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Impacts of Solar Home Systems in Rural Areas: A Case Study in Bangladesh

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Abstract: Access to electricity is important for development in general, but access at low costs is a vital tool of economic and social development, especially for those locations that lie very far from the grid. The present study investigates the impacts of solar home systems in a rural area of Bangladesh, focusing on the ways in which the adoption of SHS transforms household livelihoods. It has improved the lives of the community members through an affordable and reliable source of electricity that allowed enhanced lighting and security, increased educational opportunities, empowerment of women, reduced reliance on harmful energy sources, increased economic productivity, environmental sustainability, human relationships and well-being. These studies emphatically underscore the fact that the biggest challenge remains affordability: in most instances, SHS is accessed through family savings or loans from NGOs. In spite of these barriers, SHS has conventionally been portrayed as an empowering tool that enhances the quality of life and aids in fulfilling the goals of sustainable development in rural areas. The paper concludes by relating conventional energy sources with a comparison, emphasizing broader benefits and possible long-term potentials for SHS in tackling energy poverty within rural Bangladesh.

Keywords: Solar Home System, Electricity, Sustainability, Remote Village

1. Introduction:

In 2000, 2 out of every 10 people in the world did not have access to electricity (Hannah et al., 2024), while in 2020 that number had been brought down to 733 million people (World Bank, 2024). In 2021, the number was 775 million; around 80 percent of those without electricity lived in rural areas (World Bank, 2023), and nearly half of the world's population without access resided in South Asia (Hannah et al., 2024). Improving access to electricity has gained great attention from many scholars and policy analysts and has since long been one of the main focuses of international development programs. This interest has been largely motivated by a broad belief by many economists and policymakers that electrification is actually a prerequisite for development. As access to electricity is considered one of the preconditions for modern production, it has also been considered vital to alleviating poverty by making a basic adjustment in household time-use patterns and organization. Most of the literature would place most stress on the fact that the rise in women's opportunities through electrification creates a gain for all these changes and, therefore, broader prosperity because of expanded grid access (Vidart, 2024).

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Bangladesh's journey toward achieving near-universal electricity access offers valuable insights. In early 2003, electricity access reached only 27 percent of the rural population, with universal access expected to take much longer. However, Bangladesh implemented the world's largest off-grid solar power program, which has since become a model for other countries seeking to expand access to clean and affordable electricity. By 2013, the Solar Home System (SHS) program had peaked in sales, with 816,000 units sold, providing electricity to 16 percent of the rural population. By 2018, over 4.1 million SHS units had been sold, bringing electricity services to about 20 million people (World Bank, 2021).

Research supports the critical role of electricity in economic development. A preliminary study by Ferguson et al. (1997) demonstrated a strong correlation between electricity use and wealth creation in the G7 countries, which constitute two-thirds of the global economy. Interestingly, no correlation was found between total energy use and wealth, highlighting the unique importance of electricity in modern society's development and its substantial associated market and non-market benefits (R. Ferguson et al., 2000).

While the economic benefits of electrification, such as wealth creation and increased productivity, are well documented, the social impacts are no less significant. In fact, much of the development literature has noted that electricity access bears significantly on socio-economic variables such as education, income, health, and labor allocation (Dinkelman, 2011; Lipscomb et al., 2013). Solar home systems have been able to provide not only access to electricity in the Bangladeshi countryside but have also brought remarkable changes in the social texture of those areas. Access to dependable electricity has opened up opportunities for improved educational prospects by way of increased study time available for children, an improved level of living by virtue of enhanced entertainment facilities, and even security with the lighting of streets. Additionally, it has empowered women by allowing them to work in the evening, improved lighting for better healthcare, and facilitated mobile phone charging and easier movement at night. These changes indicate that electrification is relevant in improving the quality of life and achieving sustainable development in rural areas.

2. Methodology:

This case study was carried out at Dokkhin Cor Pecakola Upazila, which is located in the Pabna district, Bangladesh (location in fig 1).This area was chosen as this area is not connected to the national grid. The study area selected in this study thus represents ones with true rural characteristics of Bangladesh away from urban facilities. A total of 132 households with SHS users were surveyed by the face-to-face questionnaire method. The survey contained both closed-ended questions (i.e., respondents were given a list of predetermined responses from which to choose their answer) and open-ended questions (respondents were asked to answer in their own words). Data were collected on the basis of a five-point Likert scale, ranging from 1 = strongly disagree to 5 = strongly agree. Both the open-ended and surveyed by the face-to-face

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questionnaire method. Both the open-ended and closed-ended questions were included in the questionnaire. Questionnaire was carefully developed and tested before it was finalized to find out customer satisfaction of the SHS customers. Here the Servqual Model is used to assess the gap between the expectations and perceptions of the customers. The data analysis involved quantitative and qualitative methods (numerical and descriptive). Qualitative data were analyzed based on content analysis, while quantitative data were analyzed using descriptive and inferential statistics.

