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POSSIBILITIES OF PROMOTING THE USE OF SOLAR PHOTOVOLTAIC ELECTRICAL ENERGY IN KENYA AND HUNGARY TO REDUCE ENERGY PRICES AND CARBON DIOXIDE EMISSIONS.

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ABSTRACT

Burning of fossil fuels to generate electrical energy is accompanied by emission of carbon dioxide, a greenhouse gas associated with climatic change and global warming. To limit negative impacts of burning fossil fuels, nations of the world are shifting from fossil fuels to renewable energies driven economy. The aim of this thesis was to investigate possibilities of promoting the use of solar photovoltaic electrical energy in Kenya and Hungary for reduced energy cost and carbon dioxide emissions. This entailed investigation of selected literatures and databases on the current use levels for solar photovoltaic energy in the two countries. It was notable that despite the high solar potential in the two countries, it has barely been exploited. A review of legal policies and regulation influencing exploitation of photovoltaic energy in the two countries was done. Technological background review was carried out to assess current technological barriers limiting exploitation. Finally, a statistical background review with the help of questionnaires was carried out to investigate the general public on the attitude toward solar energy, environmental protection and conservation, and challenges in the use of solar photovoltaic energy. The reviews brought out challenges in solar electrical energy use which could be classified as global or specific to an individual country. Inefficient battery storage for solar energy for example is a global challenge. Extra high cost and presence of counterfeit solar equipment in the market is a challenge particularly in Kenya. This is despite government regulations exempting import duty and value added tax on solar equipment. Recommendation of this research is the Kenyan government to take charge in controlling market prices for solar equipment to ensure suppliers don’t exploit customers despite exemption from import duty. Also, to implement the regulation requiring all player in the solar industry to be registered in order to minimize cases of counterfeit goods and substandard services. For the Hungarian situation, I recommend the government to adopt favorable policies, such as making permitting procedure simple and short, financial assistance to prospective investors and easing the tax burden. These policies have been adopted by various EU countries like Germany and Denmark and are doing significantly well in solar photovoltaic energy exploitation.

Keywords: Greenhouse gases, Fossil fuels, Photovoltaic, Kenya, Hungary.

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ABBREVIATIONS AND DEFINITIONS

AC	Alternating Current
CPV	Concentrated Photovoltaic
CSP	Concentrated Solar Power
DC	Direct Current
EPRA	Energy and Petroleum Regulation Authority
EU	European Union
EUR	Euros
FIP	Feed-in Premiums
FiT	Feed-in Tariff
GDC	Geothermal Development Company
GDP	Gross Domestic Product
GHI	Global Horizontal Irradiation
GJ	Gigajoules
GoK	Government of Kenya
GW	Giga Watts
GWh	Giga watts hours
HEP	Hydro Electric Power
HES	Hydrogen Energy Storage
HFO	Heavy Fuel Oil
IPPs	Independent Power Producers
KenGen	Kenya Electricity Generating Company ltd
KETRACO	Kenya Electricity Transmission Company limited
KNEB	Kenya Nuclear Electricity Board
KPC	Kenya Pipeline Company
KPLC	Kenya Power and Lighting Company
KPRL	Kenya Petroleum Refinery Limited
KSH	Kenya Shillings
KW	Kilowatts
KWh	Kilowatts hours
KWp	Kilowatt peak power
LED	Light Emitting Diode
LTD	Limited
MW	Mega Watts
MWh	Mega Watts Hours
NOCK	National Oil Company of Kenya
PJ	Peta Joule
PSI	Pounds per square inch
PV	Photovoltaic
REREC	Rural Electrification and Renewable Energy Corporation
RES	Renewable energy source
SHS	Solar Home System
TGC	Tradable Green Certificates
UK	United Kingdom
UN	United Nations Organization
UNFCC	United Nations' Framework Convention on Climate Change

US	United States
USA	United States of America
USD	United States Dollar
VAT	Value Added Tax
W	Watts

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1. INTRODUCTION

Energy is the most significant problem facing humanity today. Richard Smalley lists top ten problems of the world starting with energy. He argues that these problems can be solved if an economical, environmentally safe, sustainable energy source can be found (Mohanty, 2003). For a long time, until 1950s, most world's nations have relied on fossil fuels as source of energy to run their economies. However, burning fossil fuels produces hazardous emissions into the environment, including greenhouse gases such as carbon dioxide. Greenhouse gases trap heat leading to greenhouse effect that disrupts the weather patterns and hence climate change evident by global temperature increase. (Hoegh-Guldberg *et al.*, 2019).

Due to limited stocks of fossil fuels and massive mining processes that are both capital and labor intensive, the cost of running economies on these fuels has been increasing rapidly. The cost pressure coupled with environmental risks of emitted greenhouse gases from fossil fuel burning has led the world to turn its focus on renewable energy sources (RES) (Floyd *et al.*, 2020). In this research work, I will look at how generation of electrical power from solar energy (renewable energy source), can be promoted in Kenya and Hungary to ease the pressure of electricity from non-renewable energy sources such as coal, natural gas and diesel. Solar energy can be harnessed by two equipment, solar concentrators to tap solar heat by producing hot water or solar panels to generate electricity. This research work focusses only on solar panels and related equipment for electrical power generation.

In the last one decade, the world has experienced a huge technological advancement in solar panels manufacturing. This has led to invention of high efficiency and cheap solar PV cell. In Germany specifically, the cost of solar PV for roof top application dropped from over 5000 EUR per KWp in 2006 to about 1640 EUR per KWp in 2017. The efficiency has increased to over 30% from 15% (Samoita *et al.*, 2020). China is a great producer of PV cells and has gone along to construct large solar power plants, both PV and concentrated solar power (CSP) based. Other countries that have shown great progress in solar electrical power generation include Morocco, Chile, United Arab Emirates and USA (Iñigo-Labairu, Dersch and Schomaker, 2022).

Kenya is geographically located at a strategic position to enjoy significant solar energy resource nearly all year round. It is estimated that about 70% of Kenya's total land area has an annual solar energy potential of above 5kWh/m^2/day and about 5-8 hours of sun per day (Kiplagat, Wang and Li, 2011), (Oloo, Francis, Luke Olang, 2016). This shows an abundant potential to generate electricity from solar energy. Despite this potential, barely 1% of the country's total energy supply has been utilized (*Solar Energy – Renewable Energy Portal*, 2023), (Kiplagat, Wang and Li, 2011). From the study by (Kumar *et al.*, 2021), Hungary is said to have the greatest solar potential, of the four Visegrád Countries in central Europe (Poland, Hungary, Czech Republic and Slovakia). It further shows that for the last nine years (2010-2018), the share of solar energy to total Hungarian renewable energy sources has grown to only 16.6%, despite its great potential. For this reason, I find it necessary to investigate the barriers and give possible solutions towards exploitation of solar electrical energy in Kenya and Hungary.

1.1 Justification

Nations of the industrialized world are moving away from using fossil fuels as the primary source of energy to use of RES due to the rising costs of mining and environmental risks associated with burning of fossil fuels. (Samoita *et al.*, 2020), (Hansen, Pedersen and Nygaard, 2015). The United Nations (UN) has laid a strategy to achieve a zero (or a near zero) level carbon economy by 2050. The Paris and Kyoto protocols clearly outlines a strategy for achieving this and Kenya and Hungary are among the 198 signatory members of this organization that have submitted emissions reduction goals, under the UNFCC (United Nations' Framework Convention on Climate Change). It is no doubt that an efficient and sustainable energy source is mandatory to achieve this agendum. For Kenya and Hungary, solar energy if properly exploited will contribute to achievement of this goal.

1.2 Objectives

Objectives of the study;

1. Carry out an investigation on current government policies concerning PV solar power and how they influence its exploitation, making reference to Kenya's development goals under vision 2030 and European Union policies.
2. Investigate the general Kenyan and Hungarian public with the help of a questionnaire to determine the knowledge and attitude toward solar PV electrical energy exploitation, and,
3. Investigate EU legal standards on solar PV electrical energy and look at what Kenya could borrow in order to promote exploitation.

1.3 Hypothesis

In order to effectively accomplish the project's objectives, the research topic is decomposed into the following hypothesis:

1. Using solar cells is for rich countries/rich people and requires ten to fifteen years to recover the investment,
2. Kenyan and Hungarian earth surface receive adequate solar radiation to meet more than 50% of total electrical energy demand if fully exploited,
3. The lifespan of a solar PV installation is short hence recovery of investment made is not possible,
4. There is no reliable technology for bulk solar energy storage hence not possible to rely on solar energy sources when there is no solar radiation,
5. In the field of solar PV electrical energy, there is limited knowledge and expertise.
6. Government has not put proper policies to encourage ordinary citizens and investors to venture in to solar energy.
7. Solar cells and other equipment necessary for electrical energy generation from solar energy are not easily available to consumers at the right quality and prices.
8. The general public has no concern for environmental pollution from use of fossil fuels for electricity generation and that is why electricity generation from solar panels (renewable source) is not very popular.

2. LITERATURE REVIEW

In this section, general electrical energy situation in Kenya and Hungary will be investigated. This will call for study of past literatures and relevant government institutions websites on electricity sources and the position taken by solar electrical energy as part of the gross annual electricity production. I intend to find out trend in solar power development for the last five to ten years. Interest will be in emerging technologies in countries where great progress has been made. With Kenya being a developing country, I will be looking at what could be borrowed from developed countries doing well in solar electrical energy exploitation.

2.1 Electrical Energy Situation in Kenya

According to the 2019 population census, there are 47.6 million people living in Kenya ('2019 Kenya Population and Housing Census: Volume II', 2019). Of this, roughly 60% have access to national grid electricity connection, and 10% off grid connections, which majorly include small scale household based solar panels. The remaining about a quarter, entirely relies on biomass as the only absolute energy source ('ENERGY PROFILE', 2020).

2.2 Power Sector Institutions

All energy institutions are under the ministry of energy as shown in the organizational structure, figure 1 below. The various institutions are to enhance distributed responsibilities lather than a centralized system in energy sector.

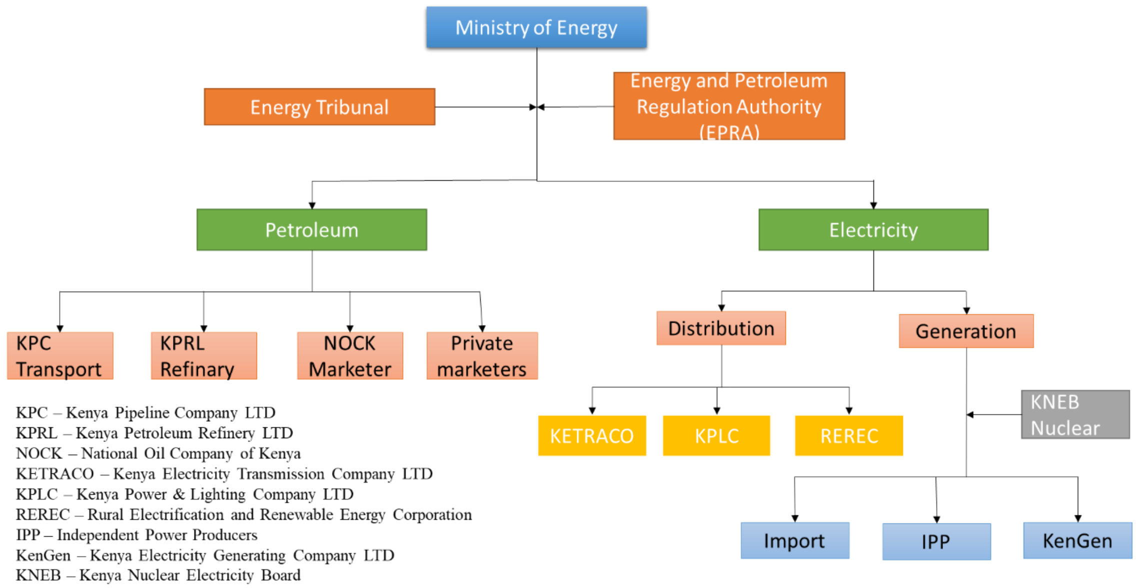

Figure 1: Kenyan Energy sector institutions (My own sketch). data from ministry of Energy – Kenya website (Departments – Ministry of Energy)

2.3 Electrical Energy Consumption

The electrical energy consumption at 2015 stood at an average of 167 kWh pa capita annually, translating to about 7.9 billion kWh of total annual consumption (*Electric power consumption (kWh per capita) - Kenya | Data*, 2015). Kenya Electricity Generating Company (KenGen) is Kenya's major electricity generation company, supplying more than three quarter of all power consumed nationwide. Rural Electrification and Renewable Energy Corporation (REREC) is taking part in harnessing of renewable energy as evident from the Garissa 55MW grid connected solar power plant commissioned in 2019. It intends to construct off grid solar power plant in various counties in line with the government vision 2030 plan of improve Kenyan's standard of living by supplying electric power to households.

