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Assessment of Small off-Grid Photovoltaic Solar Home Systems Deployed For Rural Electrification: A Case Study of Rural Island Communities on Rema Village, Ethiopia

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Abstract— *The installations of Photovoltaic cells on the roofs of Ethiopian houses for electricity production gives families access to lighting and improves the livelihoods of people living in the rural regions of Ethiopia. The use of solar lighting instead of kerosene lamps has positive effects on people's health and leads to reductions of greenhouse gas emissions. This paper discuses on solar PV based rural electrification and its impact on environment and socio-economic development in Rema village, northern Ethiopia. Interviews from villagers, inspections of physical assets, and reviews of available written documentation were included in the study. According to the village survey the existing PV home system has a positive impact on environment and socio-economic development of the village. Questionnaires were prepared and conducted to the dwellers by considering agriculture, mixed and small scale business as main income. From the interviews data analysis of the three cases, villagers who have small scale business for their income showed high interest for extra PV modules for longer lighting time. Total CO2 emission reduced due to the use of solar PV by replacing kerosene lamps is equivalent to 504 tons of CO2/year.*

Keywords— off-grid; Photovoltaic; Solar Home Systems; Rural Electrification; Renewable

1. INTRODUCTION

Most of the world's energy consumption and electricity generation is principally dependent on fossil fuel and is being used extensively due to continuous escalation in the world's population and development. On the other hand, in process of electricity generation, by means of these fuels, a number of poisonous by-products adversely affect the conservation of natural eco-system. Therefore, this valuable resource needs to be conserved and its alternatives need to be explored. Solar energy, which is the primary source of energy for every other resource, would be expected to play a prominent role in the attempt of substituting the conventional fossil fuel with renewable energy source. Moreover, in developing countries, it will have a significant impact in reducing deforestation which is brought about by direct combustion of biomass, for providing heat energy. As most of the developing countries are found in the region where there is high amount of sunshine hour throughout the year, solar energy is expected to be one of the most promising sources of energy for both electricity generations as well as for heat energy supply [1-2].

The majority of the populations in developing countries dwell in the rural areas. Most of these people do not have access to electrical energy from the national grid. Consequently, kerosene-powered lamps became predominant power source for most rural dwellers. The alternative solution to this, calls for extension of the nation's central power grid system to the vast majority of the rural areas or to establish a Diesel Generating Set System. The inherent problems could be solved by the provision of electricity power to remote locations through solar powered plant [3-5].

As a developing nation, Ethiopia is rapidly increasing its energy consumption and is short on energy supplies. Fortunately, Ethiopia is located in that part of the world where sun shines for maximum number of hours. '13 Months of Sunshine' is the slogan of the Ethiopian Tourism Commission [6-8]. It gives a first hint on the potentials for renewable energy sources in the country. Providing grid electricity for the rural population of Ethiopia is not economical due to the scattered ways of settlement and low and seasonal income of the rural households. Off-grid rural electrification with the help of renewable energy technology is the best alternative to provide electricity for the rural population. The cost of renewable energy technology is too high for the rural population of Ethiopia like many other developing countries. To make renewable energy technologies affordable to the rural households there should be should proper financing mechanisms in place [9].

A small-scale photovoltaic (PV) system is a technology that is particularly appropriate for use in rural households. It is sometimes even suitable in urban areas if the main grids are not very reliable. This technology is also a modern alternative to oil, kerosene, candles, gas lamps and dry cell batteries [10-13]. A photovoltaic system is one suitable solution because of its flexibility, low environmental impact and freedom from fuel requirements for rural electrification [14-15]. Therefore, the use of solar energy for small scale domestic use in urban and rural centers is an alternative direction and a possibility for rural electrification.

Using renewable energy technologies like solar photovoltaic, rural areas can be electrified. Providing electricity to the individual households from a centralized PV power plant for lighting has not been successful due to the high initial investment and subsequent maintenance problems [16-17]. Off-grid PV systems can provide electricity to remotely located households and villages that are not connected to the main grid [18-21].

Photovoltaic systems, such as Solar Home Systems (SHS), are being promoted by both governments and international aid organizations as a feasible and cost effective alternative for the basic electrification of rural households [25-26]. A number of successful SHS pilot projects received widespread attention all over the world. After these success stories, solar home systems gradually came to be adopted as a viable option for rural electrification.

