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Renewable Energy for Gender Equity: Solar Electricity and Women's Empowerment in Developing Regions

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ABSTRACT

The Sustainable Development Goals (SDGs) highlight women's empowerment and gender equality as essential objectives to eradicate poverty and foster human resource development. However, despite significant progress, women worldwide, especially in developing countries, continue to face systemic discrimination and gender inequality, limiting their social and economic potential. Approximately 75% of women are engaged in the informal sector, while the global unpaid household economy, valued at $10 trillion, accounts for one-eighth of the world's GDP (ILO, 2019). Access to electricity, particularly solar energy, in remote rural areas offers transformative potential to empower women across multiple dimensions. This review explores the social, economic, and environmental impacts of solar electricity access on women's empowerment in developing countries such as Bangladesh, India, Pakistan, Nepal, Kenya, and Ethiopia. Solar electricity, as a clean and sustainable energy source, reduces indoor air pollution, enhances women's health, and improves mobility and personal security. It saves time from household tasks, enabling women to engage in teaching, socializing, and building community relationships. Furthermore, solar electricity increases household income by extending working hours and facilitating participation in income-generating activities (IGAs). Drawing on a comprehensive literature review, this study proposes a theoretical framework illustrating the mechanisms through which reliable solar electricity empowers women. The framework highlights critical pathways, including access to human and social resources, enhanced mobility, greater control over assets, and improved decision-making capacity. By addressing these areas, solar electricity has the potential to transform the everyday lives of women, fostering gender equality and advancing sustainable development in resource-constrained regions.

1. INTRODUCTION

For many years, international development organizations have prioritized gender equality and women's empowerment. The sustainable development goals recognize women's empowerment and gender equality as development objectives to combat poverty and advance the development of human resources. Despite these development efforts, women face discrimination and gender inequality globally, particularly in developing countries which impedes their social and economic potential.

In developing countries, discriminatory social norms and practices impede women's access to decision-making, education, mobility, and access to and control over resources. Because of uneven access to economic resources women comprise 70% of the world's poor (OECD, 2008). In 2013, 783 million people lived below the international poverty line, but the number of women and girls is unknown (UN,2018). Women face wage discrimination with males getting 23% more than women. Around 75% of the women work in the informal sector of the economy. The global unpaid household sector is worth US$ 10 trillion which accounts for one eight of the world's GDP. There are 700 million fewer women in paid jobs and 600 million in uncertain and risky jobs. According to Oxfam (2017), the gender imbalance in developing countries costs women $9 trillion (US$), which might be used to boost their capability in

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homes and society. One of the major causes of the facts mentioned above is the inheritance of disempowerment. As a result, empowering women is critical to resolving these issues. Access to electricity could improve women's access to various resources thus improving women's empowerment.

Electricity is recognized as a crucial factor in economic growth and poverty reduction in developing countries. Affordable, reliable, sustainable, and modern energy, especially in developing countries, is vital for achieving SDGs. Per capita electricity consumption is low in developing countries. Rural communities in developing countries have high illiteracy rates, gender disparities, and inadequate infrastructure, making access to electricity essential for sustainable and inclusive development. Electricity significantly impacts development indicators like women's empowerment, education, and health, enhancing quality of life.

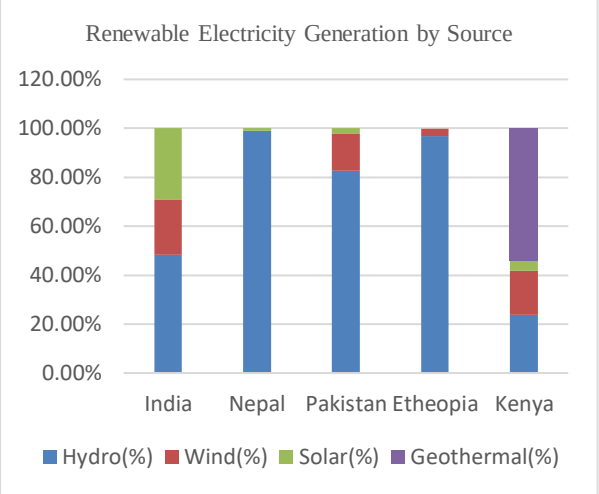
Despite the benefits of access to electricity, developing countries have been facing many challenges in providing electricity. Rural electrification strategies involve grid-based extension, mini-grids, and individual systems. Among them, the extension of the national grid is the most desirable solution to increase access to electricity. However, as grid extension is costly, and cost increases as the distance from the existing infrastructure increases, many countries cannot provide grid electricity to rural areas.

In off-grid locations where grid expansion is challenging for a variety of legitimate reasons, such as remoteness, isolated homes, riverine locations, etc., mini-grids offer an alternative to grid extension. Traditionally, rural mini-grids have only used fossil fuels and a diesel generator for power. Off-grid small-scale power systems can now be crucial to the electrification of rural areas in developing nations. Mini-grids may generate energy from biomass, solar, wind, hydropower, and fossil fuels in addition to these sources. Mini-grids, particularly solar mini-grids, provide electricity to remote areas of Asia and Sub-Saharan Africa, enabling millions of women and women's groups to raise their standard of living through business creation and expansion, active participation in marketing, installation, and maintenance, and search for profitable applications (ESMAP 2013a; World Bank, 2016).

2. A Brief Overview of The Renewable Electricity Scenario in Bangladesh

The World Bank (2020) reports that 789 million people worldwide lack access to electricity, and hundreds of millions have inadequate or unreliable power. According to the IEA's World Energy Outlook (2016), over 1.2 billion people worldwide, or 40% of all rural residents, live in off-grid rural areas in developing and less developed nations without reliable access to electricity.

In many developing countries, solar electricity has been widely used as an off-grid electrification alternative, with differing degrees of success. South Asia has had success with it (Palit and Chaurey, 2011). Additionally, it is cost-effective for Sub-Saharan Africa's rural electrification (Baurzhan and Jenkins, 2016). Figure 1.1 shows the electricity generation using various renewable sources including solar for some developing countries of South Asia and Africa. It depicts that these developing countries' renewable electricity generation mostly depends on hydro except in the case of Kenya.



