Harnessing Solar Energy: Insights from a Case Study in Ampara District– Sri Lanka

A.F. Nazhath Akshana[1], A.L Husna Begum[2], and S.L Rasmiya Begum[3]

[1,2,3]*Department of Biosystems Technology, South Eastern University of Sri Lanka, Sri Lanka*

[1]1997nazna@gmail.com, [2]alhusna4567@gmail.com, [3]imara@seu.ac.lk

Abstract

The study examines the utilization of solar energy in the Ampara District, a region with high solar potential but low penetration due to socio-economic and infrastructural constraints, as the global energy landscape shifts towards renewable energy sources like solar power due to the threat of fossil fuel depletion and global warming. A descriptive-analytical research design with the quantitative survey method was employed. Primary data were collected through a systematic questionnaire survey among 207 households, business, and institutional users and were analyzed in SPSS version 27.0 using descriptive statistics. Findings showed that the most prevalent adoption existed among middle-income households 58% with LKR 50,000–100,000 incomes, with government officials (37.7%) and entrepreneurs (30.9%) constituting the largest group of the users. Solar energy awareness was near universal (99.5%), with friends, family members, and social media as the major sources of information. Solar energy was dominantly for household purposes by the majority of homes (62.3%), with 69.9% using monocrystalline modules and 5–10 kW systems. Problems included inverter malfunctioning (14.98%), wiring problems (10.63%), panel damage (9.66%), and high initial cost (67.5%) as the greatest limitation. While 57.3% engaged in maintenance activities, 42.7% of them failed to practice them, losing their efficiency. To enhance adoption, the respondents emphasized the need for improved loan facilities (39.8%), increased awareness programs (31.1%), subsidies (14.6%), and improved quality equipment and training. The study examines the socio-economic drivers, constraints, and technical impediments to solar adoption in Ampara, offering valuable lessons to policymakers, NGOs, and private sector actors to enhance decentralized renewable energy projects in Sri Lanka.

Keywords: - Household energy use, On-grid and off-grid solar, Photovoltaic Systems, Renewable energy, Solar energy, System capacity and maintenance

I. INTRODUCTION

There has been a shift in the energy paradigm in the 21st century. As there are growing concerns related to depletion of fossil fuels, greenhouse gas emissions, and climate change, governments and societies are on the lookout for sustainable alternatives. Solar energy is one of the most promising renewable energies worldwide because of its abundant availability, sustainability and environmental friendliness and widely high potential for the generation of electricity (International Renewable Energy Agency [IRENA], 2020).

Solar photovoltaic (PV) technology is particularly well known for its capability to decentralize energy generation, promote rural electrification and empowering local communities via reducing their dependence on fossil fuel-based electricity grids. The world's installed solar PV capacity grew from just 40 GW in 2010 to more than 1,200 GW in 2022 (International Renewable Energy Agency [IRENA], 2020).

Sri Lanka's high solar insolation renders utilizing of solar energy highly feasible (SEASL, 2020). The average solar irradiance in Sri Lanka measures between 4.5-6.0 kWh/m²/day. Seeing its potential, Sri Lanka has introduced many policies and programs to promote solar power such as the "Soorya Bala Sangramaya" (Battle for Solar Energy), which was launched in 2016. The aim of the campaign is to add 1,000 MW of solar electricity to the national grid by year 2025 and boost the share of renewables in the energy mix to 70% by year 2030 (Ministry of Power and Energy, 2021).

ISBN 978-955-627-161-4

The Ampara District of Sri Lanka is economically productive, consisting of isolated villages, farming communities, and peri-urban centers. Despite abundant solar radiation throughout the year, data on solar system adoption at the household level in the Ampara District remains limited. The district also faces intermittent grid electricity supply during drought periods when hydropower generation is curtailed, while reliance on thermal power plants has not been fully addressed. In this context, expanding decentralized solar energy systems could strengthen energy security, improve livelihoods, and enhance climate resilience. Nevertheless, potential negative impacts, such as grid hosting capacity constraints, must also be considered.

A. Gap in knowledge and justification for the study

There have been many national initiatives to promote solar energy. However, micro-level studies that investigate the socioeconomic perception, technical performance and hurdles to adopting solar energy in rural Sri Lanka are scant. Most existing studies focus on urban or national patterns. No research related to this topic has been conducted in Ampara.