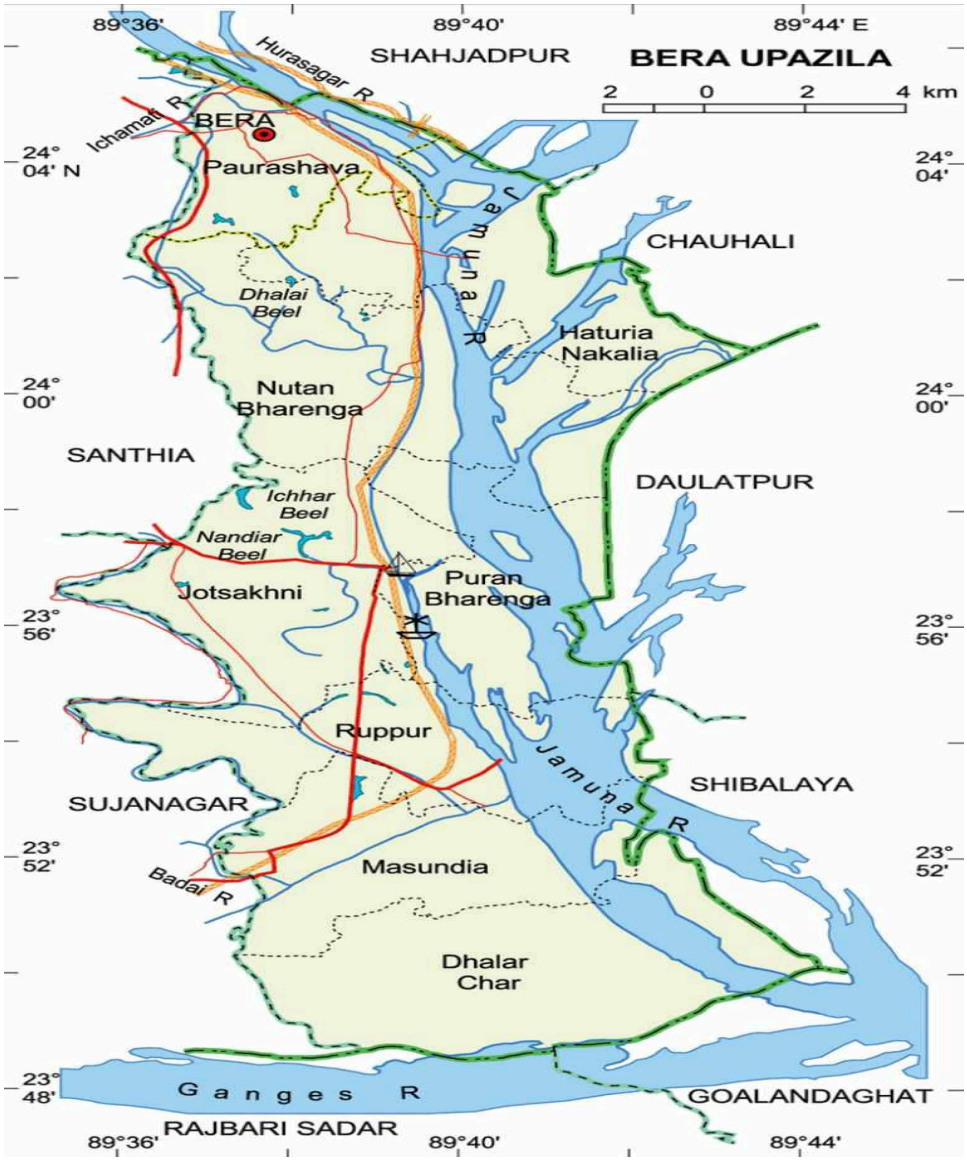

Fig. 1. Geographic location of study area

2.1. Sample Surveys:

Case Study 1:MD Hazrat Molla, a farmer, used kerosine lamps for lighting purposes. He has replaced these lighting systems with two 40 W solar panels. Before installation of the solar

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panel, he had to pay BDT 20 per day to buy kerosine. Now, he is using 3 fans and 4 bulbs. Moreover, he is enjoying the phone charging facility. Fundamental information of case 1 is presented in Table 1.

Name	MD Hazrat Molla
Age	48
Education	Illiterate
Occupation	Farmer
Address	Village: Dokkhin Cor Pecakola, Post Office: Bera, Thana-Bera, District: Pabna
Family members	8
Monthly family income	12000 BDT
Panel & battery	2,40W panel and 12 V, 100Ah battery
Company name	Rahimafrooz Solar Battery (LM)
price	28400 BDT
Payment Method	One Time payment
Purpose	Lighting,fan, charging mobile phone.

Table1. Fundamental information of case 1

Case study 2 : Mst. Farida Begum is a housewife, and she is the most educated woman in that study area. Instead of using 1 kerosene lamp for lighting, she has installed a 40 W SHS with 1 fan, 3 bulbs, and 1 mobile phone. Before installation of the solar panel, she used kerosene, which costs about BDT 560, and had no mobile phone access. Fundamental information of case 2 is presented in Table 2.

