they are a faster way of connecting the people. There are numerous renewable technologies and emerging markets that could be eligible for development, and they are often the options that can reach people more quickly and more precisely than grid expansion alone. These alternatives can eliminate long-distance transmission expenses and provide access at a lower cost than diesel generators for local use. Even if their cost per kWh is frequently higher compared to the grid connections, they necessitate a lower capital for initial investments, moreover, they eliminate the transportation costs that present with a centralized arrangement and the general costs are lower compared to the implementation of traditional diesel sources. The benefits are the quick enabling, reduced local pollution from fossil fuels use and increased supply reliability. It could be particularly effective to implement such off-grid solutions considering the quantity of people that live in rural areas in Sub-Saharan Africa (Corfee-Morlot et al., 2019). Therefore, solar energy could be the best suited first solution that might alleviate energy poverty in a faster timeframe, in addition, it is a prevalent resource in the region. Solar and wind technologies have seen great advancements in recent years, which managed to make the products less expensive and consequently reach various people in East Africa and are passing over to West Africa as well (World Bank 2018).

In terms of type of technologies, the literature suggests that the best approach for power supply is the "*Lego design*", which is structured around the idea of having multiple solutions at the same time, each suiting its different end consumers (Corfee-Morlot et al., 2019). *Figure 21* shows a recap of the ideal type of electrical grid systems that could be implemented in Sub-Saharan Africa and its final purpose.

Figure 21: Technology options for expanding renewable energy access by target



Source: Corfee-Morlot et al., 2019

First off, Pico devices are tiny solar-powered gadgets with one light and/or one charging connector that offer minimal access to electricity. They were first funded by governments, charities, or impact investors while today they operate commercially, where they are sold at market prices. The gadgets play a vital role for allowing the extremely poor the ability to receive basic power services. They have grown significantly since 2010, especially in Sub-Saharan Africa where sales have reached 4 million units in a year (GOGLA, 2022). Pico systems are mainly utilized to power lights, small appliances, and occasionally TVs and refrigerators. Solar home systems (SHS) can instead power from 10 to 100W allowing them to supply electricity for lights, fans and bigger equipment. They come with batteries, charge controllers, and solar panels and are mode adapt to poor and middle class families. Pico and Solar Home Systems are the two off-grid systems that could be expanded to more households to achieve electricity access even in rural areas, where most of the poor population of Sub-Saharan is located. Demand for these types of decentralized systems is increasing, in particular for larger ones. At the moment SHS cannot handle supplying large quantities of energy, although future advancements could change this. This process could result in a change of customers from poor and middle class to richer families, hence the need of public investment for rural household that could not afford off grid electric systems otherwise (Corfee-Morlot et al., 2019).

For larger demand of energy, in more urban areas, conglomerates of households and commercial environments the best option is the installation of grids or grids. While the off grid systems can only be powered through solar energy, these larger systems can operate thanks to solar and hydropower. Mini grids have a lower electricity capacity, but their benefit is that they can still be somewhat decentralized especially if they are solar powered (Corfee-Morlot et al., 2019). According to a 2021 report by the EU Agency for the Cooperation of Energy Regulators (ACER), to diminish initial costs and consumption of materials for the creation of electric grids, it could be more efficient to convert the current gas infrastructure to function for hydrogen. The salt caverns and pipelines are appropriate for the change. Some additional variations need to be made and require time and money, however, it should be less expensive that construction entirely new services. Nonetheless, the restoring old gas infrastructure in Sub-Saharan Africa is less feasible, therefore, the majority of the projects implemented should focus more on off-grid powering systems (IAE, 2022). Usually, Pico and Solar Home Panels are sold to private consumers which indicate that they are installed only people that can afford it. There is a strong need for public financing of these electricity sources that should be local as well as international. The International Energy Agency claims that Sub-Saharan Africa require about 27 million US$ yearly to reach full accessibility by 2030, which is servery under the current level of endowments currently given to the region (IAE, 2018). It highly necessary to redirect subsidies that are now upheld for fossil fuels production towards green energy generation, considering the capital amounts invested in the traditional energy sources are around the funding needed for universal access (Corfee-Morlot et al., 2019). Said subsidies could be employed to ensure that the private sector advances power infrastructure and subsequently enables rural and underprivileged communities to gain health benefits that come with electricity access (Lee & Yuan, 2024).

Although allowing households to have access to clean energy solves the health problems brought about by indoor pollution, yet the extent of the impact of electrification on health is not limited to it. As explained in the paragraph above regarding health consequences, shortage of electricity in public services such as hospitals and education facilities has a considerable impact of the well-being of individuals in Sub-Saharan Africa. The objective of domestic governments should not imitate to household power accessibility but focus on the public establishments as well. Despite the fact that healthcare has a higher power supply compared to inhabited buildings, the rural areas struggle even from this standpoint. Distance from hospitals is a big component of the impact on health as well as electricity deficit of faculties. The two options for people living in rural areas is to have healthcare faculties nearby that lack electricity or having them far away (Moner-Girona et al., 2021).

Although, the literature is not in entirely agreement that implementing renewable energy would be the best approach, there are some opposing opinions. For example, Zhao et al. (2022)

claim that although, in general, there is an existing correlation between the implementation of green energy and energy poverty mitigation, the relevancy is very much regional dependent. The authors postulate that incrementing the production of renewable energy can only greatly reduce energy poverty in European countries.

Energy Price Regulation

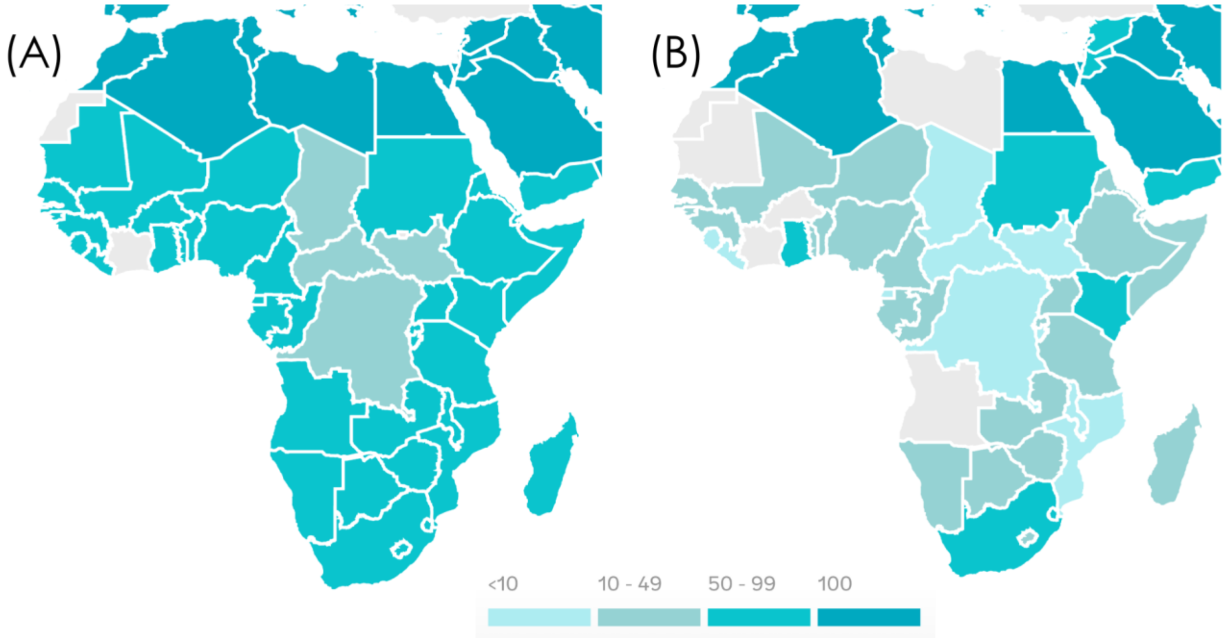
The factors that impact the cost of electricity in a specific location at a particular time are numerous. The mechanism for which energy prices are based is market dynamics: the price is mainly set by the assessment the market makes on the supply and demand for each source in that specific moment. The equilibrium price decided by the market is the wholesale price that is thereafter bought by energy wholesalers and distributed to retailers and end consumers at a higher price that includes the distribution and transportation costs. Usually, wholesale electricity prices are established using one of two methods: bilateral transactions that are market-based or centralized auctions. Centralized auctions are events organized by regional entities like Independent System Operators (ISOs) or Power Exchanges (PXs) where energy suppliers sell or bid to wholesalers for future time periods, usually a day-ahead (Mousavi, 2021). Prices are affected by the fluctuation of demand and supply that could be caused by availability that cannot satisfy the demand or weather collateral damages brought to infrastructure caused by weather conditions such as extreme temperatures and adverse weather. In these cases, both power outbreaks and permanent issues that need additional resources to be fixed can result in electricity price increase. Delays in obtaining replacement parts essential equipment can impede the operational efficiency of power plants affecting the supply capacity. Underperforming grid infrastructure and distribution has the consequence of affecting prices as well, this is particularly relevant in Sub-Saharan Africa. Additionally, geopolitical factors are a big component of price fluctuations, events like health crises, wars, or border conflicts can disrupt power generation and distribution on an international scale, creating uncertainties in the energy market and affecting prices (EIA, 2023). The factors influencing electricity prices are so complex and multifaceted that the way to counteract these externalities is to have a strong and flexible system and reactive governments that mitigate the arise in prices by enforcing regulatory policies.