2.4 Energy Sources

The table 1 below is a summary of Kenyans energy sources.

Source	**MW**	**Percentage (%)**
Hydropower	820	42.954
Geothermal	707	37.035
Wind	26	1.362
Solar	55	2.881
Thermal	254	13.305
Biomass	28	1.467
Off grid	19	0.995
Total	**1909**	**100**

Table 1: Kenyan electrical Energy sources Data from ministry of energy Kenya; (Energy Sources Statistics – Ministry of Energy, 2022)

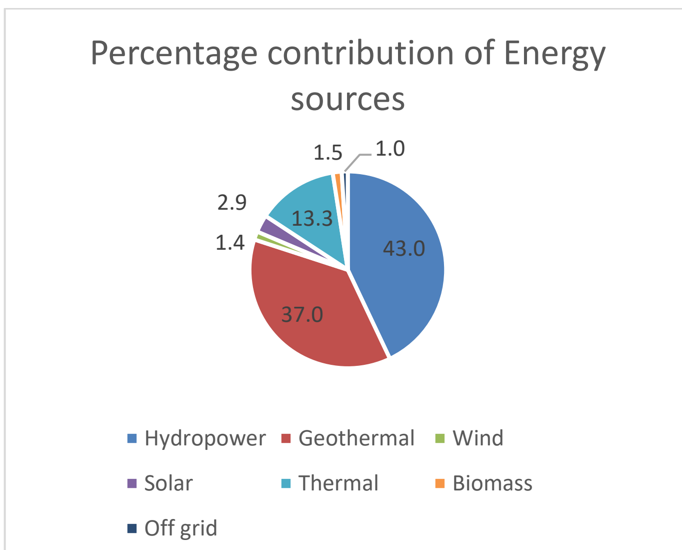

Figure 2: Energy sources. (own construction) data from (Energy Sources Statistics – Ministry of Energy, 2022)

2.41 Hydro-Electric Power (Hep) in Kenya

In Hydro Electric Power (HEP), water stored in dams provides potential energy that is then transformed into kinetic energy to run the turbines. The rotating turbine is linked to the generator rotor through a shaft. When the generator rotor is run by the shaft, it produce electrical power (Kishor, Saini and Singh, 2007).

The rivers that form the basis for Hydro power generation in Kenya have their sources from the forested catchments/water towers mainly from Mt. Kenya, the Aberdares, Charangani and Mau catchment basins. The total estimated capacity of Kenya's river basin to harness HEP is 1,500 MW (Kengen, 2022). Presently, total installed capacity is 818MW. Kenya's HEP comes from the following stations as shown on table 2 below:

S/NO	**RIVER**	**HEP NAME**	**INSTALLED CAPACITY(MW)**	**YEAR COMMISSIONED**
1.	Tana	Kiambere	168	1988
		Gitaru	225	1999
		Kamburu	94	1974
		Masinga	40	1981
		Upper tana	20	2010
		Kindaruma	72	1968
2.	Sondu Miriu	Sondu Miriu	60	2007
		Sang'oro	21	2013
3.	Turkwel	Turkwel	106	1991
4.	Gucha	Gogo	2	1957
5.	Maragua	Wanji	7.4	1952
		Mesco	0.38	1930
6.	Sagana	Sagana	1.5	1955
7.	Sosiani	Sosiani	0.4	1955
TOTAL			**818**	

Table 2: Kenyan Hydro-electric power stations

2.42 Geothermal Energy

Geothermal energy is the naturally occurring heat held within the earth's crust. This heat energy is exhibited on the earth's surface in the form of fumaroles, hot springs and hot-altered grounds. To extract this energy, wells are drilled to tap steam and water at high temperatures (250-350 ^{o}C) and pressures (600-1200 PSI) at depths of 1-3KM. The internal structure of earth and the physical processes taking place there are related to the source of this heat. It emanates from residual heat which was produced by planetary accretion, heat generated by radioactive decay of potassium (K), Thorium (Th) and uranium (U) isotopes (McCay *et al.*, 2014), and possibly heat as a result of overlying mass.

To generate electricity, steam is piped to a turbine, which rotates a generator to produce electrical power. Kenya's first geothermal plant came into effect in 1981 at Olkaria I (Hung, Resources and Xuan, 2001). Currently there is 707.31 MW total installed capacity, representing 38% of total electrical power generation. Geothermal energy will supply more than half of the nation's installed capacity, with a projected capacity of 5530 MW, according to the Kenyan ministry of energy. Various geothermal power plants are as shown on table 3 below.

Station	MW	Year Commissioned
Olkaria I	45	Three phases; 1981, 1982 and 1985
Olkaria II	105	2003
Olkaria IV	149.85	2014
Olkaria IAU	150.52	-
Olkaria V	173.40	2022
Eburru	2.44	-
Wellhead	81.10	-
Olkaria Modular	50	2019
Olkaria 1 – Unit 1 Rehabilitation	17	2019
Olkaria 1 – Unit 2 Rehabilitation,	17	2020
Olkaria 1 – Unit 6	70	2020
Olkaria 1 – Unit 3 Rehabilitation	17	2020
Menengai 1 Phase I – Stage 1,	103	2020
Olkaria Topping	47	2021
Menengai I – Stage 2	60	2022
Olkaria 6 PPP	140	2022
Olkaria 7	140/	2023
Eburru 2	25	2023
GDC Wellheads	30	2023
Olkaria 8	130	2024
Menengai III	100	2024
Baringo Silali – Paka I	100	2024
Marine Power Akiira Stage 1	70	2024
Total Pending	**1,116**	
Total after completion	**1823.31**	

Table 3: Kenyan Geothermal power stations

2.43 Wind Power

The use of air flow through wind turbines to generate electricity is what is called wind power or wind energy. Wind power utilization dates back to medieval times. It is a sustainable and renewable energy that has become popular across the world over the recent years, perhaps as a result of its low electricity production cost, low contamination and abundance of wind as a resource. In 2018, the global wind power capacity stood at 600GW, with China leading amongst the world's wind energy producers (Zafar and Staubach, 2018). Today in Kenya, about 26MW, which is 2% of KenGen's installed capacity, comes from wind energy. The first wind farm to be built in Kenya and in East Africa as a whole, was at Ngong Hills, Kenya. (Kengen, 2022).

Figure 3: KenGen's wind farm in Ngong hills. Source, KenGen Website

Wind Power Plants in Kenya

Project	MW	Completion date
Ngong 1 phase I	5	2021
Ngong 1 phase II	7	
Ngong 2	14	

Table 4: Kenyan Wind power station, Data from KenGen website

2.44 Solar Power in Kenya

Kenya is geographically located at a vantage position to enjoy significantly a good amount of solar energy resource nearly all year round (Kiplagat, Wang and Li, 2011). According to Energy and Petroleum Regulatory Authority (EPRA), only 1% of Kenya's solar potential has been exploited (*Solar Energy – Renewable Energy Portal*, 2023). Rural Electrification and Renewable Energy Corporation (REREC) has managed to complete one solar power plant, 55MW grid connected at

Garissa. REREC Plan to construct solar power plants in identified fourteen counties is underway. Construction of a 40MW solar power plant at seven forks by KenGen is still ongoing.

The table 5 below shows documented solar power projects by KenGen and REREC.

Name of Project	MW	Year of completion	Comments
PV grid Garissa	50	2019	PV
Gitaru solar	40	In progress	PV
Total	**90**		

Table 5: Kenyan solar power station, Data from KenGen and REREC websites

2.45 Thermal Power Plants

Coal is the commonly employed fuel for thermal power generation in many countries. Heavy fuel oil, diesel and natural gas are also used for coal power plants to generate electricity (Al-Degs *et al.*, 2014). In Kenya, thermal energy engines are fired on heavy fuel oil (HFO). KenGen has two thermal power plant in Kipevu and two other smaller one in Muhoroni. The table 6 below shows thermal power plants in Kenya, managed by KenGen.

Station	**MW**	**Year of Completion**
Kipevu I	74	1999
Kipevu II	120	2001
Muhoroni GT1	30	1987
Muhoroni GT2	30	1999
Total Completed	**254**	

Table 6: Kenyan thermal power plants, Source; KenGen Website (Power Plants, 2023)

2.5 ENERGY SITUATION IN EUROPEAN UNION AND HUNGARY SPECIFICALLY

The energy sector in Europe is characterized by a significant gap between its energy production and consumption. While the EU and the UK consume about 12% of the energy available globally, just 5.4% of the total produced globally is produced domestically.(De Rosa *et al.*, 2022). Much of the energy consumed in EU comes from the non-renewable sources. The table 7 below show the primary energy production and percentage contribution of each source to total primary energy sources in the EU.

S/No	Energy source	Percentage Contribution
1.	Natural gas	24.14
2.	Oil	37.23
3.	Nuclear power	13.52
4.	Coal	15.46
5.	Renewable and others	9.57
6.	Import electricity	0.08

Table 7: European Union primary energy sources, percentage contribution by various sources to total primary production. Source; (Sáfián, 2014)

2.6 Hungarian Situation

With around 9.7 million citizens, Hungary is a nation in Central Europe. It is a medium-sized European Union member state. (Bakó, Berkes and Szigeti, 2021). The total primary energy consumption of Hungary has been fluctuating over the years and is estimated at about 1100PJ annually. The value was 1157.5PJ in 2021 while total primary energy production was 440.8PJ annually (*Hungarian Central Statistical Office*, 2022). Hungary relies on imported energy source, mainly natural gas from Russia, which accounts for over 70% of total energy requirements. The natural gas plays an important role in heating and electrical power generation. Non renewable energy sources account for over 90% of total Hungarian primary energy supply. This is in spite of the fact that Hungary has poor fossil fuel stocks. Most of the coal stocks have been depleted or have become so uneconomical to exploit apart from the low calorific value lignite, which provide 8-9 million tons annually. The total lignite stock is estimated at 4.45 billion tons, forming the largest fossil stock for Hungary. Natural gas and crude oil stocks are negligible. Hungary’s main electrical power source is nuclear power plant at Pak, with a capacity of 2000MW, and accounts for 40% of total electrical power consumption. Nuclear energy is regarded as domestic source though fuel rods are imported (Sáfián, 2014). Table 8 below show the primary energy production and percentage contribution in Hungary for the year 2021.

S/No	Hungary's Primary Energy source	Amount (PJ)	Percentage Contribution (%)
1.	Natural gas	48.9	10.90
2.	Nuclear power	174.8	38.95
3.	Coal	32.3	7.20
4.	Hydro power	0.7	0.16
5.	Combustible renewables and wastes	123.2	27.45
6.	Petroleum and petroleum products	45.6	10.16
7.	Wind power	2.4	0.53
8.	Other non-combustible renewable	20.9	4.66
Total		**448.8**	**100**

Table 8:Hungary's Primary Energy production, data source; (Hungarian Central Statistical Office, 2022)

In Hungary, renewable energy sources contribute about 10% of total energy consumption. Table 9 below shows exploited renewable energy sources and percentage contribution for the year 2020.

S/No	Hungary's primary renewable Energy source	Percentage Contribution (%)
1.	Biomass	30.1
2.	Biogas	5.9
3.	Wind	11.8
4.	Hydro power	4.4
5.	Renewable part of municipal waste	3.0
6.	Solar power	44.5
7.	Geothermal	0.3
Total		**100**
Percentage share of renewable energy sources in total energy consumption		**11.1**

Table 9: Hungary's renewable energy share, Source; (6.1.1.12. Share of electricity produced from renewable energy sources, 2020)

2.61 Solar Photovoltaic Electrical Power in Hungary

Comparing to majority of the nations in the European sub-region, Hungary has a higher solar energy potential that is barely utilized. She receives 1280 kWh/m^2 of horizontal solar radiation yearly, with its annual sunlight hours ranging from 1950 to 2150 hours. (Atsu, Seres and Farkas, 2021). Figures 4 below show the Global Horizontal solar radiation (GHI) intensity of Hungary and figure 5, the photovoltaic power potential in Europe.

