Social-Economic Factors Influencing Solar Energy Adoption in the Built Environment in Kenya- Towards Mitigating Climate Change

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Abstract

Average global temperatures have in the last decades risen resulting to climate change. Solar energy is becoming a game changer in the fight against climate-change. With Kenya's geographic location within the tropics, solar energy is one of the abundantly available clean energy sources. One of the key drivers for economic developments is the availability of inexpensive and abundant energy supply in Kenya. With devolution, demand for solar energy use within Counties in Kenya continues to rise. While the built environment is one of the highest energy use areas, social- economic factors continue to influence adoption of solar energy in the built environment affecting strategies towards climate change mitigation. This paper therefore purposes to examine these social economic factors influencing adoption of solar energy within the built environment towards mitigation of climate change. Rogers & Marshall (2003) diffusion theory is the main guide of the study in examining the social-economic factors influencing adoption of solar energy in the built environment. This paper is based on literature review. Content analysis was done to arrive at the argument within the different sub-themes there-in. Clean energy sources like solar energy are a key drive-in combating climate change and a study into social-economic factors influencing adoption of the same will be an important tool towards increased adoption of solar energy and in turn mitigating climate change. The review concludes that an increased adoption of SETs within Kenyan built environment spaces would directly reduce the amount of GHGs gases released by the sector and contribute to mitigating climate change.

Key words*: Social-economic, influencing, solar energy, mitigating, climate change, built environment*

INTRODUCTION

Researchers (AGECC, 2010; Gitone, 2014; IRENA, 2018; IRENA, 2019; SusWATCH Kenya, 2020) collectively agree that emission of greenhouse gases into the atmosphere from different sectors and industries worldwide is the main cause of climate change. Approximately 11% of greenhouse gases (GHGs) are emitted from the built environment. While no study has shown one technology capable of completely reducing these GHGs, several technologies have been proposed with solar energy technology seen as a solution that can significantly reduce GHG emissions in these sectors and industries like the built environment. IRENA (2019) reported that worldwide, approximately 3 billion people are dependent on fossil fuels for their cooking and heating needs that increases GHG and approximately 1.5 billion people having no access to electricity or having unreliable electricity networks making them “energy-poor”. These “energy-poor” people suffer from a myriad of energy related consequences caused by buildings that are insufficiently ventilated, health complications from solid fuels that combust inefficiently, economic degeneration or stagnation from lack of reliable energy sources for basic services like education and health. Lack of reliable and affordable energy sources also causes these “energy-poor” to suffer from ineffective pumping capacity resulting to lack of access to clean water, poor sanitation, and adverse effects to food security leading to devastating impacts on populations that are very vulnerable (UNDP, 2012).

According to Gwalema (2002), social, economic and environmental development is greatly influenced by energy with global prosperity being dependent on the availability of reliable, clean and affordable sources of energy for the success of these developments. Modern and reliable energy sources are especially needed for improvement of health, reduction of poverty, and promoting economic development in developing countries like Kenya that are going through a phase of industrial development (Gitone, 2014). According to a study done by World Bank, 1-2% of potential growth in developing countries is lost due to power outages, energy loses and subsidies and inefficient use of energy sources that are scarce. Globally, 60% of total GHG emissions come from energy systems i.e.; the supply, transformation, delivery and the use (IRENA, 2019).

In 2015, SDGs were adopted to provide a framework to access the connection between 1.5°C of global warming or 2°C and the development goals that include global equity and poverty reduction (IRENA, 2019). UN’s SDG7 shows the importance of energy in fostering pathways capable of keeping global warming below 2°C and meeting several SDG target by ensuring access to sustainable, affordable, modern and reliable energy for all by 2030. Despite the availability of renewable energy solutions, the world is not on track to meet the SDG7 goals by 2030 and more improvements will be needed through energy funding, policy interventions, training and awareness and a people's increased willingness to embrace renewable developing technologies like solar energy use (UNDP, 2012).