To address this gap, the present study has undertaken an in-depth analysis of the current status of solar energy adoption in Ampara District. The analysis draws on quantitative survey data and incorporates a comparative review of relevant literature. The ultimate aim is to generate knowledge that benefits not only the academic community but also local policymakers, NGOs, private sector installers, and funding agencies.

B. Objective of the study

To evaluate the current status, applications and challenges about solar energy technology in the Ampara District.

II. METHODOLOGY

A. Research Design

This study employed a descriptive-analytical research design using quantitative methods to examine the current status, influencing factors, and challenges of solar energy adoption in the Ampara District, Sri Lanka.

B. Study Area

Ampara District, located in the Eastern Province, is characterized by a mix of urban, semi-urban, and rural settlements. It receives ample sunlight throughout the year, averaging 5.5–6.0 kWh/m²/day, making it ideal for solar PV applications.

C. Sampling Method

A stratified random sampling method was adopted to ensure representation from different geographical areas and socio-economic strata within Ampara District. A total of 207 respondents were surveyed, comprising household heads, small business owners, and institutional users of solar power.

D. Data Collection

The primary data for this study were collected through a structured questionnaire survey. The questionnaire was carefully designed to capture key variables such as socio-economic characteristics of respondents (family size, income level, occupation), awareness of solar energy, type of solar system adopted, system size, purpose of use, and maintenance practices. These independent variables were measured systematically to ensure uniformity and reliability in capturing the respondents' perceptions.

E. Data Analysis

Data collected were analyzed using SPSS 27.0 (Statistical Package for the Social Sciences) employing descriptive analysis such as frequencies, percentages, and graphical presentations to summarize the findings.

III. RESULTS AND DISCUSSION

A. Profile of End-Users

Figure 01 illustrates that solar energy adoption in the Ampara District was highest among households with 4–6 members, which accounted for 75.16 percent of the sample. This can be explained by the fact that families of this size typically have higher electricity demands, making solar systems more cost-effective in meeting long-term household consumption. In terms of occupation, the largest share of solar energy users were government employees, who represented 37.7 percent of users as shown in Figure 02. Entrepreneurs accounted for 30.9 percent and private employees 20.8 percent,

ISBN 978-955-627-161-4

adopting solar energy significantly due to the need to reduce electricity costs in both business operations and household expenses. By contrast, farmers accounted for only 9.7 percent and graduates 1 percent, which may be due to irregular income sources, limited capital for investment, and lower exposure to awareness campaigns. When considering income levels, 58 percent of solar energy users in the Ampara District were from the moderate-income group earning between LKR 50,000 and 100,000, as shown in Figure 03. In contrast, adoption among low-income households earning less than LKR 50,000 was only 11.6 percent.

The findings of the present study were in line with Wickremasinghe and Thrishali 2022, who highlighted the significant role of moderate family size 48 percent and middle income 71 percent influencing rooftop solar photovoltaic system adoption. High-income households show lower solar adoption mainly due to the high cost and maintenance of larger systems, rooftop and grid capacity limits, and reliance on alternative power sources like generators or hybrids.