Name	Mst Farida Begum
Age	30
Education	9
Occupation	Housewife
Address	Village: Dokkhin Cor Pecakola, Post Office: Bera, Thana-Bera, District: Pabna

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Family members	4
Monthly family income	8000 BDT
Panel & battery	1,40W panel and 12 V, 100Ah battery
Company name	Rahimafrooz Solar Battery (LM)
price	26200 BDT
Payment Method	One Time payment
Purpose	Lighting,fan, charging mobile phone.

Table 2. Fundamental information of case 2

Case study 3: Sufiya Begum, housewife, used kerosene at night for lighting purposes. She had to pay BDT 1000 per month to buy kerosene. She has replaced these lighting systems with a 50W and a 100W panel. Now she is using 2 fans and 3 lighting facilities in her home. Fundamental information of case 3 is presented in Table 3.

Name	Sufiya Begum
Age	50
Education	Illiterate
Occupation	Housewife
Address	Village: Dokkhin Cor Pecakola, Post Office: Bera, Thana-Bera, District: Pabna
Family members	11
Monthly family income	20,000 BDT
Panel & battery	2 Panels (50W, 100 W),and 12 V, 100Ah battery
Company name	Rahimafrooz Solar Battery (LM)
price	35000
Payment Method	One Time payment
Purpose	Lighting and fan.

Table 3. Fundamental information of case 3

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3. Results and Analysis:

3.1. Average Income Condition and Ability to Afford SHS:

This village is unique and different from other traditional villages in Bangladesh. The village has given insight into the old ways of life, especially in the people's occupations and life patterns. Very far from town, it is surrounded by water, being disconnected from the main town. Without any markets or grocery shops nearby, in order to reach the nearest market, people have to involve themselves with boats daily for traveling 2.5 hours. While this boat travel is considered to be a relief during the monsoon season, during the summer it itself turns into a huge challenge. As soon as the river starts drying up, villagers are forced to cross the cracked riverbed, submerged in water in parts—sometimes deep up to the waist—just to get the basics of life.

This isolation, therefore, has a clear impact on their livelihoods: the community is notably reliant on self-sufficiency, as shown in Fig 2. The majority, 42%, are farmers, and through surveys, it was established that nearly every home had domestic animals, which included cows, sheep, or goats depending on family resources. The rest are a small population of fishermen, 5%; cowherds, 15%; and hawkers, 11%, who move to the main town for selling. Others hire themselves out as day laborers or contractors; many are employed in construction or as barbers in shops.

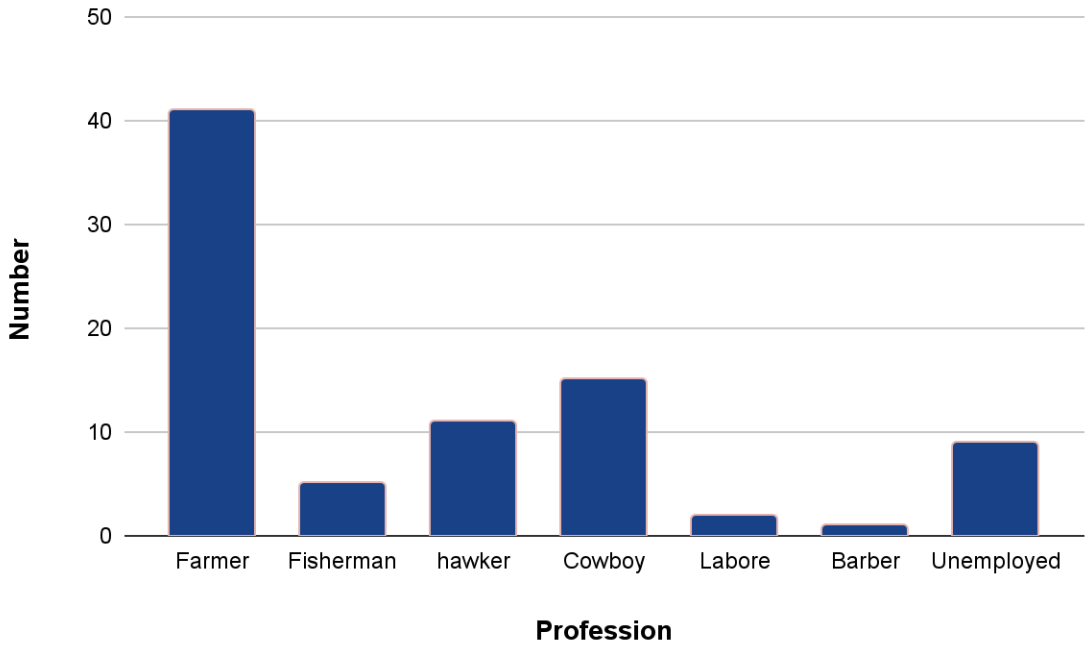

Fig 2: Professions of the villagers

Their income condition is below average according to the Bangladeshi livelihood scale. During surveys, their livelihood vulnerability and survival strategies were noted down carefully. It's

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nearly impossible to manage a healthy life, but they are living. Fig 3 below describes their income condition briefly, where the vulnerability is easily illustrated.

