Jayanandana, U., Tennakoon, G.A., Kodituwakku, D. and Chan, M 2026. Managing end-of-life impacts of solar photovoltaic systems: A Sri Lankan perspective. In: Waidyasekara, K.G.A.S., Jayasena, H.S., Chandanie, H. and Tennakoon, G.A. (eds). *Proceedings of the 14th World Construction Symposium*, 10-11 July 2026, Sri Lanka. pp. 1109-1122. DOI: https://doi.org/10.31705/WCS.2026.81. Available from: https://ciobwcs.com/papers/

MANAGING END-OF-LIFE IMPACTS OF SOLAR PHOTOVOLTAIC SYSTEMS: A SRI LANKAN PERSPECTIVE

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ABSTRACT

The rapid expansion of Solar Photovoltaic (PV) systems as part of the global transition toward renewable energy has raised increasing concerns regarding the environmental impact of their End-Of-Life (EOL). Although solar PV technology contributes significantly to renewable electricity generation and has been widely adopted in Sri Lanka, the management of PV systems that have reached their EOL remains insufficiently explored in the local context. With projections indicating that global PV panel waste could reach approximately 78 million tonnes by 2050, effective EOL management strategies have become increasingly important. This study investigates how the EOL management of solar PV systems can be improved to minimise their environmental impact. A qualitative research approach was adopted, using semi-structured interviews, with participants selected through purposive sampling based on their professional experience in the local solar PV sector and their knowledge of EOL practices. The collected data were analysed using thematic analysis. The findings revealed ten strategies for improving EOL management, grouped into five key categories: government leadership, recycling infrastructure, circularity in design, extended producer responsibility, and awareness building. Government leadership emerged as a significant contributor, highlighting the need for supportive regulations, incentives for recycling, and the establishment of collection schemes for EOL solar PV systems. Moreover, the study emphasised integrating circularity principles into solar PV system design, including the use of recyclable and sustainable materials, modular components, and less material-intensive components. The findings provide practical insights for strengthening EOL management and supporting the sustainable expansion of solar PV systems in Sri Lanka.

Keywords: *End-of-life (EOL); Environmental Sustainability; Renewable Energy; Solar Photovoltaic (PV); Sri Lanka.*

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1. INTRODUCTION

With the evolving discussions around environmental sustainability, the use of renewable energy sources has grown significantly in recent years. This is evident through the increase in the share of renewable energy in the global energy mix from 7.4% in 2016 to 12.8% in 2021 (Yolcan, 2023). Among the different sources of renewable energy, solar PV systems occupy a prominent place. As of 2022, solar PV systems accounted for 3.6% of global electricity generation and 31% of renewable energy capacity (Pourasl et al., 2023). The use of solar power as a renewable energy source began in the 19th century, with the first demonstration of the conversion of solar energy to electricity by French Physicist Alexandre Edmond Becquerel with his invention of solar PV cells in 1839 (Lameirinhas et al., 2022). Moving forward, in 1940s and early 1950s, the development of silicon based solar cells was a significant milestone which increased efficiency and commercial viability of solar power usage (Jones & Bouamane, 2012). Currently, silicon based solar cells are the dominant technology in the solar PV market, accounting for approximately 95% of global solar cell production (Zhu et al., 2022). With the increasing concerns regarding environmental degradation and climate change impacts associated with the usage of fossil fuels, renewable energy sources, more specifically solar energy, has gained widespread attention, both globally and in Sri Lanka, and the demand for solar PV systems is expected to grow into the future (Yolcan, 2023; Thennakoon et al., 2023).

From a local perspective, Sri Lanka has embraced the adoption of solar PV technology as part of its renewable energy strategy. The country's solar PV sector is managed under the "Soorya Bala Sangramaya" (Battle for Solar Energy) programme launched in 2016 by the Sri Lankan Government (Thennakoon et al., 2023). Following the initiation of this programme, the solar PV sector in the country has grown significantly and it is expected that the sector will contribute 1.5 GWs of electricity to the national grid by 2030 (Sri Lanka Sustainable Energy Authority, n.d.). Further, the country's tropical climate with higher solar irradiation levels have provided a favourable environment for electricity generation through solar PV systems (Mendis et al., 2019). Although solar PV systems make a substantial contribution to both global and local renewable energy transitions, the potential environmental impacts associated with their life cycle, from manufacturing to EOL disposal, require careful consideration. Previous studies have identified several negative environmental impacts linked to solar PV systems, including the release of hazardous substances such as heavy metals, high water consumption and contamination of water resources, GreenHouse Gas (GHG) emissions, and degradation of ecosystems leading to habitat loss and decline in biodiversity (Bošnjaković et al., 2023). Given these environmental challenges alongside the critical role of solar PV in achieving renewable energy targets, increasing attention has been given towards mitigating such impacts while sustaining the use of solar PV technologies.