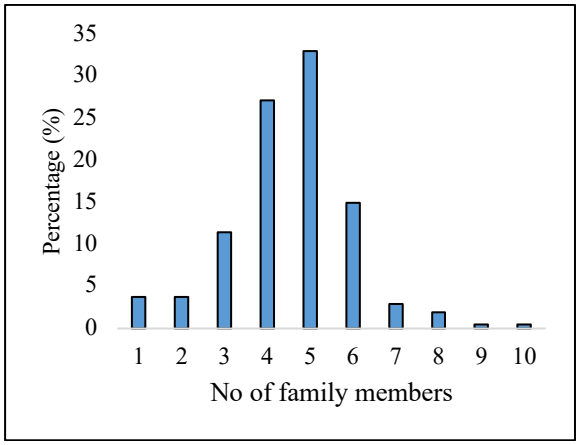

Figure 01: Family size

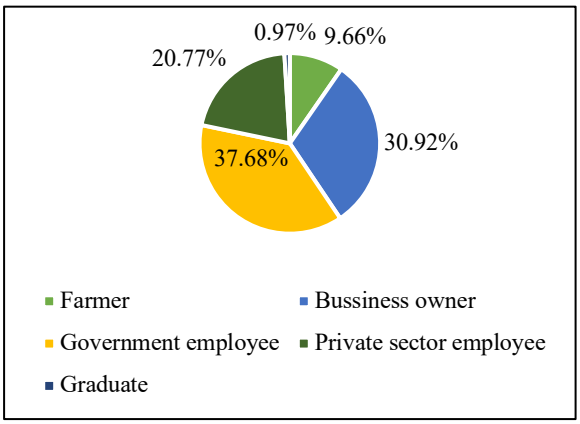

Figure 02: Occupation

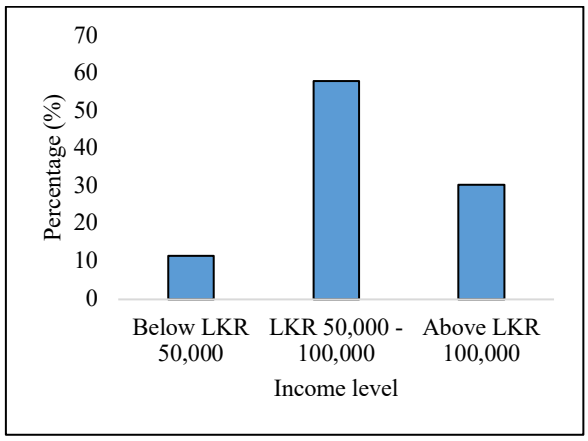

Figure 03: Monthly income

B. *Awareness of Solar Energy Usage*

The 99.5 percent of the interviewed participants in the Ampara District were aware about harnessing solar energy (Figure 04), whereas it was solely used for generating electricity. Friends and relatives were the most common source of information (45.4 percent), followed by social media and the internet (26.1 percent), government schemes (15.5 precent), and nongovernmental organizations (13 percent), as shown in Figure 05.

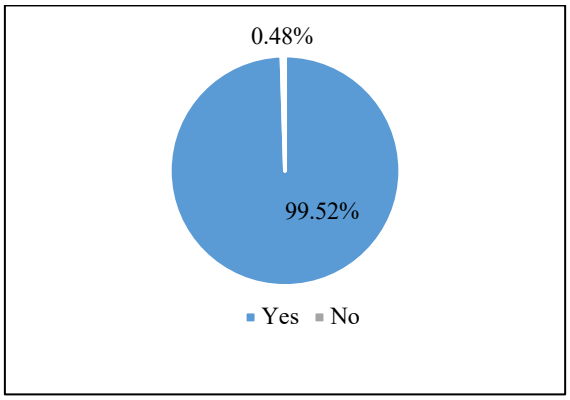

Figure 04: Aware of solar energy application

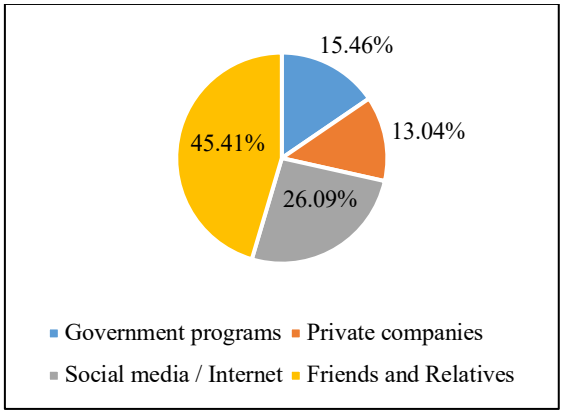

Figure 05: Source learnt about solar energy

ISBN 978-955-627-161-4

C. Facts about harnessing solar energy

As the main application of solar energy in the Ampara District was electricity generation, the photovoltaic systems were used primarily for household purposes, which accounted for 62.3 percent, while 35.3 percent were for commercial purposes, as shown in Figure 06. Only 2.4 percent of respondents utilized solar energy for agricultural purposes. Hence, the main reason for adopting solar systems was to earn money, with 46.4 percent benefitting from export tariffs and net metering, indicating a strong investment orientation. Meanwhile, 38.6 percent invested in solar systems to reduce their electricity bills, emphasizing cost savings and energy self-reliance, as illustrated in Figure 07. There was a significant positive correlation between the type of solar system and the economic return from the Ceylon Electricity Board. Approximately, 3/4th of end users in the Ampara District, or 78.3 percent, employed on-grid systems because they can connect directly to the national grid and earn through net metering, as shown in Figure 08. By contrast, only about 9 percent adopted off-grid systems, since batteries make them costlier and harder to maintain.