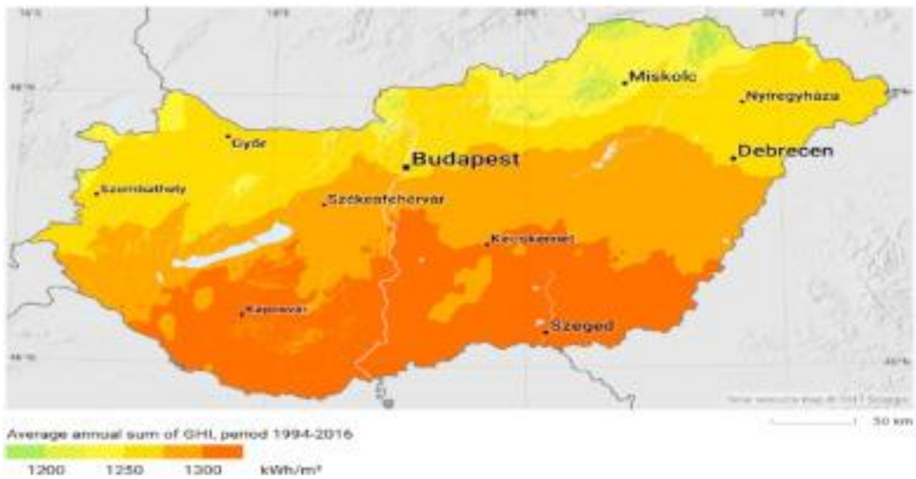

Figure 4: Global Horizontal solar radiation (GHI) intensity of Hungary, Source; (Atsu, Seres and Farkas, 2021)

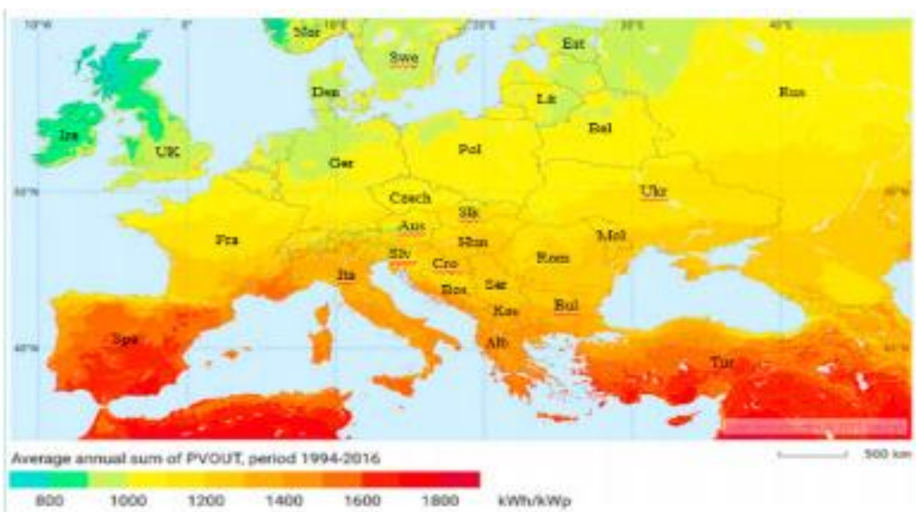

Figure 5: photovoltaic power potential in Europe, Source; (Atsu, Seres and Farkas, 2021)

In Hungary, the annual average PV energy potential ranges between 1050 and 1450 kWh/kWp. The total installed grid-connected solar PV system capacity by end of 2018 was 790MWp. This means that every inhabitant gets about 80Wp from solar PV. The government has been promoting exploitation of solar PV by creating supportive policies. Hungary is ranked top ten in Central Eastern and South-Eastern European countries as being attractive to solar PV investment (*Hungary's Solar Photovoltaic (PV) Power Market: Outlook 2018-2027 - ResearchAndMarkets.com | Business Wire*, 2022). Table 10 below shows large PV plants in Hungary as of 2021.

S/NO	Name of Plant	Capacity (MW)	Location	Year of Commission
1.	Kaba Solar Park (UC)	43	Kaba	2020
2.	Kapuvár Solar Park	25	Kapuvár	2020
3.	Paks Solar Park	20.6	Paks	2019
4.	Mátra Solar Power Plant	20	Bükkábrány	2019
5.	Fels˝ozsolca Solar Park	20	Fels˝ozsolca	2018
6.	Duna Solar Park	17.6	Százhalombatta	2018
7.	Szügy Solar Park	16.5	Szügy	2019
8.	Mátra Solar Power Plant	16	Visonta	2015
9.	Tiszaszo˝lo˝s Solar Park	11.6	Tiszasz˝ol˝os	1019
10.	Pécs Solar Park	10	Pécs	2016
11.	Csepreg	5.5	Csepreg	2018
12.	Vep	4.5	Vep	2018
13.	Monor	4	Monor	2018
14.	Sajóbábony	0.5	Sajóbábony	2016
15.	Szombathely	0.385	Szombathely	2015
16.	Újszilvási solar park	0.4	Újszilvási	2011
17.	Bojt	0.49	Bojt	2014

Table 10: Hungarian solar PV power plants

2.62 Nuclear Electrical Power

It is important to discuss nuclear electrical power in Hungary because it accounts to 40% of total electricity generation. There are four units of nuclear power plants situated at Paks, each generating 500MW. The current four units are planned to close sequentially between 2032 and 2037, after 50 years of operation. The Hungarian authority target 90% electricity generation from carbon-free energy by 2030. To achieve this, the government will have to phase out coal in the power sector and replace it by increasing solar PV and nuclear power capacity (International Energy Agency, 2022). Table 11 below shows the various units of Paks nuclear power plants and other details of each of them.

S/NO	UNIT	NET POWER	GROSS POWER	COMMISSION	SHUT DOWN
1.	Paks-1	470MW	500MW	1982	2032
2.	Paks-2	443MW	500MW	1984	2034
3.	Paks-3	443MW	500MW	1986	2036
4.	Paks-4	473MW	500MW	1987	2037

Table 11: Hungarian Nuclear power plants

2.7 Challenges Facing Solar PV Exploitation

From the various literatures explored, similar challenges are faced in the attempt of exploitation of solar electrical energy by PV system in the two countries. They are as described below;

1. Technical challenges. This is because the current PV modules have a low conversion efficiency of 40% maximum. Solar energy storage for stand-alone PV system has remained a great challenge. This is because the readily available battery storage system is not effective for bulk energy storage. In addition, batteries are quite expensive. There is also the challenge of electronic waste disposal after the life span of PV equipment, Declining raw material for manufacturing PV modules and related equipment, among others.
2. Economic burden in that investors in solar energy have a difficulty in accessing finance assistance. Solar projects have a high initial capital investment and most financial institution are usually not willing to finance. majority of the end users especially rural households in developing countries like Kenya have low purchasing power. Introduction of counterfeit PV products in the market is a major bottleneck.
3. Lack of skilled personnel in the solar PV industry with required skills to maintain solar infrastructure and low number of engineers who can build the infrastructure.

3. SOLAR PHOTOVOLTAIC SYSTEMS TECHNOLOGY BACKGROUND

The sun is a gigantic nuclear reaction in which approximately 4 thousand tons of hydrogen is transformed into helium per millisecond (Goswami, 2015). In fact, all kind of life and energy on Earth is possible courtesy of the sun and its energy which comes in form of solar radiation; (Kalogirou, 2013). The sun determines climate and weather patterns on earth.

Solar energy is the radiant light and heat from the Sun that is harnessed by numerous rapidly evolving technologies, such as solar heating, photovoltaic, solar thermal energy, solar architecture, molten salt power plants, and artificial photosynthesis. It is an important source of renewable energy. Techniques of capturing solar energy are typically categorized as either passive solar or active solar, depending on how solar energy is captured, disseminated or transformed into solar power. Active solar techniques include the use of photovoltaic systems, concentrated solar power and solar water heating to harness the heat energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light-dispersing properties, and designing spaces that naturally circulate air.

Solar energy can be harnessed for electrical generation through two main ways:

- Photovoltaic (PV)
- Concentrated solar power (CSP)

3.1 The working principle of solar PV

A photovoltaic devise (module) is made up of a series of silicon cells in which a p-n junction drives the electrons (generated by utilizing the band gap of the semiconductor) in a certain direction. (Goswami, 2015). Silicon is a semiconductor with atomic number 14 and band gap of 1.17. All solar cell devices generate electricity through a series of light absorption, electronic excitation, and charge separation events. First, the silicon cell absorbs solar radiation leading to excitation of the valence electrons which moves to conduction band. As they move, they leave holes which are in turn occupied by other electrons. This constitutes the flow of electric current (photovoltaic effect). The generated current is in DC form.

3.2 Concentrated solar power (CSP)

It is employed in the large-scale production of electrical power. Solar rays are concentrated and directed by use of mirrors. The rays heat fluid, which creates steam to drive a turbine that runs the generator. CSP is superior to a solar PV power plant in that it can be equipped with molten salts that store heat, thereby making it possible to generate power even at night (Nwaigwe, Mutabilwa and Dintwa, 2019).

3.3 Grid connected solar electrical system

The system can either be pure photovoltaic (PV) system, pure concentrated solar power (CSP) system or hybrid (PV-CSP) system. A PV system consists of PV generator i.e., an array of solar modules that generate direct current. An inverter which transforms the direct current (DC) output of the solar modules to alternating current (AC) which most commercial appliances use. Despite changing load conditions, the inverter must provide constant voltage and frequency as well as supply or absorb reactive power in the case of reactive loads. PV system use batteries for energy storage. CSP use mirrors to concentrate heat energy at a point. This heat is used to heat a fluid to produce steam. The steam drives the turbine, which run a generator to produce electricity. The system employs thermal heat storage where heat energy is stored in molten salt and is used to generate electricity when sunlight is not available. Hybrid PV-CSP is a combination of both PV and CSP systems which offer several advantages compared to an individual system. The PV-CSP hybrid system can generate electricity with greater power quality as compared to PV systems alone. Also, the price of producing electricity can be lower when compared to using a CSP system alone. The overall generating efficiency will be greatly improved in the PV component and the CSP component of the hybrid system. Hybrid PV-CSP projects have been established and operationalized in countries like China, Chile and Morocco (Iñigo-Labairu, Dersch and Schomaker, 2022), (Ju et al., 2017).

3.4 Solar Home System (SHS)

This system is used for domestic electrical power generation, usually in small scale. It is made up of a Photovoltaic cell, generally referred to as a solar panel, a charge controller, energy storage battery/batteries and power inverter. The solar panel converts sunlight energy into DC electrical energy. The charge controller has two functions, to monitors and controls voltage and current coming from the PV module and going to the battery, and to controls the charging and discharging of the battery. This protects batteries from damage, hence extend their lifespan. The battery stores the DC electrical energy for use when there is no sunlight. The inverter converts DC power produced by the PV Module or the one stored in the battery into AC power to enable powering of AC loads (Osaretin, 2015). The complete SHS is as shown on the figure below.

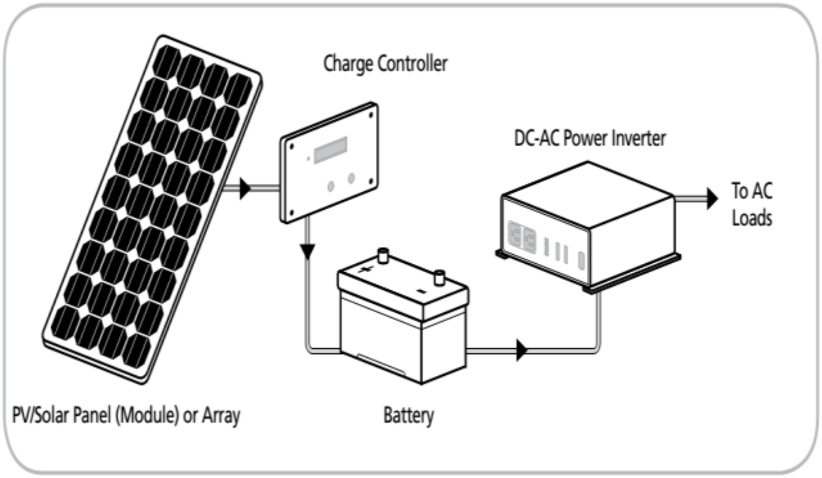

Figure 6: Solar Home System schematic diagram, Source; (Osaretin, 2015)

3.5 Photovoltaic (PV) Modules

In the year 1839, a French physicist by the name Alexandre-Edmond Becquerel discovered Photovoltaic effect. There was not much development in solar electrical energy made until 1946 when Russel Ohl came up with the first silicon made modern solar cell. Earlier photovoltaic solar cells were thin silicon wafers that transform sunlight energy into electrical power (Sharma, Jain and Sharma, 2015). The current PV technology works on the principle of electron-hole creation in each cell composed of two different layers (p-type and n-type materials) of a semiconductor material, as shown on figure 7 below.