The first implementation that could have a lessening effect on the price of energy would be to increase the supply. This means that by implementing and financing projects that expand electric grids and offering reliable sources, African governments would be able to start the process of lowering the energy prices. Following, the governments should promote diversification across electricity resources. In particular, drifting away from usage of fossil fuels and investing in renewable energy has a direct effect of price decrease. Additionally, energy from solar and wind could be produced on Sub-Saharan soil which entail strikingly lower costs of transportation. Pricing policies can be useful approaches towards making energy more affordable for the poorest individuals. If governments factor the consumer capacity to pay, they could set a network of subsidies to provide to low-income households or put in place a progressive pricing system that charges higher price to higher incomes families and lower rates to the poorer counterparts. Finally, even if it does not have unambiguous effects, people could benefit from a more transparent energy sector. Governments should enhance regulations that control the price setting and production and distribution processes. By doing this, it may be possible to guarantee that business runs well and that costs stay reasonable for all customers (Omata, 2023).

Urbanization Enhancing

In the study by Lee & Yuan (2024), the objective of the analysis is the connection between presence of affordable energy and urbanization levels. The results show that, while this effect is noticeably smaller in other locations, affordable energy under the influence of urbanization offers a new avenue for improving public health especially in Sub-Saharan Africa. According to the authors, a nation's degree of urbanization is the primary determinant of how energy poverty affects public health in that nation. Hence the strong recommendation for governments of Sub-Saharan countries to emphasize urban development by improving transportation, infrastructure systems, expand employment possibilities and efficiently manage the space available in order to create a welcoming environment for the expansions of sustainable cities to entice population from rural spaces to move to urban areas that can provide for more electricity and consequently advance public health. The maps in *figure 22* display the difference in share of the population that has access electricity as of 2021 between the urban and the rural areas of countries in Africa.

Figure 22: Electricity access rate in urban (A) and rural (B) areas in 2021 (% of population)

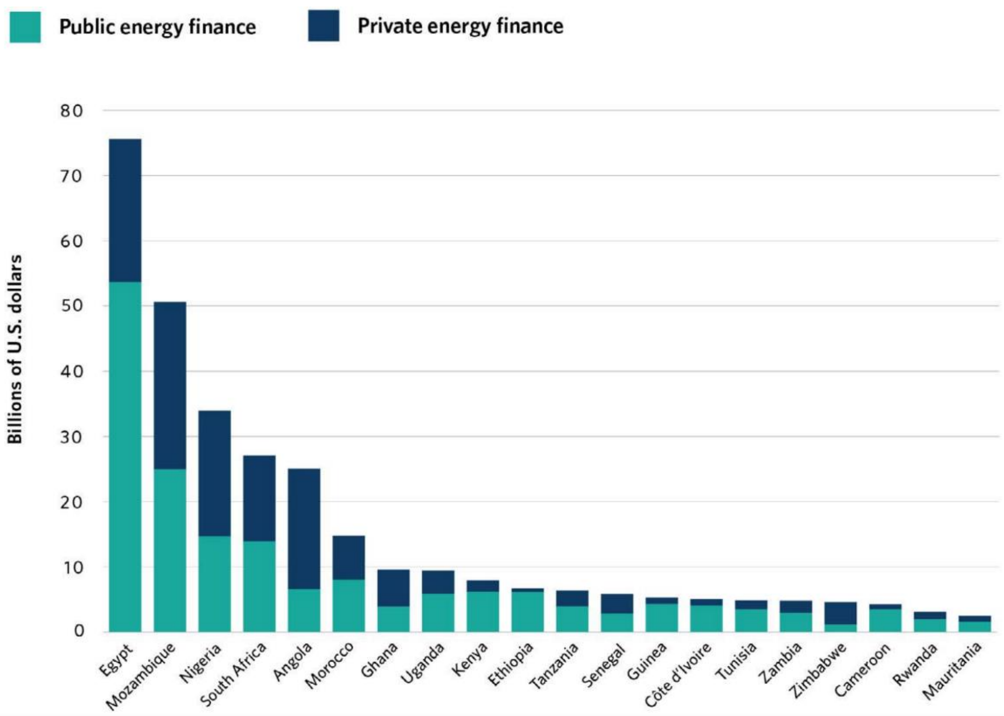


Source: The Energy Progress Report (World Bank, 2023)

1.3.3. Financing and Governance

As the electrification projects necessitate large amounts of capital, and because the downturn in the economy has left government budgets tight, and in many nations in Sub-Saharan Africa, public investment is hindered by the public debt levels, the emerging countries need to find other ways to allocate capital for the electrification of the energy poor households and investments in the upcoming markets (Egli et al., 2023). This paragraph will discuss the role of governance in the allocation of capital in the energy market. Governance encompasses the various processes or institutions through which individuals establish and facilitate the necessary rules to achieve desired results. When discussing governance in this paragraph the objective till be to include all stakeholders involved in decision-making processes that influence Sub-Saharan Africa, understanding the role of financial, political and technological governance (Gregory & Sovacool, 2019). Local governments should work towards encouraging private investment and enable more effective public investment, which entails the importance of reforming domestic policies. It will take enormous political efforts on the part of both local players and the international community to mobilize the necessary investment and scale up domestic capabilities to manage these changes. Enhanced planning and cooperation within the nation will also be necessary to redirect existing public and private resources towards the newer technologies (Corfee-Morlot et al., 2019). From 2012 to 2021, the capital amount invested by private entities in Africa amounted to 148 billion US$ while the public energy finance was around 197 billion US$ although majority of these investments combined were devoted to fossil fuels and gas, in fact, only 11% was geared towards solar energy and only 7% to hydropower. Additionally, the peak of investments Africa received was in 2015 after the financial crisis and the monetary resources implemented in 2021 were so low that it amounted to be the years where less money was almost half the budget of 2020. *Figure 23* shows the distribution on public and private investments received in the 10 years' periods across different countries in Africa. Nonetheless, a big chunk of the finances is devoted to Egypt while Mozambique, Nigeria, South Africa and Angola also receive some resources. Meaning that the countries that are the most well-equipped are the ones receiving the funds, Northern Africa received 29% of total finances, and a lot of countries in Sub-Saharan Africa that present a high degree of energy poverty are not considered. As a matter of fact, 10 African countries receive 77% of the total resources. (Moses, 2023).

Figure 23: Top countries that receive energy finance in Africa (2012-2021)

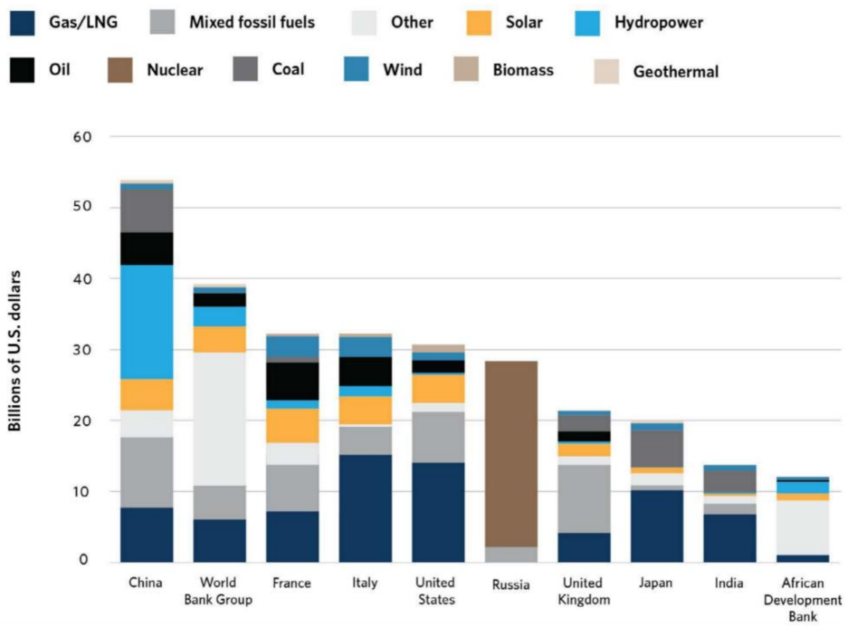


Source: Moses (2023); data from Public Finance for Energy, fDi Markets', and Dealigic's M&A databases

It has been made extremely clear that the private sector is not enthusiast about investing in Sub-Saharan Africa. Usually, the discussion around the lack of investments is mistakenly explained by the corruption present in the area. Although it is a valid argument, it cannot be the sole cause because throughout history private investment has still flourished in other regions of the world that denoted similar behaviours (Gregory & Sovacool, 2019). The various determinants that stray away investment from Sub-Saharan Africa can be allocated to the three governance dimensions. First of all, countries of the region often possess insufficient local banking capabilities and due to the low level of liquidity of the African coins and strict exchange regulations, there are many difficulties in revering the capital invested and the earnings into the original currency. Additionally, electricity tariffs often do not reflect the true cost of investment due to local policies and investors are not protected because of the low protection from theft from local legal entities. A variety of problems arise the investment period such as uncertain security of physical assets, revenue security, unearned equity dilution, attempt to appropriate excess value from an investment by unrelated recipients, corruption by officials, patrimonialism, and unexpected reallocation of project ownership. Furthermore, regarding technical problems, the government and monopolistic electricity industries are very resistant to change causing them to be stuck in outdated energy sources due to personal interests, lack of working capital, knowledge and complementary assets needed to sustain, run, and maintain the technology system at optimal levels. The above mentioned concerns are the main causes of a complex and uncertain private investment environment. Thus, governments in Sub-Saharan Africa need to construct a new regulatory framework in order to address these systemic issues by minimizing the uncertainty that investors go through and creating a promising environment. Lastly, governments should give up the monopoly control they have over the energy market since decentralizing the delivery of electricity services would be highly beneficial, permitting for greater flexibility in the adoption of new technologies, and facilitating access to electricity the rural areas where minimizing costs and maximizing flexibility are crucial (Gregory & Sovacool, 2019).

