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Theoretical Implications of Renewable Energy using Improved Cooking Stoves for Rural Households

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ABSTRACT

Majority of the rural people from developing countries are dependent on agriculture sector and the major source of energy is traditional biomass. Due to radical climate changes, their dependency on traditional biomass and agriculture sector increases their vulnerability and deteriorates the environment as well. Therefore, this study attempts to highlight the potential of using renewable energy options to reduce this vulnerability. The focus of present research is the efficient utilization of solar energy and biomass using improved cooking stoves. Additionally, the vulnerability can be reduced by optimizing solar energy utilization and enhanced individuals' adaptive capacity with the use of improved cooking stoves. The environmental benefits of the use of improved cooking stoves through solar energy are also discussed. It is concluded that the efficient use of biomass and solar energy reduce individuals' susceptibility and improve their socio-economic status, education, health and climate change as well. These findings provide the guidelines to the regulators that they should enhance their focus towards renewable energy to reduce this vulnerability.

Keywords: Health Benefits, Solar Energy, Renewable Energy, Biomass, Climate Change
JEL Classifications: Q26, Q54

1. INTRODUCTION

The utilization of the sources of renewable energy (RE) has remained a matter of attention for centuries, yet its potential has recently been recognized in terms of enhanced scope. Thus, its promotion and usage has received an increased attention in recent times. The reason behind its increased usage and promotion is its ability to fulfill energy demands of the society being environmental-friendly. Additionally, a number of policies have been initiated at domestic as well as international level in addition to the approval of several agreements for the promotion of RE.

The United Nations Conference on Environment and Development was held in 1992 at Rio de Janeiro, in accordance with the notion of sustainable development, entitled "Agenda 21" was developed (Karekezi, 2002; Nation United, 1992). The United Nations Framework Convention on Climate Change (UNFCCC) also came into effect on March 21, 1994 which also emphasized on the significance of renewable energy (Reddy et al., 2017). The common point in both conventions was the increased emphasis on the significance of renewable energy for meeting the energy demands of the world with the preservation of the environment. Moreover, the significance of renewable energy among various forms of energy was also realized for achieving sustainable development.

The matter of sustainability and the use of renewable energy (RE) comes against the traditional notion of development, which is led by the overdependence and utilization of fossil fuels causing several negative effects to the society including a deteriorated environment (Riti et al., 2018). In the past, the focus of several governments was the central electricity grid, which has failed to meet the energy demands of rural households, which in turn, left the masses to depend on biomass sources. This overdependence on biomass causes them to be trapped in energy poverty (EP) and underdevelopment. The availability of clean energy at reasonable prices helps rural masses in improving their living standards through poverty reduction (UNDP, 2012). Therefore, many organizations and countries are focusing on projects to offer renewable energy access to rural populations across the world.

The dependence of rural population on various fossil fuels, like kerosene for lighting purposes and biomass for cooking, brings several disadvantages. Renewable energy technologies (RETs) like solar electricity are perceived as a helping hand for people suffering energy poverty. However, only a fraction of population has access to the solar energy and they are not using for cooking due to the fact that the amount of energy required for cooking is higher than that of provided by the standalone units of solar electricity (Hou et al., 2017). This leaves a huge population in rural areas dependent on biomass (particularly, wood fuel) for cooking purposes. The present study envisages to explore the potential of RETs, mainly the solar energy, to find a solution for energy poverty (EP) in rural areas. Moreover, this study also outlines the efficient use of biomass by limiting deforestation among rural households. Furthermore, this study examines the ways of reducing vulnerability through solar electrifications and efficient biomass usage through using improved cook stove (ICS).

This study envisages that efficient biomass utilization and the use of RE transform the rural lives, thereby, reduces the vulnerability. Hence, the provision of efficient means of biomass utilization is considered essential since people in rural areas continue to use biomass even in the presence of RETs. Therefore, this study aims at exploring the potentials of RE alternatives to reduce people's vulnerability in rural areas in addition to exploring the potential of these REs in limiting deforestation in developing economies.

2. ENERGY POVERTY

EP refers to the households' inability to access modern and clean sources of energy and subsequent dependence on fuels from solid biomass for the purpose of cooking and other domestic uses (Baqir et al., 2019). According to International Energy Agency (IEA, 2010a) and Practical Action (Practical Action, 2013), EP refers to the inadequate energy services in order to fulfill basic lighting, heating, cooking, communication, education, healthcare and income-generation activities (IGA). Moreover, energy poverty is characterized by the dependence on solid biomass fuels such as crop residuals and firewood to fulfill other energy needs. In present research, EP refers to the inability of rural households to access clean and modern services of energy for meeting basic energy needs and their subsequent dependence on solid biomass fuels in developing countries.

3. SOLAR ENERGY AND RURAL ELECTRIFICATION

The rural areas can be developed through "*Rural Electrification (REC)*" as evidenced in the literature (Lee et al., 2019; Mamaghani et al., 2016). As majority of the population in developing countries residing in remote areas and those rural areas lack energy services through which the living standards of people can be improved. The rural development being emphasized here refers to the sustainable development (SD). The G8 renewable energy task force (G8, 2001) and the Intergovernmental Panel on Climate Change (IPCC, 2012) declare the provision of clean and reliable energy service in affordable prices as an essential element in attaining sustainable development and that RE (i.e., solar energy) fulfill aforementioned all three criteria.

The exiting literature on the impacts and the significance of using decentralized and stand-alone solar PVs for achieving REC in underdeveloped economies is voluminous because (Bhandari and Stadler, 2011; Rathore et al., 2018). The reason behind popularization of solar energy is its ability to provide economical energy to distant and inaccessible areas that could not be linked to the main electricity grid and because of its positive environmental impacts. However, another strand of literature (Alizadeh et al., 2016) is against such solar PVs projects due to the involvement of high initial costs despite its benefits and that the poor people in rural areas, who are actual target of such projects to reduce their EP, often cannot afford these solar PVs by themselves. Therefore, the governments have to subsidize them at the cost of other development projects, thereby involving high opportunity cost.