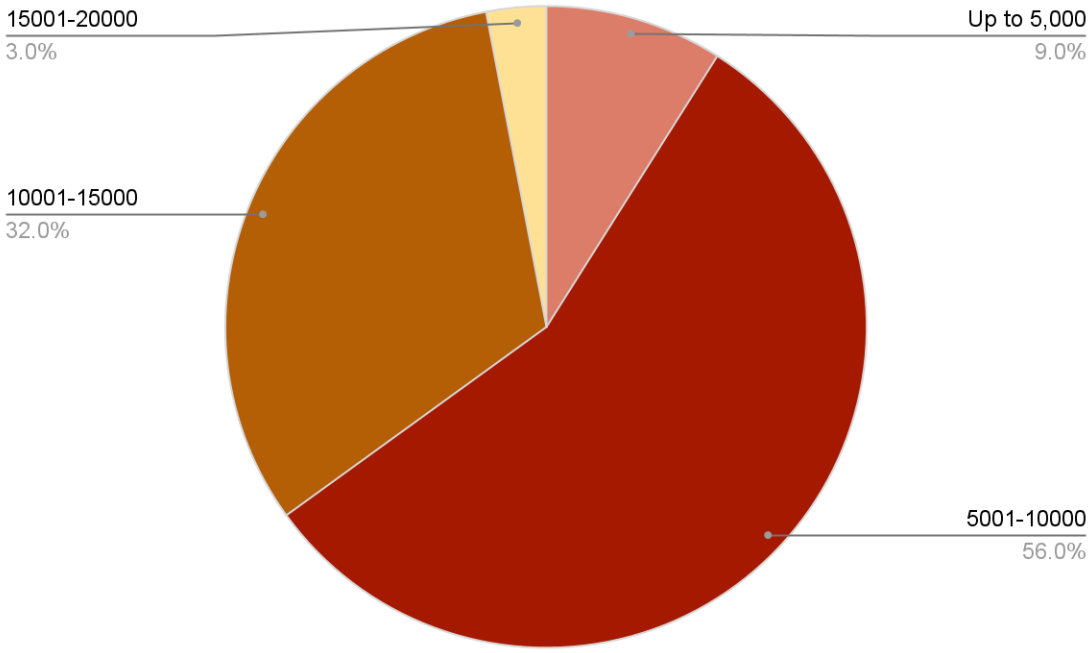

Fig 3: Monthly income of the villager's

Affording SHS with this income was hard for all of them. Some of them saved money for several months to afford this. Some of them took loans from various NGOs. But all of them consider solar as a blessing.

3.2. Most Used Solar Home Systems (SHS) in the Area and details:

During the early days of the solar energy revolution in Bangladesh, various initiatives were taken to reach solar power to all. The government, along with various NGOs, was very active in making solar systems more affordable. But with the gradual expansion of the national electricity grid into every nook and cranny of the country, the number of areas without access to electricity started to diminish with time. Still, in those remaining pockets, the anomaly has become jarring—such as in voiced deep frustration during a recent survey. They related their current struggles, focusing in large part on the initiative once spearheaded by Grameen Shakti. Though very helpful initially, many of those systems have now fallen into disrepair.

During the early days, SHS could be acquired by villagers through low-cost loan schemes. They can provide a small down payment and can return the loan in installments of 230 BDT for 32 months. Such flexible financial options are not available today. The villagers need to pay the entire cost in a lump sum upfront, which, for them, is a big financial burden. Left with no

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alternative, many squander hard-earned savings, sell their cattle, or take loans from NGOs just to buy solar systems.Although they purchase primarily from renowned brands like Rahimafrooz and Hamko, many people purchase at a lower price, such as Chinese or Indian products; specifically, batteries are much cheaper in comparison to their price. Fig 4 illustrates this situation.