Regarding public investments, China is the institution that sponsors publicly the most, also being the one that invests more than another in hydropower, followed by the World Bank Group as seen in *Figure 24* (Moses, 2023).

Figure 24: Top providers of public energy finance to Africa by energy source (2012-2021)



Source: Moses (2023); data from Public Finance for Energy, fDi Markets', and Dealigic's M&A databases

The World Bank Group is a financial institution that declares its mission to be "*reducing poverty, increasing shared prosperity, and promoting sustainable development*" (World Bank Group, 2024). It possible to understand its clear influence that it can have on energy poverty and the green transition, considering that the institution explicitly considers sustainability one of its core values. However, it has been extensively criticized because of its reoccurring decisions to invest in fossil fuels, contrasting with its objective of implementing low-carbon solutions for providing energy (Harvey, 2023).

2. METHODOLOGY

Energy constitutes a fundamental element that profoundly influences the quality of life of individuals and affects the economic development of cities and industries, facilitating their capacity to thrive and engage in productive activities. Addressing energy poverty is an inherently complex challenge, facing further difficulties when confronted within one of the most economically disadvantaged regions globally. The analysis of the literature review brings up several variables that come into play in the Sub-Saharan Africa's scenario, with the most influential factors including inadequate or nonexistent infrastructure, affordability concerns exacerbated by the rising energy prices, and the impact of climate change. Notably, approximately three-quarters of global greenhouse gas emissions are the direct consequence of the unsustainable materials utilized in energy production, particularly prevalent in these impoverished areas (World Economic Forum, 2022).

Solving this issue transcends its economic implications: governments' failure to provide clean energy to these communities causes social instability and severe health consequences. For this reason, the study seeks to bridge existing gaps in understanding how to provide the SSA's household with clean energy, merely depending on renewable energy or improving the existent infrastructure and dealing with the affordability and health concerns of the communities. Although the literature review emphasizes the impact of using traditional fuels for lighting and cooking in poor families. This thesis will focus specifically on the issues that can be solved through electrification of households. Bad cooking equipment is also part of the issue at large but will not be included in the solutions proposed since this thesis focus on the delivery of electricity services to households.

The following case studies will be used to understand the effectiveness of methods that have been implemented in the last decade specifically choosing the ones that were implementing more sustainable practices: either by installing mini-grids or off-grids renewable energy systems or upgrading the current malfunctioning infrastructure.

2.1. Data Collection and Analysis

With the aim of comprehending the origins and various dimensions of energy poverty, the research begins with an exhaustive analysis of pertinent literature. Firstly, the thesis offers a comprehensive analysis of the literature aiming at understanding the definition around energy poverty, how the diverse methodologies of measuring it can have implications on our perception of the phenomenon, and underlines the need for an intervention in the energy market to mitigate its negative impact on the environment, emphasizing the need for a switch to renewable and sustainable solutions. The materials from the literature review come from a thorough research comprehending published academic papers, annual reports and sites of global energy institutions and datasets.

Subsequently, valuable information and insights were drawn from official sites of international organizations such as The World Bank, the African Development Bank Group, WWF, Global Green Growth Institute, the United Nations Sustainable Development and from sites of governmental entities in Sub-Saharan nations, mostly taking into examination official reports of physical projects, to effectively conduct a qualitative and quantitative analysis on the economic and energy landscape in the area of interest. The results discussed are gained from a comparative analysis of four different case studies, each showing empirical projects in Sub-Saharan Africa with the aim of facilitating energy accessibility through the adoption of renewable energy solutions. The comparative analysis has the aim of understanding the best approach to gain more sustainable and impactful results.

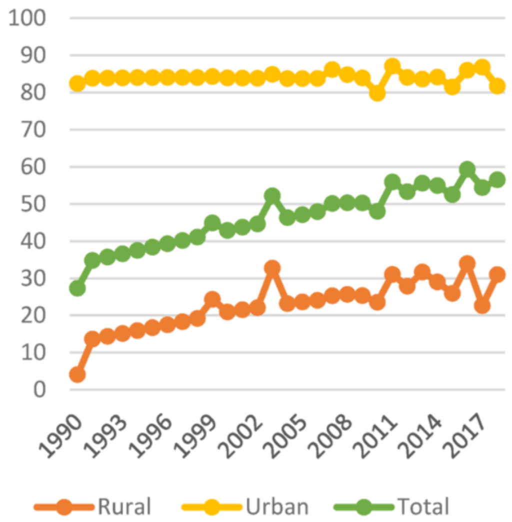
As a lead to the discussion chapter, the author concludes the thesis by comparing the case studies examined to each other and to the suggestions made by the literature, followed by a discussion structured around the lessons learned from the case study analysis accompanied by a policy proposal offering a comprehensive framework highlighting five main areas of actions that should be accommodated in the design of future electrification projects in Sub-Saharan Africa and some additional considerations. The case studies were intentionally chosen to incorporate countries from the different regions within Sub-Saharan Africa, although way less projects are being implemented in Central Africa. Three of the four case studies are larger programs enacted by the local energy authorities namely the Nigeria Electrification Project (NEP), Last Mile Connectivity Program (LMCP) in Kenya and the Scaling up Energy Access Project Phase II in Rwanda. Additionally, the thesis takes into consideration a smaller initiative by the no-profit Barefoot College that has been practicing in numerous nations in South-East Asia and Sub-Saharan Africa. The countries that took part in the project of the Indian College that are recapped in this thesis are Madagascar, Burkina Faso and Ghana. Although the project is structured on a small scale and electrifying just single villages it is taken into consideration due to the original perspective it can bring.

3. CASE STUDIES

3.1. NIGERIA ELECTRIFICATION PROJECT (NEP)

Nigeria is the most populated country of the African continent and the sixth most populous worldwide (Statista, 2024), which entails that the country presents one of the lowest net electricity generation per capita rates worldwide (Nweke-Eze, 2022). In 2017, the renewable energy share was of 16.1%, while the non-renewables were 83% of total energy provided in the country, composed predominantly by fossil fuels. Majority of the renewable energy created utilized hydropower (15,98%), followed by solar (0,2%), wind (0,02) and bioenergy (0,08). The generation renewable electricity other than hydrogen sources is pretty recent since it started around 2014. The electricity accessibility rate has been increasing, although it is extremely unequal between urban and rural areas as exhibited in *figure 25*. In 2018 56,7% of the total population was electrified, 81,7% of those located in cities while only 31% of rural inhabitants had access to electricity services. Before the project started majority of the infrastructure was made up of central electric grids. Some off-grids structures were already present in more rural areas (Olanrele & Fuinhas, 2022).

Figure 25: Renewable electricity generation and electricity access in Nigeria (in %)

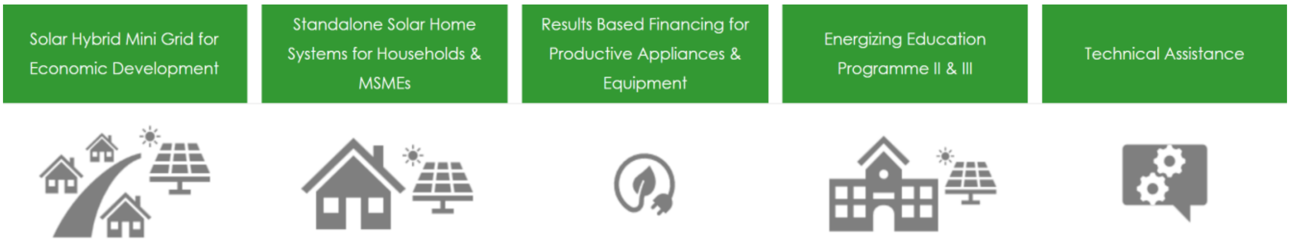


Source: Olanrele & Fuinhas, (2022); data from The World Bank (2019)

As the rest of Sub-Saharan Africa, the desired green transition has been slow because of the uninviting investment environment. Nonetheless, the government has enforced some regulations with the intent of creating incentives, for example, the feed-in tariff and zero import duty for renewable gadgets presented in the Energy and Energy Efficiency Policy of 2015. None of these incentives were successful. While government and public-private partnerships offer financial incentives such as tax waivers for renewable energy projects, independent initiatives are typically not eligible for these benefits (Olanrele & Fuinhas, 2022). The Electric Power Sector Reform Act launched in 2006 established the Nigerian Rural Electrification Agency (REA). The organization's goal is to enable the nation's rural and semi-urban areas to have access to reasonably priced power for social, commercial, industrial, and residential uses through programs like the Nigerian Electrification Project (Nweke-Eze, 2022).