Discussing the environmental aspects of solar PVs, some authors discussed some problems associated with the manufacturing and disposal of PV panels and batteries (Devabhaktuni et al., 2013; Wijeratne et al., 2019). The chemicals used in the process of manufacturing PV panels, such as polycrystalline silicon, cadmium telluride, micro-crystalline silicon, brominated flame retardants, lead, chromium, cadmium and copper indium selenide are harmful to the workforce and to the environment afterward (Dong et al., 2019). The hazardous chemicals in solar products can damage environment, if not properly disposed of (Dong et al., 2019).

The existing research documented and revealed that the high initial cost of PV panels is getting down which can be associated to the economies of scale due to large scale production, introduction of improved technology and enhanced PVs performance (G8, 2001; Jamil et al., 2017; Oliver and Jackson, 2000). This indicated that the rural poor population can soon afford the PVs and that in few years, solar energy is likely to attain large scale competitiveness as maintained by IEA/OECD (IEA, 2010b). Moreover, the high installation cost of solar home systems (SHS) is one of the reasons which affect its purchase, even though SHS has no user fee and lower maintenance cost.

Concluding the discussion, it can be maintained that adoption of solar PVs is a feasible approach in REC despite having few environmental and cost issues. The environmental pollution can be addressed if used PVs are properly disposed of and recycled. Furthermore, solar systems of energy have substantial environmental benefits as compare to traditional sources of energy, thereby, contribute in attaining the SD goals (Corbett and Mellouli, 2017).

4. CLIMATE CHANGE AND SOLAR ENERGY

The significance of solar energy (RE) is emphasized in adaptation in UNFCCC and climate change mitigation, an important international convention on climate change and renewable energy (Nation United, 1992). Similarly, the role of renewable energy is emphasized in 2001 by the IPCC (IPCC, 2001b). A voluminous research can be found on said issue. Following section offers literature analysis on the renewable energy usage in climate change mitigation as well as adaptation separately in two sub-sections.

4.1. Climate Change Mitigation and Solar Energy

The climate change mitigation refers to the anthropogenic interventions for the reduction of green house gases (GHGs) emissions as defined by IPCC (2012). Alternatively, UNDP (2013) explained climate change mitigation in terms of efforts for preventing or reducing the GHGs emissions. A study conducted by Corbett and Mellouli (2017) on solar PV shows the use of RE in climate change mitigation, in which he noted that the usage of PVs carry more environmental benefits as compared to its disadvantages. His assertion is supported by his illustration in which he placed one 5 kWp PV system on the roof of a home. His illustration reveals that a single PV, in 1-year time period, prevents burning of 3.3 tons coal, emission of 8.47 tons of carbon dioxide (CO_2) to enhance greenhouse effect, about 22.68 kilogram of sulphur dioxide (SO_2) and nitrous oxide (NO_x) both from atmospheric pollution and acid rain, particulates of 2.5 pounds to prevent health hazards, ash of 571 pounds from landfills disposal, and more than 5000 gallons of water is conserved.

Above numbers were calculated on the basis of electricity generation from coal. The work of Pearce clearly demonstrated that the climate change is mitigated by using PVs for electricity generation. The higher the PVs usage is, the larger the mitigation will be. Moreover, the official lifespan of PVs is often long as 20-25 years, therefore, it carries the tendency of farfetched climate change mitigation (Demski et al., 2017; Kamalapur and Udaykumar, 2011). Likewise, Posorski et al. (2003) attempted to investigate whether SHS usage contributes to the mitigation of climate change by reducing GHG emissions. Their comparison between conventional lighting using fuel lamps and using one 50 Wp SHS revealed that SHS usage helps to reduce approximately 09 tons of CO_2 equivalent GHG emissions in a usage period of 20 years. They concluded that the efficient use of SHS as a substitute of kerosene oil effectively reduces GHG emissions, which in turn, mitigates climate change.

On the other hand, Drennen et al. (1996) used Zimbabwe as case study to examine the correlation between climate change and solar energy usage. The empirical findings depict that they maintained that the role of solar power is insignificant to mitigate climate change in years to come. The reason behind this conclusion could be the low usage of PVs due to higher cost of installation. However, an increasing trend is observed in PVs and related RETs usage these days due to falling prices and its important contribution in mitigating climate change (Alizadeh et al., 2016; Leng et al., 2018). The growth rate of the installed capacity of PVs is illustrated in Figure 1.

The graph clearly illustrates that since 2005, the PVs installed capacity has continuously been increasing. From 2009 to 2015, the PVs installed capacity has increased dramatically (total 203 GW) which is in contrast of the argument regarding PVs significance by Kurtz et al. (2017). Therefore, the conclusion drawn by them is in sharp contradiction with the empirical evidence. Subsequently, the increased usage of PVs lessens the released emissions, which in turn, mitigates climate change. The emphasis on the use of PVs or SHS by Posorski et al. (2003) for protecting the climate is in line with the evidence presented in the Figure 1. Likewise, Figure 2 shows the cumulative global PV installations all over the world in 2016. In this regard, China is leading the world with 23% installations followed by USA and Japan with 14% installation each. Moreover, Germany and Italy also installed Solar PV with 13 and 6% respectively. However, rest of the world installed only 30% solar PV in 2016 as shown in Figure 2.