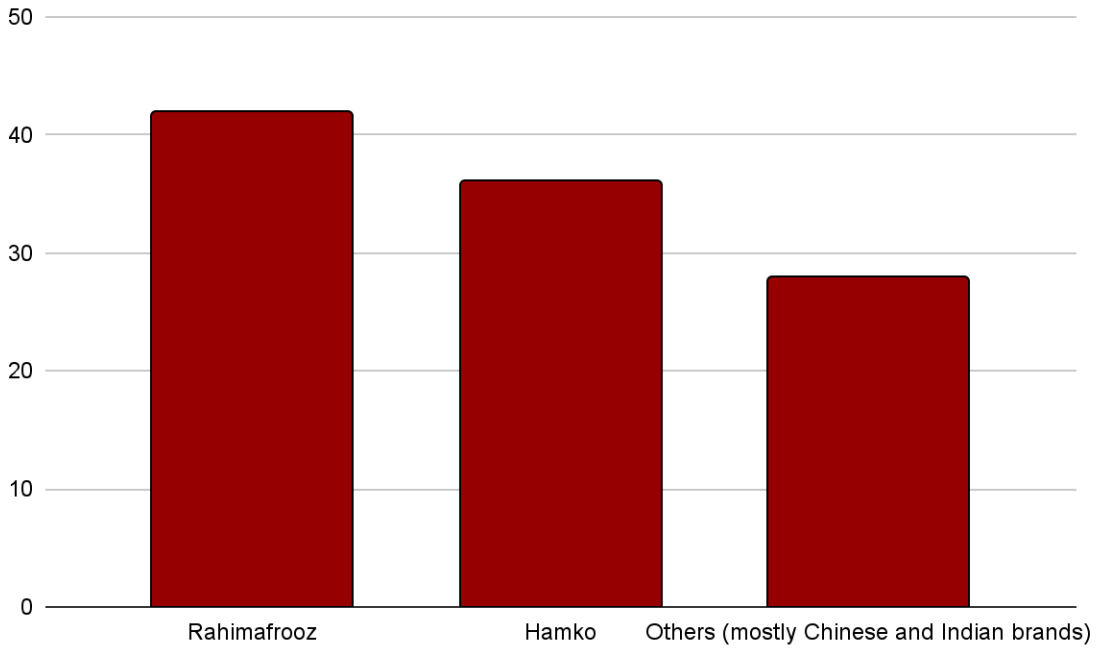

Fig 4: Most used solar systems in that village

3.3. Present Load Using Scenario:

The main use of the SHS in the village is for nighttime lighting. Some residents also power small table fans but not larger ceiling fans, which are so often common elsewhere. These small fans are still a luxury that many people cannot yet afford. The use of mobile phones has also become more frequent over the last few years, although digital mobile phones remain few and far between. The villagers have the desire to use digital phone services, but this is made hard as there is a complete lack of on-home charging facilities. They are completely dependent on the main stem to charge those. That's why they simply avoid it. Additionally, no one in the village owns a radio, television, or refrigerator. Fig 5 below describes the scenario from the field survey.

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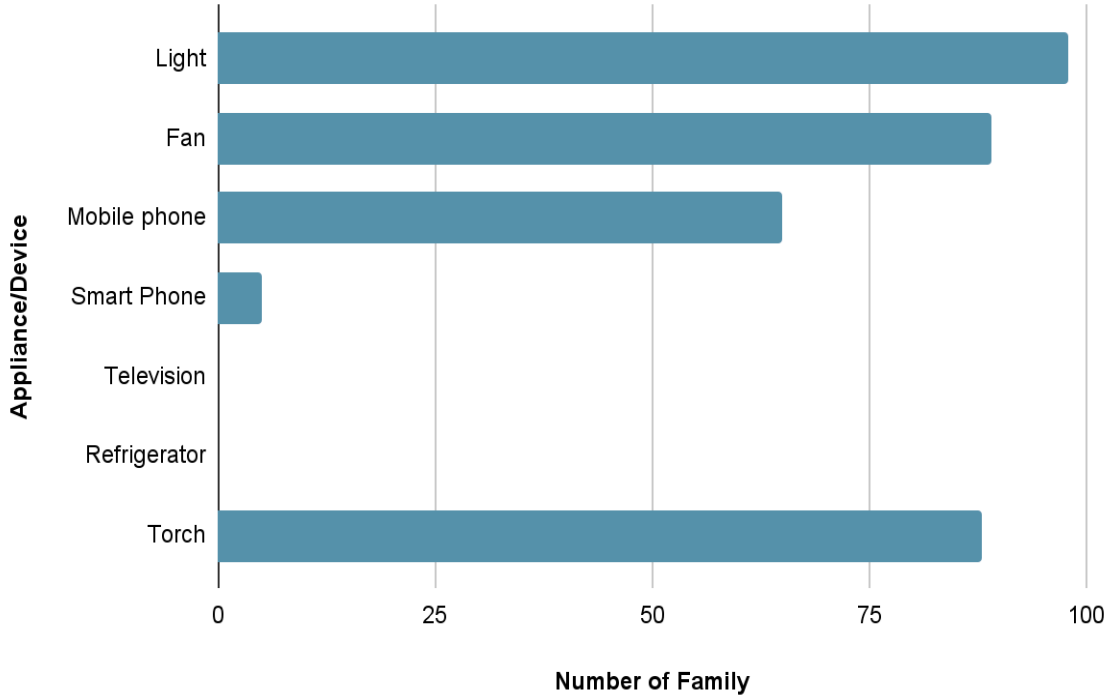

Fig 5: Present load using scenario of SHS

3.4. Conventional Energy Sources in the Study Area Other than SHS:

The SHS heavily relies on sunlight for energy production; therefore, winter and the monsoon create issues for this system. Continuous rain or a clouded sky reduces its ability to generate energy. In these situations, which generally last for days, villagers switch back to the more traditional modes of energy supply (as shown in fig 6). As agriculture is the primary source of employment and nearly all houses have domestic animals, they need lighting at night. Because of this demand, most of the villagers have to depend on kerosene lamps and candles even in case of a power shortage; they stay up all night long looking after their cows and goats under the same circumstances.