Within this background, EOL management of solar PV systems has emerged as a pressing concern. Projections indicate that global PV panel waste, which is primarily composed of glass, could reach approximately 78 million tonnes by 2050, while the recoverable materials from EOL PV panels could be valued at over USD 15 billion (International Energy Agency (IEA), n.d.). As the adoption of solar PV systems continues to grow, the volume of associated waste streams is expected to increase correspondingly, thereby intensifying the need for effective and sustainable EOL management strategies. Recognising both the environmental risks and the economic opportunities associated with EOL solar PV systems, several countries have introduced regulatory and technological measures to improve EOL management of such systems. For instance, the United Kingdom has implemented the Waste Electrical and Electronic Equipment (WEEE) Directive, which places responsibility on manufacturers and suppliers for the collection, recycling, and disposal of PV panels (Umar et al., 2025). According to the authors, Japan has advanced chemical recycling techniques to recover silicon, a key component of solar cells. Similarly, Germany has integrated PV waste into its electronic waste management framework, while states such as California in the USA have undertaken initiatives to regulate PV disposal and improve recycling efficiency (Umar et al., 2025). Despite growing global interest in the EOL management of solar PV systems, this issue remains underexplored in the Sri Lankan context, particularly from a research standpoint. Existing studies in Sri Lanka have predominantly focused on PV adoption, policy mechanisms, and general environmental benefits, with limited attention given to EOL management considerations (Danthurebandara & Rajapaksha, 2019; Thushara et al., 2019). While the use of solar PV systems has been actively encouraged through government policy interventions, comparatively little emphasis has been placed on addressing the environmental impacts associated with their EOL phase. This gap is particularly significant given that many PV systems installed following the introduction of net metering in Sri Lanka in 2010 are expected to reach their EOL within the next decade (Thennakoon et al., 2023).

Against this backdrop, the present study looks at answering the question "*How can the end-of-life management of solar photovoltaic systems be improved to minimise their environmental impact.*" The study aimed to investigate strategies for improving the EOL management of solar PV systems to minimise their environmental impacts in the Sri Lankan context. The findings of this study are expected to support the environmentally sustainable and economically viable renewable energy transition efforts in the country.

Solar PV systems can be broadly categorised into different installation types, including rooftop systems, Building-Integrated PhotoVoltaics (BIPV), and utility-scale solar farms. These categories differ significantly in terms of system scale, design integration, material composition, and operational context, which in turn influence their environmental impacts and End-Of-Life (EOL) management requirements. For instance, rooftop systems are decentralised and typically involve lower material use and reduced environmental burdens per unit capacity compared to ground-mounted utility-scale systems, which require extensive supporting infrastructure and land use (Roy & Pearce, 2023). In contrast, BIPV systems are integrated directly into building components, which can complicate dismantling processes and create additional challenges for material recovery due to their structural coupling with buildings (Zhou & Li, 2025). Furthermore, previous research indicates that EOL management processes including collection, transportation, recycling, and disposal vary depending on installation type and scale, highlighting the need for tailored approaches across the PV value chain (Biyouki et al., 2024). Despite these variations, the solar PV sector in Sri Lanka remains at a relatively early stage of development in terms of EOL management practices, with limited regulatory differentiation across PV system types. As a result, this study adopts a generalised perspective on EOL management, focusing on identifying common strategies applicable across different PV installation categories. Section 2 provide a brief literature review on the use of solar PV systems in Sri Lanka. Section 3 provides an explanation regarding the study methodology, followed by Section 4 outlining the study findings. Finally, Section 5 presents the conclusions and recommendation of the study.