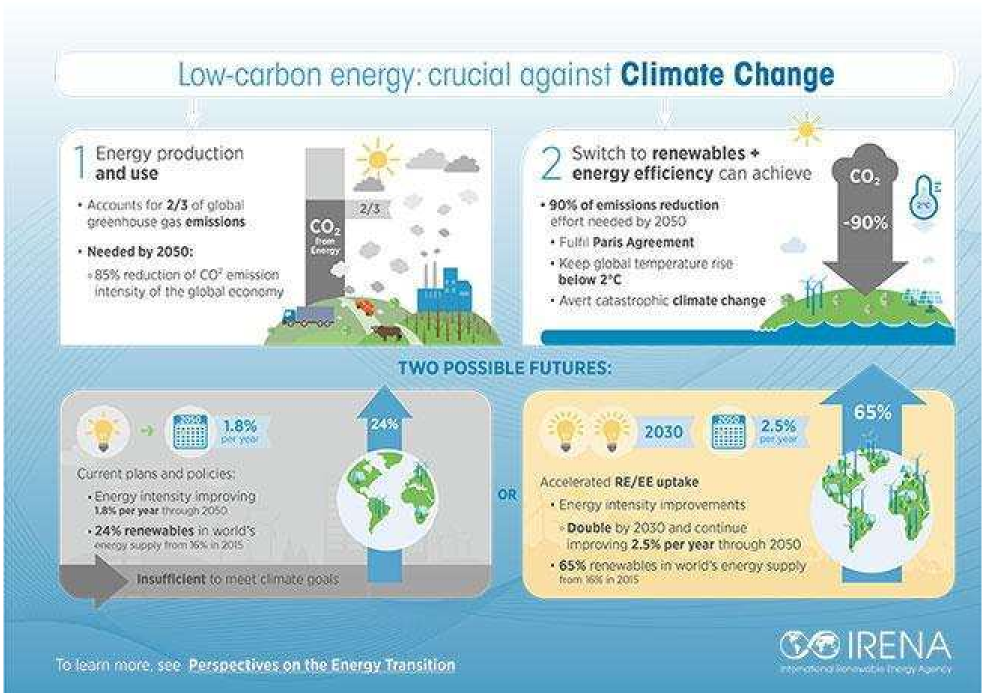

Figure 1: Low Carbon Emission Projections by 2050. (IRENA, 2018)

IRENA (2018) through a report named 'A roadmap to 2050' indicated that to reach the Paris Agreement's objectives a reduction of global energy demands would be required in all industries. The report indicated that this could be done through energy efficiencies like adoption of renewable energy sources, which should by 2050 amount to two-thirds of the total final energy supply globally. An increase of renewable energy with the power sector to 86% in 2050 from 25% in 2017 would be needed to accelerate change towards distributed, decarbonized and digitalized energy systems like solar energy (Moriarty & Honnery, 2022). Cox (2016) argues that through accelerating deployment of renewable energy sources promises, a myriad of benefits such as job creation, economic growth, reduced air pollution and most importantly climate change mitigation. With several governments worldwide reducing energy related C02 emissions that is the basis of energy transition, projected C02 emissions between 2015 and 2050 according to IRENA have reduced by 11% (IRENA, 2018).

Adoption of the 2030 Agenda for Sustainable Development that included SDGs and the Paris Agreement resulted from various forums worldwide negotiating and taking action towards accelerating energy transformation after the outcomes of 2015s international climate change negotiations (UNDP, 2012). AGECC (2010) proposes that strategies are put in place to enable global C02 emissions be reduced by 3.5% every year from now until 2050 and beyond in order to meet the aims of the Paris Agreement. Increasing electrification using renewable energy sources like solar will be a major driver in mitigating climate change through change in global energy transformations (Ekins-Daukes, 2009). By 2050 global share of energy use through electrification in the built environment will increase from the current 20% to 49%. An increase of energy use within the built environment alone needs to reach 68% renewable energy by 2050 especially in the sector's lighting, heating, ventilation and cooking needs. The International Energy Agency (IEA) estimates solar energy to provide approximately 11% of electrification needs by 2050, (IRENA, 2019).