Figure 1: Global capacity of solar PVs and annual additions, 2015

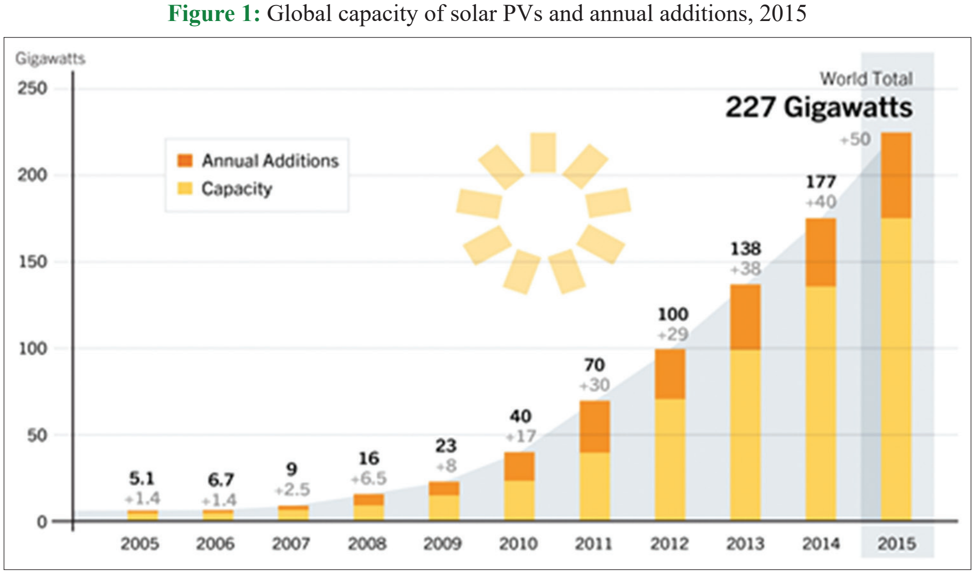
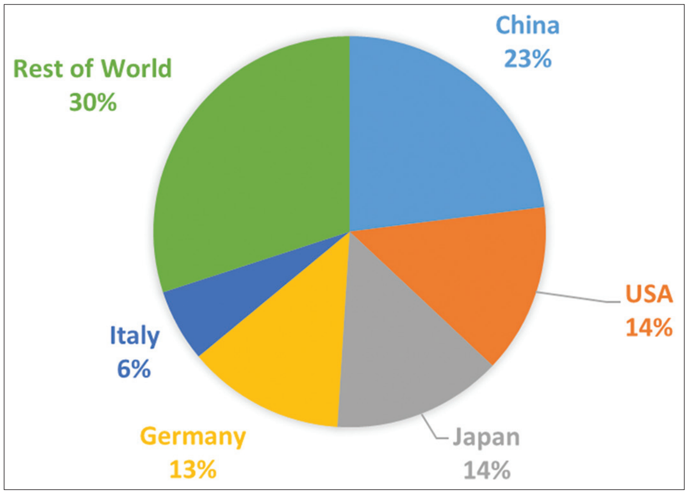


Figure 2: Solar PV insulation 2016



Source: HIS

4.2. Climate Change Adaptation and Solar Energy

Climate change adaptation refers to the human or natural system adjustment in reaction to expected or actual climatic changes and their impacts which regulates harmful damages and exploits advantageous opportunities (IPCC, 2007). The IPCC (2001a) clamined the poor developing nations as the extreme vulnerable because of climate change that aggravate current resource and environmental poverty. This rapidly climate change vulnerability among LDCs is more associated to their lower adaptive capacity as compare to any other factor (Wheatley et al., 2017). In this regard, for LDCs, climate change adaptation is considered as the main priority issue and not the climate change mitigation. As the climatic needs of one area are different than that of other, thus the climate change adaptation can be considered as an area-specific phenomenon. In addition, the relationship between climate change adaptation and renewable energy is not as direct as that between climate change mitigation and renewable energy. Following section presents literature on the relationship of solar energy and climate change adaptation.

A research was conducted on decentralized solar energy center in Ikisaya village. This study found that people received help from the energy center services for climate change adaptation. The services provided at the Ikisaya energy center include Video/TV watching, charging of laptops and mobile phones, scanning, photocopying, printing, typing, other computer services, renting of moveable LED lanterns, and a retail center for selling small SHS and solar lanterns. She maintained that business, trade, remittance, and casual employment are some of the support benefits from energy center, thereby, increasing the adaptive capacity of the local population.

Moreover, the charging services provided at the center helped in enhancing communication by talking on the mobile phones instead of meeting each other after walking long distances that helped in time savings (Quantity, 2018). The saved time can alternatively be utilized in some other productive activities. The livelihoods individuals can be improved through access to up-to-date information received from Video/TV shows. However, people living farther from the centers were unable to get benefits from the services offered at energy center, thus, having lower adaptive capacity as compare to those who receive those services.

Likewise, Vognild (2011) carried out another research on climate change adaptation and found a significant impact of solar energy supply on climate change adaptation in India, where most of the people were agriculture dependent. It is concluded in her research that the regular climate stresses can be coped with the provision of solar energy on the island. In addition, electricity supply helped in providing opportunities for increased income generation in the form of extra hours of work and improved working conditions in the availability of light in addition to visit one another for the purpose of learning and carrying out IGAs (Vognild, 2011). Therefore, the availability of lighting services has enabled the population of the island to enhance their incomes through extended working hours and job diversification (Esen, 2004). Additionally, the job diversification reduced their dependency on agriculture, thereby, reducing their vulnerability to climatic changes (Vognild, 2011) (Pearson and Newman, 2019).