2. LITERATURE REVIEW

2.1 SOLAR PV SYSTEMS IN SRI LANKA

Solar PV systems have attracted significant interest in Sri Lanka as a response to the country's increasing energy demand. Owing to its tropical climate, Sri Lanka benefits from consistently high levels of solar irradiation, making solar energy a technically suitable and environmentally sustainable alternative for electricity generation and for reducing reliance on fossil fuels (Mittal, 2023). Recognising this potential, the Sri Lankan government has prioritised the adoption of solar PV systems within its national energy strategy and introduced a range of incentives aimed at lowering fossil fuel dependency while harnessing renewable energy sources such as solar (Koswatte et al., 2024). Among the key initiatives supporting this transition is the net metering scheme introduced in 2010, which enables households and organisations to export surplus electricity generated from solar PV systems to the national grid (Thennakoon et al., 2023). Beyond providing direct financial benefits to system owners, this mechanism has also played an important role in encouraging wider adoption of solar PV technologies. In addition, fiscal measures such as tax exemptions and grant schemes for solar equipment have reduced upfront investment costs, thereby improving affordability for both residential and commercial users (Kannan & Asharp, 2023).

The regulatory environment has also evolved to facilitate the uptake of solar PV systems, notably through policy instruments such as the National Policy for Renewable Energy (NPRE) introduced in 2010. Initiatives, including the "Soorya Bala Sangramaya" (Battle for Solar Energy) programme implemented by the Sustainable Energy Authority of Sri Lanka, have further reinforced national efforts to accelerate the transition towards solar-based electricity generation (Thennakoon et al., 2023).

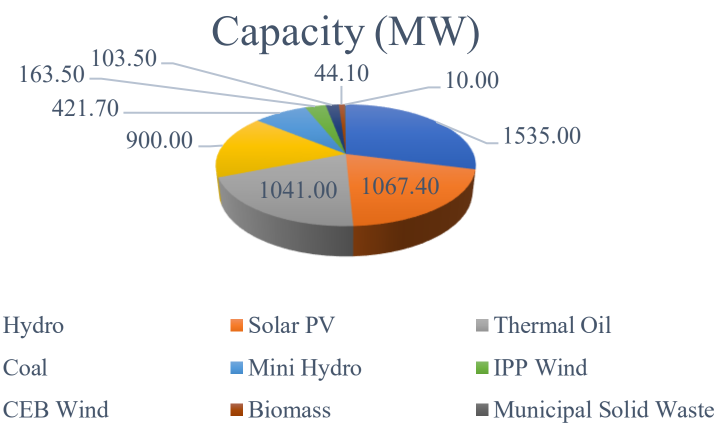

Figure 1: Energy capacity mix (Adapted from: Public Utilities Commission of Sri Lanka)

Consequently, solar energy now accounts for a notable component of Sri Lanka's energy mix (refer Figure 1), with an installed capacity exceeding 1000 MW, thereby contributing to national energy security and supporting long-term sustainability objectives. Notwithstanding these advancements, the diffusion of solar PV systems continues to be limited by administrative complexities and extended approval processes, which remain key challenges for prospective users. More critically, despite the strong policy emphasis on expanding solar PV use, limited attention has been directed towards the EOL management of solar PV systems. The absence of structured policies and regulatory provisions governing the disposal and recycling of decommissioned PV system components raises concerns regarding their potential environmental impacts (Rabaia et al., 2021). Existing studies indicate that EOL considerations for solar PV systems are largely absent from Sri Lanka's current policy framework. Against this backdrop, providing greater attention towards effective EOL management of solar PV systems is essential to ensure that the transition to solar energy in the country aligns with broader principles of environmental sustainability and circular resource use.

2.2 ENVIRONMENTAL IMPACTS OF SOLAR PV SYSTEMS

The global environmental impact of solar PV systems is increasingly recognised as a critical factor in the transition towards sustainable energy systems. Solar PV systems play an important role in the mitigation of Greenhouse gases through the generation of renewable energy, and it is expected that they can reduce about 2.3 Giga Tons of CO2 each year (Jan et al., 2023). However, the production process of solar PV systems is not without their impacts on the environment including the use of scarce materials, hazardous materials and notable levels of water usage (Basit et al., 2022). In addition, the life cycle assessments of solar PV systems show that although they have many environmental benefits during the operational phase, their manufacturing and decommissioning phases present negative environmental impacts that need to be carefully evaluated. Therefore, understanding the environmental impacts of solar PV systems is essential for maximising its benefits while minimising its adverse effects on the environment.

2.2.1 Impacts During the Manufacturing Phase

Manufacturing of solar PV systems is an energy and material intensive process, which affects their overall environmental impact. PV manufacturing has demonstrated varying energy intensities across different manufacturing stages, particularly in production of silicon wafers and module assembly. For instance, the energy required to extract Silicon from the raw materials for crystalline Silicon solar cells is significant and makes up a considerable part of the carbon footprint of the solar cells (Akhter et al., 2024). While second generation thin film PV technologies typically consume less energy in production than the first generation, they also have their own environmental challenges, specifically related to material inputs and toxicity. Apart from silicon, the manufacturing process of solar PV systems requires other raw materials such as cadmium and tellurium, the mining of which can cause significant environmental degradation in terms of the destruction of habitats, soil erosion and water pollution (Adekanmbi & Wolf, 2024). As the demand for renewable energy evolves, new materials and manufacturing techniques will be required to enhance the environmental sustainability of solar PV systems.