Cox *et al*., (2015) state that the day and season of the year largely influences the solar irradiation arriving at ground level. Countries around the equator like Kenya experiences more solar irradiation most of the year without many seasonal variations. This makes the possibility of solar energy use within built environments attainable throughout the year with no interruption. Solar Photovoltaics (PV) commonly referred to as Solar Cells convert daylight in solar power without delay. The physical technique termed "Photovoltaic" impact or "PV impact" involves conversion of light (Photons) to electricity (Voltage) (Ekins-Daukes, 2009). Global PV production grew from 100GW in 2012 to an approximate capacity of 180GW by the end of 2014 globally (Cox *et al*., 2015).

Energy in the Built Environment

Within the built environment in many countries globally, interventions put in place for mitigation of climate change have resulted into efforts towards reduction of fossil fuels use by minimizing energy demand through rationally using energy and use of energy from ambient ground air to recover heat and cold (ventilation) especially in buildings (IRENA, 2019). Moriarty, & Honnery, (2022) argue that renewable energy should cover residual energy demand of a building in order for the building's sustainability levels to be relative to its positive environmental impact, i.e.

GHG emission. In order to meet sustainability requirements and positively impact mitigation strategies for climate change in the built environment, energy demands especially electricity remain one of the crucial elements (Ciriminna *et al.*, 2018).

Building design of windows, walls, doors, roofing and walls as well as insulation improvements can lead to immense energy savings as well as efficiency in heating, ventilation and lighting. Effectively introducing and maintaining building codes relating to energy use in China and Denmark has led to significant energy savings in the built environment (Ciriminna *et al.,* 2018). This has been done through switching to efficient appliance and lighting with low stand by power consumption for short-medium life appliances and switching to LEDs. In countries like Bangladesh, Rwanda, Ethiopia, South Africa, Uganda, Thailand and Kenya sensitizing people on the use of more energy efficient lighting like the solar lamps has increased energy efficiency (Ekins-Daukes, 2009).

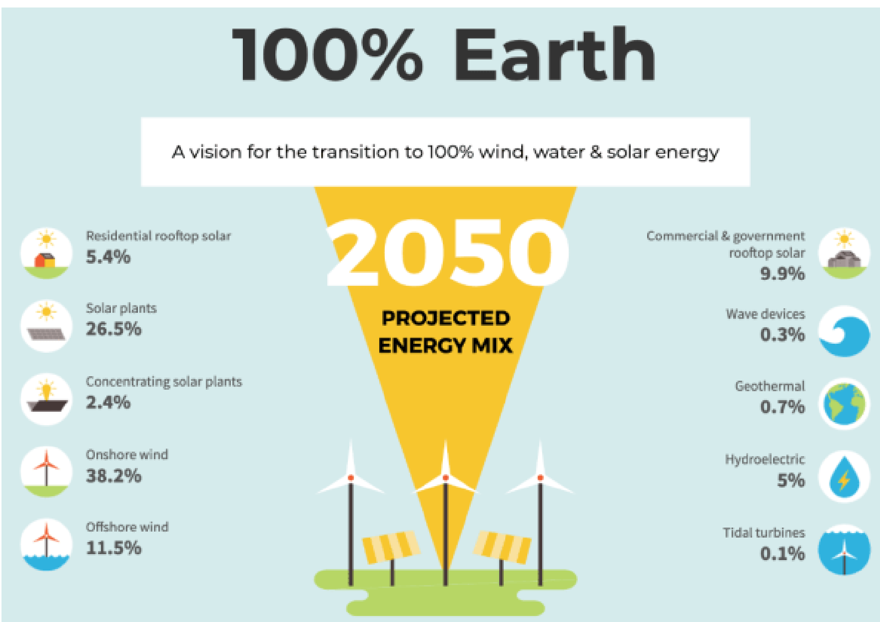

Figure 2: Project Global Energy Mix by 2050. (www. cleantechnica.com)