The Nigeria Electrification Project is a federal government design appointed in 2019 that emphasizes involvement and participation from private sector entities in its implementation and operation and has the objective of implementing off-grid renewable solutions to electrify households, small and medium enterprises, healthcare establishments and educational facilities. It operates rural areas that has no access to electric services or little to none by providing mini grids, Solar Home Systems (SHS). The project is financed by the World Bank and the African Development Bank (AfDB), respectively contributing b 350 and 200 million US$, collaborating with other partners. Ideally, the success of operations of the plan should attract investors that could add a supplementary amount of capital (about 660 million US$). The objective of the initiative is to deliver sustainable and clean energy sources to 250.000 small and medium commercial activities and 1 million residential units. As of 2022, the program achieved the installation of 250 solar mini-grids, 24,000 photovoltaic panels (SHS), mini-grids in 15 national universities (Nweke-Eze, 2022). The result of these practices were that an additional 3.800.000 individuals, 681,563 households, 4,795 MSMEs are now powered by clean energy. Moreover, in the medical field 3 hospitals, 14 treatment centres and 400 primary health centres are receiving electrification The project is constructed into five main components lifted in *figure 26* that are subsequently divided in sub-components (Rural Electrification Agency, 2024).

Figure 26: Nigeria Electrification Project components



Source: Rural Electrification Agency (2024)

Solar Hybrid Mini-grids for Economic Development

Mini solar hybrid grids are panels that combine renewable sources of renewable energy, usually adding wind electricity to the photovoltaic one. The aim is to let the private sector expand in neglected areas with significant potential for economic development. The ways the Nigerian government designed to achieve is through the enactment of four initiatives.

The first two options are Minimum Subsidy Tenders (MST) one in collaboration with the World Bank and the second with the African Development Bank. Both of them will undergo two phases each, out of which only the first step of either project has presented clear plan of actions. The MST in collaboration with the World Bank focuses on communities that were pre-selected by the Nigerian Rural Electrification Agency because of the economic possibilities they present. Where eligible private entities will be able to construct, own, and manage solar hybrid mini grids. The WB has chosen 163 locations so far that were based in various different regions of the country, namely Abia, Anambra, Bauchi, Cross River, Kano, Niger, Ondo, Ogun, Plateau and Sokoto. In the case for he AfDB, the first phase of the MST involves 99 sites in the Kwara, Oyo and Nasarawa states. Although the areas of interest were selected by the REA, the specific companies that received the subsidy has to undergo a selection process where they should come up with a technical proposal themselves, present the customers they will supply and submit an estimation of the subsidy amount they would need to fulfil the energy demand. The firms appointed will receive the grant amount appointed in the selection stage and use it to assemble the mini-grid structures and connect their clients to it. The decision to implement mini-grids stems from the idea of exploiting the opportunity of economies of scale and maximizing operational efficiency (Rural Electrification Agency, 2024).

Additionally, the Performance-Based Grant Programme (PBG) has the objective of closing viability gaps and is more focused on community engagement. This grant targets areas that may have implemented projects that may have arisen in informal ways without centralized planning because of energy demands. Once the communities are located the program plan is to connect them with mini-grids developers and potentially improve projects that were already arranged but were not economically viable. The programs regard the creation of mini solar hybrid systems that can power a maximum of 1MW. The grants amounts are of 600 US$ per connection are delivered in the Nigerian currency (naira) to reliable developers based on first arrivals until all of the funds of the programme are used. Multiple grants could be attributed to some developers if they reach three milestones: distribute items like batteries, inverters, distribution poles, meters, and solar panels to the sites, mini-grid commissioning and initial relationships with customers and the final evaluation ensuring fulfilment after 3 months from the instalments. Indeed, the application for the program works in a similar way to the subsidy, however the developers will receive the grants only after confirming that the networks are in place and well-functioning (Rural Electrification Agency, 2024).

The Covid-19 outburst forced the Nigerian government to take action on various sectors and enforce new regulations. Therefore, the Covid-19 & Beyond programme was introduced as part of the first component of the Nigerian Electrification Project (NEP), which included the implementation of mini electric grids for medical facilities such as Isolation & Treatment Centers (ITCs), primary healthcare, Sustainable and clean power to Centers (PHCs), Primary Healthcare Centers (PHCs) for tools for diagnosing and curing patients. The REA also provided for an architecture that offers quick basic emergency services, stable water supply via solar-powered water pumping devices and ungraded gadgets that minimize consumption of electricity for healthcare facilities (Rural Electrification Agency, 2024).

Standalone Solar Home Systems for households and MSMEs

The Rural Electrification Agency decided to also deploy Standalone Solar Home Systems provided by the private sector to assist millions of Nigerian homes and micro, small and medium enterprises in having access to better energy services at a reasonable price. As an added bonus, the implementation of SHSs for domestic use will also foster the market. There are two options for funding for this component.

The first one, dedicated for new entrants and start-ups, is the Output Based Fund (OBF) which implies that the NEP would cover up to 60% of the cost of the panels installation and certification. The companies producing Solar Home Systems can apply for the grants until the fund is exhausted provided that they must be able to claim that they can supply consumers with quality services. The 20% of the grant amount is going to be used to ease the affordability for end consumers Thanks to this assistance, the businesses will be able to afford the necessary investments in personnel, education, marketing, procedures, and logistics. Secondly, the Accelerator Grants (AC) should go towards stronger SHS producers that subsequently have to prove they are eligible by demonstrating capabilities for quick growth. As a matter of fact, this will draw in investors to capitalize in the sector and therefore increment liquidity. The endowment will be granted in large sums after the achievement of the steps agreed in the scheme (Rural Electrification Agency, 2024).

Results-based Financing for Productive Appliances and Equipment

In the Results Based Financing for Productive Appliances & Equipment program the objective is maximise energy efficiency in households and MSMEs situated in rural areas through the expansion of the availability of more productive technologies. The goal of this component is to provide renewable electricity to 24.500 MSMEs and allowing 1.050.000 more to improve the quality of systems through the Productive Use Equipment (PUE) scheme. The program works on supporting developers to include the efficient use of power and energy-saving appliances into their overall mini-grid viability plan and, as a consequence, foster the market for energy efficient equipment and appliances. The idea behind this component was to be designed to make it easier for PUEs to be deployed in micro grid communities because its primary goal is to stimulate demand for mini grids (Rural Electrification Agency, 2024).

Energizing Education Programmes

The Nigerian government deemed the powering of educational facilities as an extremely a prominent issue in Nigeria and a highly relevant driver of socio-economic development which is why it is also tackled by the Electrification Project. The Energizing Education Programmes aims to provide reliable and affordable green power to federal universities and university teaching hospitals around the country, to also enable the expansion of healthcare services. The program is sub divided in two phases (Phase II and III), the first one being funded by the World Bank and the second by the African Development Bank. Firstly, the EEP will focus on 7 national universities and 2 teaching hospitals, namely: Federal University of Agriculture in Abeokuta, Michael Okpara University of Agriculture in Umudike, University of Calabar & Teaching Hospital, University of Maiduguri & Teaching Hospital, University of Abuja, Federal University Gashua, Nigerian Defence Academy. The African Development Bank (AFDB) powered 8 universities: Modibbo Adama University of Technology in Yola, Federal University of Dutsin-Ma, Federal University of Lafia, Federal University of Lokoja, Federal University of Technology Owerri, University of Port Harcourt, Federal University of Uyo, Federal University of Technology Akure (Rural Electrification Agency, 2024).

The funds of the WB and the AfDB are used to finance the Engineering, Procurement & Construction (EPC) aspects for the installation of electric systems, streetlights to increase campus security, the renovation of the campuses' current distribution infrastructure and training buildings and workshops. As explained in the paragraph regarding consequences of energy poverty, electricity in education is fundamental for the well-functioning of the institutions and therefore has direct impact on the livelihood of individuals and development of communities. Additionally, the introduction of renewable energy specific Workshop Training Centres (WTCs) include the theoretical and applied teachings of the new technologies necessary for the implementation of the energy transition. The program powers these universities through the use of gas (8.5 MW) or solar hybrid (11 MW) power systems. Both phases also focus on promoting STEM subjects (Science, Technology, Engineering, and Mathematics) to become a more common path of studies especially for women. Thus, twenty female STEM students were brought on to participate to the project and have been learning about the planning and building of electrical infrastructure (Rural Electrification Agency, 2024).

Technical Assistance

The last component of the Nigerian electrification plan is to deliver strong technical assistance and knowledge sharing on an institutional and commercial level. Providing a wide spectrum of stakeholders in the nation's off-grid market with technical assistance and capacity building will not only be beneficial for companies entering or expanding in the sector but will also assist the Rural Electrification Agency in creating a framework for rural electrification and provide funding for the project's execution. As the previous component, there are two projects based on the institution that finances it, although the aims are similar. In the TA WB, the goals of this component are aiming at facilitating execution of the project while simultaneously fostering long-term growth and sustainability. It establishes robust project management practices, ensuring that all aspects of the initiative are coordinated and executed, it prioritizes the enhancement of capacity building efforts, empowering stakeholders with the requisite knowledge, skills, and resources to effectively contribute to the project. Furthermore, it can be useful for financing purposes, and it contributes to the establishment of a framework for rural electrification for future projects. The Technical Assistance project financed by the AfDB also plans on improving managerial and theoretical capabilities for the stakeholders of the off-grid sectors. In particular, it involves establishing monitoring, supervision, and auditing to assure project quality and compliance. The project intends to advance rural electrification goals and social development by strengthening the skills and procedures of entities involved in the electrification of the country (Rural Electrification Agency, 2024).