2.2.2 Impacts During the Operational Phase

While the environmental impacts of solar PV systems during the operational phase are a minimum, there are several concerns related specifically to large-scale solar farms, primary among them being the excessive land use and habitat disruption (Dhar et al., 2020). Utility scale solar farms consume large land areas and can therefore result in the displacement of local flora and fauna (Karban et al., 2024). According to the authors, this is a particular concern in ecologically sensitive regions that already have their biodiversity under threat. In addition, the competition for lands between the large-scale solar farms and farming for food concerns raise concerns regarding, food security as well as land scarcity, especially where land availability is low. Several mitigation measures to address these concerns are already emerging, with technologies such as agrivoltaics, which allows combined production of solar energy with agricultural work (Muñoz-García & Hernández-Callejo, 2021).

2.2.3 Impacts During the End-Of-Life Phase

Prior research has shown that environmental impacts related to poor end-of-life management of solar PV systems is crucial (Mao et al., 2024). Due to the rapid increase in the adoption of solar technology, there is a considerably high volume of end-of-life solar panels and system components that will produce a significant amount of waste in the next few decades (Mao et al., 2024). Specially, if the PV panels and components like batteries are not properly disposed, heavy metals such as lead and cadmium can leach into the environment, which is highly hazardous (Nain & Kumar, 2020). Furthermore, the current recycling practices for solar panels are still in their infancy, with many systems lacking effective recovery methods for valuable materials (Nain & Kumar, 2020). This lack of recycling of used solar PV systems coupled with the growth in the focus on renewable energy means that there would be a higher demand for virgin materials used in manufacturing PV systems anew, contributing to further depletion of natural resources and increasing the overall environmental footprint of solar PV systems. Therefore, in terms of different phases of the solar PV system lifecycle, the EOL phase is to be considered as a crucial determinant of the overall sustainability of solar PV systems, as failure in effective management of this phase may offset the environmental benefits achieved during the other phases. Hence, there is an urgent need for focusing on managing the environmental impacts of the EOL phase of solar PV systems to ensure that they create a net positive environmental impact.

3. METHODOLOGY

The methodology establishes the overall framework through which the study was designed and conducted to achieve its stated aim. A critical component of methodological design is the selection of an appropriate research approach. Broadly, research approaches can be classified as quantitative, qualitative, or mixed methods (Saunders et al., 2019). Each approach offers distinct advantages and is suitable for addressing different types of research questions and contexts, thereby influencing the robustness and validity of the research outcomes. Quantitative research primarily focuses on numerical measurement and statistical analysis, whereas qualitative research seeks to develop an in-depth understanding of phenomena through non-numerical methods, such as interviews and observations. Mixed-methods research integrates both approaches to capture both quantitative and qualitative insights, especially for complex research problems that require detailed analysis.

Given the relative novelty of EOL management of solar PV systems within the Sri Lankan context, the need for in-depth exploratory insights, and the difficulty in conducting a large-scale quantitative study due to limited domain-specific expertise, this study adopted a qualitative research approach. Qualitative research typically uses data collection methods such as interviews, focus groups, and observations to gain detailed insights into the phenomenon under investigation. For this study, interviews were selected as the primary data collection method. Observational methods were considered unsuitable for the research problem, while focus group discussions were deemed unnecessary as the study did not seek to establish group consensus on specific issues. Interviews can be broadly categorised as structured, semi-structured, or unstructured. Semi-structured interviews were used in this study to balance consistency across participants with flexibility to explore emerging themes. The interviews aimed to identify potential strategies for improving the EOL management of solar PV systems. An interview guideline was developed based on the findings of the literature review, while allowing for probing questions to clarify responses and explore issues in greater depth.