Cox (2016) submits that exploitation of renewable energy sources like solar energy within the built environment can reduce the use of fossil fuels significantly. Despite the built environment having a significant contribution to global GHG emissions, the sector is still struggling with promotion of energy transitions to cleaner sources like solar energy (Ciriminna *et al.,* 2018). It is estimated that by 2050 the built environment will increase renewable energy use to 81% with electricity demand in the sector increasing by 80% (IRENA, 2019). According to Ekins-Daukes, (2009), shifting from fuels to electricity for cooking, improving appliance efficiency will promote more adoption of renewable sources like solar energy. Built environments needs to promote innovative renewable applications as well as reinforce renewable energy markets to preserve the ecosystem and mitigate climate change through reduction of fossil fuels both at the local and global levels (Ciriminna *et al.,* 2018). Building policies with a focus on renewable heating, lighting, ventilation and cooking can also greatly contribute to reduced air pollution that in turns leads to amelioration of environmental conditions that result to or from climate change (Cox *et al*., 2015). Policies relating to building codes encouraging adoption of renewable energy sources like solar energy and financial incentives to both manufacturers and household owners can also influence solar energy use in the built environment leading to mitigation of climate change (IRENA, 2018).

Energy Use in Kenya

Kenya, an East African country located on the equator, boasts of a total area of approximately 580,370 Km^2 and a population of approximately 48.5 million people (Sofie, 2018). Most of the energy use in the country is for cooking and lighting constituting mainly of fossil fuels like gas, kerosene & diesel and wood fuels like charcoal & firewood (Mutea, 2013). Within the built environment in Kenya, of the national primary energy supply, households cooking account for two-thirds of these demands and energy efficiency could significantly lower these demands. According to Energy Petroleum and Regulatory Authority (EPRA) 36% of the population has access to electricity with less than 2% of the national energy need being from solar energy (Gitone, 2014).

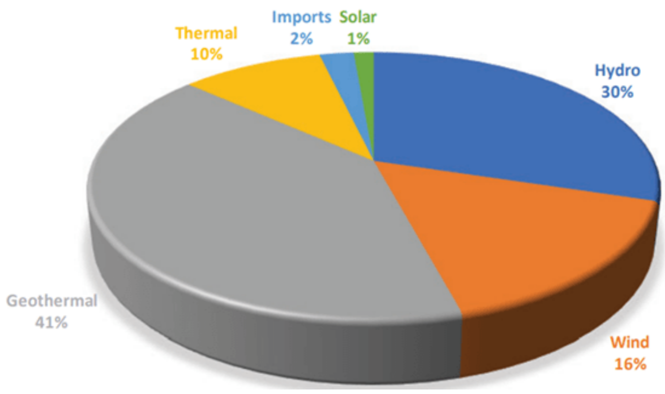

Figure 3: Kenya's Average Energy Mix. (Kenya National Bureau of Statistics, 2021)

According to Mutea (2013), traditional stone fires (wood fuels) are still used by approximately 78% of the Kenyan households in rural areas and by approximately 9% of the urban household. These emit large quantities of GHG especially CO_2 leading to air pollution and environmental degradation. While in urban areas access to other sources of energy like LPG for heating and cooking is better than rural areas thus reduced CO_2 emissions, adopting cleaner energy sources like solar would better help in mitigating effects of climate change (SusWATCH Kenya, 2020). With devolution and subsequent growth experienced within the built environment, electricity use is increasing rapidly with household electricity demand being approximately 12PJ in 2020 from 3PJ in 2000, which is an increase above the population growth. Electricity efficiency like use of solar power, hydropower and geothermal power among others within the built environment by 42% from 2000 and is projected to keep increasing each with adoption of renewable energy sources. These assumptions therefore indicate that demand for electricity and light in household will increase with population growth and approximately 84% of GDP growth in relation to 2020 (UNDP, 2012).