3.2. LAST MILE CONNECTIVITY PROGRAM (LMCP)

The Kenyan Last Mile Connectivity Program (LMCP) was announced in 2015 and had the objective of achieving universal access to electricity to the nation by 2020. The approach chosen by the government was to thoroughly study where the problems relied in the country and analyse the practices that worked in other countries in order to replicate them but with a clear understanding of the specific needs of Kenya. The program was designed to be in 4 main phases and the intention of exploiting economies of scale and increase accessibility for 5 million people in just 5 years. The first phase financed publicly trough a loan (150 million US$) from the African Development Bank (AfDB) and was focused on connecting households within close proximity to existing transformers. Utilizing a 150 million US$ loan from the World Bank, the second phase targeted areas on the periphery of urban centres, necessitating the installation of new transformers and expansion of the low-voltage network. In phase III the additional loan from the AfDB aimed at extending the low-voltage network and installing additional transformers. In the last step of the project the Government of Kenya received loans from various entities, such as the French Development Agency, the European Union, and the European Investment Bank for a total of 180 million US$. It centers the increase of installation of new units and expansion of connections to distribution transformers, greatly improving the availability and dependability of electrical services. The plan was to specifically target individuals living in '*slums*', informal communities of extreme poverty proximal to cities but that do not have access to functioning infrastructure, and poor households in rural areas. The results were extremely positive, as to this day, Kenya went through the fastest increase in electricity access by going from 56% in 2016 to 73,4% in 2018 (Global Infrastructure Hub, 2019).

Although the lack of good infrastructure usually presents itself to be the biggest challenge to overcome, the Kenyan government realized a few years prior to the project that the investments in the grid systems were not actually eradicating the problem. In practical terms, a big amount of homes that were in the grid radius of maximums 200 meters of a power line with low voltage that should ensure for a fairly cheap connection price. Moreover, many households have an affordability problem with various stages of the electrification process: the expense of hooking the residence, the connection fee, and their capacity to pay the bills. Therefore, the resolution should include connectivity improvement by reaching the only people that were not under the grid and that subsidies and innovative methods for economic sustainability are required to take advantage of economies of scale and the infrastructure that is already in place. Before the intervention with the project, the kick-starting fee for the connection was of 398 US$ (KES 35,000), which is extremely high considering the majority of families in Kenya earn about 1.000 US$ yearly. Naturally, due to such high fees, electricity becomes a luxury because people prefer to spend money on daily needs (Global Infrastructure Hub, 2019).

The government of Kenya through the Rural Electricity Authority (REA), understood that the best price that would encourage the household will to connect to the electric would be of 171 US$ (KES 15,000). The households that could benefit from the lowered price had to be no more than 600 meters from transformer. The participants were chosen by the Members of the County Assembly and although the poverty threshold was not included as a driver, many families of selected were indeed low-income and, the absence of electricity prevented them from partaking in remunerative projects. Due to technological and budget limitations, a large number of Kenyans may get their energy from private companies that invented the pay-as-you-go (PAYG) distribution methods for mini-grids and off-grid solar equipment. The World Bank and the Kenyan government agreed on the incorporation of both systems for a better functioning and diverse sources which is why the 2018 Kenya Off-grid Solar Access Project (KOSAP) works on the implementation of mini-grids and off grids solar panels.

In the Last Mile Connectivity Project (LMCP) three main action areas are depicted. The first objective is the affordability where the efforts are concentrated on making electricity more accessible for low-income families that are detached from the grid. Additionally, attention is also regarded to public polices and regulations and to the involvement of the communities therefore by understanding the targets of the project by income but also specific groups that are majorly affected such as women and children (Global Infrastructure Hub, 2019).

Affordability and Financing of the Connection Fee

The majority of low-income homes will utilize electricity for illumination. In the beginning of the century, the median monthly cost per household for lighting in with kerosene in Kenya was 1,55 US$ (KES 156), and for electricity it was 3.30 US$ (KES 332). As a natural consequence, households struggling with money favour kerosene for powering lighting. General low economic development of the country together with poverty and spending patterns all contributed to the low demand for electrical connections. In particular, in 2016 in rural areas the electrification rate was 39% before the enactment of the project despite the financial support and the subsidized connection fees that were proposed. Other than households preferring to spend their money on other commodities such as food and clothes, the lack of investment in the electricity market due to high risks and the unfavourable landscape that led to heightened implementation, building, and operating expenses, presented extra troubles. The Rural Electricity Authority (REA), Members of the County Assembly, and representatives of constituencies collaborated to choose the communities that would be electrified. The requirements to be included in the project were that current access to electricity was necessary. Households that were more ready to partake were prioritized, based on how keen the county was to assist particular communities due to infrastructural differences. For example, Phase I focused on homes that were 600 meters or less from the current grid, whereas Phase II included communities that were one to 2 km away (Global Infrastructure Hub, 2019).

To understand how low the connectivity fee should be in order to entice household to invest in electric systems, a baseline survey concerning 150 installed transformers was carried out in the counties of Busia and Siaya. The These areas were recognized as having vulnerable populations due to their low rates of electricity, relative high population density, and lack of economic development. After applying the criteria of Phase I, a total of 2,504 households, 2,289 of which were unconnected and 215 of which were connected, were examined in greater depth based on their energy consumption patterns and preferences. The spending for these households were respectively the average of 5,52 US$ and 15,38 US$ per month. Additionally, the survey discovered that the family nucleuses are extremely susceptible to price increase for the activation. The fee established was significantly higher than the theoretically acceptable price that the results indicated. Even for reasonably more financially secure homes and companies, the connectivity rate was low despite significant investments in grid infrastructure had been made in the past. It is relevant to denote that this case study focuses just on the connection cost, and it does not account for the regular cost of electricity.

In 2015, the connection tariff was lowered to 171 US$ thanks to government funding and subsidies for those included in the Last Mile Connectivity Program. The program included an option where the payment can be distributed over three years with monthly expenses of 4-5 US$ added to the regular electricity fee through the Stima Loan Program. Ideally, with more and more household joining, an economy of scale can be reached, resulting in lower cost per household and therefore allowing the reduced connection rate. For instance, the average total cost (ATC) function evaluated in the project showed that the ATC would decrease from 3.500 US$ per connection with zero participants to 1.000 US$ with just 15 households attached. Thus, indicating the need to correctly place the transformer in order to maximize coverage for households, considering the 600-meter restriction, with an additional requirement to ensure connectivity to a health facility. The decision by the REA was executed through a site assessment of the design of the network grid, the creation of the budget, and identification of the materials (Global Infrastructure Hub, 2019).

Policies and Regulatory Bodies

The Rural Electrification Authority (REA), founded to improve rural electrification across the nation in 2007, is greatly pertinent to the Last Mile Connectivity program. The authority is the one that overviews and promotes electricity access of households located near powering transformers. The REA has the goal of forwarding universal access to electricity in rural areas in order to gain socioeconomic growth. Supplementary, the first and most important regulation the Kenyan government composed as part of the program, was the establishment of the independent body Energy Regulatory Commission (ERC). The role of the institution is to formulate licensing procedures, issue permits, suggest additional energy regulations, set and modify tariffs, approve power purchase agreements (PPAs), and create national energy plans. The combination of an autonomous energy regulator and an oversight body that is responsible for improving connectivity and advancing development is contributing to the regulatory strategy (Global Infrastructure Hub, 2019).

The Energy Act 12, developed for the LMCP, assigns several key functions to the Rural Electrification Authority (REA). Firstly, it is responsible for managing the Rural Electrification Program Fund, ensuring efficient allocation and utilization of resources. Additionally, the REA is mandated to develop and regularly update the Rural Electrification Master Plan, guiding the strategic expansion of electricity access across the country. Another crucial role involves supporting and advocating the adoption of renewable energy sources, such as small hydro, wind, solar, biomass, geothermal, hybrid systems, and oil-fired components. The necessary aspect of the authority's purpose is that every proposed solution should be customized fit certain requirements through an understanding of the needs of designated locations, for example by including the support of irrigation and income-generating activities. Furthermore, the REA as part of the national government, should earn towards an increase of capital investment in the Kenyan electricity market to support its expansion efforts. Finally, it ensures accountability and transparency in the project execution process by managing the portrayal and contract endowments processes for licenses and permits essential for rural electrification projects. The Rural Electrification Authority is therefore an essential to the advancement of energy access, sustainability and development in the country because of these many functions (Global Infrastructure Hub, 2019).

Community Engagement

The Kenyan government really worked towards comprehending project advantages and impact, hazards, and possible mitigating actions. In order to do so, local communities and other interested parties were consulted prior to the beginning of any construction activities. The shared conversations also contributed to determining potential technical barriers and identify the main difficulties by screening residents' electricity usage and deciding how to meet different stakeholders' needs. A group of advisors was assigned by the REA to manage the interactions with the communities. The consultants' team in collaboration with the local member of the County Assembly and settlements' rulers to create a space where there could be continuous conversation between the target of the study and the decision-makers of the project. It was achieved through the establishments of frequent meets up where even the most vulnerable participants, such as women and households with the lowest income, and could take part of. On top of that, the team decided to further the lines of contact by collecting names and contact information of the attendees in order to increase communication between all parties of the Last Mile Connectivity Project. The decision for which communities could be included in the electrification plan depended on strict benchmarks, such as distance from current electrical infrastructure and radius from a transformer. In fact, if a household farther than 600 meters wanted to be connected it had to submit an application to Kenya Power, but for a possibility to have a project carried out the Rural Electrification Authority would need to identify other households willing to participate in the area since the project works on the expense division between a community (Global Infrastructure Hub, 2019).

The LMPC has as a strong principle the consideration of the people involved in the project and was indeed engaging with endangered individuals, but it did not actually put emphasis on empowering specifically women, youth, or the really poor (Global Infrastructure Hub, 2019).