Participants were selected using purposive sampling, based on their professional involvement in the Sri Lankan solar PV sector and their knowledge of EOL management practices. As EOL management of solar PV systems remains an emerging area in Sri Lanka, the number of interviews was limited to eight. Even though the number of interviews was limited to eight, qualitative research does not aim for statistical generalisation yet rather depth of understanding. Methodology literature suggest that smaller sample sizes are appropriate when participants possess high levels of expertise and when the study focuses on a narrowly defined topic. The adequacy of the sample size was determined based on the principle of data saturation, which refers to the point at which no new themes, insights, or patterns emerge from the data. Accordingly, during the data collection process, it was observed that after the sixth interview, recurring themes began to stabilise, and subsequent interviews largely confirmed previously identified insights rather than introducing new concepts. The final two interviews were conducted to ensure consistency and confirm saturation, thereby strengthening the reliability of the findings. This indicates that sufficient depth and coverage of the research topic had been achieved despite the relatively small sample size. The interviewees selected possessed extensive experience related to the study domain, and the interviews yielded rich insights into the EOL management of solar PV systems. The profiles of the interviewees are presented in Table 1.

Table 1: Profile of interview participants

Interviewee Code	Designation	Experience	Qualifications
I1	Professor	20+ years	Professor in Building Economics at a Sri Lankan leading university with research expertise related to circular economy, disaster management and resilience
I2	Solar PV Consultant	10+ years	Worked as a Solar PV Consultant in Sri Lanka and abroad with expertise in solar panel installation and energy optimization strategies
I3	R&D Engineer	7+ years	Research and Development Engineer specializing in solar energy systems with experience in designing energy-efficient solutions for residential and commercial clients.
I4	Chief Executive Officer	15+ years	Chief Executive Officer at a leading solar technology company in Sri Lanka with substantial experience in the production of solar panels and renewable energy solutions
I5	Electrical Engineer	6+ years	Electrical engineer specializing in solar power systems with experience in both grid-connected and off-grid solar systems

Interviewee Code	Designation	Experience	Qualifications
I6	Solar Operations Manager	12+ years	Solar Operations Manager at a renewable energy firm in Sri Lanka, overseeing large-scale solar installations and maintenance operations
I7	Policy Advisor	9+ years	Policy advisor focusing on renewable energy policies in Sri Lanka, with a background in environmental law and energy regulation
I8	Project Manager	7+ years	Project Manager in a leading solar energy firm in Sri Lanka, responsible for overseeing solar energy project implementation, from planning to execution

The qualitative data collected were analysed using thematic analysis, with the coding and interpretation process conducted primarily through manual methods, supported by Microsoft Excel.

4. FINDINGS

The interview findings revealed a range of strategies that could be implemented for improving EOL management of solar PV systems to minimise their environmental impact. These individual strategies are explained in detail under the following sub-topics.

4.1 GOVERNMENT LEADERSHIP

The interview findings revealed that the government has a key role to play in terms of improving the end-EOL management of solar PV systems. Herein, the interviewees emphasized that the government should be actively involved in setting up **supportive regulations** that drives the use of solar PV systems in a responsible manner. Such regulations should focus on aspects such as setting up requirements around product returns and material recovery so that EOL solar PV systems are managed responsibly with recoverable resources being brought back into productive use. As noted by I4, the EOL management of solar PV systems in Sri Lanka is currently not regulated. In the absence of proper regulations, private sector entities that are primarily involved in the supply of solar PV systems are highly unlikely to invest in developing recycling infrastructure for these systems, since such investments would eat into their profits.

In addition to regulatory support, I6 recommended that the government could focus on providing **incentives for recycling** EOL solar PV systems, especially the solar panels and battery systems that consist of recyclable glass and rare earth metals, which would drive both users and manufacturers to focus on recycling such systems. The interviewee noted that similar to the tax breaks and subsidies provided for the installation of solar PV systems, financial incentives can be provided to encourage the return and recovery of EOL solar PV systems. However, I2 pointed out that while incentives could encourage responsible EOL management, there is also the need to **develop collection schemes** for effectively collecting system components that have reached the EOL. I2 elaborated on this as follows: "*In addition to providing incentives, we should also set up a good way to collect old solar panels from individuals and companies; it requires setting up collection spots and informing people about the proper way to get rid of their old solar panels. Good logistics are necessary to make sure that the panels are recycled, instead of being thrown* *away improperly*." As evident through the above extract, there is the need to set up collection centres for collecting the EOL solar PV systems and providing accessible logistics facilities so that such systems are returned to the collection centres. Adding to this, I7 emphasized that such collection schemes should be set up and implemented at the national level, which recognises the need for government leadership and involvement in setting up the collection systems and the relevant logistics infrastructure.