Likewise, a research has been conducted by using various RETs in five countries namely, Zimbabwe, Senegal, Brazil, Bangladesh and Argentina. Authors, in their research, indicated the way how the projects of decentralized renewable energy (DRE) such as SHS, can be used in climate change adaptation in LDCs. This climate change adaptation can be done in several ways ranging from alleviating poverty to improving livelihood security. Firstly, the electricity access engages people in different IGAs which helps in diversifying their employments, thereby augmenting their income levels and reducing the pressure of poverty. Secondly, electricity access offers health benefits such as reduction in the respiratory problems caused by the smoke since there are zero smoke emissions from the electricity. Improved health in the form of reduced health risks and infections such as waterborne diseases through electricity access (in the form of the availability of safe drinking water) guarantees people a productive and healthy life, thereby, enhancing adaptive capacity of individuals.

A careful review of literature presented in this section allows us to conclude that solar energy plays a crucial role in enhancing the adaptive capacity of individuals through enhanced livelihood, poverty reduction, and enhanced security in addition to the access to improved health, among others. Therefore, it is maintained that the socioeconomic benefits of the use of solar energy enhance the adaptive capacity of individuals and adaptation process as a whole.

5. CLIMATE CHANGE AND IMPROVED COOK STOVES

The term "Improved cook stoves (ICS)" refers to the stoves intended to augment the cooking productivity through enhanced energy efficiency and elimination of smoke from indoor living spaces (Leng et al., 2018). The concept of ICS came to handle the disadvantages of 3-stone fire (3SF) which is commonly used in remote areas of LDCs. The disadvantages of 3SF are not limited to people only, it affects environment as well through increased emissions. Various research studies have been carried out to investigate the ICS role in the mitigation and adaptation of climate change. Following sections offers a critical review of such studies.

5.1. Climate Change Mitigation and Improved Cook Stoves

Several authors have been documented the role of improved cook stoves in the mitigation of climate change (Jeuland et al., 2020; Mitchell et al., 2019; Panwar et al., 2009). They conducted a review study on the scope of CO_2 mitigation using solar cookers and ICS. The findings of their research revealed that biomass combustion with the use of ICS generates lesser emissions, thereby, saving approximately 161 kg of CO_2 emissions per stove annually. Therefore, the reduction of CO_2 emissions using ICS helps climate change mitigation.

Similarly, Adkins et al. (2010), studied the institutional rocket 21 design ICS that consume fuel wood in comparison of 3SF in school kitchens randomly selected in Western Kenya. Numerous food types in the school feeding program were included in their experiments. The findings of research reveal that the consumption of fuel wood was lesser in case of rocket design ICS than that of 3SF on two different food types and the fuel savings of 48% and 42% were achieved using rocket design ICS. Additionally, using IPCC's conversion factor of 1.747 tons of CO_2 emission from burning one ton of fuel wood (41), Adkins et al. (2010) predicted that approximately reduction in CO_2 emission each school per year is 9 tons provided that each school use rocket design ICS on a regular basis. Conclusively, the findings of aforementioned research provide an evidence that CO_2 emissions can be reduced by using ICS, thus, it can be concluded that ICS helps in climate change mitigation (IPCC, 2006).

5.2. Climate Change Adaptation and Improved Cook Stoves

As developing and LDCs are more vulnerable to the impacts of climate changes, thus climate change adaptation is of crucial importance for such countries (IPCC, 2001b). Generally, 3SF that consume huge amount of biomass are used for cooking purposes in the rural areas in LDCs and developing countries. Since ICS consume lesser amount of biomass in the process of cooking, which requires less time for biomass collection, thereby, saves time for other activities. Numerous research studies have been carried out on the efficiency of ICS in terms of cooking time and biomass usage. These studies also reveal that ICS helps in climate change adaptation. Following section documents few such studies.

Umogbai and Orkuma (2011) conducted a research using the traditional 3SF in comparison to the locally made ICS in Nigeria. The findings of their research reveal that the average time to boil one liter of water was about 8 min consuming 69 g of fuel wood per liter of water. In contrast, the 3SF took approximately 25 min by consuming 326 g of fuel wood for boiling the same amount of water. Therefore, the average burning rate (consumption of fuel wood) was found to be higher in case of 3SF (10.1 g/min) as compared to ICS (6.7 g/min) showing that ICS consume lesser fuel wood as compared to 3SF in the same duration and for the same task (Umogbai and Orkuma, 2011). This means that the use of ICS reduces saves the time and trips for the collection of biomasses because ICS use lesser biomass for the purpose of cooking.

In addition, Adkins et al. (2010) conducted two more studies in Western Tanzania and Western Uganda. The usability and performance of biomass cooking stoves used in the households are evaluated in their research involving qualitative surveys and cooking tests in the kitchens. They made a performance comparison between traditional 3SF and rocket design ICS. The performance of *"StoveTec"* and *"Ugastove22"* was compared with the performance of 3SF.

On similar tasks, the findings of their experiments revealed that fuel wood saving from *Ugastove* and *StoveTec* are 46% and 38% respectively as compared to 3SF stoves. They compared the performance of traditional 3SF with *Advent Stove*, *Envirofit23* and *StoveTec* ICS in Tanzania by cooking beans and maize flour paste (termed as *ugali*) and found that in the process of *ugali* cooking, *Advent* stove, *Envirofit23* and *StoveTec* achieved fuel wood savings of 25%, 41% and 41% respectively against traditional 3SF. While, the experiment of beans cooking revealed that *Advent* stove, *StoveTec* stove and *Envirofit23* stove achieved fuel wood savings of 36%, 34% and 22% respectively against traditional 3SF. These findings show that firewood can be saved by using ICS. Discussing the time required for cooking the food, approximately 60% of the respondents in Tanzania testified that the time required to cook food on *Envirofit* and *StoveTec* stoves was much lower, thus they were able to save a lot of time in the process of cooking using ICS.