In Ethiopia, off-grid solar PV is a highly attractive energy source for rural population due to the scattered rural settlement and abundant solar energy resource. In recent years, non-government organizations are trying to electrify rural villages as a pilot project using PV panels. The model project area is Rema village which is located in northern-central part of Ethiopia. In this area more than 2,000 solar home systems have been installed for free by Solar Energy Foundation (a charitable nongovernmental organization) with a 10 Wp PV module, charge controller and gel lead acid battery [27-29]. This paper presents an assessment of Small off-grid pv solar home systems deployed for rural electrification of Ethiopia using Rema village as a case study. The gathered information allowed to assess the rural electrification efforts made based on a set of indicators considered in this paper which includes: Villagers attitude towards the technology, socio economic developmental and environmental impacts.

2. STUDY AREA AND METHODOLOGY

Rema, 150 miles north of the capital Addis Ababa, is home to Ethiopia's largest solar project. Every house in the village has electricity powered by solar lighting systems. This is unique in Ethiopia, 80% of the population live in rural areas where only 1% of the population have access to electricity. In this remote rural village the solar energy foundation has installed 2130 small solar home systems with 10Wp PV module, gel lead acid battery, charge controller and four light emitting diode (LED) lights It provides lighting and power small entertainment devices such as radio for not more than two hours.

Solar Energy foundation, a charitable nongovernmental organization established in 2005 in Germany and registered in Ethiopia as an international NGO in 2007. Main aims of the organization include Poverty alleviation and creating a long-term sustainable solar market in Ethiopia, knowledge transfer by train solar technicians and make them available for the developing solar market and creating jobs. This organization is working in rural electrification mainly in Ethiopia by using model projects, where Rema village is one of the model project [27]. In Rema village, the initial PV system is fully funded by Solar Energy Foundation but but people have to pay for maintenance, service and have to deposit money for spare parts, e.g. battery. This money is collected in monthly rates since 2005 by the village community.

The methods used to conduct this research were literature review of project plan documents and previous studies, site tour and field survey. Field survey was conducted in Rema Village to observe the activity related to PV based electrification. Questionnaires were prepared and conducted to assess the dwellers attitude and socio-economic performance of the installed PV systems with 213(10% of population) in which 128 have agriculture, 53 have mixed and 32 have small scale business as main income.

3. RESULT AND DISCUSSIONS

Villager's Attitude towards the Technology

Villagers were interviewed about their attitude towards the technology. Most of the villagers were happy with the technology. Many of them were surprised when electricity is coming from solar energy. They feel modernity and solved the main problems caused by traditional lighting using kerosene. They responded that unlike kerosene lamp, it gives high quality light and has no smoke that can cause health problems. The electricity that comes from the solar PV is also advantageous in terms of safety. Fire hazards are a common phenomenon using kerosene lamp based lighting systems. When performing interviews it was clear that there has been people that lost their lives and properties due to such accidents.

In Rema village the capital cost of the PV systems are covered by charitable organization, but the organization have a plan for the future the customers themselves have to pay for the capital cost directly or through loans. There are persons whose income is based on small scale business, agriculture only (both farming and herding animals) and mixed type of income (agriculture and some small scale business activity). Interviews were done for each income type and the following chart is developed based on the responses about solar PV. All numbers are in percentage where 100% is for total number of villagers interviewed in each income level.

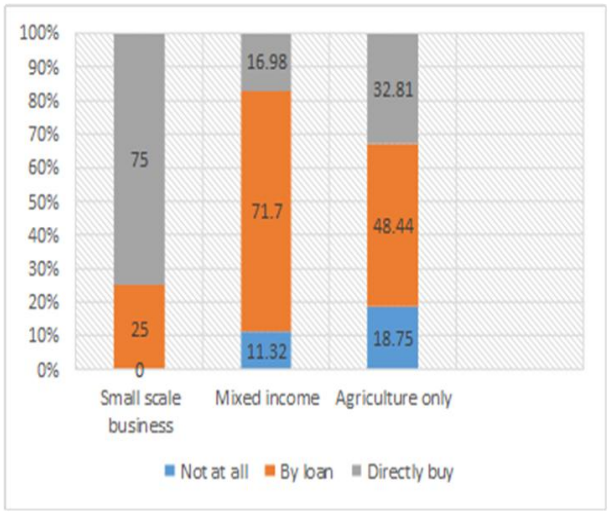

Chart-1: Interview responses about having the solar photovoltaic system

Small scale business showed high interest towards the technology. 75% of the interviewed showed an interest for direct buy option. This is due that they want to grow their business and the understood electricity is crucial for expansion. Villagers of mixed income households showed an interest for loan based payment. This can be due to the lower income compared to villagers who have small scale business. It can also be that electric lighting has lower impact on their income level compared to small scale business owners. Households whose incomes depend on 100% agriculture showed less interest for the technology compared to others. This can be due to the low level of income and their agricultural activities mostly do not depend on the electricity.