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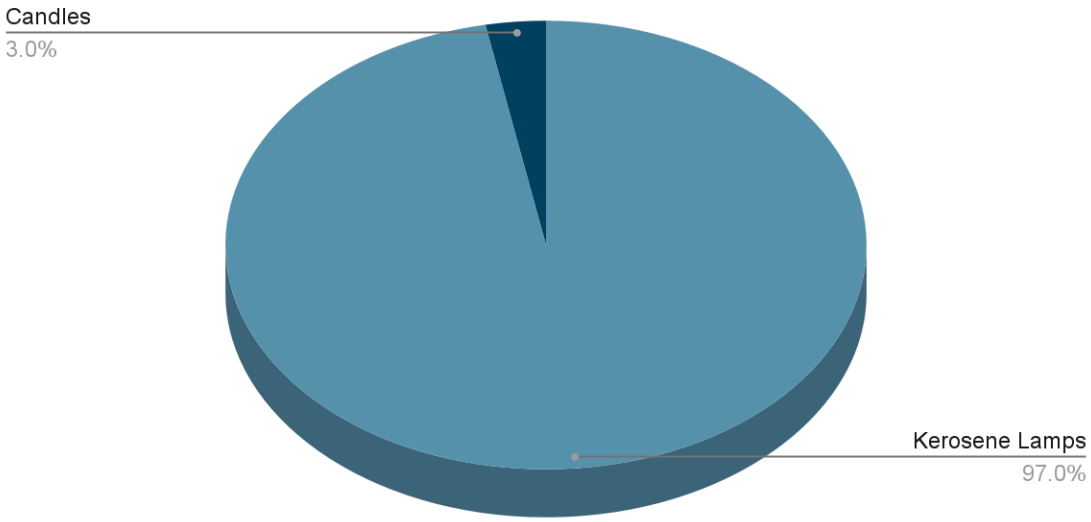

Fig 6: Conventional energy sources

3.5. Growth of Electronic Materials in the Rural Area Over the Last 10 Years:

The village has not been much affected by the rapid changes in this digital era. People there are surviving on a hand-to-mouth basis, with no facility for modern technological amenities. Even proper toilets with sanitary conditions remain a scarcity. Unlike many villages in Bangladesh, where one can clearly see improvement, their lifestyles have still remained the same as they were ten years ago. They work, though, very hard, sometimes more than anybody else, but the outcome is always stagnant, like a vicious circle from which nobody can be freed.

From the last 10 years' data, the improvement in the living conditions is barely visible (shown in fig 7). Yes, the data may indicate some improvement, but it is quite contrary in reality. The basic facilities provided include fans and bulbs, which hardly work or are underutilized; bulbs remain merely for security purposes, while torchlights are more useful day to day. There is no internet access, and it is not possible even to charge a smartphone—residents manage their lives with button phones. Lacking the entertainment from television sets and the facility of refrigerators, they have been left with little progress in their livelihoods for the last ten years.

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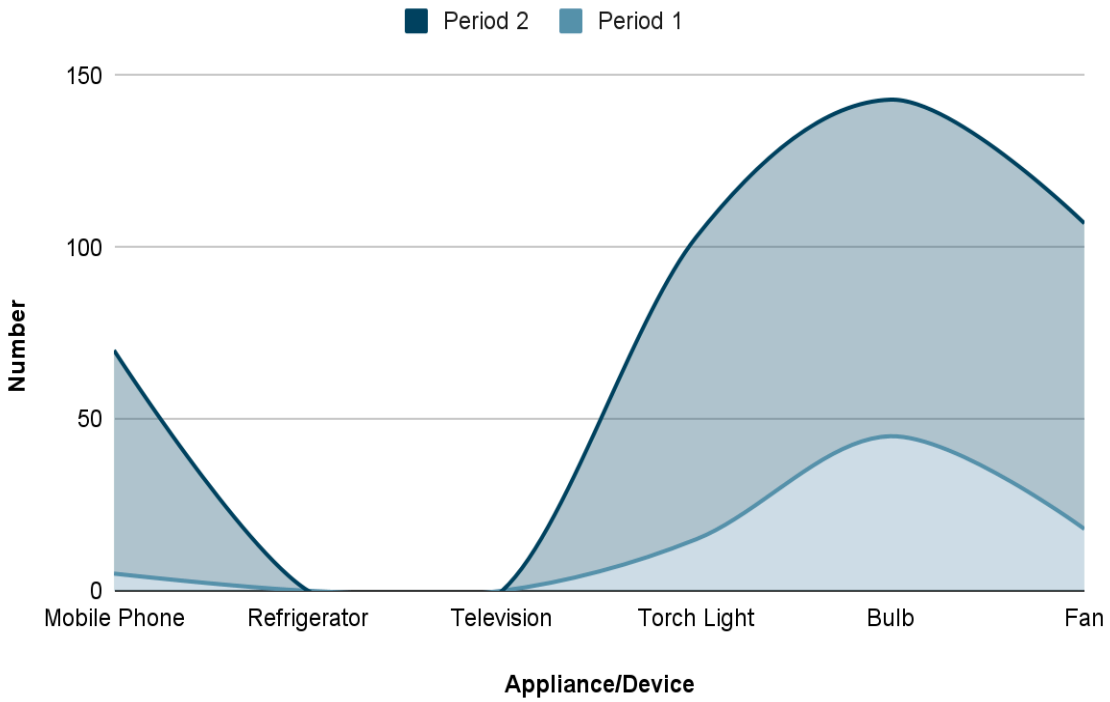