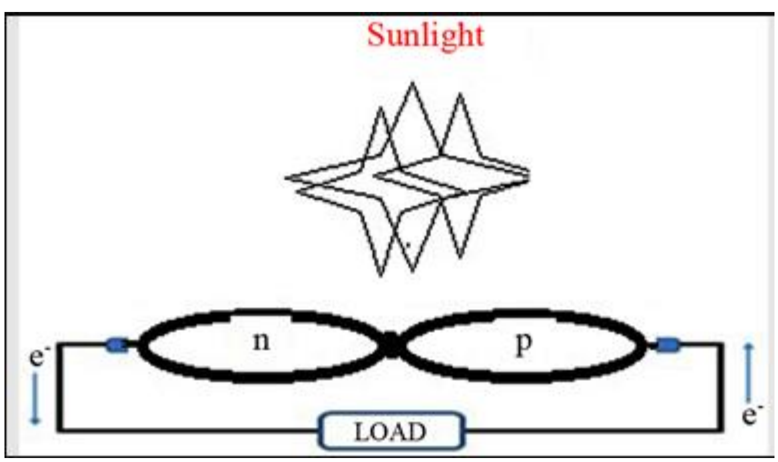

Figure 7: P-n junction solar cell on load, Source; (Sharma, Jain and Sharma, 2015)

Various materials are used to manufacture PV solar cells and include silicon (single crystal, multi-crystalline and amorphous silicon), cadmium-telluride, copper-indium-gallium-selenide and copper-indium-gallium-sulfide. Depending on which material is used, PV solar cells can be categorized into various classes as shown on figure 8 below;

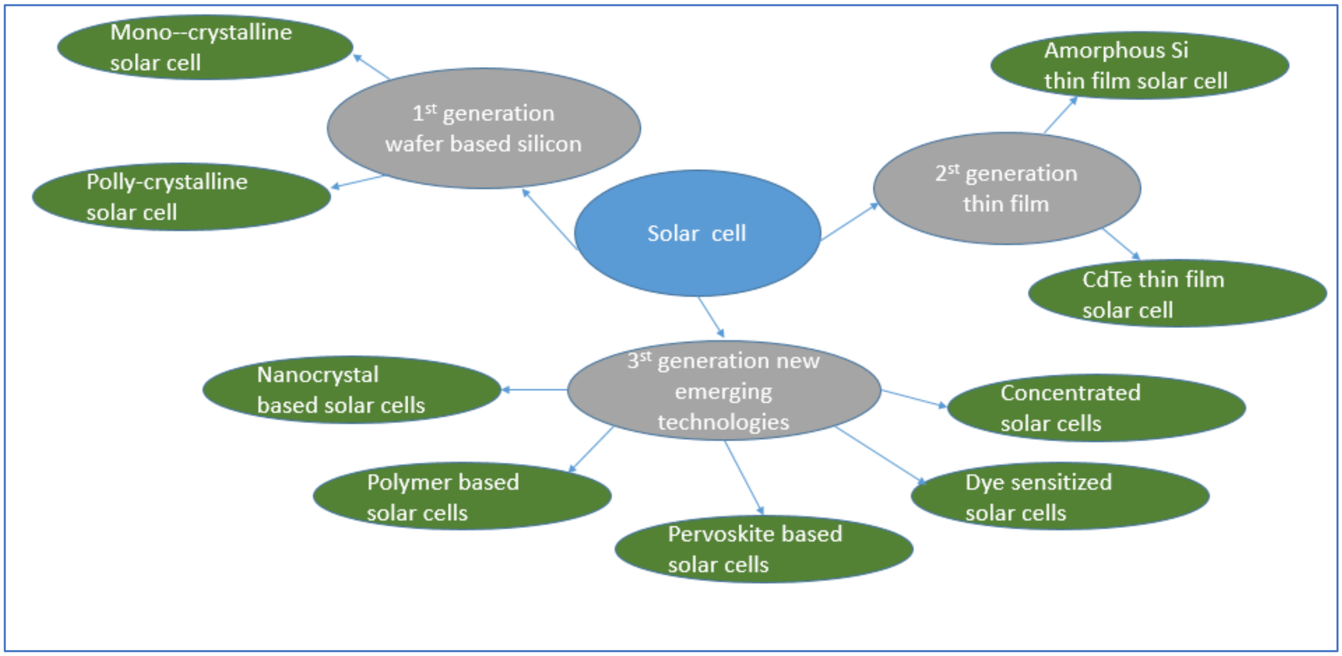

Figure 8: PV solar cell categories, (own Sketch), information from (Sharma, Jain and Sharma, 2015)

3.51 First Generation Solar Cell-Wafer Based

First generation solar cells are manufactured on silicon wafers. It is the most popular technology because it results to high power efficiency. There are two categories of solar cells in this wafer-based technology;

- Mono-crystalline silicon solar cell
- Multi-crystalline silicon solar cell.

Mono-crystalline silicon solar cell

Mono crystalline solar cells are manufactured from single crystals of silicon by Czochralski process. In this process, Silicon crystals are sliced from the big sized ingots. The large single crystal production process requires specific processing as recrystallizing the cell is more expensive and takes several stages. Their efficiency lies between 17%-18% (Bertolli, 2008).

Polycrystalline Silicon Solar Cell

Polycrystalline PV modules are manufactured by combining several crystals together to form a single cell. This technology is cheaper than production of monocrystalline solar cells. They are the most sold solar cells in the market currently. Though they are slightly cheaper to produce compared to monocrystalline cells, their efficiency is lower and it's approximately 12%-14% (Jayakumar, 2009).

3.52 2nd Generation Solar Cells—Thin Film Solar Cells

They consist of thin film and amorphous silicon. They are cheaper to produce compared to first generation silicon wafer based solar cells. Thin film solar cells have a thin light absorbing layer in the order of 1 μm thickness (Chopra, Paulson and Dutta, 2004). They are of three categories;

- Amorphous Silicon (A-Si) solar cell
- Cadmium Telluride (CdTe) Solar Cell
- Copper Indium Gallium Di-Selenide (CIGS) Solar Cells

3.53 3rd Generation Solar Cells

Third generation solar cells technology is promising though not much research has been carried out on it. Cells in this category include the following;

- Concentrated solar cells.
- Pervoskite based cells
- Nano crystal-based cells.
- Polymer based cells.
- Dye sensitized solar cells.

The most promising technologies in this generation is the concentrated solar cells and Pervoskite based cells because they offer high conversion efficiency. More details about the two are provided below.

3.54 Concentrated Solar Cells

Concentrated photovoltaic (CPV) solar cell is the most modern technology in the solar cell research and development. The primary goal of concentrated cells is to concentrate sunlight onto a small area of the solar cell in order to capture a great amount of solar energy there, figure 9 below. This is accomplished by employing huge mirrors and lens arrangements. (Bertolli, 2008). The sun radiation concentrated at one point produces a large amount of heat energy, thus necessitating a cooling mechanism to prevent thermal destruction of the solar cell. (CPV) can be categorized as low, medium, and high concentrated solar cells depending on the power of the lens systems. The system has several advantages such as high efficiency of above 40%, has low semiconductors requirements.

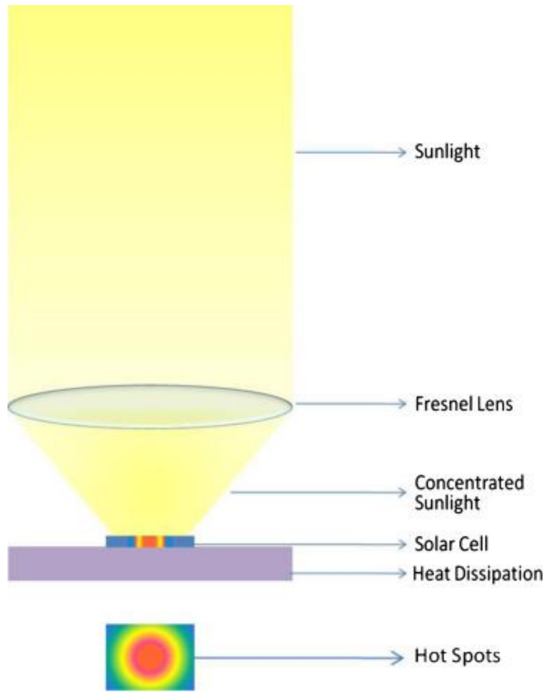

Figure 9: Concentrating photovoltaic solar cell, Source (Baig, Heasman and Mallick, 2012)

3.55 Perovskite Based Solar Cell

Perovskites are a class of compounds defined by the formula ABX_3 where X represents a halogen such as I^-, Br^-, Cl^-. A and B are cations of different size (Sharma, Jain and Sharma, 2015). This is a recent technology and has several advantages over Silicon based and thin film solar cells one being high efficiency of up to 31%. Their fabrication process is much cheaper compared to earlier technologies. The main disadvantages of these cells are their low stability and durability. The material deteriorates quickly leading to drop in their efficiency.

3.6 Solar Electrical Energy Storage

One of the main challenges with RES such as solar and wind energy is that they can't produce a steady power because production varies with time, days and seasons. In order for a renewable energy source to become more dependable as a primary energy source, energy storage is a crucial factor. Energy from, for example solar must be stored when it is available in plenty then released when it is not available (Amirante, 2017). In power systems, energy storage is used in three regimes, charging, storage and discharge. Several options for electrical power storage are available (Kousksou , 2014). In this section, I'm going to discuss some viable options.

3.7 Battery energy storage systems

Batteries are electrochemical devices which have the ability to produce electrical energy from the chemical energy stored in them. Energy conversion is through electrochemical reactions within them. The reaction basically is the movement of electrons from one terminal to the other through an external electrical circuit. A battery consists of a one or many cells, connected in series or in parallel or both depending on the anticipated output voltage and capacity (Amirante, 2017). Each cell consists of;

- The cathode which provides electrons to the load and undergoes oxidation during the electrochemical reaction;
- The anode which receives electrons and undergoes reduction during the reaction;
- The electrolyte which is the medium for electrons movement between the anode and the cathode;
- The insulator between the anode and the cathode.

Various battery system technologies include the following;

- Lead-acid batteries
- Nickel-based battery
- Lithium-based batteries
- Sodium-sulfur batteries (NaS)

The most common battery storage systems for bulk power are Lead-acid batteries and Nickel-based battery. With the rise of electronic devices such as mobile phones, computers and other portable electronics, Lithium-based batteries have also increased in production since they are most commonly used with these devices.

3.8 Hydrogen based energy storage (HES)

Hydrogen is among the most efficient, clean and light fuel. It does not occur naturally in the environment and has to be produced (Winter, 2009). Like electricity, it must be produced and transported to consumer stations, but can be stored. There are four main technologies of hydrogen storage currently but two of them are much more explored (Sherif, Barbir and Veziroglu, 2005). These technologies are;

- Hydrogen pressurization
- Hydrogen adsorption in metal hydrides
- Adsorption of hydrogen on carbon nano-fibers
- Liquefaction of hydrogen

Hydrogen can be used directly in fuel cells or can be used to produce electricity. Fuel cells uses hydrogen and oxygen to produce electricity and water as shown in figure 10 below.

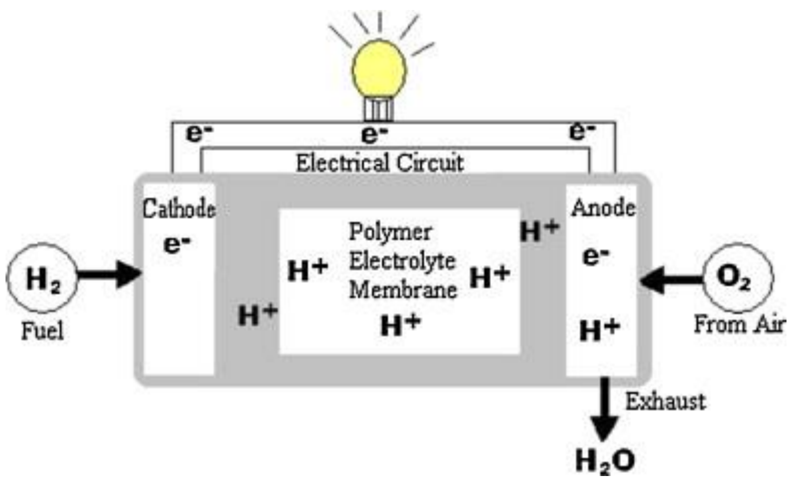

Figure 10: Hydrogen fuel cell, Source: (Mekhilef, Saidur and Safari, 2012)

The reversible hydrogen fuel cell could also use electricity and water to produce hydrogen and oxygen. Hydrogen fuel cells have several advantages over other battery technologies such as high energy density, applicability at small and large scale. In terms of their useful life cycle, they are estimated at over fifteen years and 20, 000 charge and discharge cycles (Winter, 2009). Hydrogen storage technology is considered one of the most promising technologies for energy storage in renewable energy exploitation. Some shortcoming with hydrogen storage fuel cells is that they are expensive compared to other battery technologies and have low round trip efficiency (20–50%) (Chen *et al.*, 2009).