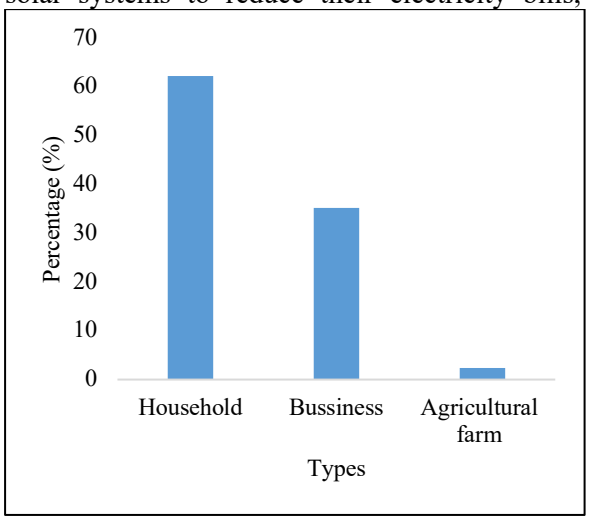

Figure 06: Purpose of use solar energy

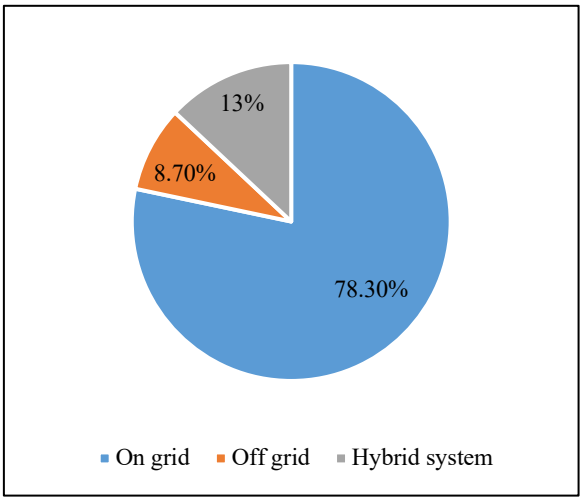

Figure 08: Type of solar system use

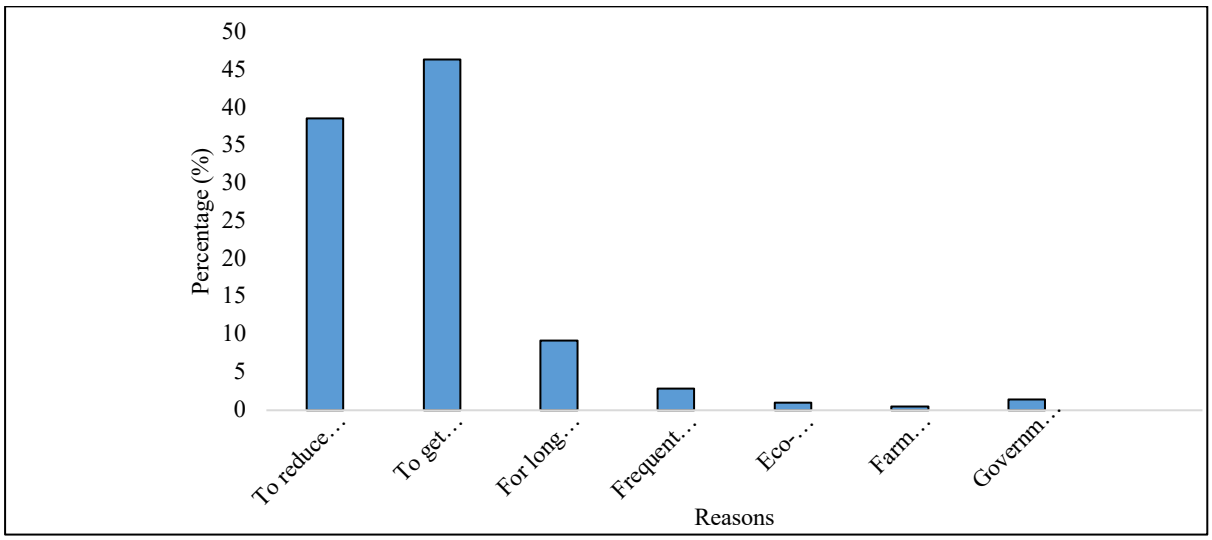

Figure 07: Primary reason for adopting solar system

ISBN 978-955-627-161-4

D. Description of Solar System in Ampara District

In the context of the design of solar photovoltaic systems in the Ampara District, the systems used for residential purposes were most commonly 5 kW in capacity, representing 20.3 percent of installations. These systems are typically used for meeting household electricity needs such as lighting, appliances, and general domestic consumption. Semi-commercial systems of 20 kW, accounting for 18.4 percent,

were mainly installed to support small businesses and commercial establishments, often with the aim of generating additional revenue through net-metering agreements. Larger systems consisting of 40 modules, representing 11.1 percent of the sample, were employed by businesses and high-consumption residences to cover extensive energy demands, including machinery, air conditioning, and other power-intensive activities. Smaller sets of 12 modules, each with 72 cells and accounting for 10.6 percent, were commonly installed by average households and small-scale enterprises to balance affordability with essential energy needs.

The choice of system capacity can be influenced by household income. Previous studies have shown that income positively influences photovoltaic system size, installed capacity, and the number of modules, with wealthier households tending to adopt larger-scale installations (Perera et al.,2023). However, in the present study, system capacity and the scale of solar usage appeared to be independent and showed no significant relationship with monthly income, with correlation analysis yielding a value of r = 0.140 and p = 0.046.