Source: IEA, 2022

Fig. 1. Renewable Electricity Generation for Developing Countries

Bangladesh, a developing nation of 170 million people, and the second-largest economy in South Asia, is transitioning to a green economy, with 85% of the population now having access to electricity (Hossein, 2021).

Fossil fuel-based energy sources, namely natural gas, dominate Bangladesh's energy landscape. In Bangladesh, traditional energy sources including coal, oil, natural gas, and diesel account for a startling 98% of total energy output, with renewables making up only 2% (BPDB, 2022). In terms of installed capacity for power generation, Bangladesh has the lowest percentage of renewable energy with just 1.69%, placing it near the bottom of the South Asian rankings (Table 1.1).

Table 1. Electricity Generation and Share of Renewables, 2021

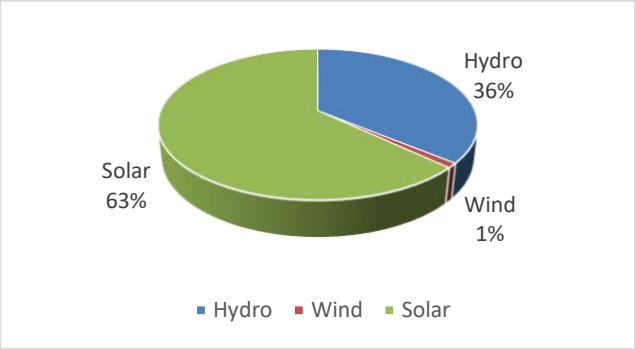
Country	Electricity Generation	% of Non-Fossil fuel(/Renewable)
Bangladesh	80.57	1.69
India	1,702	22.59
Nepal	6.12	100
Pakistan	150.17	41.12

Source: Energy Information Administration 2022

Bangladesh is diversifying its energy landscape by focusing on renewable energy and liquefied natural gas (LNG), despite challenges faced by dwindling domestic gas reserves. As of 2008's renewable energy policy aiming for 10%, the country has only achieved 3%. The government now aims for 15% by 2030, 40% by 2041, and 100% by 2050(UN BD,2023). Fossil fuels (Natural Gas) still produce the majority of the nation's electricity, although wind, hydropower, and solar PV contributions are all increasing.

However, the renewable energy sector has made impressive progress in Bangladesh. Solar home systems (SHSs) are a success story, especially in rural areas. They are becoming increasingly popular in off-grid areas. The largest off-grid solar power initiatives in Bangladesh have given 20 million people access to clean and affordable electricity, setting an example for other countries looking to increase access to renewable energy (WB, 2021).

Additionally, in remote regions of Bangladesh, the Sustainable and Renewable Energy Development Authority (SREDA), the Global Environment Facility (GEF), and the United Nations Development Programme (UNDP) have successfully installed solar PV-based mini-grid projects, giving homes and small businesses access to grid-quality electricity (www.undp.org). The programs have decreased CO2 emissions by 29,300 tons throughout their duration and given jobs and livelihoods to almost 16,000 people(www.idcol.org).



(Source: sreda.gov.bd)

Fig. 2. Present Renewable Energy Condition in Bangladesh

Furthermore, Bangladesh is an ideal place (latitudes 20°34' and 26°39' north and longitudes 80°00' and 90°41' east) to use solar energy because of its subtropical temperature and plenty of sunshine (Hussain, M., 1987). With daily sun radiation of 4-6.5 kWh/m2, which peaks in March and April and falls in December and January, solar energy may be a good way to address Bangladesh's electricity needs (Siddique and Karim, 2017).

3. Definition And Measurement Of Women's Empowerment

Empowerment is the concept of gaining the power to take charge of one's life, enabling one to accomplish tasks, set priorities, and influence events (Young, 1993). It is a process where individuals denied decision-making abilities acquire this ability, thereby enabling change. Empowerment can be measured in three dimensions: resources (economic, social, and human), agency (decision-making, negotiation, bargaining), and achievements (valuable outcomes in different contexts) (Kabeer, 1999).

According to Winther, T. et al. (2017) women's empowerment is a process towards gender equality, involving equal rights of men and women, access to resources, and power to influence matters. It is influenced by Kabeer's framework, which emphasizes access to resources, agency, and rights, focusing on marginalized groups.

Empowerment is a process that improves an individual's or group's ability to make deliberate decisions and translate those decisions into desired actions and outcomes (Alsop et al., 2005). It has two components: agency expansion and an institutional context that allows for agency exercise. Acquiring assets promotes agency, but it does not always result in empowerment if opportunities are not provided to individuals. Formal and informal institutions, such as legislative frameworks and strong socio-cultural norms, constrain women's employment and mobility, restricting their decision-making power.

Depending on the diverse socio-cultural contexts' empowerment has different meanings in the literature. It encompasses various attributes such as agency, self-determination, liberation, participation, mobilization, and self-confidence (Solava and Alkire, 2007). Empowerment is more than just having access to resources and the capacity to exercise agency; it also entails having self-worth, control over one's life, and influence on the direction of societal development.

A woman's empowerment may be assessed at the individual and household levels based on her ability to make decisions, share household chores, regulate her reproductive system to choose the size of her family, avoid abuse, and maintain her self-worth (Medel-Anonuevo, 1993).

The Demographic and Health Surveys (DHS) have been collecting data from women worldwide since 1984 to better understand their status and level of empowerment concerning several areas, such as money management, freedom from violence, rights to sexual orientation and reproduction, and mobility (Afridi, 2005; Durrant & Sathar, 2000; Kishor, 2005).