Socio economic developmental impacts

The villagers of Rema were using Kerosene lamps, and fire wood for lighting. The use of solar PV light increases the activity of the villagers. People who have children at education, perform activities like string a tile, making cultural household dressings and do different business activities want to have additional time of lighting. On the other hand, people whose activity is mainly agriculture requires minimum lighting time unless they have children who attend education (as the students want the light for performing homework and studying).

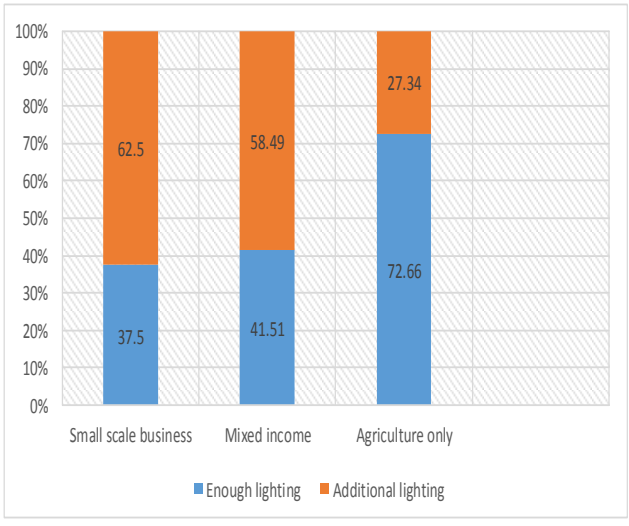

Chart-2: Interview responses about lighting time of solar photovoltaic

Currently, PV system is mostly used for lighting and sometimes for radio and tape due to its power limitation for about 4 hours. Villagers with small scale business were interviewed about their demand for

extra PV modules for their business activity and 37.5% said the existing lighting is enough and 62.5% needs an additional lighting time and for other services. They were also interviewed about how the technology changed their life style and economic activity, where 75% of them are happy and got a change in the level of their economic activity.

Households with mixed income were also interviewed about the impact of PV in their life style and economic activity. 41.51% of the interviewed said the current lighting level is enough, 58.49% of them want to have additional lighting time and other services. 86.79% of the interviewed are happy and got change in their level of activities. 72.66% interviewed villagers whose income is agriculture only said the lighting time is enough, 27.34% of them want to have an additional lighting time and 26.56% of them got the change in their level of activities.

Chart-3: Interview responses about level of economic activity due to solar PV lighting

From the interviews data analysis of the three cases, villagers who have small scale business for their income showed high interest for extra PV modules for longer lighting time and other services such as refrigerators, whereas lower positive response in households having income from agriculture only. From the interviews, it can be concluded that although the PV based electrification has brought positive impacts on the villagers, the demand of most villagers is hardly met.

Solar Photovoltaic for climate mitigation and adaptation

Producing electricity with photovoltaic (PV) emits no pollution, produces no greenhouse gases, and uses no fossil fuel resources. The environmental benefits of PV are great. A survey in Rema village by solar energy foundation suggested that households were using about 1.6 kerosene lamps on average. The actual savings in terms of the amount of CO2 reduced due to the use of solar PV by replacing kerosene lamps was calculated based on the following information:

Number of households =2,130
Average house hold use =1.6 lamp
Amount of kerosene used per lamp =70 liters/year
Emissions Factors for Kerosene =2.45 kg/liter [30]

Thus for the 2,130 solar home systems installed by the foundation, the total saving of greenhouse gases is over 584 tons of CO2/year.

4. CONCLUSION

This research focused the roles that solar home systems play at the household level in rural areas in Ethiopia, Rema village. At the most basic level, nearly all off-grid solar PV products are promoted as sources of clean, modern lighting. Household-level solar lighting has been especially favored by the development community, with an oft-cited rationale being that it improves health and safety by eliminating kerosene lamps, the dominant lighting source for many off-grid populations that is associated with many adverse. Decentralized PV based rural electrification improved the livelihood of Rema village. It improved the socioeconomic activities of villagers and quality of life. Using PV decreases deforestation and CO2 emission.

In addition to high-quality, affordable, healthy, and environmentally friendly solar lighting, it is hoped that larger solar products could also provide additional basic electrification benefits. After all, improved electricity access should be used for more than just electric lighting. The following points are raised as recommendation for future works:

- •Investment in solar energy technology should be encouraged as the merits include: pollution free

environment, free renewable and energy source, high reliability and low maintenance costs.

- •Conducting consumer awareness promotions during which consumers would be adequately educated about PV technology, products and quality issues.

- •Producing sufficient number of well trained technicians on the use of renewable energy sources is also an important area where major emphasis has to be made.

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