Furthermore, with respect to module type, the majority of users 69.9 percent adopted for monocrystalline modules, which are valued for their efficiency and application on small rooftops as illustrated in Figure 09. The rest of 25.7 percent adopted for polycrystalline modules. A minority of 4.4 percent adopted thin-film modules, typically for light or flexible applications. The different choices in solar module technologies among the respondents might be associated with the difference in occupation, but there was no significant correlation with the type of solar module used (r = 0.148, p = 0.034). Occupational background significantly correlates with PV module type choices, driven by affordability and exposure to technology (Bandara & Fernando, 2022). Such clear dominance by monocrystalline systems reflects global market trends as decreasing prices and increased performance in tropical environments bring it widely into use.

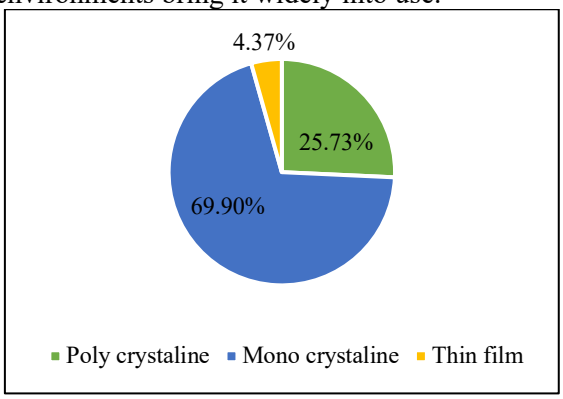

Figure 09: Type of solar system used

E. System Maintenance and Challenges

In dry and humid conditions, proper maintenance is essential to prevent yield loss and equipment failure. In the Ampara District, 57.3 percent of the users regularly carried out cleaning and inspection, while 42.7 percent neglected these processes, resulting in efficiency loss and reduced system lifespan, as shown in Figure 10. Subsequently, 41.55 percent of the surveyed respondents reported experiencing issues with their solar systems. The most common problem, affecting 14.98 percent, was inverter failure, often caused by grid fluctuations or overheating.