Researchers measure empowerment from different viewpoints since it involves multiple requirements to be met. Garikipati et al. (2017) and other researchers (Ganle et al.,2015; Goldman & Little, 2015; Mahmud et al., 2012) measured women's empowerment by examining their influence on financial decision-making. The literature also emphasizes the importance of controlling resources such as income, savings, and assets (Weber & Ahmad, 2014; Mahmud et al., 2012; Garikipati, 2008).

4. Effects Of Solar Electricity On Women's Empowerment

This section provides a narrative review of the literature on the effects of solar electricity on women's empowerment. Using empirical data, this review examines the social, economic, and environmental effects of solar electricity access on women's empowerment in developing countries (namely Bangladesh, India, Pakistan, Nepal, Kenya, and Ethiopia).

Access to affordable and clean energy significantly improves women's living conditions globally. According to studies, it reduces household work and improves health, economic opportunities, entertainment, education, and women's empowerment, improving overall living conditions (ADB, 2012).

4.1 Social Effects of Solar Electricity Access on Women's Empowerment

- *Reduce Household Work and Time Saving*

In India, using SHSs resulted in longer workdays, especially for women (Barman et al. 2017). According to Mishra and Behera (2016), solar electricity enhances women's quality of life by creating a more comfortable indoor environment for living and working long and productive hours, such as using a sewing machine and completing nighttime tasks linked to stitching.

According to Pac Myanmar (2018), women tend to spend more time at home taking care of household chores that might

be done more efficiently with consistent access to electricity. This would also mean less manual work and fewer household obligations. However, since women have to spend so much time gathering firewood and obtaining water, rural women frequently experience time poverty (UNDP 2007: 13). For instance, fetching water takes women in rural Kenya around two hours per day (Winther et al., 2019). Electricity from solar mini-grids has shown various advantages for women. Nepalese women saved significant time by using electric rice cookers and electrified water pumps (Winther et al., 2019).

- *Mobility and Communication*

The availability of electricity modifies how people interact with one another both inside and outside the house. With less manual labor and the advent of electric lights, television, and mobile phones, women have more leisure to mingle and relax (Annecke 2005). Several authors have highlighted that light has increased women's outside mobility, which is typically limited, and has improved the feeling of security surrounding homesteads. Women have improved their well-being by using mobile phones to increase connectivity with the outside world, especially with their natal families (Tenhunen 2014, 41; Winther 2014; Standal and Winther 2016). Access to electricity increases mobile phone usage. There is no doubt that mobile phones are critical communication tools in rural regions. The following table presents the gender-based reported ownership of mobile phones and the prevalence of phones in three countries.

Table 2. Mobile phones and gendered ownership occurrences

Country	Share of HH who keep at least one mobile	Mobile phones owned by women	Mobile phones owned by men	Mobile phone owned by others//jointly
Nepal (Mahadevstan)	80%	35%	36%	29%
Kenya (Homa Bay)	91%	53%	41%	6%
India (Chhattisgarh)	68%	3%	93%	4%

Source: This table adopted from EFEWEE (Exploring Factors that Enhance and Restrict Women's Empowerment through Electrification), ENERGIA, 2019

From the above table, we can see both genders widely used mobile phones. Mobile phones play a central role in keeping families in contact in rural Nepal, where many men migrate for work. Additionally, network connection and internet availability increase social media usage in Nepal. Mobile banking services help Kenyans achieve greater financial inclusion. Two-thirds of the sample in Chhattisgarh own a mobile phone. Despite being mostly (93%) owned by men, they are also utilized for communication by all family members (ENERGIA, 2019).

Solar electricity improved women's mobility and security, resulting in more time spent socializing, tutoring children, and visiting friends and neighbors (Cabraal et al. 2021). In rural West Bengal, a study investigates whether empowering women through the installation of micro solar domes (MSDs) might promote solar energy socialization. In addition to increasing women's mobility, financial autonomy, and social activities, the MSDs appear to have raised users' living standards and increased their involvement in decision-making (Bera, Ranajit et al., 2024).

- *Access to Information*

According to the World Bank (2017a), increasing television exposure often leads to easier access to information and might be interpreted as new norms like family planning and small family size which could alter desired fertility. Mobile phone charging improves communication, access to information, social networks, and convenience for Nepalese women by eliminating the need to travel (ENERGIA, 2019). Further evidence indicates that access to electricity improves girls' education in rural India. The girls were allowed to watch cable television for informational and entertainment purposes, which changed their perceptions of gender-discriminatory behaviors (Winther et al., 2017).

- *Recreational Effect*

In rural Bangladesh, improved availability of electricity through solar systems mostly improves recreation and leisure (Rahman and Ahmad 2013). According to research solar electricity is more strongly linked to radio, television, and mobile phone charging (Jacobson, 2007). Rural residents, particularly women, could connect to the outside world through TV, radio, and cell phones, providing them with thoughts on various issues. Having access to TV also allowed them to witness the rights and traditions that women in other societies exercise, which assisted them in reshaping their rights and customs (Cabraal et al. 2021).

4.2 Environmental Effects of Solar Electricity Access on Women's Empowerment

Better health outcomes foster women's agency and empowerment, demonstrating the connection between empowerment and health. Good health allows women to actively participate in markets and society fostering personal interest (Partnership for Maternal, Newborn and Child Health, 2013, p. 2).

Women as well as children who are spending more time at home with their mothers pose a higher risk of environmental health crises (WHO, 2016). Because of traditional family roles, women are exposed to smoking while cooking using polluting fuels, and because of this type of indoor air pollution globally over 4 million women die annually which is higher than the combined mortality rates of Malaria, HIV, and tuberculosis (IEA et al., 2019: 55). Women in underdeveloped nations have less access to and control over resources like reliable electricity and other infrastructure necessary for livelihood, are more vulnerable to the negative consequences of indoor air pollution (ibid).

Electricity has improved people's health, hence strengthening human resources. According to a health clinic head in Kenya, the use of electric light has decreased the usage of polluting paraffin lamps, leading to fewer respiratory and eye diseases. In Nepal, health workers' usage of mobile phones boosted women's access to healthcare services, enhancing their human resources and empowering them (ENERGIA, 2019).