Fig 7: Growth of electronic materials over last 10 years

3.6. Daily life changing by SHS:

The villagers live with very minimal resources and consider the SHS a real blessing, at least to lighten up their hope during dark nights. Most of them have returned their gratitude with this survey for the basic conveniences it was able to afford. With SHS, they could utilize very simple mobile phones for urgent communication and could maintain proper lighting throughout the night to continue work even after dark. The water-surrounded village has a threat from wild animals like snakes at times, though the light protects them from those threats and thieves. It's a huge thing to them because they have domestic animals in every house, and the concern of thieves is very common in this area. On the other hand, the small fans powered with SHS soothe the children and elders during the scorching summer heat.In this process, SHS has ceased to be mere electricity for the villagers and turned into a way of life. SHS not only upgrades the respondent's day-to-day living but also gives them a sense of security and empowerment through safety, increased productivity, and comfort in harsh conditions. This simple yet amazing technology beamed its small yet effective light into the house, brightening not only the rooms but also the future.

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3.7. Benefits of Solar Home Systems (SHS):

The benefits of Solar Home Systems (SHS) in rural areas, particularly in regions like Bangladesh, are transformative and far-reaching. In my survey area, It was their only bacon of hope. This section outlines the key advantages of SHS, along with descriptions of their impact:

3.7.1. Enhanced Lighting and Security:

One of the most significant and immediate advantages of SHS is the replacement of inefficient, harmful energy sources (such as kerosene lamps) with dependable, clean illumination in residential applications. This not only provides very little light but also produces smoke, which degrades air quality and health.

SHS now provides bright lighting to households in rural regions, improving life, particularly after sunrise. This is a huge benefit, especially in this community, which is not linked to the national grid. Families may now utilize electricity after dark for longer hours.

- **Additional Security:** The light produced by SHS has significantly enhanced the security of this community. Well-lit homes and streets discourage theft and lessen the risk of wild animals, which is especially significant in remote locations. For example, in my research, several people claimed that lighting had kept their livestock from being stolen—a typical issue in rural regions where families rely primarily on agriculture for a living. Also, villagers suffer constant attacks by foxes that steal chickens and ducks or even attack cattle. In some cases, snakes are found relishing cow's milk too. It is a critical threat to the animals as well as their owners.Here, a lone bulb can be the difference between life and death for livestock. To the villagers, a chicken, a duck, or a cow is not just food or income for them but a symbol of hope and survival, sometimes their most valuable asset. SHS provides this critical lighting, which is one of the steps that ensures a means of basic survival for people in rural communities.

- **Reduced Reliance on Hazardous Fuels**: Prior to SHS, many homes used kerosene lights, which are not only flammable but also costly. SHS eliminates the need to purchase kerosene on a daily basis, providing a more sustainable, long-term lighting alternative. Also during the survey, some villagers shared some stories of huge fires caused by the kerosene lamps. SHS now saves them from such disasters.

3.7.2. Increased Educational Opportunities;

One of the most significant social benefits of SHS is an increase in educational possibilities for children. Many rural youngsters struggled to study after dark owing to the restricted lighting offered by kerosene lamps. SHS has altered this by providing bright, consistent lighting that enables students to prolong their study hours in the evening.

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- **Better Academic Performance:** Children in SHS families have more time to study and are therefore better positioned to perform well academically. Greater access to light, in turn, results in better literacy rates and educational outcomes. I noticed during the fieldwork that parents mentioned how much better children were able to study for exams and handle school work, thereby leading to an increase in their academic results.

  This increase in school-going children is also contributing to the overall rate of literacy. The rate was less than 1% prior to electricity access. As that village scene, it was normal because when they are so young, they are involved in farming or do households. Therefore, they could not study at home during the daytime. They went to school for an astonishing 2–3 hours. But after the integration of SHS, now they use night in study. It forms a mobile link between their studies and profession.

- **Long-Term Impact**: Education is the most effective way to end the cycle of poverty. SHS indirectly encourages long-term social mobility by allowing children to study more. With these children from the rural areas getting more educated, they can look up to better job opportunities, driving their families out of poverty and, in turn, uplifting their quality of life.

3.7.3. Empowerment of Women:

SHS has helped greatly empower women in rural areas to use the extra hours of light for their contribution to a better world. This empowerment also has social as well as economic dimensions since women now earn more in terms of family income and also have better control over their time and activities.

- **Extended Hours of Work:** The availability of light after sunset has enabled women to work or do handicrafts and other income-generating activities, including completing household chores. A large fraction of the women in this study described how SHS freed them up to work well into the evening, either to sew or cook or tend to animals, all significantly increasing productivity. They were so thankful for that. They mentioned how they saw their mothers and grandmothers working like animals on an empty stomach. But with the grace of SHS, they can make nakshi kantha or shitol pati at night, which gives them a taste of independence besides household chores.