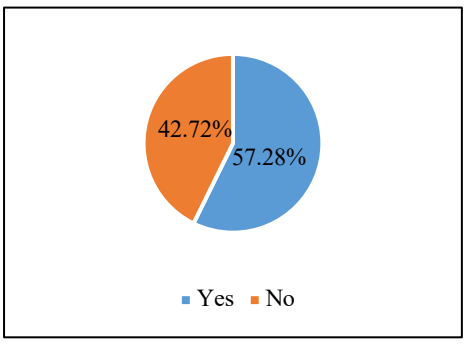

Figure 10: Maintenance activity of solar system

Faulty wiring was also reported by 10.63 percent of respondents, which can be attributed to improper installation practices. Panel damage, accounting for 9.66 percent, was generally due to adverse weather or mishandling during installation. Battery failures, reported by 6.28 percent, were typically linked to poor

ISBN 978-955-627-161-4

management practices or the use of low-quality products in hybrid configurations, as shown in Figure 11.

Additionally, the surveyed respondents revealed that the adoption of solar systems is challenged by many factors. As shown in Figure 12, the most significant barrier to solar adoption was the high initial cost, reported by the high initial cost, reported by 67.5 percent of users, followed by weather dependence at 8.4 percent, financial or technical difficulties at 7.4 percent, and lack of awareness at 6.9 percent. During periods of low irradiance, some users adopted coping strategies such as switching to grid electricity, which accounted for 33.3 percent, using stored electricity from batteries, or reducing electricity consumption. However, about 50 percent of respondents did not take any action, as shown in Figure 13. These challenges underscore the need for high-quality equipment and technologically sophisticated installation and support services.