A study examined the socioeconomic and environmental impacts of the people living in the rural remote areas of Pakistan who installed SHS. The authors concluded that the solar home system has a positive effect on human and material capital (Rahman et al. 2017). Another study revealed that solar home systems save Tk. 8775 million annually, reducing kerosene consumption, and indoor air pollution, and improving household health in Bangladesh (Hossain et al., 2018).

The World Bank's solar project in Bangladesh barred the use of 4.4 billion liters of kerosene and reduced greenhouse gas emissions by about 9.6 million tons between 2003 and 2018 (Cabraal et al. 2021).

4.3 Economic Effects of Solar Electricity Access on Women's Empowerment

- *Income-generating Activity*

Studies show that providing women with electricity and time-saving home appliances can help them start small businesses or part-time jobs while reducing household chores (Winther et al., 2019; Haves, 2012; UNDP, 2007). Light is the most commonly used appliance when electricity is available and reliable, impacting the entire family by extending the day (Haves, 2012).

Due to increased lighting in Nepal, some women from the mini-grid electrification village were seen using electricity to start new companies for poultry farming and tailoring and to enhance their working conditions (Winther et al., 2019). Similar studies conducted in Sri Lanka and Indonesia revealed that women have begun new home-based businesses to generate revenue, like packing cigarettes and processing nuts (Haves, 2012: 3). Women's income-generating activities would enable them to raise their family's standard of life and improve their social and economic position (Lambrou and Piana, 2006). Additionally, ample evidence supports the notion that women who make a living outside the home have more influence over household decisions (Haves, 2012).

A study in India found that small rural microbusinesses connected to solar mini-grids reported a 12% to 15% increase in monthly revenue (Smart Power India, 2017). Solar home systems (SHSs) or mini-grids could increase household income by allowing residents to improve their working hours by using evening lights and allowing individuals to start or grow businesses providing mobile phone charging services (Obeng & Evers, 2010; Bisaga, I. et al., 2020, World Bank, 2018; Mondal & Klein, 2011).

In India, off-grid solar electricity may empower communities particularly women by creating economic and social responsibilities (Gaurav and Komali, 2020). Nevertheless, women's income-generating activities do not benefit them rather they may increase their workload and create a burden when combined with traditional roles and new activities (UNDP, 2007).

A study investigates the influence of solar home systems (SHS) on socio-economic circumstances in Ethiopia and it finds that SHS has no substantial impact on household income, it improves family well-being and financial inclusion (Abebe D. et al., 2024).

- *Expansion of Educational Opportunity*

Access to reliable electricity improves children's particularly girls' school enrolment and attendance. In India, electrified water pumps save up to three hours per day potentially affecting the school enrolment of girls. The findings of the study showed that having access to electricity helps both women and girls who spend more time fetching water and collecting firewood, reducing their school attendance (Köhlin et al., 2011).

A reliable electricity supply has also led to an increase in women's literacy rates. Women's literacy rates in electrified homes are more than 20 percent higher than those in non-electrified households in Bangladesh (Dutta et al., 2017). Girls who are electrified in Brazil are 59% more likely to complete their primary schooling than males (O'Dell et al. 2014).

Brighter solar lights extend children's study hours, allowing them to study for 10-12 minutes more each day and increasing school completion rates for both boys and girls in Bangladesh (Cabraal, A. et al. 2021).

4.4 Negative Effects of Solar Electricity

A study conducted in India and Kenya found no significant correlation between off-grid solar power and socioeconomic growth in rural households. Despite increased electricity access and decreased kerosene expenditure in the black market, the researchers did not find any systematic evidence of changes in savings, spending, business creation, or other indicators of socioeconomic development. This finding is consistent with previous studies in Kenya and India (Aklin, M. et al., 2017; Pueyo & DeMartino 2018).

Several studies have indicated that the cost of maintaining and repairing off-grid solar systems is sometimes not covered by the company that provides them and may be too costly to afford for the low-income rural households of Bangladesh, Sri Lanka, and Malawi (S.A. Sarker et al.,2020; D. Laufer, M. Sch¨afer, 2011; P.M. Dauenhauer, et al., 2020). Shakila and Chowdhury (2020) conducted research in Bangladesh to compare solar hydropower systems (SHS) with off-grid solar mini-grids. The study discovered that while mini-grids are relatively cost-effective, their market potential is frequently overestimated or undervalued, which results in inefficiencies. The report emphasizes the demand for more economical and efficient solar energy options.

Amin et al. (2023) investigate gender inequality, green financing, and energy availability in Bangladesh's hilly regions. The findings show that increasing electricity availability might increase women's empowerment. However, the study did not find gender parity in off-grid families. Poor households are more likely to oppose renewable energy adoption due to high prices and a lack of financial incentives. Besides the high cost, adopting solar electricity has some other negative impacts such as the disposal and recycling of lead-acid batteries can contaminate landfills with lead sulfate, posing health risks (Khan, 2019).

In a study in Hatiya, Bangladesh (Saim and Khan, 2022), authors found that solar home systems (SHS) offer basic electricity to residents in rural areas. However, the system has become ineffective due to concerns such as regular light and controller changes, kerosene lights, and charging problems during monsoon season.

5. FINDINGS AND DISCUSSION

Based on the literature review we have developed the following framework which depicts the various channels through which clean and reliable solar electricity might affect women's empowerment.