Solar PV, according to Sofie (2018), form approximately 1% of energy sources in Kenya despite Kenya strategic position along the equator with 4-6kWh/m2/day of insolation allowing for higher adoption of solar energy use. The electricity capacity of the wind and solar power grid is approximately 1.420GW with the installed capacity being 2.4GW. The cost of household connection to the national grid is about 319EUR (Kshs. 35,000) making it a problem to expand electricity services to smaller businesses and poor areas due to high cost of connection. The cost of electricity per month is also very high compared to other countries like South Africa with most household using energy inefficient appliances that raise the cost of electricity. This is mainly due to lack of awareness on energy efficient appliances and the cost implication for purchase and installation. The lack of strict regulation from government of type of appliances being shipped also influences the use of energy inefficient appliances (George *et al*., 2019).

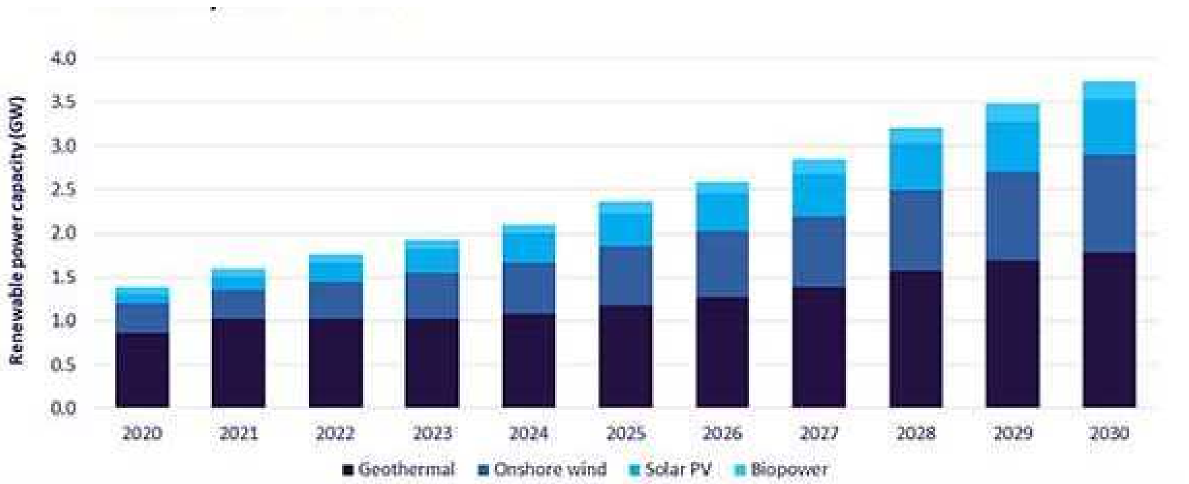

Figure 4: Kenya's Renewable Energy Installations Projections 2020. (www.globaldata.com)

Kenya has a rich supply of sunshine that averages 5-7 hours of sunshine per day resulting into 4-6 kWh/m^2 indicating a rich availability of solar energy in the country. 10- 14% of this energy can be converted to electricity with today's conversion efficient PV modules translating to about 23,047 TWh yearly enough for energy needs of over 70% of the built environment in the country (Sofie, 2018). Due to various socio-economic factors adoption and utilization is, however, much lower than it should be. There has however been an increase in the uptake of solar energy especially solar water heating within the built environment following the Energy (Solar Water Heating) Regulations of 2012 (Gitone, 2014). With increased adoption of solar energy use, efficient cooking appliances like computer-controlled cookers capable of cooking with only 10% of energy needed can be adopted. These cookers are currently being promoted in neighboring countries like Tanzania and Europe as well as Asia (RECP, 2018).