The above-analysis of studies concluded that the use of ICS requires lesser time for food preparation in addition to lesser biomass consumption. This shows that if ICS are used in a particular household for cooking purposes, the collectors of biomass in that particular house save time that they were spending in the collection of wood fuel, which they can use in other accomplishing other productive tasks because they do not need to go for the collection of any kind of biomasses and fuel wood on a regular basis. In addition to that, individuals can also save the time as ICS require lesser time in the preparation of food. The spared time can alternatively be utilized in other IGAs such as improving social capital (gossiping with friends), relaxing (physical rest), economic activities (to enhance the household earnings), sharing ideas to learn and make others leanr new things (through engaging in local community gatherings) in addition to fulfill other domestic responsibilities such as cleanliness of the household and its surroundings, which in turn, helps in maintaining a good health of the family members through environmental hygiene. In addition to the time saving benefits from biomass collection and the preparation of food using ICS, the usage of ICS is comparatively easy than that of 3SF as the kitchen will not be smoky, thereby saving the cook from running nose and itching eyes, which in turn, reduces the cooking stress in the process of preparation of food. The adaptive capacity of the individuals will be enhanced with all these benefits of using ICS. Therefore, the utilization of ICS facilitates in attaining climate change adaptation, particularly, in remote areas of under develop and poor countries.

6. SOLAR ENERGY AND SOCIO-ECONOMIC IMPACTS

In order to achieve the sustainable development, a strong emphasis has been made by international organizations such as G8 (2001), the World Bank (1996) and UNDP (2012) on RE utilization, especially in rural areas of developing countries. A number of research studies on RE, particularly on solar energy (Baqir et al., 2019; Dong et al., 2019; Rathore et al., 2018; Sahoo, 2016; Singh et al., 2020), claims that the use of solar energy brings a lot of health as well as socio-economic benefits to the peoples living in rural areas.

Among such studies is the research carried out by Gustavsson and Ellegård, (2004) who investigated the positive impacts of using SHS in rural areas in Zambia. The findings of their study revealed that the benefits of using SHS include education benefits to the children as they get access to lighting in the evening and night time where they can study. In additon, SHS usage provides innovative ideas for socialization and entertainment using radios and other audio video devices at night, and the access to the light for home lightening. Moreover, the economic benefits include financial savings on lighting, the extended working time at business, jobs and at home. The lighting enables to utilize time in the night at home fulfilling household responsibilities such as cooking and others. The reduced emissions are another benefit of using SHS that further helps in maintaining and improving the health of individuals, protects against several respiratory problems in addition to environmental protection.

Likewise, a study was conducted by Jacobson (2007) in rural areas of Kenya on social change through solar electrification. The findings of the research have shown that the connectivity of individuals with one another in rural areas as well as with urban areas have increased significantly using solar energy since this energy enabled them to charge their mobile phones very easily. Moreover, solar energy enabled them to do more socialization and receive entertainment from TVs and radios. Other benefits of using solar energy include extended working hours giving more economic support, extended IGAs, enhanced information access, and better education facilities in terms of extra study hours (Jacobson, 2007).

Furthermore, the socio-economic impacts of RE are analyzed by Wamukonya (2007) in Namibia. They compared the household that were un-electrified and those receiving electricity from solar and grid stations. Their findings have shown that general welfare of the household increased with the consumption of solar electricity since this source of electricity enable them to get entertainment using TV channels, socialize through mobile phones and social media, increase study hours for the students, thereby, increasing their performance in education. Additionally, solar electricity provides access to people to different educative programs on radios and TVs, extensions in working hours as length of the day increases by getting electricity supply in the nights. Moreover, solar energy also contributes to improve health of the people in addition to the provision of safety and security through lighting in the nights. However, they could not find the initiation of any IGAs through solar electricity in the focus area.

The impacts of RE, especially solar energy, can be categorized into five main groups namely; social impacts, economic impacts, health impacts, education impacts and environmental impacts Firstly, the positive health effect of using solar energy is due to lesser exposure of households to gas emissions and indoor air pollutants (IAOPs) that are extremely harmful for an individual's health. Solar electricity also enables people to get more information through radios and TV programs that help them to follow improved health practices to avoid a number of dangerous diseases.

Secondly, the lighting enables students to extend their study hours after the day hours which ultimately helps them to perform better in their education. The lighting after the day hours also enable adults to read and enhance their knowledge, thereby, benefiting them from educational perspective. Additionally, radios and TV programs also help people to update their knowledge.

The third main benefit of using solar energy is monetary saving in the electricity bills. The larger the installation is, the greater the electricity savings are. Moreover, solar panels not only help in saving the electricity bill, it also generates passive incomes via channels of savings since they are not spending on expensive sources of lighting such as kerosene. Moreover, increased revenues from mobile phones charging and increased working hours help to contribute to economic benefits of using solar electricity. Furthermore, the economic advantages of solar energy are easily measurable in monetary terms.

Fourthly, the social impacts of using solar energy include socialization through mobile phones and entertainment using radios and TVs. People can also socialize after their jobs and working hours due to the availability of lighting in the nights. Moreover, it also provides safety and securit to the individuals as well as to the population as a whole. The transfer of information using mobile phones also increase socialization among community members as well as it enables access to the urban population.

However, the positive environmental impacts of solar energy are no less tangible. The reduced emissions by using the solar energy is the greatest environmental benefit, which in turn, provides a clear and hygienic atmosphere to the community population. In addition, fossil fuels such as kerosene are replaced with solar energy for the purpose of refrigeration and lighting, thereby, helping to clean the environment since solar energy does not emit any hazardous gases. Additionally, this transition has enormous benefits such as improved health through cleaner water, air and soil, enhanced energy security from fall in imported fuels, green jobs creation and reduction in GHG emissions which the main cause of severe weather, global warming and catastrophic climate change.