3.7.4. Reduced Reliance on Harmful Energy Sources:

Before SHS had been introduced, many rural homes used to resort to traditional energy-based sources like kerosene and candles for lighting and cooking. Besides not being eco-friendly, those

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energy sources bring more health risks. Burning kerosene gives off toxic fumes, which can cause respiratory illnesses—especially to women and children who tend to spend more time indoors.

- **Health Benefits**: Homes are shifting to solar power in order to have cleaner, safer indoor air. SHS lowers dependence on kerosene and wood burning, reducing air pollution, which causes severe health implications. In the long run, this change can greatly reduce the prevalence of respiratory diseases in rural areas, which will lead to a better quality of life for local people.

- **Cost savings:** Initial investment costs in SHS systems may be high, but overall savings that they deliver over the long term are immense. Households no longer need to buy kerosene or other fuel sources on a regular basis, a considerable cost for low-income families. In my research, families said that the savings they made from no longer having to purchase kerosene were transferred to other vital necessities such as education, healthcare, and food. This financial assistance offered by SHS enabled households to invest in these vital parts of their lives, contributing to their overall well-being and allowing them to raise their standard of living.

3.7.5. Increased economic productivity:

Electricity is a major engine of economic growth, and SHS helps rural households become more productive. Farmers and craftspeople may operate after sunset with longer illumination hours, increasing revenue and contributing to community economic stability.

- **Increased Economic Activity:** SHS has enabled farmers and livestock owners to labor beyond daylight hours, boosting production. Farmers can now tend to their crops and animals after dark, while craftsmen may work on handicrafts in the evening. This increased productivity immediately translates to better income levels and more economic resilience for rural households, allowing them to make the most use of their limited resources.

- **Mobile Phone Charging & Connectivity:** In the digital era that we live in, a mobile phone means business as it is required for economic activity. SHS helps households to charge their cell phones regularly. With this ability, they can communicate properly and remain connected. This is especially critical in remote areas where mobile phones are an important access point to markets, health services, and educational information. Households in this survey were particularly grateful for the ability to charge their mobile phones, which allowed them to remain in touch with family members living outside the region and communicate with associates. This increased connectivity provided a substantial benefit by bridging the gap between their remote rural areas and critical social and economic networks.

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3.7.6. Environmental Sustainability:

One of the most significant benefits of SHS is its impact on environmental sustainability. Solar power is a renewable energy source that produces no hazardous emissions, making it a far cleaner alternative to fossil fuels. The widespread use of SHS in rural regions reduces carbon emissions, benefiting both local and global efforts to mitigate climate change.

- **Reduced Carbon Footprint:** SHS systems decrease dependence on nonrenewable energy sources such as kerosene, which produce considerable volumes of CO_2 and other greenhouse gasses. Rural communities use solar energy to reduce their carbon impact, which aligns with national and global sustainability goals.

- **Sustainable Development:** In addition to environmental benefits, SHS promotes sustainable development by providing a consistent and clean supply of electricity. This helps rural people develop more resilient lifestyles that are less reliant on fossil fuels and more environmentally friendly.

3.7.7. Human Relationships and Wellbeing:

SHS has not only a clean and healthy effect on individual households but also plays a significant role in the improvement of rural communities' living conditions due to its social benefits. Electricity also contributes to strengthening community unity and increasing access to services, as well as nurturing hope and progress.

- **Improving Quality of Life:** For many families, SHS means access to basic services and therefore means a better quality of life with light, ventilation, and a cell phone charging opportunity. It has enhanced living conditions and made people's lives more comfortable and less onerous. Families in my study also reported that SHS has enabled them to better cope with the daily challenges of rural life, such as extreme heat and the need for nighttime lighting. Many expressed their gratitude for the convenience and safety that SHS provides, highlighting how it has made their lives more manageable and secure in difficult conditions.

- **More Information and Entertainment:** The installation of SHS has made access to a reliable source of electricity for household socio-economic development, which also includes communication systems and entertainment opportunities that were lacking before the introduction to rural areas. Electricity means radios, televisions, and all the futuristic digital gadgets keeping families urbanized in national and international news. Increased connectivity mitigates feelings of rural communities being left out or not a part of the larger society. In my study area, there were no radios or televisions, but mobile phones are helping them a lot.

4.Conclusion:

In fact, the deployment of SHS has improved both the social and economic dimensions within the communities in rural Bangladesh that currently have limited access to electricity. Regardless of the income level, SHS has provided vital services such as lighting, ventilation, and mobile phone charging. These services caused an increase in productivity, improved education, and greater security. Most of all, women have been empowered and benefited with the extended hours of lighting for work and social activities. Affordability is still the issue, as many families depend on loans and savings to access SHS. However, these long-term benefits far far exceed its initial costs. The study shows how crucial decentralized solar power is for rural development in improving the lives of poor, marginalized communities. In such a background, continuous policy support and further expansion will enable SHS to go forward with rural electrification, reduction of energy poverty, and sustainable development in countries like Bangladesh.

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