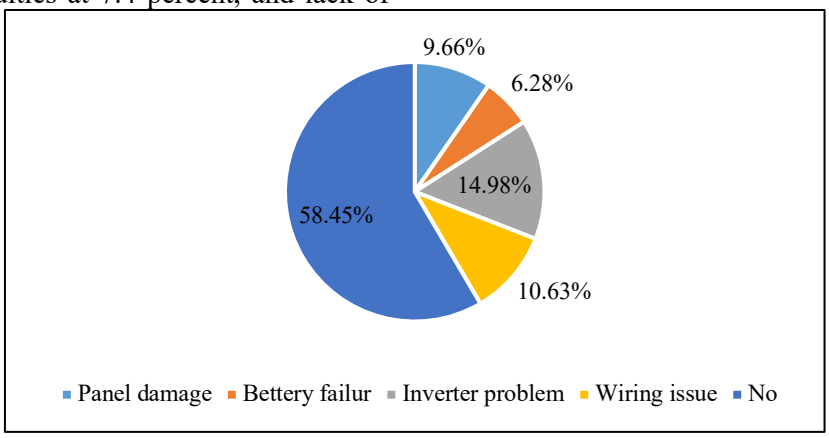

Figure 11: Type of issues faced

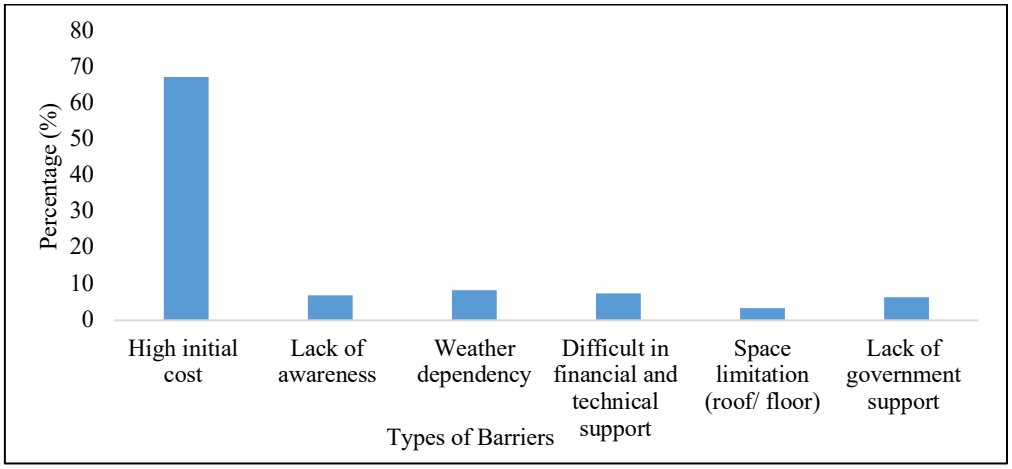

Figure 12: Barriers of solar energy adoption

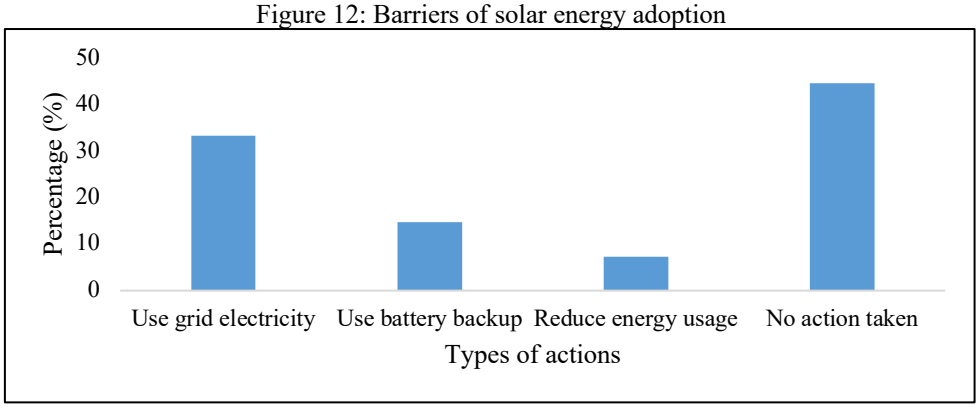

Figure 13: Action during low sunlight

ISBN 978-955-627-161-4

In this context, the respondents were interviewed to seek their opinions. As shown in Figure 14, the suggested measures included providing better loan facilities, supported by 39.8 percent of respondents, conducting awareness programmes at 31.1 percent, increasing subsidies at 14.6 percent, and offering more training programmes with better-quality solar equipment at 7.8 percent. These observations taken collectively emphasis on the area of funding, awareness generation, and quality control towards securing solar energy usage in Ampara District.

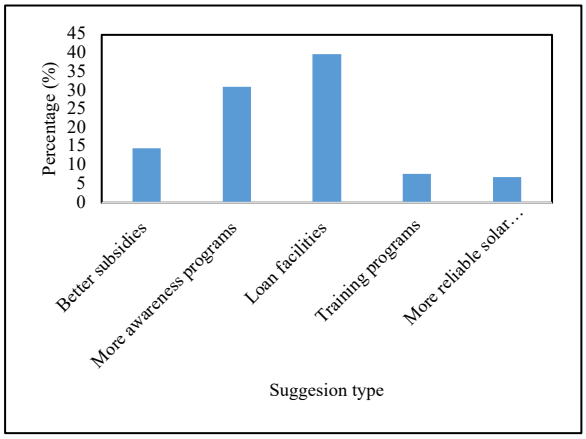

Figure 14: Suggestions for adopting solar energy

IV. CONCLUSION

The present study assessed the status of solar energy usage in the Ampara District of Sri Lanka. The research shows that solar energy utilization as an alternative energy source is prominent among the people of medium sized family, moderate income and government workers. Solar energy is primarily harnessed for electricity generation and it's substantially used in domestic and small scale commercial applications, while limited to agricultural operations. The people in Ampara district employed large 20 kW on-grid solar systems with monocrystalline modules for business and bigger residential purposes while 5 kW systems were adopted for domestic purposes. Only half of the end users properly maintain the installed systems and poor and or no maintenance led to technological faults such as inverter, wiring faults, panel damage and batteries failures. Even though, the people in the Ampara district are aware about solar energy usage, its takeoff is still hindered by initial capital expenses, weather dependency and restricted fund opportunities. To cope with these challenges, affordable finance, subsidies, promotion, and equipment and installation quality control are essential. Addressing these challenges will not only enhance household energy security, but also enable the transition towards renewable energy and climate resilience in Sri Lanka. Ultimately, the Ampara District has the potential to be a model for decentralized solar uptake if socio-economic, financial, and technical barriers are systematically addressed.