3.9 Flow battery energy storage (FBES)

Flow batteries also called redox flow batteries is an emerging technology. In this system the liquid electrolyte is contained in separate tanks. Charging and discharging is achieved through a reversible chemical reaction between the two electrolytes, figure 11 below.

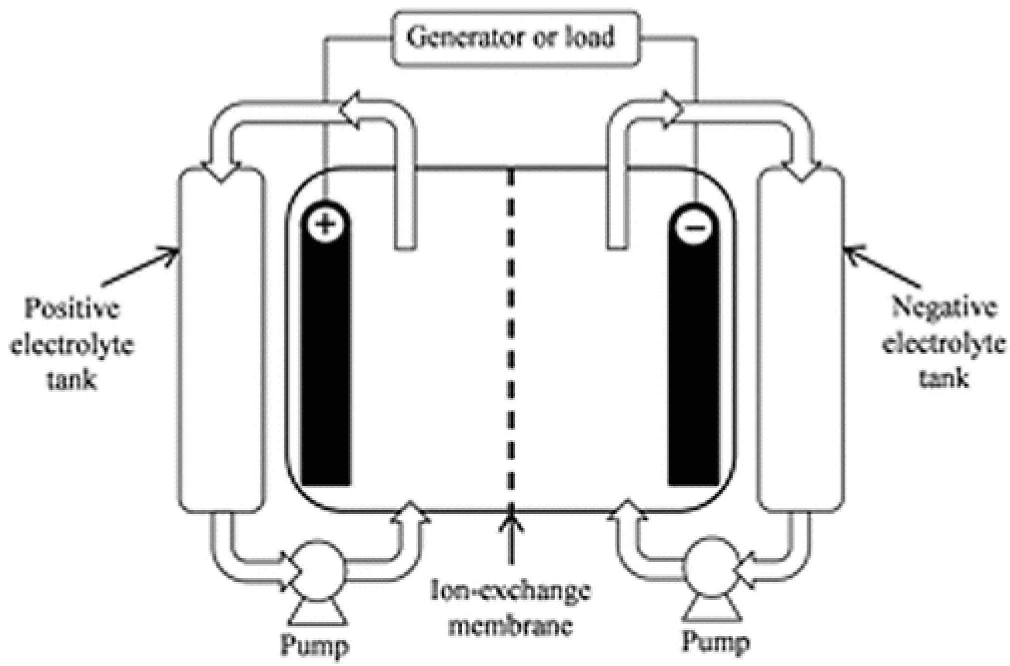

Figure 11: Flow battery, Source: (Kear, Shah and Walsh, 2012)

When the battery is operating, the electrolyte is pumped through the electro-chemical reactor where a redox reaction occurs producing electricity. Storage of electrolyte separate from the reactor is of advantage in that the specification of the battery are flexible meaning that the power and the energy content of the system can be specified independently. It also offers the advantage that the electrolyte can be replaced or increased easily. Redox batteries can produce energy continuously at a high rate of discharge for up to 10 hours (Ponce de León *et al.*, 2006). Their energy capacity is easily adjustable because it depends on the volume of the stored electrolyte. This minimizes installation cost for big systems. Other important feature of redox batteries is that they can be completely discharged without any damage and very low self-discharge rate since electrolytes are stored in different sealed tanks. Flow batteries have long life and low maintenance (Rabiee, Khorramdel and Aghaei, 2013). They come in three categories;

- Vanadium redox battery (VRB)
- Polysulphide Bromide Batteries (PSB)
- Zinc bromine battery (ZnBr)

3.10 Conclusion

In this section of technology background, I have explored the various scales which solar PV can be installed to generate electricity, in large scale grid connected/off grid PV system or small-scale solar home system (SHS). I have highlighted major components and explained their functions in each scale of implementation. For the PV cells and batteries, an investor would review the various options and make a decision on what technology to choose based on such aspects as efficiency, cost, environmental friendliness and durability.

4. SOLAR PV LEGAL BACKGROUND

4.1 Kenya Vision 2030

Kenya’s developmental road map is anchored on development goals. The vision 2030 is long term development goal that was developed in 2008 and was to be actualized until 2030. The aim was to create a newly industrializing, middle-income country providing a decent life to all its citizens in an environment that is clean and secure (*KENYA VISION 2030, THE POPULAR VERSION*, 2008). A comprehensive and interactive stakeholder consultation approach was used in the formulation of the vision. There are three pillars that support the 2030 Vision, the economic, social and political pillar. The economic pillar seeks to raise the well-being of every Kenyan through an economic development program that spans the country's regions and targets an annual average Gross Domestic Product (GDP) growth rate of 10%. The social pillar works to create a society that is fair, coherent, and safe with social equity. The political pillar aspires to the realization of a democratic political system built on issue-based politics, which upholds the rule of law and safeguards the rights and freedoms of all Kenyans.

Development projects recommended under Kenya’s vision 2030 will increase energy demand. Currently Kenyan energy costs are higher compared to states of her category. Realization of vision 2030 will call for Kenya to generate more energy at a lower cost. This can only be possible through exploitation of renewable energy sources that shows high potential such as solar and geothermal energy.

4.2 Legal policies and regulations

Most development projects are planned and executed by the government for countries. This is done through formulation of appropriate policies and regulations. For solar PV energy in Kenya, the government has made a considerable milestone in promoting exploitation through various policies and regulation. The Ministry of Energy is in charge of developing and carrying out energy policies, with a mandate to control players in the energy sector and guarantee energy security, efficient use, and energy conservation. (George *et al.*, 2019). In this section, I highlight important regulatory policies and tariffs used by Kenya to promote exploitation of solar electrical energy.

The first significant legal framework was formulated in the sessional paper no. 4 of 2004 on energy. The aim of this regulation was to promote adequate access to quality energy and energy services at a cost-effective price while protecting the environment. The extra environmentally friendly electrical energy was to come from exploitation of high potential renewable energy of solar and wind. This paper advocated for expanded sources of clean energy that directly promoted exploitation of solar energy in Kenya (MoE, 2004).

The 2017 energy bill was seeking to authorize energy distributors and retailers to supply electricity to end users. It gave dealers authority to procure energy, inspect premises, metering, selling, billing and collecting revenues from end users. The government, through EPRA was required to give license to dealers and oversee their operations to ensure that they operated in accordance to the law. This gave opportunity for investors to venture in new electrical energy sources especially renewable energy source since they could sell electricity to consumers legally. This was to end the KPLC monopoly in the electrical power distribution and create a level ground for all players (Government of Kenya (Ministry of Energy and Petroleum), 2017). The end user could choose from who to get electrical power depending on reliability, quality and cost of their product.

The energy (solar PV) regulation of 2012 formulated by then energy regulation commission, now EPRA, provided the much-needed policy framework. It defined key players in the solar energy sectors to give them legal recognition, ranging from solar equipment manufacturers, vendors, promoters and technicians. The main objective was to improve quality of solar product in the market and ensure end user satisfaction (Energy Regulatory Commission, 2012). This showed the government interest in promoting exploitation of solar energy especially electrical power. Consequence to this regulation and in the spirit of promoting quality solar products, the regulation required suppliers to guarantee the following minimum warranties to solar products;

S/NO	**COMPONENT**	**WARRANTY PERIOD**
1.	Solar panel	20 years
2.	Inverter	10years
3.	Battery	1 year
4.	Light bulbs/ LEDs	1 year
5.	Light fittings/device	2 years
6.	Controller/regulator	10 years

Table 12: solar products warranty periods in Kenya, source:(Energy Regulatory Commission, 2012)

4.21 Feed in Tariff (FiT) Policies in Kenya

As a means of encouraging private sector investment, FiT intends to boost the production of electricity and raise the nation's ranking of renewable energy sources. It enables IPPs to sell electricity generated from RES to designated buyers at a fixed price for a set period of time. The FiT policy framework includes renewable energy sources like wind, biomass, small hydro, solar, biogas, and geothermal. (GoK, 2019). In developed countries, the main objective of FiT policies is to relocate production of electrical energy from fossil fuels to renewable energy sources, while in developing countries, the main aim of these policies is to encourage investments in renewable energy sector to enhance the inadequate sources of energy supply. The Kenyan government developed a FiT policy for renewable energy electricity with the goal of encouraging private sector investors to renewable energy electricity generation as a channel for modernizing the nation's power generation, enhancing the country's energy security, generating income, and creating employment.

4.22 Subsidies

The Kenyan government uses subsidies for solar energy projects as a tool to encourage their growth. Subsidy comes in the form of soft loans (interest subsidies), capacity payments or an investment grant and output or production-based payments. The GoK only provides subsidies to REREC for the mini-grids construction, national electricity grid connections and operating costs. This has made it difficult for private contractors to put up mini-grids and provide cost-reflective tariffs, thus investment in this field is unsustainable.

4.23 Tax exemptions

The Kenyan government offers some tax exemptions for solar power equipment importation in order to promote solar energy exploitation and enable more homes access electrical power in rural homesteads. This has been made possible through constitution amendment and enactment of new laws. For example, in the 2013 act on VAT and 2014 Amendment Act, GoK provided for an exclusion from import duties and VAT for supplies or purchases of equipment and materials for the construction of electricity generating plant, geothermal exploration, in addition to specific plants and machinery. Table 13 below shows solar equipment exempted from import duty and VAT in Kenya (Assocation, 2019).

S/NO	Item	VAT	IMPORT DUTY
1.	Solar Panels	Excused	Excused
2.	Charge controllers	Excused	Excused
3.	Deep cycle batteries	Excused	Excused
4.	Inverters	Excused	Excused
5.	Solar pump control unit	Excused	Excused
6.	Solar Lanterns	Excused	Excused
7.	Solar Lanterns (integrated solar panel)	Excused	Excused
8.	Solar Lanterns (non-integrated solar panel)	Excused	Excused
9.	Battery Control Unit	Excused	Excused
10.	Solar lighting system kit (includes panel, control unit, lights and primary cables)	Excused	Excused
11.	Solar pump	Not Excused	Not Excused
12.	Specialized solar module mounting structures (for large systems)	Not Excused	Not Excused
13.	Solar fan	Not Excused	Not Excused

Table 13: solar products exempted from taxes in Kenya, source: (Assocation, 2019)

4.3 RENEWABLE ENERGY POLICIES IN EUROPEAN UNION

In order to reduce reliance on fossil fuels, minimize greenhouse gas emission and increase energy supply security, the EU focus on increasing energy production from renewable sources. In 2009, EU member states agreed to legally binding national targets of 20% renewable energy of the total annual energy consumed by 2020 in the Directive 2009/28/EC (‘Directive 2009/28/EC’, 2009).

To achieve a target of 20% renewable energy production, a lot of capital investment in new renewable energy projects was required. Also needed strengthened political support (Kitzing, Mitchell and Morthorst, 2012).

The EU (Directive 2009/28/EC) required every member state to stipulate its own means to achieve the target. The individual EU countries apply a variety of different policy supports for electricity from renewable energy sources as follows;

4.31 Feed-in tariff (FIT)

In this policy, the price of electrical energy from a new renewable source is guaranteed either for a specific period (a number of years, as in Germany) or a pre-determined amount of production (e.g., the first 10 TWh, as in Denmark).

In most implementations of FiT, the renewable electricity producers are exempted from market participation, and receive the guaranteed price for delivering the power to an obliged off-taker. The institution obliged to off-take electricity from renewable producer are transmission or distribution system operators, who then sell to consumer on behalf of the producer. They have to include the cost of the scheme in the customer's bill.

4.32 Feed-in premiums (FIP)

The guaranteed premiums in this policy are paid as a fixed addition to the market price. A green electricity producer typically earns premium per unit (MWh) in addition to the money made by selling the electricity on the open market. The premiums are often guaranteed for either a specific duration or a predetermined production, similar to FiT.

4.33 Tenders (TND)

In this process, the relevant authority requests bids for particular projects. Afterwards, prospective bidders compete for the chance to develop the project by submitting their proposal for the necessary support level and a number of additional requirements. The most attractive bid wins the tender.

4.34 Quota obligations with Tradable Green Certificates (TGC)

TGC is also known as Renewable Portfolio Standards (RPS) with Renewable Energy Certificates. This scheme requires by law that either producers or suppliers of energy to have a specific share of renewables in their portfolio (the quota obligation). A certificate of compliance to production of certain amount of renewable electricity, as agreed in the quota obligation, is issued to producer by the authorities. The certificates indicate compliance period.