3.3. SCALING UP ENERGY ACCESS PROJECT (SEAP II)

In 2013, Rwanda signed onto the Scaling up Energy Access Project (SEAP) with the African Development Bank (AfDB). The project is a governmental initiative implemented by the Rwanda Energy Group (REG) and the Energy Development Corporation Ltd (EDCL). The SEAP is consistent with the long-term development plan that Rwanda, especially with regard to the infrastructure development and was created as a part of the multi-phased Electricity Access Rollout Program (EARP) that had the universal accessibility to electricity goal comprised of both on and off technologies. The ideal the EARP was to increase the share of population with access to electricity from 6% in 2009 to 70% in 2018. The role of the Scaling up Energy Access Project specifically was to reach a 45% access rate for domestic use (25.438 households) through an electric grid and also cover health facilities (29), public workplaces (25) and 80% of educational buildings (179) in Northern and Western Rwanda. Although some technical challenges resulted in the postponement of the project that required additional funds and therefore the goals were not reached in 2018. Nonetheless, the additional time framed was beneficial to the project since it allowed to electrify even more entities than the plan's objective. (African Development Bank, 2021).

The second phase was initiated in 2018 after the completion of the first successful project, this step of the program had a renewable approach to expanding the electricity access. The objective was to tackle Kigali City and the Southern and Western provinces by raising on and off-grid access, improve the reliability of the power supply and foster capacity building from a managerial and institutional perspective to guarantee long-term success. The program was supposed to last three financial years through two loans: 165 million Units of Accounts (the bank's units) from the African Development Bank and 53 million from the African Development Fund. SEAP II was supposed to be concluded in 2020 but because of the delay from the first phase and the Covid-19 pandemic, the projective is currently still being implemented. Nonetheless, it is still possible to analyse the results achieved to this day to understand if the approaches were correct.

The main issues at the time of the creation of the SEAP II design in the energy sector are the malfunctioning of existing infrastructure, in fact, even when the electrical grid is present, it is not uncommon to experience power outbreaks and an overall unreliable supply system, considering the increased growth of population Rwanda is experiencing, the government is slow at providing new connections. Additionally, electricity remains a costly good because the existing hydropower plants are run-of-river, meaning that they are smaller and in more remote areas and transmission costs are higher, and half of the energy created in the country was made by fossil fuels in 2018, resulting in elevated tariff fees. Moreover, regional grid interconnection projects and hydropower projects are behind schedule, which has forced the nation to rely only on costly thermal power sources. The Rwanda Energy Group has also a skill problem in regard to planning, contract management, and negotiating that is limiting the process of project design and implementation, once again resulting in high electricity prices (African Development Bank, 2018).

To contrast these circumstances, the project outlines four main areas of focus: firstly, it aims to enhance the reliability of electricity supply, allocating €64.36 million. To achieve this, the action plan is improving the substations by raising the voltage, and institute a Supervisory Control and Data Acquisition/Distribution Management System (SCADA/DMS system) which combined should all work towards changing the current electric grid to be more reliable. The DMS will work with local producers for providing and installing the equipment needed. Secondly, it seeks to expand on-grid access to electricity for domestic and productive purposes, with a budget of €150 million. To be able to connect an additional 193.366 individuals to the grid the Ministry of Infrastructure (MINIFRA) will expand the transmission and distribution of the already existent grid. The first two objective of the program will focus on reaching new customers in Kigali, while the next components focus on other more remote areas of Rwanda. Thirdly, to increase access to electricity to low-income rural households the plan is to deliver off-grid renewable energy solutions with almost €9 million. Ideally, the Standalone Solar Home Systems are deemed to be the best approach from a financial and practical way. The objective to reach 124.800 more people, out of which 52% should be female in order to tackle the inequality between genders of the country especially in poor contexts. Finally, the program, assign €6 million for implementing institutional and commercial capacity building, out of which, €1.29 million designated for the appointment of the Office of the Auditor General (OAG) (African Development Bank, 2018).

Overall, the project aims to benefit various stakeholders, including existing industrial, commercial, and domestic. Local contractors involved in the supply and installation processes will also experience positive outcomes, potentially enhancing their business opportunities and contributing to local economic growth. Moreover, the project holds promise for the local population, offering increased employment prospects during its implementation phase. Off-grid solutions are particularly anticipated to create opportunities for women entrepreneurs, thereby fostering greater welfare, income generation, and empowerment, especially among women and children, including girls, residing in non-urban areas. Furthermore, over 70% of Rwandans are employed in agriculture, and access to adequate and dependable electricity for homes and productive users is expected to encourage sustainable agricultural growth by enabling irrigation systems to increase productivity and fostering value-adding activities in the agro-manufacturing industries (African Development Bank, 2018). As of July 2020, the date of the last evaluation report, the African Development Bank Group declares that the project is on the right track and is actually projected to reach more people than the original projection. The indicator that evaluates grid reliability, the Improve System Average Interruption Duration Index (SAIDI), has been decreasing as a result of the infrastructure improvements. The connection to the grid of people residing in Kigali City has been successful as 140.000 additional households have been reached, out of which more than half is comprised by women. The families have been benefitting from the newfound electricity also from a commercial perspective, in fact, 471 productive users have been linked to the on-grid framework. In regard to the off-grid systems, 24,881 new standalone Solar Home Systems (SHSs) have been installed around the Southern and Western regions of the country. There are, however, some financial issues since the AfDB has not received always on time the quarters despite being part of the obligations of the loan agreement (African Development Bank Group, 2020)

3.4. BAREFOOT SOLAR ENGINEERS

Fist began in India, the Solar Programme seeks to advance sustainable energy and rural communities' socioeconomic growth. Its main objective is to teach uneducated rural women from how to install and sustain solar technology. The Indian NGO Barefoot College was introduced in 1972 and currently functions as a key training facility in India dedicated to sharing straightforward but long-lasting solutions for problems associated with rural living, such as clean water access, education, healthcare, and the use of renewable energy sources. The initiative promotes the preservation of the environment, lifestyle improvement and independency of the engineers that were affectionately nicknamed '*Solar Grandmas*'. The choice of the target of the program has two main rationales: promoting women empowerment and more specifically to the Sub-Saharan area, men and young individuals would be leaving the villages to seek out better prospects after receiving the engineering knowledge, while elderly women are more attached to their land and people and are more prone to use their skills to improve the well-being of the community (United Nations Development Programme, 2024). The implementation of sustainable technologies for the creation of electricity has various benefits for the communities: heightened access to power, enhancing quality of life from a health and economic perspective as well as environmental turnaround due to lower carbon emissions. Barefoot College actively combats energy poverty and enable participants to become change agents in their communities The college is able to leverage a peculiar training methodology its global network of 27 centers through color-coded instruction, local language explanations, hands-on workshop exercises, and mentorship (Global Green Growth Institute, 2022). Barefoot College ensures that knowledge stays within communities to benefit future generations and the socioeconomic developments of rural areas through the electrification process (Barefoot College International, 2023).

3.4.1. Madagascar

The "Barefoot solar engineers" initiative in Sub-Saharan Africa was first launched in Madagascar in 2012 as a collaboration between WWF, Barefoot College, the governments of India and Madagascar, as well as a number of other international organizations. A few women of Ambakivao, a small town in Madagascar's Menabe area, have volunteered to become the first "solar engineers" in support of WWF's effort to provide access to sustainable energy. Remeza, Kingeline, Yollande, and Hanitra, are the ladies between 35 and 50 years old that collaborated with Barefoot College to help almost 200 homes in their neighbourhood get electrified as of 2017. The main allocation for electricity in the village is going towards lighting, that was previously powered by petroleum. These four women flew from their homes to Tilonia in India, as many other women from other countries were to attend a six-month course in applied solar technology at the Barefoot College. Majority of the women embarking in this experience had never travelled before or even left their region. The women are selected based on community-wide discussions and must uphold predetermined standards that guarantee reliability, although reading capabilities are not required. The personal desires of the participants are taken into consideration as well. To ensure the program's financial stability, the village democratically elected a delegation that has the role of managing the administrative, social, and financial elements of solar equipment. As previously establishes, the program was a success since in just four women they were able to bring renewable electricity to hundreds of households back to their region and have been personally satisfied by their achievement; Hanitra has stated *"We left Madagascar to learn how to build solar gears and lamps to improve our village's condition but also to reduce our footprint as possible as we can, […] but with this solar technology we are spreading in our village, humans are feeling good, and nature also. It doesn't smoke and doesn't smell bad"* (WWF, 2017).

3.4.2. Burkina Faso

In Burkina Faso, the '*Solar Grandmothers*' program's goal remained the same, however, in collaboration with the Prince Albert II of Monaco Foundation and the Global Green Growth Institute (GGGI), it was able to build a local subsidiary for the school. In fact, the initiative falls under the control of Burkina Faso's Ministry of Environment, Water, and Sanitation. The Training Center of Barefoot College in Burkina Faso trained 31 rural women from seven regions of the country. After completing the training cycle, the women will get kits for solar homes that they may assemble and install in their communities. By empowering elderly women, the project aims to mitigate fossil fuel consumption in Burkina Faso by advocating for clean technologies and renewable energy sources. This initiative enhances local proficiency in solar technology, broadens access to solar energy in rural areas, facilitates the proliferation of green income-generating activities and it impacts the living conditions of women, raising community awareness of renewable energy, reducing gender inequalities, and enhancing household well-being. The trainees are taught how to maintain solar equipment by women who attended Barefoot College in India beforehand and have installed solar kits within their own communities (Global Green Growth Institute, 2022).