4.2 RECYCLING INFRASTRUCTURE

In the quest towards improving the EOL management of solar PV systems, the interviewees reiterated the significance of **setting up recycling infrastructure locally** to recycle EOL solar PV systems. I4, the CEO of a leading solar technology company, pointed out that there is the opportunity to build local recycling facilities with the growing demand for solar PV systems locally as well as in the region. As elaborated by the interviewee, "*Sri Lanka could set up its own recycling plants for solar PV systems – this will help to solve the waste problem and also create new jobs and boost the economy; in fact, we can turn Sri Lanka into a major recycling hub for things like solar panels in South Asia, considering our strategic location in the South Asian region*." According to the above extract, if Sri Lanka can invest in recycling facilities, it can reduce solar PV waste generation, while also recovering valuable materials such as glass, silicon, aluminium and silver, which are required for manufacturing new solar PV systems.

While investments in recycling infrastructure would ideally have to be kick-started by the government until the demand for recycling catches up, the interviewees noted that this might not be viable in a highly cash-crunched economy like Sri Lanka, due to the high upfront costs of setting up recycling infrastructure. Considering this, I6 noted that options such as foreign funding arrangements or public-private partnerships could be considered to initiate the setting up of recycling infrastructure and acquiring the relevant expertise. As noted by I6, "*working together with international companies that specialise in solar panel recycling can introduce the required technologies and knowledge to Sri Lanka, and collaboration between public and private sectors could support the setting up of recycling systems*." However, as noted by the interviewees, investments in recycling infrastructure would not be successful without supportive regulatory or policy initiatives that drives recycling EOL solar PV systems. As explained by I4, "*until there are policies that encourage recycling solar PV systems, companies will not invest in the necessary infrastructure – the government must introduce regulations that require recycling and help drive the return on investment on recycling infrastructure*." As noted by the interviewee, if the regulatory and policy frameworks do not drive the recycling of EOL solar PV systems, people will not be interested in recycling unless there is an economic benefit. This would make recycling facilities idle, which in turn would make it difficult to recover the investment on the recycling facilities, thus discouraging such investments.

4.3 CIRCULARITY IN DESIGN

Interestingly, most of the interviewees highlighted that the responsible EOL management of solar PV systems should ideally commence at the design stage itself. As noted by I2, "*if solar panels are designed to be recycled from the start, we can lessen the effect on the environment from the beginning*." Herein, the interviewees identified several circularity principles that can be adopted in the design of solar PV systems. Among them, improving the resource efficiency of solar PV systems was emphasized to make them **less material**

intensive. To achieve resource efficiency in design, I3 noted that the design of solar PV systems should be improved to use less materials while also **selecting materials that are comparatively easy to recycle**. This will ensure that the resources committed to the production of solar PV systems are minimized while at the same time, any recyclable materials are recovered and diverted back towards new production processes.

Moving further, I4 advised that the local suppliers of solar PV systems should investigate **modular designs** which would make it possible to replace individual components of the solar PV systems instead of replacing the entire system. For instance, the interviewee pointed out that by making the solar panels modular, any faulty cells could be removed and replaced rather than replacing the entire panel. This would ensure that the solar panels last longer while also cutting down on the waste generated. This aligns with the current trends in product design which urges companies to make products that can be repaired, upgraded or taken apart for recycling. Moreover, I2 noted that the **use of sustainable material** alternatives when manufacturing solar PV systems could also help lower the negative EOL impacts of solar PV systems. As stated by the interviewee, "*it would be better for manufacturers to choose materials that are less harmful to the environment such as recycled aluminium or glass*." This can be specially considered when manufacturing solar panels, since aluminium, which is used as a framing material is highly recyclable, while glass which is used as a transparent layer on top of the solar cells to protect them from exposure to the elements and impact, can also be made using recycled glass since they do not have a direct impact on energy generation through solar panels.

4.4 EXTENDED PRODUCER RESPONSIBILITY

Following on from EPR requirements placed on manufacturers of products such as electronics and vehicles, the interview findings revealed that the government could consider **applying EPR requirements for suppliers of solar PV systems**. This was emphasised by I1 who noted that applying EPR requirements would make suppliers responsible for the entire lifecycle of their products, from cradle to grave. The interviewee noted that EPR schemes would encourage suppliers of solar PV systems to design and supply products with recycling and disposal in mind and be responsible for their products after they are used. Implementing such requirements is aligned with what is currently happening globally, where businesses are expected to internalize and be responsible for the negative environmental effects of their products after they are sold.