Despite aforementioned socio-economic benefits of solar energy, few authors argue that the disparities between the rich and the poor increases with the use of solar energy, especially in rural areas (Richter and Frings, 2005). As Richter and Frings (2005) maintained that the poor and rich families unequally use the facilities of electricity, thus the provision of solar electricity options further augments the gap between them, which in turn, aggravate the problem of poverty. The differences in the usage of electricity will further be translated into the use of solar electricity since the rich will have more access to solar electricity and they can utilize it to their maximum. The findings of Jacobson (2007) are in line with Davidson et al. (2011) who found that a middle-class is formed as a result of increased differences between the rich and the poor households in rural areas of Kenya with the introduction of solar electricity. On the other hand, the program of solar electrification by India are in place for the purpose of supplying free SHS to poor households to reduce disparities and for the purpose of capacity building among poor households.

Conclusively, the lives of the people can positively be transformed by using solar energy alternative as demonstrated by its numerous socio-economic impacts. The socio-economic impacts of solar energy are not restricted to the individuals only, but its spillover effects positively transform the whole society.

7. DISCUSSION AND CONCLUSION

It has been shown that the use of solar energy has brought numerous socioeconomic benefits to the rural localities. It has been observed that the use of SHS improves the economic, social and health status of individuals as well as their households. Moreover, the level of education in the area, where SHS are used, has augmented in addition to the climate change mitigation because of emissions reduction. This section presents the findings of the study regarding socio-economic impacts of solar energy which is similar to the conclusion drawn by (Gustavsson and Ellegård, 2004; Jacobson, 2007; Mitchell et al., 2019; Pearson and Newman, 2019).

For the ease of presentation, the socio-economic effects are categorized into five distinct categories such as, environment, health, education, income and social as presented in Figure 3. This research has found that SHS usage offers financial benefits to the SEs as well as the households. It is also concluded that solar energy usage transforms the lives of the people in the study area, both economically and socially. Moreover, the study also shows that solar electricity usage has enhances their social capital and improved the health of the residents, increase their incomes, as well as improve education level which effects positively towards climate change mitigation in rural areas of developing centuries. Consequently, the vulnerability of rural households has reduced by using RE and ICS, thereby, augmenting the adaptive capacity of individuals and the community as a whole.

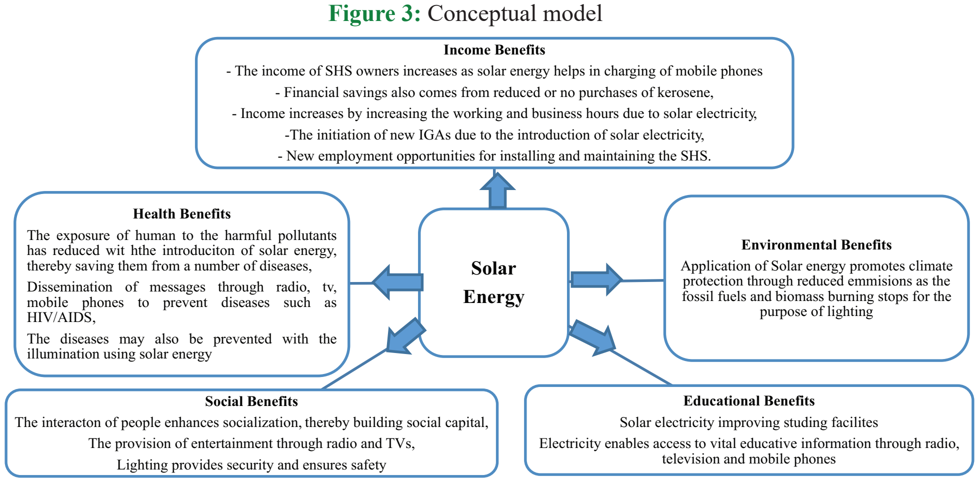
The present study has also revealed that the REs used for the purpose of REC and efficient biomass usage, has the potential to augment the adaptive capacity of individuals, which in turn, significantly improve their climate change adaptation in rural areas of LDCs and developing countries. Therefore, it is crucial that concerned authorities and their development partners must put mechanisms in place that can increase the access to RE and provide effective ways of biomass combustion amongst the poor rural households to reduce their vulnerability to climate change which previously not focused. Since the major energy source in most of the rural localities is traditional biomass in developing countries, the present study has revealed that the deforestation can be reduces with the increased use of ICS. Additionally, a number of other disadvantages associated with the usage of traditional biomass will also be addressed with the use of ICS which ignored previously. Moreover, it is also concluded that the adaptive capacity of individuals and communities to climate change can be augmented by using ICS.

8. RECOMMENDATIONS

In line with the findings of present study, a number of suggestions have been recommended that can be used to enhance the access to RE and ICS and their uses in the study area and other developing countries as well.

Firstly, appropriate and efficient mechanisms for financing RE should be introduced by the governments that enhance peoples' access to RE. However, the governments should not run this financing schemes by themselves, rather they should make the seed capital available to a devoted fund and appoint a commercial bank or an agent to take care and operationalize this scheme on the behalf of the government. The hired agent or the commercial bank should operationalize the mechanisms of financing in the same way as other loan schemes in terms of recovery and security measures should be ensured. The repayment of all the loans must be ensured in order to run this scheme efficiently in the long-run

Figure 3: Conceptual model



so it may be available for other low-income consumers in need. All these measures help to ensure the self-sustenance of the scheme for coming years so that the hired agent or bank should not ask further funding from the government for its operations. However, a research should be conducted before introducing such schemes, for investigating the factors that made other RE financing organizations a failure and collapsed (if any) and to explore the demand of RE in an area where scheme is going to be introduced. This kind of research will be beneficial for the governments as well as other stakeholders for designing an effective and efficient scheme of RE financing for consumers who need it without collapsing the scheme.