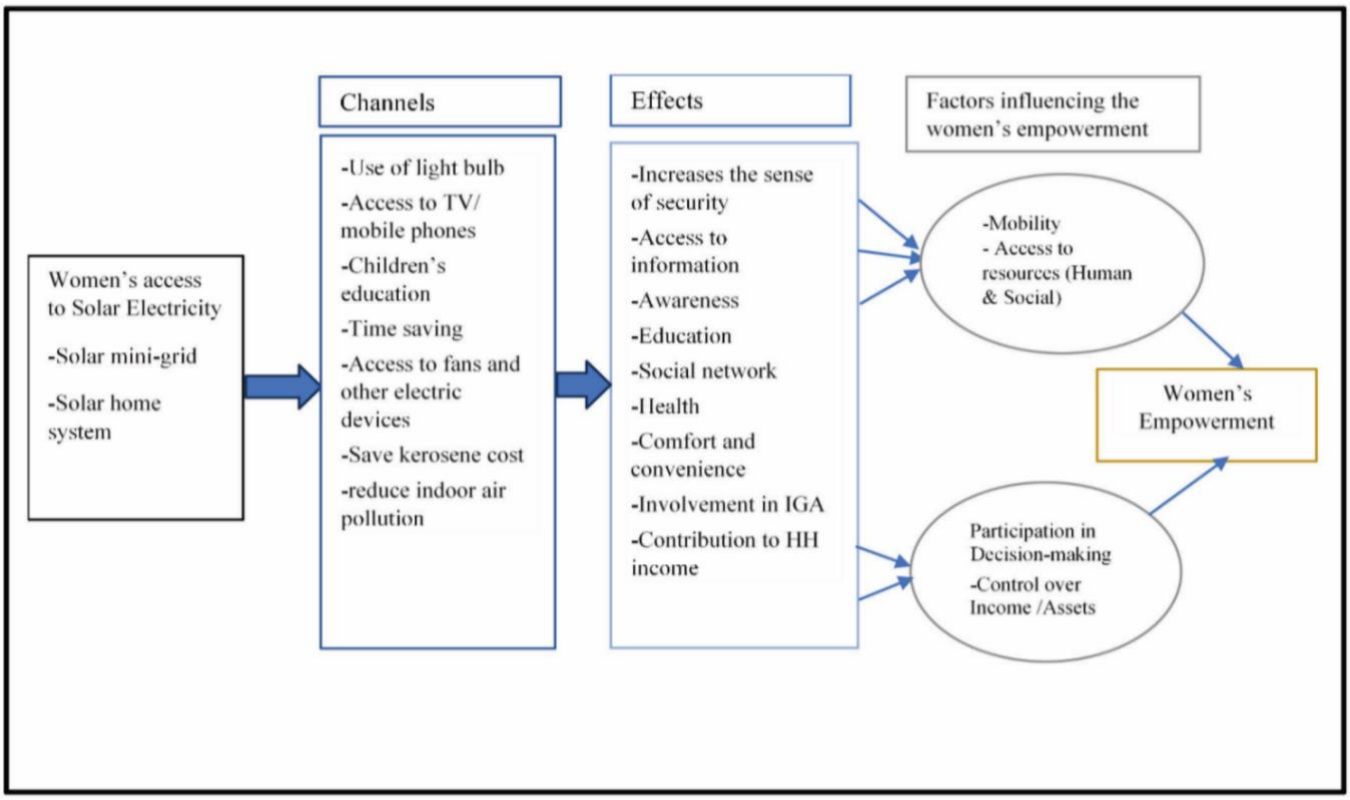


Fig. 3. Channels of women empowerment through access to solar electricity

Solar electricity is a clean energy source that improves women's health via a reduction in indoor air pollution and the reduced use of kerosene. Access to light bulbs increases women's indoor and outdoor mobility, increasing the sense of security around the homestead and neighbourhoods. Moreover, it gives them comfort and convenience as they have easier access to other electrical devices fans, electric rice cookers, water pumps, etc.

Access to solar electricity saves women time from household activities therefore women can spend more time teaching children, socializing, and visiting friends and neighbours (i.e. social networks).

Access to TV and mobile phones helps women access information that helps them connect to societal norms and rights to reshape their lives.

Solar electricity could increase household income by improving working hours and involvement in income-generating activities (IGAs). These IGAs help raise women's family standards and improve social and economic positions.

Thus, the framework given in Figure 01 confirms the pathways that facilitate women's empowerment using electricity. Additionally, this study demonstrates how solar electricity empowers women by providing access to human and social resources, increasing mobility, control over assets, and decision-making capacity to improve the everyday lives of women significantly in developing countries.

The following table summarises the socio-economic and environmental effects of solar electricity access on women's empowerment.

Table 3. Summary of the Socio-Economic and Environmental Effects of Solar Electricity Access on Women's Empowerment.

Effects	**Findings**	**Factors influencing women's empowerment**	**References**
Social effects (Positive)	-Reduce Household Work -Time savings -Increased indoor and outdoor mobility -social networks -Increased role in decision making -Increased perception of gender-discriminatory behavior -Improve HH health	-Mobility -Communication -Information -Entertainment / -Recreation -Rights and gender norms -Social networks	Winther et al., 2019; Tenhunen 2014, 41; Barman et al. 2017; Standal and Winther 2016; Pact Myanmar, 2018; Obeng & Evers, 2010; Bisaga, I. et al., 2020, World Bank, 2018; Cabraal et al. 2021; Bera, Ranajit et al., 2024
Environmental Effects	-Reduce kerosene consumption	-Clean Environment	Rahman et al. 2017;

Effects	Findings	Factors influencing women's empowerment	References
(Positive)	-Reduce indoor air pollution -Reduced greenhouse gas emissions	-Improve air quality -Better health outcome	Hossain et al., 2018; IEA et al., 2019; ENERGIA, 2019; Cabraal et al. 2021
Economic effects (Positive)	-Involvement in part-time jobs -Small business -Home-based micro-enterprise -Family well-being and financial inclusion -Increase in girls' enrolment and attendance in schools	-Income-generating activities (IGAs) -Employment -Education -Access to finance	Winther et al., 2019; Haves, 2012; UNDP, 2007), O'Dell et al. 2014; Dutta et al., 2017; Abebe D. et al., 2024)
Social, economic, and environmental effects (Negative)	-Did not find any systematic evidence of changes in savings, spending, business creation - Too costly for low-income rural households to afford - Poor families are more likely to be discouraged from adopting due to high prices and lack of financial programs - disposal and recycling of lead-acid batteries can contaminate landfills with lead sulfate, posing health risks -the system has become inefficient due to concerns such as regular light and controller changes, kerosene lights, and charging problems during monsoon season.	-High cost of connections -Environment pollution -Health risk - dissatisfaction and inefficient	Aklin, M. et al., 2017; Pueyo & DeMartino 2018; S.A. Sarker et al. 2020, Bangladesh ; D. Laufer, M. Sch¨afer, 2011, Srilanka; P.M. Dauenhauer, et al., Malawi, 2020; S.B. Amin et al. 2023; Khan, 2019; Saim and Khan, 2022