Solar Energy and Climate Change

Moriarty & Honnery (2022) argue that sunlight, which is available in all parts of the world albeit in different intervals and intensity, is responsible for the energy source used to power the earth's climate and ecosystem. This energy can be harnessed for heating, cooling, ventilation and lighting purposed within various sectors of global economies like built environments proving energy with low carbon emissions and in turn providing an attractive way to mitigate climate change. Solar energy is available within all global regions and provides a renewable source of energy that can lead to significant reduction of GHG emissions (Cox *et al*., 2015). Solar produces less life cycle GHG emissions although during manufacturing and recycling of the solar systems an extremely low (almost insignificant) amount of GHG are emitted. The generation of solar energy from a solar system result to zero GHG emissions, zero environmental impact and in turn climate change mitigation (AGECC, 2010).

According to Barnes (2007) solar energy technologies (SETs) are used as a way of enhancing living standards in developing countries'-built environments. These technologies are adopted in areas where grid services are unavailable, unreliable or where influx of solar is high. Solar technologies in these developing countries may however seem unattractive as they are associated with lack of financing to afford grid connection but can be considerably beneficial with right technologies and awareness of their benefits in reducing GHG emissions, improving energy security and mitigating climate change. In developed countries currently, SETs are more expensive that conventional sources of energy and incentives are needed to improve adoption towards mitigating climate change especially in the built environment (Cox *et al*., 2015).

SOCIO-ECONOMIC FACTORS INFLUENCING SOLAR ENERGY USE ADOPTION

Different individual, community or cultural attributes affect an individual's ability to adopt solar energy use within their households. These attributes may be linked to social dispositions or economic state, which limit the adoption of solar energy and consequently negatively affect climate change mitigation strategies (Bandara & Amarasena, 2020).

Figure 5: Socio-Economic Factors Influencing Solar Energy Use Adoption. (Source; Authors)

Education Level

An individual's education level is associated with their level of comprehension and problem-solving capabilities as well as awareness of new beneficial technologies like solar energy technologies. Knowledge therefore is a very powerful tool in inducing adoption as through access to information uncertainties are reduced. In Kenya for example, most people living in marginalized areas lack basic education making their level of comprehension a problem solving in line with renewable energy like solar very limited (Nhembo, 2003).

Population

For both commercial and residential built environments, the number of users affect the energy requirements and in turn influencing the type of energy infrastructure required for any space (Ciriminna *et al.,* 2018). The solar energy technology adopted for a smaller household in most parts of Kenya for instance, may be of lower capacity than that of a household with a larger population or higher number of users. This is primarily because as the energy needs within the different households would differ (Gitone, 2014).

Age

According to Nhembo (2003), people of a more advanced age group may not readily take up new innovations due to conservatism but may have more resources to enable them adopt capital intensive technologies like solar energy technologies than younger people. Younger age groups are however more likely to take risks linked with new technologies like SETs. As with the case in Kenya where most people of advanced age have more resources that younger people but are in most cases resistant to new technology and would rather use energy sources they are familiar with despite them not being environmentally friendly.

Income

Cox (2016) argues that availability or lack of finances is directly proportional to adoption levels of capital-intensive technologies like Solar Energy Technologies. While a people may be aware of all the benefits of a technology like solar energy in mitigating climate change lack of financing to adopt may still play a major role in impeding the adoption of solar energy use especially within built environments. At a household level, like in most parts of Kenya, efficient appliances are usually not reachable because of high costs of purchase and installation despite being quite cost saving over time (Wall *et al*., 2021). Bureaucracies and corruption levels in Kenya especially limit access to financing to adopt solar energy in built environments compounding factors affecting adoption of solar energy in built environment especially for low-income earners (George *et al*., 2019). Having money however does not always guarantee adoption as rational and priorities on problems like climate change may still impede solar energy use adoption within the built environment especially if one does not perceive climate change or the advantages of solar energy adoption towards mitigation of the same as a problem (Bandara & Amarasena, 2020).