4.35 Investment Grants (INV)

These are monetary supports given by the government and EU institution to investors in renewable energy projects in the form of non-reimbursable payments at the construction phase of a project. These payments depend on various factors such as successful completion and grid connection of a project and the fulfilment of certain performance standards. Majority of European countries have implemented this scheme for electricity generation from renewable energy sources. Grants depend on total investment cost and usually ranges from 5% to more than 70% of the total investment cost.

4.36 Fiscal measures (TAX)

These comprises various tax reliefs and other supports within EU in support of renewable electrical energy producers as described below;

a. **Income tax reliefs;** They are given either directly or through improved capital allowances and other beneficial depreciation rules on the investment cost as partial or full relief, respectively.
b. **Electricity tax reliefs;** In some countries where electricity generators are required by law to pay electricity taxes, these reliefs are given and electricity generators need not to pay such taxes.
c. **Reduced value added tax (VAT);** This is applicable for sales from qualified technologies.
d. **Net metering for own consumption;** Electricity consumers are required by law to pay such taxes as energy taxes and VAT. Renewable electricity production for own consumption is exempted from paying such taxes.

4.37 Financing support (FIN).

This involves repayable investments as defined in the Regulation no. 1828/2006 of the European Commission (2006, Article 43/1). They can be in the form of reimbursable equity investments or provisions of venture capital by governmental institutions. Also include low-interest loans to renewable projects by a governmental financial institution.

These regulations are intended to make it easier for investors in renewable energy projects to access the capital market and acquire financing on reasonable terms, enabling them to make additional investments and, as a result, contributing to the growth of renewable energy at low support costs.

4.38 EU solar energy strategy

In order to support the implementation of the REPowerEU plan, an EU endeavor to decrease its reliance on Russian fossil resources, the European Commission announced a solar energy policy in May 2022. This solar energy strategy highlights steps to address the sector's remaining obstacles and challenges in order to speed the adoption of solar technologies. The strategy proposed the following initiatives;

a) **Promote quick and massive PV deployment through the EU Solar Rooftops Initiative-** The aim of this initiative is to unlock the vast, underutilized solar generation potential of rooftops to make clean, secure and affordable energy. To materialize this, the EU will;

- Make rooftop solar energy installation mandatory for all new public and commercial structures with useful floor areas greater than 250 m^2 by 2026, for all current public and commercial structures with useful floor areas greater than 250 m^2 by 2027, and for all new residential structures by 2029.
- Limit time for acquiring permit to rooftop solar installations, including large ones, to a maximum of 3 months.

b) **Take measures to guarantee that all new structures are solar-ready**.

c) **Make permitting procedures shorter and simpler** - This will be made possible by Commission through adoption of a legislative proposal, a recommendation and a guidance alongside this communication.

d) **Establish an EU large-scale skills partnership –** The challenge of shortage of skilled workers in solar PV technology need to be addressed. To address this challenge, it is proposed that Vocational and Educational Training institutions and member States are advised to identify knowledge and skills gap in the solar energy sector and come up with training programmes suitable to bridge the gap. This should consider increasing women's participation in the soler energy sector. The proposed skills partnership will bring together all relevant stakeholders to take action on up skilling and reskilling to fill the gap.

e) **Launch a European Solar PV Industry Alliance-** The aim will be to enhance innovation-led expansion of a resilient industrial solar value chain in the EU, particularly in the PV manufacturing sector.

5. METHODOLOGY

In order to answer hypothetical questions formulated at the beginning of this study, an interview with a Hungarian solar PV firm and detailed questionnaires were necessary for investigation. Of course, some hypothetical questions could be solved from a careful review of selected literatures and publication. The question on if Kenya and Hungary receive adequate sunshine for economical exploitation could be verified from selected literatures. And indeed, from previous studies, it was verified that the potential of solar energy in these countries is huge.

The issue of the governments' involvement in formulating regulations and policies that promote exploitation of solar photovoltaic energy was investigated in the legal background review. In Kenya, policies such as elimination of import duties and values added tax (VAT) on solar equipment promote investment in this field but such bottlenecks as counterfeit equipment need to be addressed. The government has put up regulations demanding all participants in solar field such as manufacturers, distributors and technicians to be licensed. However, there are still many participants who operate illegally and need to be checked. Illegal participants are responsible for substandard services and goods in the market. Other measures that promote investment in solar energy include subsidies and favorable feed-in tariffs for investors.

In EU, authorities have made considerable milestone to promote exploitation. Introduction of favorable feed-in tariffs, feed-in premiums, investment grants, tax relieve measures and financial support all work towards promoting investment in solar energy.

An interview with Újszilvási solar park mayor was organized to help verify if EU policies in solar PV are applied in Hungary, among other issues that affect exploitation.

The questionnaire was designed so as to address other hypothetical questions that cannot be answered from review of literatures and needed investigation from the general public. Such issues as the cadre of people who can use solar photovoltaic equipment to generate electrical power could be investigated by reviewing income verses if one has invested in solar photovoltaic or not. Of course, opting to use solar energy for household could be determined by many factors but income is one of them.

Durability of photovoltaic equipment is a factor that could influence investment in solar energy. Nobody wants to invest in short-lived projects that cannot recover investment cost. This was investigated indirectly by asking challenges experienced by those that have used solar equipment in the past. Same to issues such as availability of bulk power storage equipment, access to expertise services and general public feelings about environmental pollution by burning of fossil fuels to generate energy.

Two questionnaires were prepared, in English language for Kenyan population and in Hungarian language for Hungarian population. The appropriate sample size target was 200 responses for each of them. I used lime survey platform so the questionnaire was in an electronic form. It could be accessed by prospective participant through sharing of access link via electronic communication media platforms such as WhatsApp, emails and Facebook massagers. The survey was aimed at collecting quantitative data regarding solar energy and was carried out on March, 2023.

6. QUESTIONNAIRE DATA ANALYSIS

From the English questionnaire shared to Kenyan population, a total of 286 responses were recorded out of which 205 were filled to completion and 81 filled halfway. For data analysis, only fully complete responses were considered.

6.1 Age

The participants' age was divided in the ranges of, 18-25years, 26-40 years, 41-64 years and above 65 years, table 14 and figure 12. The aim was to cut off responses from underage of below 18 years. summary of the participants' age is shown below.

Age	Frequency	Percent
18- 25 years	23	11.2
26-40 years	166	81.0
41-64 years	16	7.8
Total	205	100.0

Table 14: Respondents' age distribution, own work

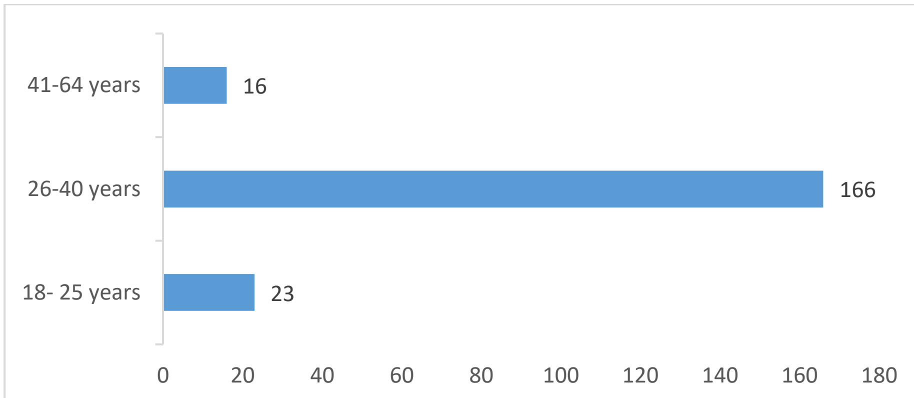

Figure 12: Respondents' Age distribution, own work

6.2 Level of education

Information about participants' level of education was collected in the categories ranging from elementary primary school level to doctorial level. The results were as tabulated on table 15 below.

Education	Frequency	Percent
Primary Certificate	1	.5
secondary Certificate/Vocational training	14	6.8
Diploma/Higher diploma certificate	46	22.4
Bachelors/Undergraduate studies	105	51.2
Masters/Post graduate	34	16.6
PhD	5	2.4
Total	205	100.0

Table 15: Respondents' education level, own work

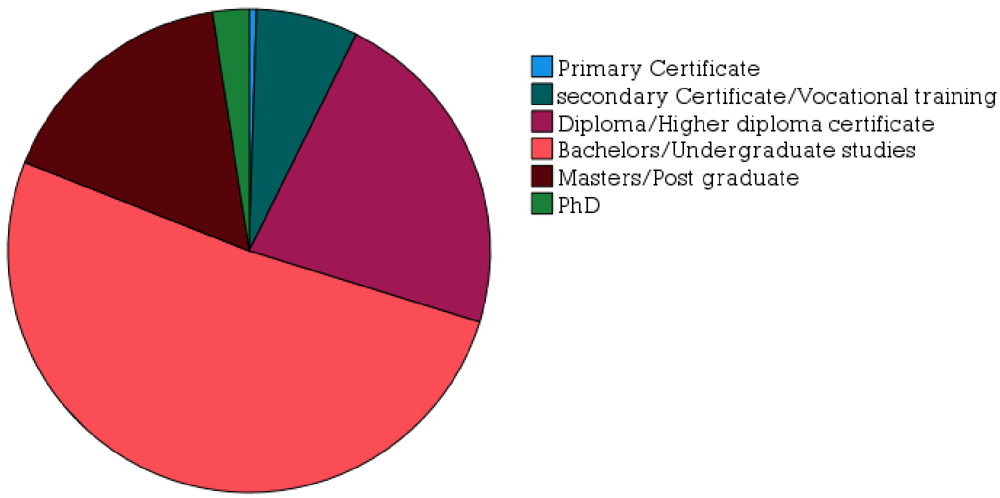

Figure 13: Respondents' education level, own work

6.3 Gross monthly income

It was important to collect this information for it relates to the participants' purchasing power. The ranges were categorized as, low-income cadre (less than Ksh 30, 000), Medium income cadre (Ksh 30, 001- Ksh 100,000 and Ksh 100,001- Ksh 200,000) and finally high-income cadre, above Ksh 200,000. The results were as shown on table 16 and figure 14 below.

Income	Frequency	Percent
Less than Ksh. 30,000	53	25.9
Ksh 30,001-100,000	106	51.7
Ksh 100,001-200,000	30	14.6
Above Ksh 200,000	16	7.8
Total	205	100.0

Table 16: Respondents' monthly income, own work

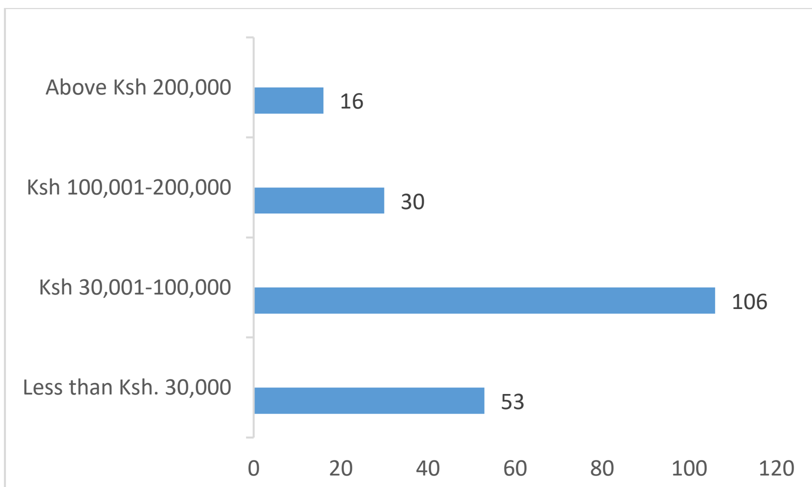

Figure 14: Respondents' monthly income, own work

6.4 Household location

Kenyan household location can be categorized in to two broad categories, urban areas, that include towns and cities and privileged to well established infrastructures such as power distribution lines

Location	Frequency	Percent
Urban centre	124	60.5
Rural area	81	39.5
Total	205	100.0

Table 17: Respondents' household location, own work

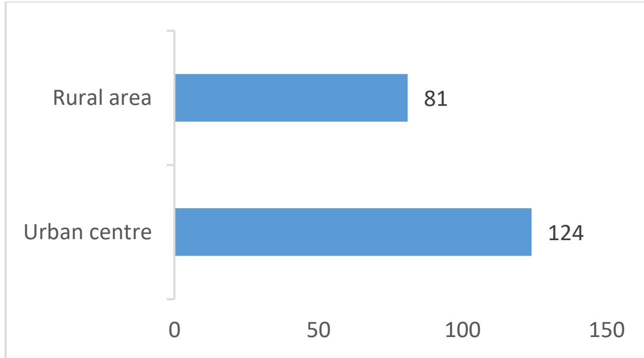

Figure 15: Respondents' household location, own work

and road networks or rural areas where these infrastructures are not well developed. The results are as shown on table 17 below.