REFERENCES

Bandara, P. & Fernando, M., 2022. Determinants of photovoltaic technology choices among households in Sri Lanka. *Renewable Energy*, 190, pp.1205–1218. Available at: https://www.researchgate.net/publication/368345678

Bandara, U.C. & Amarasena, S.M., 2020. Impact of perceived ease of use, awareness and perceived cost on intention to use solar energy technology in Sri Lanka. *Journal of International Business and Management*, 3(4), pp.1–13. Available at: https://doi.org/10.37227/jibm-2020-04-61

Dias, R., Peris, S. & Liyanage, K., 2021. Behavioral adaptation and user responses to solar PV system performance. *Journal of Cleaner Production*, 305, p.127–136. Available at: https://www.researchgate.net/publication/364567234.

IJRPR, 2023. Consumer Perception Towards the Usage of Solar Power Products in Coimbatore. *International Journal of Research Publication and Reviews*, 4(5), pp.1722–1733.

IJSDWP, 2023. Knowledge, Awareness, and Acceptance of Solar Energy in Indonesia. *International Journal of Sustainable Development & World Policy*, 12(1), pp.1–10. Available at: https://doi.org/10.18488/26.v12i1.3296.

Kabir, R., Chowdhury, T. & Karim, S., 2024. Adoption of solar home systems and sectoral use in coastal Bangladesh: A case study approach. *Energy for Sustainable Development*, 72, pp.112–120. Available at: https://doi.org/10.1016/j.esd.2023.11.009k.

Karunarathna, S., De Silva, T. & Perera, D., 2022. Impact of subsidies and policy frameworks on solar PV diffusion in Sri Lanka. *Renewable and Sustainable Energy Reviews*, 157, p.112021. Available at: https://www.researchgate.net/publication/366432198

Lee, S., 2024. A Study on the Analysis of Solar Consumer Perception Using Big Data. *International Journal of Advanced Culture Technology*, 12(1), pp.254–261. Available at: https://doi.org/10.17703/IJACT.2024.12.1.254.

Loy, N., Rachmawati, I. & Karolus, M., 2023. Solar Energy Technology Acceptance in East Nusa

Tenggara. *International Journal of Sustainable Development & World Policy*, 12(1), pp.1–10.

Malik, S.A. & Ayop, A.R., 2020. Solar Energy Technology: Awareness and Acceptance of B40 Households in Malaysia. *Technology in Society*, 63, p.101416. Available at: https://doi.org/10.1016/j.techsoc.2020.101416.

Nengai, L., Mphande, F. & Ndou, N., 2024. An intervention framework for the adoption of solar home system technology in rural Vhembe District, South Africa. *Energy, Sustainability and Society*, 14(1), Article 9. Available at: https://energsustainsoc.biomedcentral.com/articles/10.1186/s13705-024-00493-w

Pathirathna, M.P.P.Y. et al., 2023. Households' Perception Towards Solar Panel Installation in Sri Lanka. In: *Proceedings of the International Forestry and Environment Symposium*, pp.153–160.

Perera, H., Jayasinghe, G. & Wijesooriya, R., 2023. Socio-economic determinants of household solar energy adoption in Sri Lanka. *Energy Policy*, 176, p.113497. Available at: https://www.researchgate.net/publication/369123456.

Sustainable Energy Authority of Sri Lanka (SEASL), 2022. *Annual Report 2021*. SEASL.

Ud Din, S. et al., 2023. Public Perception and Willingness to Pay for Renewable Energy in Pakistan. *Frontiers in Energy Research*, 11, p.1088297. Available at: https://doi.org/10.3389/fenrg.2023.1088297.

Wickramasinghe, L. & Abeywardena, N., 2021. Awareness and adoption patterns of rooftop solar PV in Sri Lanka. *Energy for Sustainable Development*, 65, pp.115–123. Available at: https://www.researchgate.net/publication/365678912

Wickramasinghe, L. & Thrishali, N., 2022. Awareness and adoption patterns of rooftop solar PV in Sri Lanka. *Energy for Sustainable Development*, 65, pp.115–123. Available at: https://www.researchgate.net/publication/365678912

ISBN 978-955-627-161-4