3.4.3. Ghana

Ghana was the most recent country that got involved most recently in the Barefoot Solar Programme. Five ‘Solar Grandmothers’ from each of the five villages in the Upper West area of Ghana underwent training at Barefoot College in India thanks to funding from the UNDP's Global Environment Facility Small Grant Program (UNDP GEF-SGP) and became the first solar engineers of their districts.

According to World Bank data from 2021, Ghana is the country most provided with electricity in Sub-Saharan Africa, the electricity rate stems at 86.63%. Nonetheless, there is a stark difference between the urban and the rural situation. As a matter of fact, 95% of urban residents have access to the electric grid while the rate in at 74% among individuals located in rural areas. This data suggest once again that the off-grid renewable solutions can represent a quick and reliable source that can level the gap between areas with different urbanization level. In Ghanaian rural areas, lighting and other house task requiring energy are powered by kerosene in absence of electricity. The evident positive result of the practices of the ‘solar grandmas’ present a great potential for the people and the environment. These women are pushing for a revolution in renewable energy by successfully electrifying 150 homes in their villages. Solar panels installed are thought to have replaced the roughly 3.000 litres of kerosene per month. The outcomes are the rise in the use of cell phones and children are can study at night due to increased lighting potential. Collaborations between the public and private sector are essential to uplifting the remaining underprivileged populations. Through the enabling of self-sufficiency among rural communities in the electricity market, there is hope of attracting investments that could continue furthering the development of the areas (United Nations Development Programme, 2024).

4. COMPARATIVE ANALYSIS

This paragraph will be a quick comparative analysis between the four case studies: The Nigeria Electrification Project (NEP), the Last Mile Connectivity Program (LMCP), the second phase of the Scaling up Energy Access Project (SEAP II) in Rwanda and the Barefoot initiative in Madagascar, Burkina Faso and Ghana. These are very different countries that are located across Sub-Saharan Africa, and therefore, they have differing contextual factors influencing each project, such as population, national policies, regulatory frameworks, and socio-economic conditions. Nonetheless, analysing how different governments approach the energy poverty issue and, therefore, what policies they implement can help in understanding firstly what works and, secondly, what hinders the Sub-Saharan area from achieving energy security. Although an electrification project should be adapted to each country's needs and characteristics, the thesis aims to propose standard guidelines for countries that cannot escape the lack of accessibility to electricity while the rest of the world has been constantly improving. Therefore, this paper will outline only a standard plan of action which explains the choice of countries with different characteristics, as it allows the author to understand common practices and mistakes of governance in Sub-Saharan Africa as a whole. The first three case studies are a more thorough examination of specific projects of a moment in time for a country that includes various practices with specific rationales, while the Barefoot College project is on a smaller scale but has been repeated in different countries. The 'Solar Grandmas' can provide a different perspective due to its simplicity and more interactive approach with the local communities. The following comparative analysis will mainly include the first three case studies because of the similar scope and financial weight. In contrast, the last project will be included more in the discussion thanks to the unique outlook it can provide.

Before getting into the actual comparison, it is essential to understand that these case studies are self-reporting and, therefore, might be subjected to some bias, both from financing institutions and local governments that want to paint the expedition as more successful than it actually was.

The characteristics of the Nigeria Electrification Project were that it was very much private-based and therefore, it was concentrated on investing in the electricity sector in order to first implement new infrastructure for rural areas, such as mini-grids and off-grid systems, and more importantly, receive international attention from investors. This also means that for most of the projects, the companies in the electricity market decide who is receiving the final products. The program puts specific attention on other aspects of electricity aspects that influence health like health centres, hospitals and educational buildings. Lastly, there is a strong desire to enforce capacity building, which is why one of the components of the project is dedicated to the establishment of technical assistance aimed at public and private institutions for the electricity market. The Last Mile Connectivity Project in Kenya has a totally different approach: it is focused on connecting people who are most distant to the national grid. The reason for this choice stems from the fact that the Kenyan government had already implemented in the past the expansion of the infrastructure in past projects; therefore, investing in connecting to the electrical plant is less expensive and less environmentally damaging since it is a matter of covering "the last mile". The government conducted an analysis through the Rural Electricity Authority (REA) and was able to assess that the fundamental problem that was stopping households in slums and proximal areas from the grid from accessing power was the high connectivity fee. Therefore, the REA structured a plan in order to ensure that power would not be a luxury and low-income people should not be forced to rely on kerosene by maximizing the economies of scale based on the positioning of the transformer. This project, compared to the previous one, is more focused on poor informal settlements in urban areas and less remote regions, it relies on expansion of the existing structures rather than building new systems and has a way more community-led approach both in the research and by creating an entity that ensures continuous communication with the people involved in the project. Rwanda's plan is a continuation of a project that was successful and, in contrast to the two prior projects that were examined, approaches both urban and rural areas with two methods: further developing the grid for more metropolitan environments and delivering Standalone Solar Home Systems for the remote regions. This plan also differs from the previous two by being the only one that targets the inefficiency aspect of electricity generation by upgrading the infrastructure of the existing grid with the specific objective of lowering malfunctioning occurrences. Moreover, the project not only recognizes the gender inequalities that are particularly prevalent in low-income backgrounds but also incorporates the matter in the decisions of who is targeted.

It is essential to denote some key differences between the programs; for instance, the electrification projects in Kenya and Rwanda focus specifically on low-income individuals, while the one in Nigeria lets the private sector allocate the resources. All of the projects consider the possibility of households exploiting the newfound electricity access to power their commercial activity as well as household equipment. The Nigeria Electrification plan has devoted a specific component to Micro Small and Medium Enterprises by installing solar hybrid mini-grids in less economically developed areas. However, just the Scaling up Energy Access

Project II pay particular attention to the agriculture sector and understanding the relevance of agricultural activities in improving employment for the population in the Sub-Saharan region overall and in Rwanda. The common aspect across all three operations is the establishment of Technical Assistance facilities and the expression of the necessity to increase capacity building and.

The Barefoot College Solar Engineer program, although it is a smaller scale program, highlights the need for the involvement of the local community in the actualization process and, more importantly, how a project can also further the knowledge and skills of individuals, therefore supply them with the clean energy that will improve the physical and psychological health and with competences that help empower themselves and their communities.

5. DISCUSSION

All of the projects investigated in this paper are organized by the local governments and energy institutions while financed by massive international institutions aiming to promote socioeconomic development. As a matter of fact, the two most prevalent public institutions that fund projects in the energy sector in Africa, other than countries in other continents, are The World Bank and the African Development Bank. The World Bank declares its core objective to be "*reducing poverty, increasing shared prosperity, and promoting sustainable development*" (World Bank Group, 2024); consequently, this institution desires to prove the success of the programs. In her criticism of the International Monetary Fund and the World Bank, Alvarez (2019) states that the Bank's methodology for calculating poverty levels is still being debated, and many critiques reading the practices used in these large-scale projects have been evaluated, and there is doubt regarding if the recommendations for policy in general as well as its capacity actually to implement human rights in the first place. It can be useful to take into consideration projects with similar goals to the ones discussed in this thesis: The World Bank financed two projects in Laos, one on-grid hydropower and one Solar Home System for rural areas. In the case of the hydropower project, a practice that has been questioned as well due to its large impact on the environment in the construction, the plant did not favour reliable access to clean energy as only 5% of the electricity produced ended up being used for domestic use while the remaining 95% was exported to Thailand. The WB claimed that the revenue from the exports could be used to benefit the poorest people of the population through other policies. However, this argument lacks reasoning because of the known corruption of the government in Laos that could not ensure that the money would actually go towards the most vulnerable. In the SHSs project, other problems arose; the program established was a Rent-to-buy scheme ranging from 5 to 10 years. According to the World Bank and the government of Laos, the program was deemed to be a success because of the number of households that the program electrified. However, the impact that it had on the people was less than positive. Many people who partook in the initiative could not actually afford them. In the villages that were relatively more connected with roads and various types of commercial services, some individuals were able to develop some remunerative advantage, like selling handicrafts and brooms they manufactured in the evenings thanks to the light provided by the panel. At the same time, in more isolated areas, there were fewer benefits. Multiple people in smaller villages reported that they were compelled to sell their farm animals in order to keep up with the monthly payments for the solar panels (Käkönen & Kaisti, 2012).

Substantially, the World Bank and similar institutions are condemned for making the oversimplified assumption that any increase in the production or transmission of electricity corresponds to the poor having access to it. The same problem is apparent in the case studies analysed. The chapter on measurements of energy poverty in the literature review discussed how there are three fundamental ways to measure energy access: technological, physical and economic. Nonetheless, every study presents its results only with the technological threshold, thus assessing how many people were reached by the grid or connected through off-grid systems. This method is surely a beginning in understanding how to improve energy conditions for poor individuals, but it cannot be sustained by itself. A project is not well done if it does not include the comprehension of the long-term economic burden that electricity can bring to a low-income household. In the literature and past projects, it is not uncommon that the affordability issue is disregarded, while the income availability of the targets of electrification projects should always be taken into consideration. More capital should be put towards understanding the better functioning methods for an area in order to alleviate costs both for the connectivity fee like it was done in the Last Mile Connectivity Program in Kenya and for the regular monthly tariff.