Secondly, as a way of avoiding loans and subsidizations, lay-bye schemes or services should be introduced by the governments and concerned stakeholders for ICS and RETs. These types of schemes allow consumers to pay to ICS and other RETs in smaller installments. However, the new technology or ICS will be handed over to the consumers after finishing the payments. An authorized agent like a commercial bank or accredited service provider should be hired by the government to collect the payments on the behalf of the government. This scheme will carry the benefits of zero loan defaults since people have to pay completely for ICS before collecting it.

Thirdly, governments should review the policies to attract domestic as well as foreign investors in the energy sector, particularly in REC. A careful assessment of such policies will assist the governments to design appropriate policies aiming to attract energy-specific investments in line with the goals of sustainable development. However, a mere review without action will be considered a waste of time and other resources. The public sector must ensure the development of renewable energy-specific policies with the implementation of such policies. Additionally, governments must ensure to provide an enabling environment where private sector investments can flourish and to provide an environment of confidence for the investors.

As far as the policy directly related to ICS is concerned, it is strongly recommended that governments should involve women in the local level planning in order to design appropriate policies in line with the family and cultural values of each area. In other words, the local preferences and values should be taken into consideration in the process of project planning in order to enhance the acceptability and effectiveness of these project. Considering local values and preferences will add local flavors to the projects, thereby, enhancing their effectiveness and acceptability. One of the major reasons for the failure of some similar projects was the lack of local community and other stakeholders' involvement in the planning and implementation stages of the policies. Local involvement in the planning process helps to consider the local energy preferences as well as demands. In addition, the proposed new technology should be closer to what the community is already using. This will enhance the acceptability of the new technology in that locality. An induction of technology that seems to be entirely new or very difficult to use will ultimately lead to the failure of the project.

REFERENCES

Adkins, E., Chen, J., Winiecki, J., Koinei, P. (2010), Testing institutional biomass cookstoves in rural Kenyan schools for the Millennium Villages project. Energy for Sustainable, 14(3), 186-193.

Alizadeh, M., Moghaddam, M., Amjady, N. (2016), Flexibility in future power systems with high renewable penetration: A review. Renewable and Sustainable Energy Reviews, 57, 1186-1193.

Baqir, M., Bharti, S.K., Kothari, R., Singh, R.P. (2019), Assessment of an energy-efficient metal chulha for solid biomass fuel and evaluation of its performance. International Journal of Environmental Science and Technology, 16(11), 6773-6784.

Bhandari, R., Stadler, I. (2011), Electrification using solar photovoltaic systems in Nepal. Applied Energy, 88(2), 458-465.

Corbett, J., Mellouli, S. (2017), Winning the SDG battle in cities: How an integrated information ecosystem can contribute to the achievement of the 2030 sustainable development goals. Information Systems Journal, 27(4), 427-461.

Davidson, P.M., McGrath, S.J., Meleis, A.I., Stern, P., DiGiacomo, M., Dharmendra, T., Correa-de-Araujo, R., Campbell, J.C., Hochleitner, M., Messias, D.K.H., Brown, H., Teitelman, A., Sindhu, S., Reesman, K., Richter, S., Sommers, M.S., Schaeffer, D., Stringer, M., Sampselle, C., Anderson, D., Tuazon, J.A., Cao, Y., Covan, E.K. (2011), The health of women and girls determines the health and well-being of our modern world: A white paper from the international council on women's health issues. Health Care for Women International, 32(10), 870-886.

Demski, C., Capstick, S., Pidgeon, N., Sposato, R.G., Spence, A. (2017), Experience of extreme weather affects climate change mitigation and adaptation responses. Climatic Change, 140(2), 149-164.

Devabhaktuni, V., Alam, M., Depuru, S. (2013), Solar energy: Trends and enabling technologies. Renewable and Sustainable Energy Reviews, 19, 555-564.

Dong, X.Y., Ran, Q., Hao, Y. (2019), On the nonlinear relationship between energy consumption and economic development in China: New evidence from panel data threshold estimations. Quality and Quantity, 53, 1-21.

Drennen, T., Erickson, J., Chapman, D. (1996), Solar power and climate change policy in developing countries. Energy Policy, 24(1), 9-16.

Esen, M. (2004), Thermal performance of a solar cooker integrated vacuum-tube collector with heat pipes containing different refrigerants. Solar Energy, 76(6), 751-757.

G8. (2001), G8 Renewable Energy Task Force Final Report. Toronto: G8 Research Group, University of Toronto.

Gustavsson, M., Ellegård, A. (2004), The impact of solar home systems on rural livelihoods. Experiences from the Nyimba energy service company in Zambia. Renewable Energy, 29(7), 1059-1072.

Hou, B., Tang, X., Ma, C., Liu, L., Wei, Y., Liao, H. (2017), Cooking fuel choice in rural China: Results from microdata. Journal of Cleaner Production, 142, 538-547.

IEA. (2010a), Energy Poverty: Can We Make Modern Energy Access Universal? Orld Energy Outlook 2010. Paris: OECD, International Energy Agency. p237-271.

IEA. (2010b), World Energy Outlook 2010. Paris: OECD, International Energy Agency.

IPCC. (2001a), Climate Change 2001: Mitigation. Summary for Policymakers. Cambridge: Cambridge University Press.

IPCC. (2001b), Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

IPCC. (2006), In: Eggleston, H.S., Buendia, L., Miwa, K., Ngara, T., Tanabe, K., editors. IPCC Guidelines for National Greenhouse Gas Inventories. Hayama: Institute for Global Environmental Strategies

(IGES).

IPCC. (2007), In: Parry, M.L., Canziani, O.F., Palutikof, J.P., Linden, P.J., Hanson, C.E., editors. Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

IPCC. (2012), Renewable Energy Sources and Climate Change Mitigation: Special Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

Jacobson, A. (2007), Connective power: Solar electrification and social change in Kenya. World Development, 35(1), 144-162.