6. CONCLUSION AND RECOMMENDATIONS

This study provides a comprehensive review of the association between access to solar electricity and women's empowerment in developing countries. Though there is a wide body of literature on access to electricity and its various beneficial impacts on household welfare, there is scanty evidence on how solar electricity promotes women's empowerment in rural, remote areas in developing countries. This is particularly important as gender disparity is widespread, particularly in developing countries and it is strongly correlated with poverty and economic instability. Solar electricity is growing in popularity as it is a viable and sustainable option to cut carbon emissions for a better and sustainable future. It has the potential to empower women, especially in developing countries by giving them access to clean electricity and economic opportunities. With all the limitations of solar electricity in terms of intermittency, costliness, and limited coverage, women in developing countries use this opportunity to improve their livelihood.

Hence, our study contributed to the body of literature on how access to solar electricity empowers women by providing information on the channels and the underlying factors that improve women's empowerment. It demonstrates how solar electricity empowers women by providing access to human and social resources, increasing mobility, control over assets, and decision-making capacity to improve the everyday lives of women significantly in developing countries.

Solar electricity is a clean energy that improves indoor air quality and better health, reduces the use of traditional fuels, saves time by reducing household chores, and generates economic possibilities leading to the empowerment of women. However, due to the lack of gender parity in off-grid families, high costs, and potential inefficiencies, poor households are more likely to oppose renewable energy adoption due to high prices and lack of financial incentives. Additionally, the disposal and recycling of lead-acid batteries can contaminate landfills with lead sulfate, posing health risks. Therefore, while solar electricity can provide benefits for women's empowerment, it is important to take measures to mitigate its limitations to maximize its potential benefits.

Thus, this review study suggests that governments and NGOs should launch awareness programs to educate women about the health and environmental benefits of solar electricity. The government should develop gender-specific incentive mechanisms to make solar electricity more accessible and affordable in rural remote areas to foster inclusive and equitable development.

REFERENCES

Abebe D. Beyene , Alemu Mekonnen , Marc Jeuland , Sebastian Czakon (2024). Socioeconomic impacts of solar home systems in rural Ethiopia. Renewable and Sustainable Energy Reviews, Volume 192, 114197. https://doi.org/10.1016/ j.rser.2023.114197

ADB (2012). Gender Tool Kit: Energy Going Beyond the Meter. Asian Development Bank. Mandaluyong City, Philippines: Asian Development Bank.

Afridi, F. (2005). Intra-household bargaining, birth order and the gender gap in schooling in India. mimeo.

Alsop, R., Bertelsen, M., & Holland, J. (2005). Empowerment in Practice. The World Bank. https://doi.org/10.1596/978-0-8213-6450-5

Aklin Michaël , Patrick Bayer, S. P. Harish, Johannes Urpelainen (2017) Does Basic Energy Access Generate Socioeconomic Benefits? A Field Experiment with Off-grid Solar Power in India. Science Advances 3(5):e1602153. DOI: 10.1126/sciadv.1602153

Annecke, Wendy(2005).' Whose turn is it to cook tonight? Changing gender relations in a South African township'. Gender and Energy Research and Training. Gender and Energy (CRGGE) with support from the ENERGIA International Network on Gender and Sustainable Energy and the United Kingdom Department for International Development (DFID) under KaR research project R8346. South Africa

Aziz, S., and Chowdhury, S. A. (2020). Performance evaluation of solar mini-grids in Bangladesh: a two-stage Data Envelopment Analysis. Clean. Environ. Syst. 2 (100003.doi:10.1016/j.cesys. 2020.100003

Bangladesh Power Development Board (BPDP), Annual Report, 2022

Barman, M., S. Mahapatra, D. Palit, and M.K. Chaudhury. 2017. Performance and impact evaluation of solar home lighting systems on the rural livelihood in Assam, India. Energy for Sustainable Development 38, 10–20. https://doi.org/10.1016/j.esd.2017.02.004.

Bera, Ranajit , Pulak Mishra, Priyadarshi Patnaik (2024). Renewable energy for women empowerment: Experiences from rural West Bengal. Renewable and Sustainable Energy Reviews Volume 198, July 2024, 114446. https://doi.org/10.1016/j.rser.2024.114446

Bisaga Iwona, Priti Parikh, Julia Tomei, Long Seng To (2020). Mapping Synergies and Trade-offs Between Energy and the Sustainable Development Goals: A Case Study of Off-Grid Solar Energy in Rwanda. Energy Policy 149. DOI: 10.1016/j.enpol.2020. 112028

Cabraal, A., W. A. Ward, V. S., Bogach, and A. Jain. 2021. Living in the Light: The Bangladesh Solar Home Systems Story. https://openknowledge.world bank.org/handle/10986/35311.

D. Laufer, M. Schäfer (2011). The implementation of solar home systems as a poverty reduction strategy-a case study in Sri Lanka. Energy Sustain. Dev., 15 (2011), pp. 330-336, 10.1016/j.esd.2011. 07.002

Dutta, S., Kooijman, A., and Cecelski, E. (2017). Energy Access and Gender: Getting the Right Balance. Washington, D.C.: World Bank Group.

Durrant, V., & Sathar, Z. A. (2000). Greater Investments in Children through Women's Empowerment: A Key to Demographic Change in Pakistan? Population Council Policy Research Division Working Papers, No. 137, New York.