4.5 AWARENESS BUILDING

While implementing the measures, the interview findings also recognised the need for building broader community awareness regarding proper EOL management of solar PV systems. As noted by the interviewees, such awareness building efforts should focus on communicating the negative/harmful effects of poor EOL management of solar PV systems, how EOL solar PV systems should be managed and what are the avenues/options available to responsibly manage such systems that have reached their EOL. Herein, I4 specifically noted that such awareness building efforts should target stakeholders at both the supply and demand sides.

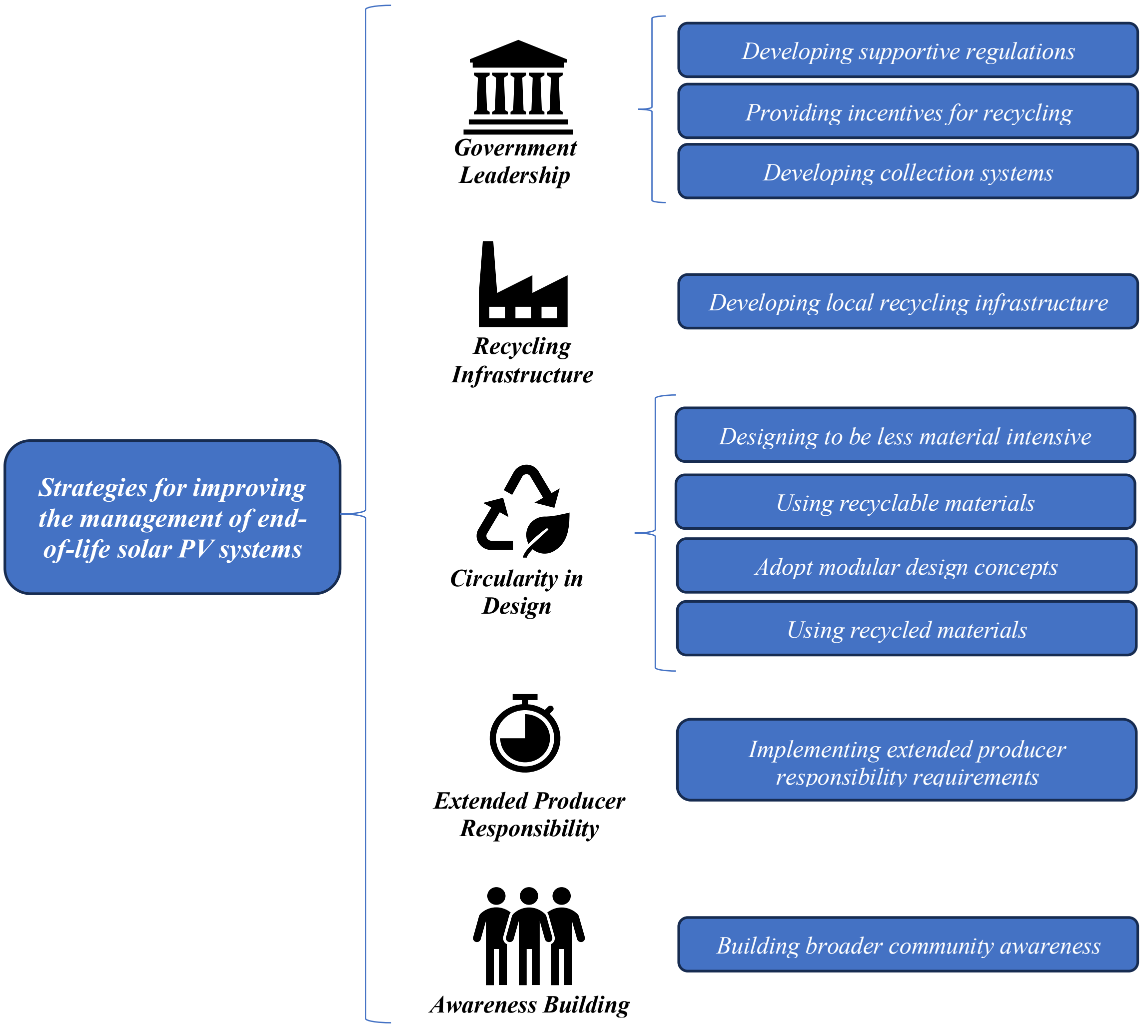

Figure 2: Summary of findings

The key findings of the study are summarised in Figure 2.