Jamil, W., Rahman, H., Shaari, S., Salam, Z. (2017), Performance degradation of photovoltaic power system: Review on mitigation methods. Renewable and Sustainable Energy Reviews, 67, 876-891.

Jeuland, M., Pattanayak, S.K., Tan, S.J.S., Usmani, F. (2020), Preferences and the effectiveness of behavior-change interventions: Evidence from adoption of improved cookstoves in India. Journal of the Association of Environmental and Resource Economists, 7(2), 305-343.

Kamalapur, G., Udaykumar, R. (2011), Rural electrification in India and feasibility of photovoltaic solar home systems. International Journal of Electrical Power and Energy Systems, 33(3), 594-599.

Karekezi, S. (2002), Renewables in Africa-meeting the energy needs of the poor. Energy Policy, 30(11), 1059-1069.

Kurtz, S., Haegel, N., Sinton, R., Photonics, R.M. (2017), A new era for solar. Nature Photonics, 11(1), 3-11.

Lee, K., Miguel, E., Wolfram, C. (2019), Experimental evidence on the economics of rural electrification. Journal of Political Economy, 128(4), 12-25.

Leng, Z., Shuai, J., Huang, F., Wang, Z., Shuai, C. (2018), Comparative advantages of China's wind energy products: A belt-and-road perspective. Quality and Quantity, 53, 1-11.

Mamaghani, A., Escandon, S., Najafi, B., Energy, A.S. (2016), Techno-economic feasibility of photovoltaic, wind, diesel and hybrid electrification systems for off-grid rural electrification in Colombia. Renewable Energy, 97, 293-305.

Mitchell, E.J.S., Ting, Y., Allan, J., Lea-Langton, A.R., Spracklen, D.V., McFiggans, G., Coe, H., Routledge, M.N., Williams, A., Jones, J.M. (2019), Pollutant emissions from improved cookstoves of the type used in Sub-Saharan Africa. Combustion Science and Technology, 192, 1-21.

Nation United. (1992), United Nations Conference on Environment and Development: Agenda 21. Available from: http://www.sustainabledevelopment.un.org/content/documents/agenda21.pdf.

Nations United. (1992), United Nations Framework Convention on Climate Change. Available from: http://www.unfccc.int/essential_background/convention/items/6036.php.

Oliver, M., Jackson, T. (2000), The evolution of economic and environmental cost for crystalline silicon photovoltaics. Energy Policy, 28(14), 1011-1021.

Panwar, N., Kurchania, A., Rathore, N. (2009), Mitigation of greenhouse gases by adoption of improved biomass cookstoves. Mitigation and Adaptation, 14(6), 569-578.

Pearson, D., Newman, P. (2019), Climate security and a vulnerability model for conflict prevention: A systematic literature review focusing on African agriculture. Sustainable Earth, 2(1), 2-9.

Posorski, R., Bussmann, M., Menke, C. (2003), Does the use of solar home systems (SHS) contribute to climate protection? Renewable Energy, 28(7), 1061-1080.

Practical Action. (2013), Energy Poverty: The Hidden Crisis. Rugby, United Kingdom: Practical Action. Available from: https://www.policy.practicalaction.org/policy-themes/energy.

Quantity, F.A. (2018), Renewable and non-renewable energy and trade into developed and developing countries. Quality and Quantity, 53, 1-11.

Rathore, P., Rathore, S., Singh, R.K. (2018), Solar power utility sector in India: Challenges and opportunities. Renewable and Sustainable Energy Reviews, 81, 2703-2713.

Reddy, P.S., Sinha, A., Dogan, E. (2017), Article in environmental science and pollution research. Springer, 24(15), 13546-13560.

Richter, M., Frings, U. (2005), Renewable energy in rural areas: Reduced poverty and improved living conditions thanks to RE? Agriculture Rural Development, 12(2), 61-64.

Riti, J.S., Song, D., Shu, Y., Kamah, M., Atabani, A.A. (2018), Does renewable energy ensure environmental quality in favour of economic growth? Empirical evidence from China's renewable development. Quality and Quantity, 52(5), 2007-2030.

Sahoo, S. (2016), Renewable and sustainable energy reviews solar photovoltaic energy progress in India: A review. Renewable and Sustainable Energy Reviews, 59, 927-939.

Singh, A., Poonia, S., Santra, P., Jain D., (2020), Ensuring Energy and Food Security Through Solar Energy Utilization. Berlin: Springer. p199-218.

Umogbai, V., Orkuma, J. (2011), Development and evaluation of a biomass stove. Journal of Emerging Trends in Engineering and Applied Sciences, 2(3), 514-520. Available from: http://www.jeteas.scholarlinkresearch.com/articles/developmentandevaluationofabiomassstove.pdf.

UNDP. (2012), Decade of Sustainable Energy for All. New York: UNDP.

UNDP. (2013), Human Development Reports. Malawi: UNDP. Available from: http://www./hdr.undp.org/en/countries/profiles/mwi.

Vognild, R. (2011), Renewable Energy and Climate Adaptation: Exploring the Role of Solar Power Supply for Climate Adaptation on Moushuni Island, India. Oslo, Norway: University of Oslo, Department of Sociology and Human Geography.

Wamukonya, N. (2007), Solar home system electrification as a viable technology option for Africa's development. Energy Policy, 35(1), 6-14.

Wheatley, C.J., Beale, C.M., Bradbury, R.B., Pearce-Higgins, J.W., Critchlow, R., Thomas, C.D. (2017), Climate change vulnerability for species-assessing the assessments. Global Change Biology, 23(9), 3704-3715.

Wijeratne, W., Yang, R., Too, E., Wakefield, R. (2019), Design and development of distributed solar PV systems: Do the current tools work? Sustainable Cities and Society, 45(1), 553-578.

World Bank. (1996), Rural Energy and Development: Improving Energy Supplies for 2 Billion People. USA: World Bank.