Cost of SETs

The price of a technology is one of the main factors affecting innovation adoption by consumers in Kenya. While income levels will influence the affordability of the technology, technologies need to be reasonably priced to attract buyers whether having high incomes or not (Nhembo, 2003). A higher benefit-cost ratio positively influences consumers' intentions to change from fossils fuel use that leads to change to cleaner energy sources like solar energy in sectors like the built environment. Studies indicate that most consumers are not willing to pay more than 5%

comparative rate with the energy source they currently use however cleaner it may be. Solar energy however has high minimum investment required and incentive to improve adoption could go a long way in increasing adoption rates in turn having a positive impact in mitigating climate change (Parsad, Mittal, & Krishnankutty, 2020).

Gender

Nhembo (2003) argues that gender either impacts positively or negatively any adoption measures for new technologies. Gender roles like financial providence or workload influence adoption of technologies like SETs. If a man or woman is the primary breadwinner in a household, for example, and deems a SET not important or too expensive, the adoption of that may be faced with resistance. On the other hand, if a man or woman does most household duties and a technology is deemed to reduce his/her workload, chances of high adoption rate for the technology are equally high. In developing countries like Kenya, women mainly do most unpaid workload burden with household organizations taking a male dominance – female subordination type of hierarchical relationship. These results to women taking up poorly regarded tasks in the homes which men rarely regard as labor like fetching water, home management and maintenance, collecting firewood, family care especially children and the old and food preparation among others. Firewood for example is wrongly looked at as a free and collected by women and children, most men may not see the need to adopt more efficient and cleaner technologies as that, according to them, means the women do not have work to do (Zulu *et al*., 2022).

Women in most parts of Kenya also face many other challenges which bars them from effectively take part in decision making towards adoption of technologies like SETs such as economic independence, education and awareness levels, technical and skills expertise and hierarchical relationship pegging women as subordinates (Nhembo, 2003). While women traditionally have little power to make decisions on technology purchase especially in these developing countries like Kenya, they shoulder the responsibility of managing household energy requirements. This makes them a very crucial gender in helping improve the adoption of solar energy use in built environments to mitigate climate change (Fontana & Natali, 2008).

Government Support

While there is need for governments, both international and local, to set up aggressively targets towards universal energy access, policies focusing on readily available clean energy sources like solar energy should be highlighted and implemented to help in mitigating effects of climate change (UNDP, 2012). Financial incentives, programming capabilities and relevant energy infrastructure need to be prioritized and supported by international agencies like IEA and IRENA among others and multilateral organizations to effectively improve adoption of technologies like SETs especially in built environments (Barnes, 2007). Cox (2016) states that most countries and communities lack the ability to influence their people to adopt technologies that can help mitigate climate change like solar energy due to lack of financial support especially in developing countries like Kenya. This financing could be used in giving incentives or creating awareness on importance of adoption of technologies like solar energy in built environments for climate change mitigation. Capacity development through reducing cost of solar energy access and the use of efficient appliances lacks in most built environments for both the private and public sectors coupled with lack of expertise and knowledge on these SETs (Mutea, 2013).

Most governments are unable to effectively leverage on the expertise of private sectors though public-private partnerships (PPPs) which can greatly help drive adoption strategies for solar energy use in built environments (IRENA, 2019). Political challenges also affect adoption of solar energy use in the built environment. According to George *et al*., (2019), has in recent years experienced political instability which results in lack of commitments from stakeholders on push for adoption of solar energy. The country has also been lacking solid and credible systems of tracking and certifying SETs in the built environment. Corruption results into systems that are not transparent and therefore enforcing guidelines and regulations becomes an uphill task towards adoption of solar energy use in the built environment (IRENA, 2018).