6.5 Household size

This information was requested as it can suggest the quantity of electrical energy requirement. It was collected in the ranges of 1-2 people in a home, 3-5 and above 5 people. The results are as shown on table 18 below.

Household size	Frequency	Percent
1-2 Members	48	23.4
3-5 Members	125	61.0
Above 5 Members	32	15.6
Total	205	100.0

Table 18: Respondents' household size, own work

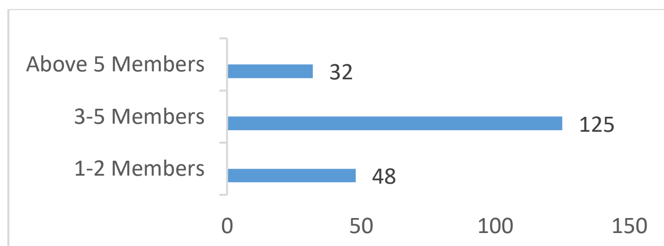

Figure 16: Respondents' household size, own work

6.6 Source of electrical energy for the household

Household electrical energy sources in Kenya can be placed in to three main categories, solar home system (solar panels, batteries and inverters), solar mini-grid and national grid. There could be others like diesel generators for an individual homestead. Respondents were able to give their energy sources as tabulated on table 19 below;

Source	Frequency	Percent
Others	7	3.4
Household solar Panel with battery (SHS)	38	18.5
Solar mini-grid	12	5.9
National grid	148	72.2
Total	205	100.0

Table 19: Respondents' household electrical energy source, own work

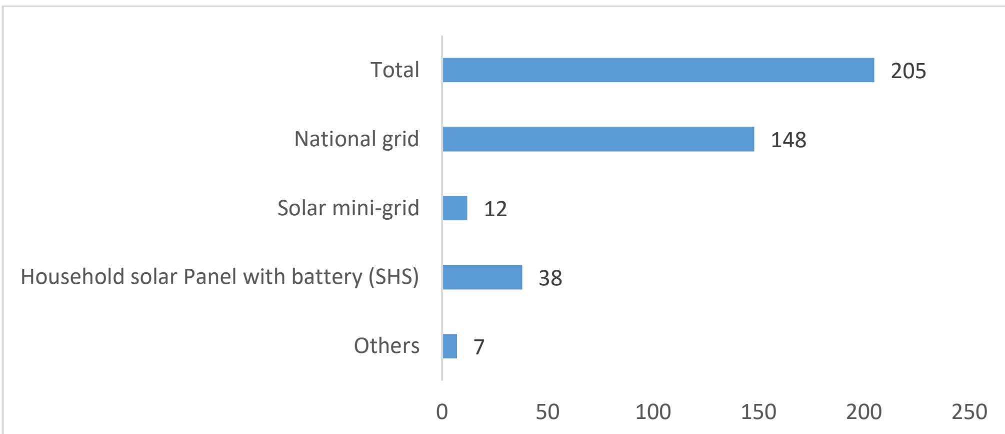

Figure 17: Respondents' household electrical energy source, own work

6.7 Correlation between household location and electrical energy source

In Kenya, most residential and commercial buildings in urban centers are electrically powered by national grid while in rural areas, households are powered by SHS. Pearson correlation coefficient show a moderate relation (r= -0.438) between household location and source of electricity for households, as shown below;

		Where is your household located?	What is the source of the electrical energy for your household consumption?
Where is your household located?	Pearson Correlation	1	-.439**
	Sig. (2-tailed)		.000
	N	205	205
What is the source of the electrical energy for your household consumption?	Pearson Correlation	-.439**	1
	Sig. (2-tailed)	.000	
	N	205	205

**. Correlation is significant at the 0.01 level (2-tailed).

Table 20: Correlation between household location and electrical energy source, own work

6.8 Willingness to pay more for electrical energy from renewable sources

Electrical energy from renewable sources is likely to be more expensive because new investors are put in feed-in tariff and premiums to protect them from market uncertainties. This question was aimed at knowing if the participants are willing to pay an additional cost and by how much. The options were; not willing to pay any additional cost, willing to pay additional 10-20%, additional 30-50% or by any additional amount. Table 21 below summarizes responses;

Additional cost	Frequency	Percent
by nothing	62	30.2
by 10-20%	96	46.8
by 30-50%	20	9.8
by any amount	27	13.2
Total	205	100.0

Table 21: Respondents' willingness to pay more for renewable electricity, own work

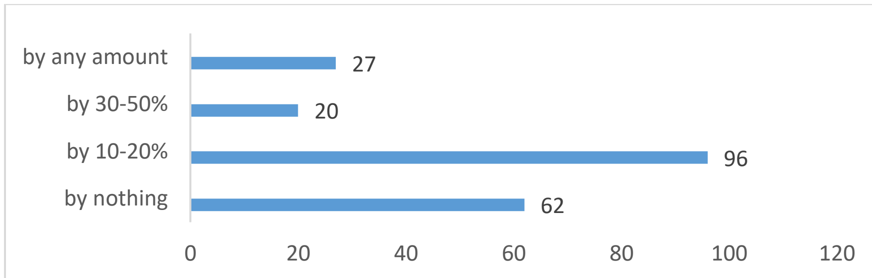

Figure 18: Respondents'' willingness to pay more for renewable electricity, own work

6.9 Correlation between willingness to pay more for renewable electricity and the level of education

Education level can influence the respondent's willingness to pay an extra cost for electricity generated from renewable sources. The scatter plot below, figure 19 shows that the level of willingness to pay more (From zero to any amount), increases with the level of education.

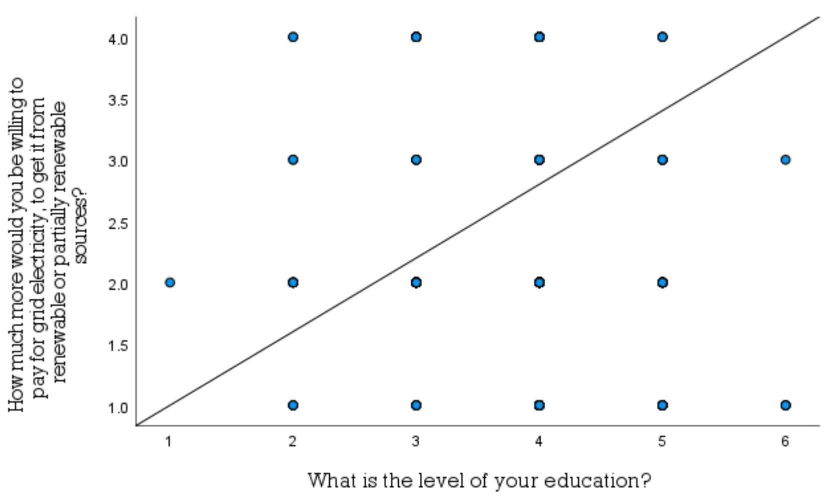

Figure 19: correlation of willingness to pay more for renewable electricity and level of education, own work

6.10 Correlation between willingness to pay more for renewable electricity and the level of monthly income

Willingness to pay extra cost for electrical energy from renewable sources increase with increasing level of monthly income as evident from the scatter plot, figure 20 below;

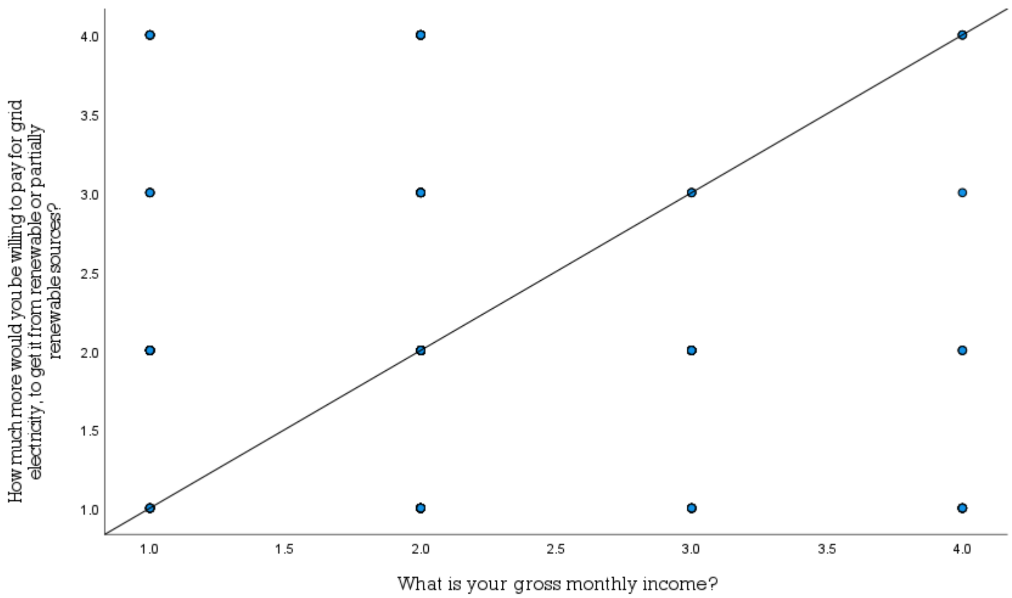

Figure 20: Correlation of willingness to pay more for renewable electricity and level of monthly income, own work

6.11 Participants' concern about burning of fossil fuels to generate electricity

The question was if the participant is bothered by fossil fuels having to be burnt to generate electricity. This was to investigate if they mind about environmental protection and conservation. Burning of fossil fuels is associated with emission of carbon dioxide, a greenhouse gas that is harmful to environment. The options for responses were; not bothered, bothered but there is nothing to do and bothered and if there was something they could do to stop they were willing to. Table 22 below is the summary of responses from the participants;

Response	Frequency	Percent
It doesn't particularly bother me	36	17.6
It bothers me, but there's nothing to do	62	30.2
It bothers me and if possible, I would actively do something about it	107	52.2
Total	205	100.0

Table 22: *Respondents' concern about burning of fossil fuels to generate electricity, own work*

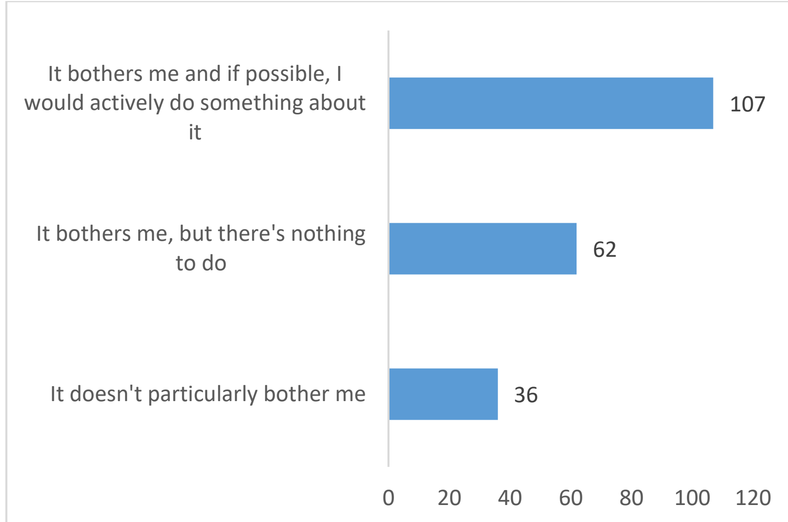

Figure 21: Respondents' concern about burning of fossil fuels to generate electricity, own work

6.12 Factors influencing choice between solar home system (SHS) and national grid

In this question, participants were required to choose between SHS and national grid for a new household, considering such factors as initial capital investment requirements, availability of skilled labour to handle SHS and reliability of power supply. Choosing SHS considering capital investment means it is cheaper compared to national grid, while choosing SHS considering availability of skilled labour means experts to handle SHS are readily available and considering power reliability, choosing SHS means it is more reliable than national grid. Table 23 below shows the results;

	Initial capital investment	Availability of skilled personnel to handle solar home system	Reliability of power supply
Solar home system	169	172	180
National grid	36	33	25
Total	205	205	205

Table 23: choices between solar home system (SHS) and national grid under various considerations, own work