ENERGIA (2019) Gender in the Transition to Sustainable Energy for All: From Evidence to Inclusive Policies. ENERGIA is the International Network on Gender and Sustainable Energy.

ESMAP (Energy Sector Management Assistance Program). 2013a. Integrating Gender Considerations into Energy Operations. World Bank. Washington, DC.

Ganle, J.K., Afriyie K.B., & Segebefia A.Y. (2015). Microcredit: Empowerment and disempowerment of rural women in Ghana. World Development, 66, pp. 335-345.

Garikipati, S. (2008). The impact of lending to women on household vulnerability and women's empowerment: Evidence from India. World Development, 36(12), pp. 2620–2642.

Garikipati, S., Agier, I., Guerin, I., & Szafarz, A. (2017). The cost of empowerment: multiple sources of women's debt in rural India. The Journal of Development Studies, 53(5), pp. 700-722.

Gaurav Joshi and Komali Yenneti (2020) ,"Community solar energy initiatives in India: A pathway for addressing energy poverty and sustainability?", Energy & Buildings Vol-210.

Goldman, M.J., & Little, J.S. (2015). Innovative grassroots NGOS and the complex processes of women's empowerment: an empirical investigation from Northern Tanzania. World Development, 66, pp. 762-777.

Haves, E. (2012). Does Energy Access Help Women? Beyond Anecdotes: A Review of the Evidence. Ashden Report. https://www.ashden.org/ sustainable-energy/reports/does-energy-access-help-women-beyond-anecdotes-a-review-of-the-evidence

Hossain, Monzur et al. (2018). Assessing the Current Situation of Solar Home System (SHS) Program of IDCOL and Recommending Action Plan, Study Report, Unpublished, Bangladesh Institute of Development Studies, 2018.

Hussain, M., (1987). "Bangladesh Energy Resources and Renewable Energy Prospects".

Hossen, A. (2021), Circular Economy: A Potential Pathway to a Sustainable Bangladesh. 16 February, 2022. The Daily Star. https://www.thedailystar. net/opinion/news/circulareconomy-potential-pathway-sustainable-bangladesh-2045333.

Infrastructure Development Company Limited (IDCOL) www.idcol.org

Energy Information Administration 2022

International Energy Agency (IEA), The World Energy Outlook 2022

IEA, IRENA, UNSD, World Bank, and WHO (2019). Tracking SDG 7: The Energy Progress Report 2019. International Bank for Reconstruction and Development, Washington DC.

Jacobson, A. 2007. Connective Power: Solar Electrification and Social Change in Kenya. World Development 35(1), 144–16.https://doi.org/10.1016/j.world dev.2006.10.001.

Kabeer, N. (1999). Resource, Agency, Achievements: Reflections on the measurements of women's empowerment. Development and Change, 30(3), 435-464.

Khan, I. 2019. Drivers, enablers, and barriers to prosumerism in Bangladesh: A sustainable solution to energy poverty? Energy Research & Social Science 55, 82–92. https://doi.org/10.1016/j.erss.2019.04.019.

Kishor, S. (Ed.). (2005). A Focus on Gender: Collected papers on gender using DHS data. Calverton, Maryland, USA: ORC Macro.

Köhlin, G., Sills, E., Pattanayak, S., and Wilfong, C. (2011). Energy, Gender and Development: What are the Linkages? Where is the Evidence? Washington DC: The World Bank.

Lambrou, Y. and Piana, G. (2006). Energy and Gender in Rural Sustainable Development. Rome: Food and Agriculture Organization of the United Nations.

Mahmud, S., Shah, N.M., & Becker, S. (2012). Measurement of women's empowerment in rural Bangladesh. World Development, 40(3), pp. 610–619.

Mishra, P. and B. Behera. 2016. Socio-economic and environmental implications of solar electrification:Experience of rural Odisha. Renewable and Sustainable Energy Reviews 56, 953–964. https://doi.org/10.1016/ j.rser.2015.11.075.

Medel-Anonuevo, C. (1993). Women, education and empowerment: Pathways towards autonomy. Report of the International Seminar held at UIE, Hamburg.

Mondal, Dieter Klein (2011)Impacts of solar home systems on social development in rural Bangladesh. Energy for Sustainable Development 15 (1):17-20. DOI: 10.1016/j.esd.2010.11.004

N. Wamukonya, (Africa2007); Solar home system electrification as a viable technology option for Africa's development Energy Policy, 35 (2007), pp. 6 14, 10.1016/j.enpol.2005.08.019

Obeng, G. Y., & Evers, H.-D. (2010). Impacts of Public Solar PV Electrification on Rural Micro-Enterprises: The Case of Ghana. Energy for Sustainable Development, 14, 223-231. https://doi.org/10.1016/ j.esd.2010. 07.005

O'Dell, K., Peters, S., and Wharton, K. (2014). Women, Energy, and Economic Empowerment: Applying a Gender Lens to Amplify the Impact of Energy Access. Deloitte University Press.

OECD (2008). Gender and sustainable development: maximizing the economic, social and environmental role of women, A Report to the United Nations Commission on Sustainable Development (UNCSD), Organization for Economic Cooperation and Development. Available at: https://www.oecd.org /social/40881538.pdf

Oxfam (2017). Why the majority of the world's poor are women? Oxford Committee for Famine Relief. Available at: https://www.oxfam.org/en/even-it/why-majority-worldspoor-are-women

P.M. Dauenhauer, D. Frame, A. Eales, S. Strachan, S. Galloway, H. Buckland (2020) Sustainability evaluation of community-based, solar photovoltaic projects in Malawi. Energy. Sustain. Soc., 10.1186/s13705-020-0241-0

Pueyo Ana & Samantha DeMartino(2018). The impact of solar mini-grids on Kenya's rural enterprises. Energy for Sustainable Development 45(1):28-37. DOI: 10.1016/j.esd.2018.04.002