Lack of Awareness

Sofie (2018) argues that public awareness on solar energy use in built environments for climate change mitigation is a major impediment for adoption of solar technologies in Kenya. Most communities in Kenya especially in rural areas lack information on solar energy use and most especially effects of climate change that would motivate them to adopt solar energy to mitigate the same. A lack of awareness on the extent to which climate change has affected or can affect various aspects of their livelihoods also limits the extent to which these communities increase adoption of solar energy use in built environments (IRENA, 2019). A lack of awareness on energy efficient appliances is also limiting to the end-users' decision making while purchasing appliances for use in their households. The degree of awareness of a new technology especially its disadvantages and advantages influence adoption rates as information gaps reduce the acceptance levels of any technology (Zulu *et al*., 2022). Rejection or adoption of any technology starts with the consumer's awareness of the technology. The more knowledgeable a consumer is about any technology therefore, the more willing they are to adopt (Sofie, 2018).

Attitudes and relative advantage

In most commercial spaces in Kenya, developers and owners are not motivated to invest in energy efficient appliances in the spaces as the investments cost for them outweighs the benefits since, they look at it as benefits going to the tenant as opposed to benefits towards mitigating climate change (Zulu *et al*., 2022). Relative advantage is the level in which an innovation or technology is seen to be better than that which it supersedes and is mainly measured using economic terms like convenience, socio-prestige factors as well as satisfaction. A high rate of adoption for any technology is experienced with a high rate of relative perception (Wall *et al*., 2021)

Several researchers have proven that consumer expectations and perceptions on the benefits or lack thereof of a technology like SET form the main points relating to attitudes towards the technology and directly influence adoption rates (Sofie, 2018). A perceived ease of use for any technology equally influences people's willingness to take up new technology (Zulu *et al*., 2022). The degree to which a consumer can easily comprehend, use, and maintain a new technology is generally, what is referee to as ease of use. Understanding living standards and way of life of a consumer can better equip manufacturers, built environment professional and governments to better create awareness that can create positive attitudes towards adoption of solar energy use in built environments as a way of mitigating climate change (Gitone, 2014)

CONCLUSION AND RECOMMENDATIONS

Of these identified socio-economic factors influencing adoption of solar energy use in the built environment towards mitigating climate change in Kenya, the focus on encouraging or dealing with them seem to be on improving governments supports, and creating awareness through education and awareness campaigns (Sofie, 2018). A combination of appropriate guidelines and regulations, energy financing, awareness campaigns, pricing technologies right and capability and capacity building within the built environment in Kenya are ways that these barriers to adoption can be overcome (George *et al*., 2019). A change of attitude on solar energy use adoption in the built environment requires appropriate regulations and most importantly training and awareness and installation, use, maintenance, advantages and disadvantages of SETs and more so how climate change affects individuals and the importance of solar energy us in mitigating the same (RECP, 2018).

Concerning high costs of installation, facilitating capital financing and creating a good environment for more investors of SETs would go a long way in improving rates of adoption in the country (Cox, 2016). There are a number of international funds providing financing for energy efficiency initiatives, such as the Renewable Energy and Energy Efficiency Fund set up by UNDP and a number of Climate Investment Funds set up by the Word Bank Group (UNDP, 2012). Women are the main users of energy and should be involved in decision making on energy uses. Women drive most economies and it goes without saying that they would drive adoption rates for SETs within built environments if adequately trained on advantages of SETs in mitigating climate change as well as being economically empowered (Nhembo, 2003). The widespread adoption of solar lamps has been achieved in most parts of Kenya through training of local women and through peer training women have been able to increase use of solar lamps in household and even in SMEs like retail shops and market places (SusWATCH Kenya, 2020).

Cox *et al*., (2015) argue that in order to change the global energy system in future decades, it is important for the international community to unite in placing greater emphasis on adoption of cleaner energy sources like solar energy in various sectors like the built environment to mitigate climate change. There is need to improve SETs access in built environments in low-income countries like Kenya to increase availability to millions of the population who experience energy-poverty severely though inadequate, unreliable and sometimes very expensive energy sources. An increased adoption of SETs within Kenyan built environment spaces would directly reduce the amount of GHGs gases released by the sector and contribute to mitigating climate change (Barnes, 2007).

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