Additionally, powering initiatives should be accompanied by employment policies that empower the poor to have their own resources. Employment enhancement was not really discussed in the literature when discussing energy poverty alleviation. Nonetheless, some consideration was made in the studies: the NEP considers the electrification of enterprises and other income-generating activities, similar to how it was done in the Rwanda project. Moreover, funding the electricity sector can impact the workers and overall economic development of the region. However, no special attention is paid to the poorest people, who are the ones struggling the most with energy poverty and who may have difficulties in affording access to power. On this aspect, the Solar Grandma's program provides a special take as it provides valuable skills to relevant figures in a community that can benefit the person involved and other inhabitants of their villages.

The conversation around how energy poverty influences health usually does not comprehend aspects other than household clean energy access and electrification of health and educational facilities. However, there are other various factors that impact the physical health of the population of a country. For instance, food quality, as well as water security, can have a great impact on the well-being of a person. These aspects are impacted by the access to electricity for refrigeration and other purposes. The project design that has the objective of providing powering services to improve the quality of life of citizens should encompass the promotion of cross-sectorial partnerships across the supply chain of basic needs. For this same reason, agricultural access to energy is even more relevant, as most farming operations occur in rural locations with limited access to power (GOGLA, 2022). As mentioned before, most of the Sub-Saharan population is employed in the sector, especially very low-income families who cannot afford electricity without assistance.

6. POLICIES RECOMMENDATIONS

The following paragraph will be consistent of different measures and approach that should be taken into consideration in the design of an electrification plan across five areas of action: infrastructure enhancement, financial accessibility, employment promotion, holistic healthcare approach, and regulatory and monitoring framework strengthening. It is important to consider that since these recommendations are simply flexible guidelines, in an actual plan, the governmental institution responsible for the plan design should consider the current energy market, resources assessment, technological feasibilities, financial viability, social and environmental impact and existing regulations. Only through studying and considering these aspects, countries can develop comprehensive electrification plans that are aligned with national development goals.

The development of infrastructure should be installed in collaboration with the private sector in order to expand the availability of electricity services and simultaneously expansion creating a more inviting investment environment, stimulating economic growth and job creation within the energy sector. The technologies selected on the basis of the recipient. In urban areas especially when trying to electrify slums and other settlements proximal to the cities the best approach is to improve and expand the grid when it is economically and environmentally convenient. Powering rural areas is more efficient through hybrid mini-grids for companies, healthcare and educational facilities and conglomerates of households that have access to a little bit more disposable income. In case for extremely remote and poor locations, installing Standalone Solar Home Systems is the best options for providing renewable access to electricity. As additional bonus, off-grid solutions are less damaging to the environment, especially on a smaller scale. Moreover, prioritizing the provision of reliable power to healthcare and educational facilities ensures essential services remain uninterrupted, empowering communities with improved healthcare outcomes and educational opportunities. These initiatives not only address energy poverty but also contribute to broader socioeconomic development goals, fostering resilience and prosperity in underserved areas. Lastly, the inefficiency of existent traditional grids should not be underestimated: improving electric plants and distribution lines conditions can avoid the frequent outbreaks that are commonly experienced in Sub-Saharan Africa and minimize the waste which will consequently increment supply and therefore reduce pricing as well.

Secondly, and most disregarded, aspect of the discourse is that to ensuring that all societal sectors have fair access to electricity requires the implementation of affordability policies. The financial accessibility, especially those in extreme poverty, have to include initiatives such as minimizing connectivity fees and maintaining low tariffs to make electricity more affordable for households. The connectivity expense was confirmed to be too high by the study made in the Last Mile Connectivity Program, that devised a practical plan to exploit economies of scale that permitted lower costs. In case the payments could not suffice, a progressive method could be executed. Giving precedence to from large and medium-sized consumers could prevent low-income families from enduring economic strain. The impact that a heightened regular tariff can have on a household was not taken into account in the projects analysed. Some policies that could be implemented could range from deploying subsidies to those who need it the most or by establishing a progressive pricing system that better contrasts the income inequality of the nations. For most of the programs that involve solar panels, the instalments costs were covered with a pay-as-you-go method, but it can still surpass the economic availability for some families. Keeping that in mind, the timing of the payments could be changed to better fit the needs of the family. If a household is not able to sustain monthly expenses, they could be sub-divided based on the specific remunerative patterns. Alternatively, training local members of the community skills that could install solar panels themselves would have an impact on the price for the consumers because of the dampening of wiring costs.

On the last note, affordability policies should be juxtaposed by employment enhancement policies allowing for more income that could let households afford more clean energy. Employment policies play a vital role in leveraging electrification initiatives to foster economic opportunities and empower local communities. One approach involves mentoring individuals from local communities, providing them with the necessary skills and training to participate in the energy sector workforce, as mentioned previously. implementing programs akin to the "solar grandmas" model facilitates knowledge-sharing and skill development among community members. By empowering individuals to install and maintain solar panels, these initiatives not only increase energy access but also enhance community resilience and improve living conditions, ultimately driving sustainable development. Additionally, ensuring electricity access to the agricultural sector is crucial, as many individuals rely on it for their livelihoods. By promoting income-generating activities for low-income households within this sector, electrification efforts can directly contribute to poverty reduction and economic empowerment.

Ensuring reliable access to electricity for healthcare and educational facilities directly impacts the delivery of essential services and educational opportunities. Additionally, fostering cross-sector partnerships, particularly across the food supply chain, holds potential for advancing quality of life and reduce diseases that spread through food. By collaborating with stakeholders throughout the food supply chain, from production to distribution, countries can leverage synergies to address energy challenges comprehensively. These partnerships can lead to innovative solutions for energy generation, distribution, and utilization, ultimately benefiting both the energy sector and the broader economy. Moreover, such collaborations can facilitate knowledge exchange and resource sharing, driving efficiency improvements and promoting resilience across interconnected sectors.

Capacity building and institutional strengthening are essential for the successful implementation of electrification projects. This involves enhancing the capabilities of national, regional, and local institutions to effectively plan, implement, and manage electrification initiatives. Providing training and support to key stakeholders, including government agencies, utilities, and community organizations, ensures that they have the necessary skills and knowledge to drive project success. Additionally, fostering community engagement and participation is critical for ensuring that electrification projects align with local needs, preferences, and priorities. By promoting community ownership and involvement in project planning and decision-making processes, projects are more likely to be sustainable and meet the needs of the people they serve. Moreover, establishing robust monitoring and evaluation mechanisms is essential for tracking project progress and impact over time. By regularly assessing project performance against predefined indicators and targets, stakeholders can identify areas for improvement and make informed decisions to optimize project outcomes. This feedback-driven approach enables adaptive management and continuous improvement, ultimately enhancing the effectiveness and sustainability of electrification efforts.

Lastly, according to the study by Lee & Yuan (2024), promoting urbanization is the most defying change a country in Sub-Saharan Africa can make for promoting a more secure electricity environment. More studies could include the enhancement of transportation systems and expansion of the urban labour market to verify if advancing urbanization can actually be beneficial to the cause. Nonetheless, it is not included in these five main areas promoted by this thesis as it does not have been proving to be an effective method to improve clean energy access and it was not included in any of the case study analysed due to the theory being so recent.

CONCLUSION

The energy poverty matter in Sub-Saharan Africa represents a pressing challenge with implications on the health and development of millions of individuals across the region. This thesis has examined the impact of energy poverty alleviation policies through the examination of four projects in nations of the region.

The main findings highlight the common mistake made by governmental institutions to rely solely on the expansion of the electricity services for the eradication of the issue but disregard the actual affordability of the new technologies provided especially for those in extreme poor conditions. The act of neglecting the needs of low-income household when the aim of electrification projects should be to advance their well-being is paradoxical. Nonetheless, the programs that are being implemented are, in fact, in line with the literature theories on how to promote universal access to sustainable clean energy, there is still room for improvement. The commitment from all stakeholders need to increase to be able to reach the Sustainable Development Goal 7 (SDG 7) of universal access goal by 2050.

This thesis presents tries to understand the best approaches that could alleviate energy poverty and outlines a framework that electrification programs in Sub-Saharan Africa should follow in the future across these areas of action: infrastructure enhancement, financial accessibility, employment promotion, holistic healthcare approach, and regulatory and monitoring framework strengthening. Regardless, the guidelines presented cannot be exhaustive in the design of a plan due to its general characteristics. Moreover, the study was developed around the examination of just four case studies that were actualized in relatively more developed countries of Sub-Saharan Africa.

The are some possible areas of research that were briefly mentioned in this thesis that could present opportunities for future research. Firstly, this dissertation suggests that urbanization promotion could serve as a significant strategy for alleviating energy poverty. Further practical studies could analyse the effectiveness of urbanization policies in addressing energy poverty within urban communities. Additionally, alternative cooking technologies supply could be explored, since they are an additional component to the indoor pollution problem. Understanding the feasibility and impact of diverse cooking technologies can offer valuable insights into improving energy access and reducing health risks associated with traditional cooking methods. Moreover, the issue of government corruption emerges as a critical factor influencing the success of energy poverty alleviation projects. Future research should delve deeper into the dynamics of corruption and examine whose responsibility it should be to design and implement these projects, whether it should be governmental agencies, international organizations, or independent bodies. By addressing these research gaps, we can advance the strategies that are necessary for tackling health and energy poverty in Sub-Saharan Africa.

In conclusion, electricity access has various implication for the development of a country but it is first and foremost a human right that can completely change the trajectory of one's life. Therefore, energy poverty eradication should be at the forefront of the international conversation around energy policies.

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