Rahman, S., Touhiduzzaman, M. and Hasan, I. (2017) Coastal Livelihood Vulnerability to Climate Change: A Case Study of Char Montaz in Patuakhali District of Bangladesh. American Journal of Modern Energy, 3, 58-64. https://doi.org/10.11648/j.ajme.20170304.11

Rahman, S. M. and M. M. Ahmad. 2013. Solar Home System (SHS) in rural Bangladesh: Ornamentationor fact of development? Energy Policy 63, 348–354. https://doi.org/10.1016/j.enpol.2013.08.041

S. Bin Amin, Chowdhury, M. I., Jamasb, T., Khan, F., & Nepal, R. (2023). Green Energy Finance and Gender Disparity: The Case of Mountain Areas in Bangladesh. Copenhagen Business School [wp]. Working Paper / Department of Economics. Copenhagen Business School No. 02-2023CSEI Working Paper No. 2023-02

S.A. Sarker, S. Wang, K.M. MehediAdnan, M.K. Anser, Z. Ayoub, T.H. Ho, R.A.Z. Tama, A. Trunina, M.M. Hoque. Economic viability and socio-environmental impacts of solar home systems for off-grid rural electrification in Bangladesh Energies, 13 (2020), 10.3390/en13030679

Saim, Md. Abu and Khan, Imran (2021). Problematizing solar energy in Bangladesh: Benefits, burdens, and electricity access through solar home

systems in remote islands. Energy Research & Social Science, Volume 74, April 2021, 101969. https://doi.org/10.1016/j.erss.2021.101969

Siddique, Md. Abu Bakr and Karim, S. M. Rezaul (2017). "Modeling of Double Diode Solar Photovoltaic Module using Matlab" International Journal of Computer Applications 179(7): 4-10

Smart Power India (2017), "Mini-Grid Model," https://smartpowerindia.org/mini-grid-modelhttps://smartpowerindia.org/mini-grid-model (Accessed Oct. 27, 2020); Rockefeller Foundation, Expanding Opportunities for Renewable Energy Based Mini-Grids in Rural India.

Solava, I., & Alkire, S. (2007). Agency and Empowerment: A Proposal for Internationally Comparable Indicators. Oxford Development Studies, 35(4), 379–403. https://doi.org/10. 1080/136008107 01701897

SREDA- Sustainable and Renewable Energy Development Authority. 2015 (www.sreda.gov.bd)

Standal, K., and T. Winther. 2016. "Empowerment through Energy? Impact of Electricity on Care Work Practices and Gender Relations." Forum for Development Studies 43 (1): 27–45. doi:10.1080/08039410.2015.1134642.

Tenhunen, S. 2014. "Gender, Intersectionality and Smartphones in Rural West Bengal." In Women, Gender and Everyday Social Transformation in India, edited by K. B. Nielsen and A. Waldrop, 33–46. London: Anthem Press.

UN (2018). Progress towards the sustainable development goals: Report of the Secretary-General. United Nations. Available at: https://digitallibrary.un.org/record/16275 73?ln=en

United Nations Bangladesh (UN BD,2023). Story: Bangladesh's energy transition journey so far.

UNDP (www.undp.org posted on 28th May 2020

UNDP. (2007). Gender Mainstreaming: a Key Driver of Development in Environment & Energy. https://www.undp.org/content/dam/undp/library/Environment%20and%20Energy/Sustainable%20Energy/Gender_Mainstreaming_Training_Manual_2007.pdf, Accessed 2020-01-12

Weber, O., & Ahmad, A. (2014). Empowerment through microfinance: The relation between loan cycle and level of empowerment. World Development, 62, pp. 75–87.

Winther, T. 2014. "The Introduction of Electricity in the Sundarban Islands: Conserving or Transforming Gender Relations?" In Women, Gender and Everyday Social Transformation in India, edited by K. B. Nielsen and A. Waldrop, 47–61. London: Anthem Press.

Winther, T., Matinga, M. N., Ulsrud, K., and Standal, K. (2017). Women's Empowerment through Electricity Access: Scoping Study and Proposal for a Framework of Analysis. Journal of Development Effectiveness, 9(3), 389-417.

Winther, T., Matinga, M., Saini, A., Ulsrud, K., Govindan, M., and Gill, B. (2019). *Women's Empowerment and Electricity Access: How do Grid and Off-grid Systems Enhance or Restrict Gender Equality.* ENERGIA International Network on Gender & Sustainable Energy. https://www.energia.org/cm2/ wp-content/ uploads/ 2019/04/RA1-Womens-empowerment-and-electricity-access.pdf

WHO, (2016). Burning Opportunity: Clean Household Energy for Health, Sustainable Development, and Wellbeing of Women and Children. Geneva: World Health Organization.

World Bank (2016). Country profile. Available at: http://databank.worldbank.org/data/views/reports/reportwidget.aspx?Report_Name=CountryProfile&Id=b450fd57&tbar=y&dd=y&inf=n&zm=n&country=BGD (Viewed on: 22/05/2018)

World Bank (2017a). Mini-Grids and Gender Equality: Inclusive Design, Better Development Outcomes: Key Issues, and Potential Actions. http://documents.worldbank.org/curated/en/386241512394615639/Mini-grids-and-gender-equality-inclusive-design-better-development-outcomes-key-issues-and-potential-actions,

World Bank. 2016. *Mini Grids: Bringing Low-Cost, Timely Electricity to the Rural Poor.* Available online at: http://www.worldbank.org/en/news/feature/2016/07/07/mini-grids-bringing-low-costtimely-electricity-to-the-rural-poor.

World Bank (2018). Myanmar - National Electrification Project: environmental assessment (Vol. 2) : Environmental and social management framework : annexes (English). Myanmar: s.n.. http://documents.worldbank .org/curated /en/228131531840015477/Environmental-and-social-management-framework-annexes,

World Bank(2020). Tracking SDG7: the energy progress report. Washington, DC.

World Bank. Annual Report,(2021) Bangladesh Solar Home Systems Provide Clean Energy for 20 million People.