5. DISCUSSION

Recent statistics suggest that Sri Lanka's dependence on solar PV systems is increasing as part of its transition towards more sustainable energy generation. However, the end-of-life (EOL) management of solar PV systems remains underexplored in the local context, indicating a critical gap that the present study seeks to address. The findings emphasise the need for stronger government intervention through appropriate regulations, recycling incentives, formal collection mechanisms, and the development of recycling infrastructure, potentially through public–private partnerships. Although Sri Lanka has actively promoted solar energy adoption, insufficient attention has been given to the eventual disposal and recovery of solar PV systems, many of which will progressively reach their EOL in the coming years (Thennakoon et al., 2023, Koswatte et al., 2024). This is particularly concerning because PV panels are classified as hazardous e-waste, yet Sri Lanka lacks structured recycling and material recovery systems capable of safely managing this waste stream and recovering valuable materials such as silicon, copper, aluminium, and glass (Thennakoon et al., 2023). Existing e-waste collection systems are largely informal, while subsequent recycling and recovery processes remain insufficiently transparent. In contrast, countries such as Japan and China have begun developing national recycling frameworks and large-scale facilities to manage solar PV waste sustainably (Umar et al., 2025). While Sri Lanka may draw lessons from these approaches, their direct applicability must be assessed in light of local financial and technological constraints. Furthermore, countries such as China benefit from economies of scale as a major global producer of solar PV panels, an advantage that Sri Lanka lacks. However, given Sri Lanka's strategic location in South Asia, the study indicates potential for positioning the country as a regional hub for solar PV recycling, provided that a robust regulatory framework is established to prevent the country from becoming a destination for hazardous waste disposal.

The findings highlight the importance of embedding circularity principles into solar PV system design, including material-efficient designs, modularity, and the use of recycled or recyclable materials. Since most solar PV components used in Sri Lanka are imported, with limited local design or manufacturing capacity (Koswatte et al., 2024), local suppliers should prioritise the importation and promotion of systems designed in accordance with such circularity principles. Closely linked to this is the adoption of EPR schemes, under which suppliers remain accountable for products throughout their lifecycle rather than only until the point of sale. Similar mechanisms have been widely used in the European Union and the United Kingdom through instruments such as the Waste Electrical and Electronic Equipment Directive to encourage EOL recovery of solar PV systems (Umar et al., 2025). Prior studies further suggest that EPR is essential for sustaining recycling schemes, as it creates legal and financial accountability for suppliers who fail to ensure proper lifecycle management (Umar et al., 2025). Accordingly, establishing EPR-based requirements is imperative for the long-term success of EOL solar PV recovery in Sri Lanka. Finally, the study highlights the need for broader awareness-building initiatives. The effectiveness of regulatory, technical, and recovery-oriented strategies will depend heavily on public understanding of proper EOL management and active community participation, a finding consistently supported in previous studies (Thennakoon et al., 2023; Umar et al., 2025).

6. CONCLUSIONS

The study findings agree with the existing literature that despite promotion of solar PV systems in Sri Lanka, their EOL management has received comparatively very limited attention, therefore necessitating a closer look at how to improve the management of the EOL environmental impacts of solar PV systems. The findings revealed a range of strategies that could be used to address and overcome the negative environmental impacts of EOL solar PV systems. Interestingly, it was found that the government has a major role to play in this regard. Herein, the findings revealed that the government should focus on enacting supportive regulations that drive product return and material recovery. The government can consider providing financial incentives for recycling EOL solar PV systems, similar to those that are provided for promoting their use. Importantly, it was emphasized that such measures should be complemented by a nation-wide collection scheme for EOL solar PV systems without which there would not be a clear pipeline for collecting EOL solar PV systems for material recovery. While aforementioned measures are being implemented, the study also recognised the significance of setting up recycling infrastructure locally, which could be set up through foreign funding arrangements or public-private partnerships, considering the high initial costs involved in setting up such infrastructure. If successful, there is the potential for Sri Lanka to be a hub for recycling solar PV systems in the region. Considering the notable impact that system design can have on EOL management, the importance of considering circularity principles in system design was highlighted. Circularity strategies such as using less materials, using recyclable and sustainable materials (e.g., materials with recycled content) and following modular design principles were recognised as avenues for improving the EOL management of solar PV systems at the design stage itself. Further, the study recognised the potential for applying EPR requirements for manufacturers/suppliers of solar PV systems, so that they themselves are held responsible for the EOL impacts of solar PV systems, which in turn would drive them to consider EOL management during design and manufacturing of solar PV systems itself. Finally, the need for building broader community awareness regarding proper EOL management of solar PV systems was emphasised.

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