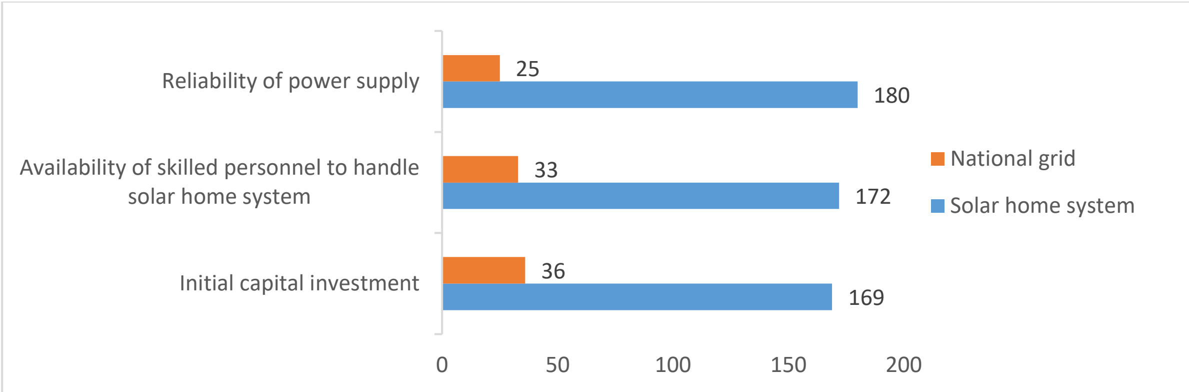

Figure 22: choice between solar home system (SHS) and national grid under various considerations, own work

6.13 Government initiative in promoting exploitation of solar energy in Kenya

The question was if the respondent was aware of government's initiatives to promote exploitation of solar photovoltaic energy in Kenya. The impact of such initiatives should be experienced by majority of citizens since renewable energy is a global concern. Options provided for respondents were yes, he was aware of such initiatives, no, not aware of such and not sure he/she is aware or not. The results were as shown on table 24 below;

Response	Frequency	Percent
Yes	40	19.5
No	137	66.8
Not sure	28	13.7
Total	205	100.0

Table 24: Participants' feeling towards government' initiative to promoting solar PV exploitation, own work

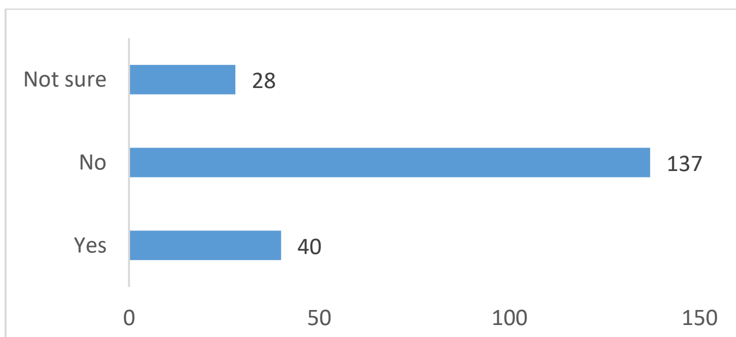

Figure 23: Participants' feeling towards government' initiative to promoting solar PV exploitation, own work

6.14 Respondent knowledge on SHS

This question was seeking to know if the respondents could determine a system suitable for them, both technical and costs details, in case they intend to install a SHS in their household. It was a test on the level of public interest in SHS and renewable energy as a whole. The response options were yes, able to determine and no, not able to determine. Table 25 is the summary of the responses received;

Responses	Frequency	Percent
Yes	132	64.4
No	73	35.6
Total	205	100.0

Table 25: Respondents' knowledge on SHS, own work

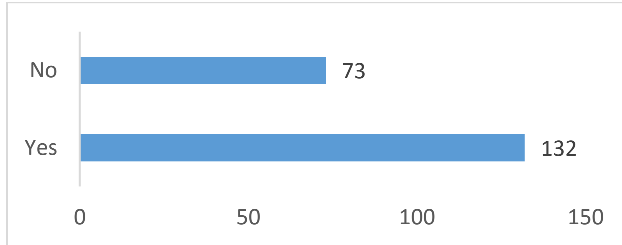

Figure 24: Respondents' knowledge on SHS, own work

6.15 Accessibility of SHS equipment for purchase

This part was testing if SHS equipment are easily accessible to customers for purchase in their residential areas at good quality and fair prices. The response options were yes or no and the results were as tabulated on table 26 below;

Response	Frequency	Percent
Yes	120	58.5
No	85	41.5
Total	205	100.0

Table 26: Ease of accessibility of SHS equipment for purchase, own work

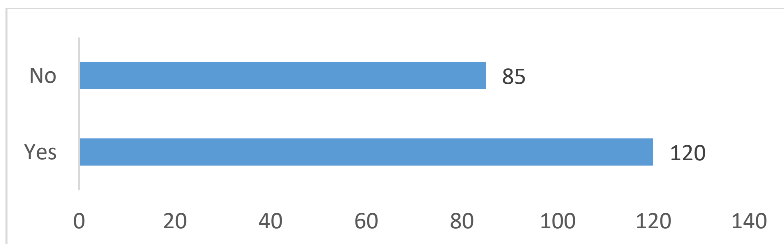

Figure 25: Ease of accessibility of SHS equipment for purchase, own work

6.16 Challenges in the use of SHS

This was an open-ended question seeking to know challenges experienced in the use of SHS for those that have used it before. Respondents were free to share their own experiences through long text descriptions. A total of two hundred and eighty-six responses were received, some of which were related. The main issue raised in the order of strength are as outlined below;

1. Storage of electrical energy in the SHS is the main issue. Batteries storage system has proved ineffective. Large batteries are needed for a system that can power the whole household for the time when sunshine is not available and requires periodic maintenance.
2. Interruption of energy supply when there is prolonged cloudy weather. Also related to inadequate storage system.
3. High initial installation cost for a large system that can power the whole household.
4. Counterfeit SHS equipment in the market that tend to have a short life span.

5. Since the output of solar panels and batteries is direct current, SHS would be more suitable for direct current appliances. Unfortunately, most household appliances are run by alternating current (AC).
6. Shortage of experts in SHS.
7. Since such equipment as solar panels are kept outdoor on the roof top, there is the risk of theft and vandalism.

7. RESULTS AND DISCUSSION

7.1 **Demographic information of the participants**

Analysis of the received demographic data shows that most of the respondents' age was in the range of 26-40 years (81%). This is the age level that is quite exposed to interaction through internet and easily accessible by social media. The questionnaire was electronically shared so majority of respondents reached fall in this age range.

Most of the respondents were graduates, forming 51% of total respondents. Analysis show that most of the respondents have a college diploma and higher levels of education. 60% of the respondent lived in the urban areas. It should be noted that in Kenyan urban areas, power infrastructure is well developed and almost all living and office buildings are powered by national grid. SHS is more common in rural areas. Because most respondents live in urban areas, (60%), it explains why most of the respondents are powered by national grid (72%).

The age bracket 26-40 years, consist of people with young families. This explains why household size of 3-5 members is the majority with 61%.

7.2 Attitude towards environmental protection and conservation

The sample population showed great concern for environmental protection and conservation. This is evident from the fact that 70% of respondent were willing to pay extra amount for clean electricity i.e electricity from renewable energy. Asked if they are bothered when fossil fuels have to be burnt to produce electricity, 82% of the respondents confirmed to be bothered with 52 % willing to actively do something to stop it. These responses show a population that is mindful of environmental protection and conservation.

7.3 Preference of SHS over national grid

Considering various factors that affects domestic power supply from either solar home system or the national grid, the respondents' preference was toward SHS. For instance, for a new home and considering the initial installation capital, 82% of the respondents would prefer installing SHS over the national grid. According to these responses, it shows that SHS is cheaper to install compared to getting power supplied by the vendor, KPLC for this case. This may be attributed to the numerous application steps, time required and payments that should be made before finally having your building connected to power. Considering availability of skilled man power to handle SHS, 84% of the respondents preferred SHS. This means that experts to handle SHS is not big problem as such. Compared to national grid, SHS is more reliable, according to responses. Grid supply by KPLC is characterized by prolonged period of black out especially in rainy weather. 88% of the respondents preferred SHS over national grid considering reliability of energy supply.

7.4 Government of Kenya initiative towards promotion of photovoltaic utilization.

Analysis of responses show that government's initiative towards promotion of solar photovoltaic use is not experienced by most of the population. 67% of the respond believe that government has not done anything to promote solar photovoltaic energy exploitation while 13% of the respondents is not sure of any measures. This means that solar photovoltaic energy policies and regulations are not well communicated to the masses.

7.5 Ease of access to SHS equipment for purchase

From the received responses, 58% of respondents say they can easily access SHS equipment for purchase. This number relate to the observation that 60% of the respondents lived in urban centers. In other words, people living in rural areas have difficulties accessing SHS equipment for purchase.

7.6 Interview with Újszilvási Mayor

Újszilvási solar park is located in Újszilvás village of Pest County in Hungary. It is a 400KW solar power station, established since 2011 on a 2-hectare piece of land and managed by Újszilvás municipality. The cost of installation was HUF 600millions, of which 85% was financed by the EU through Hungarian government. The output energy of the plant is 630, 000 KWH annually which is sold to the government. Expected life of the plant is 30 years. The interview was scheduled on 27th April, whereby we visited the solar park and had the following issues to discuss with the host;

Figure 26: Újszilvási solar park, 27th April, 2023

1. **Capacity of Újszilvás solar park**; The response was 400KW
2. **What PV cells and energy storage technologies are in use?** The PV cell technology in use is monocrystalline solar cells, it’s the best suited for Hungarian climate. they don’t have any energy storage equipment and power production is during day time only.
3. **What is the Expected lifespan of the park, Can the cost of installation be recovered?** Expected life is 30years from the date of installation. They generate 630, 000KWH annually.
4. **How do you sell your electricity to customers?** The response was that the state buys electricity from them.
5. **Are new producers/investors protected from market risks? Through feed-in tariffs? Are there benefits like access to financial assistance?** The response was that electricity supply is state owned, so the government buys electricity from manufacturers. For instance, the mayor said the government buys electricity from the solar park at HUF 37/KWH then for the municipality consumption they buy from the government at HUF 400/KWH, but the policy would be changed by 2027. About financial assistance, it’s not guaranteed.
6. **Are there challenges in government’s permitting procedure to install a solar park and start operation?** The response was that the procedure is slow and took them 1 year to get permit for installation.

8. RECOMMENDATIONS.

8.1 Kenyan system

Throughout this study, challenges identified in the use of solar photovoltaic electrical energy revolve around the ineffective battery storage system, high cost of installation for an adequate system to power all home appliances when sunshine is not there or during rainy weather and counterfeit equipment in the market. From the legal background review, the government of Kenya has crafted regulation that exempt import duty and VAT on solar photovoltaic equipment. In another regulation, it has specified warranty period that should be given to customers by manufacturers and vendors. Despite exemption of taxes by the government, dealer tend to exaggerate retail prices to increase profit because Kenya is a free market situation. I would recommend the government to closely monitor market situation and give the recommended retail price for solar PV equipment since they are exempted from import duty and VAT. This will greatly solve cost related problems. Then ensure there are no illegal dealers in the market (the law demand all players in solar system equipment be registered). This would reduce cases of counterfeit goods.

Increase public awareness through adverts in the main stream media and social networks. From the questionnaire, 67% of the respondents believe government has done nothing to promote exploitation of solar PV electrical energy in Kenya, yet it has put good policies in place. Public should be made aware of the government initiative in promoting solar PV utilization.

Like in EU, I would recommend Kenyan government to adopt the rooftop initiative. In the EU, in order to exploit the underutilized rooftop solar PV potential, it will be mandatory to install rooftop solar PV for all new public and commercial structures with useful floor areas greater than 250 m^2 by 2026. For all current public and commercial structures with useful floor areas greater than 250 m^2, it will be made mandatory by 2027 and for all new residential structures, it will be mandatory by 2029. This is important for a clean, secure and affordable energy.

8.2 Hungarian system

Following The EU (Directive 2009/28/EC) that required every member state to stipulate its own means to achieve 20% renewable energy, some EU members states like Germany and Denmark adopted favorable policies that resulted to significant solar PV energy exploitation. They include feed-in tariffs and feed-in premium to protect new investors from market risk, government's financial assistance to new investors (not guaranteed in Hungary) and fiscal measures where producers enjoy relieve from various government taxes (from the interview, Hungarian government buy electricity at HUF 37/KWH but sell back to municipality at HUF 400/KWH).

I would recommend adoption and implementation these policies or formulation of much better policies in Hungary to see solar PV exploitation grow like in Germany and Denmark.

Also, make permitting procedure simple and shorter, the respondent in the interview said it took them 1 year to get permit for installation.

9. LIMITATIONS OF THE STUDY

This thesis was divided in to 4 main research areas, Literature review, legal background, technology background and statistical background in relation to solar PV in Kenya and Hungary. I was able to successfully handle the first three parts. Statistical background was partially successful in that, due to low number of responses received on the Hungarian questionnaire, I could not do the statistical background for the Hungarian questionnaire. However, an interview with Újszilvási solar park mayor was organized and carried out as a compensation for the questionnaire.

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