Exploring End-of-life Photovoltaic Panel as a Building Material: A Case of Crystalline Silicon PV

The renewable energy share in the energy mix worldwide is rising sharply to mitigate climate change, with Solar Photovoltaics (PV) carrying a large share of 3.6%. However, the end-of-life (EoL) management of decommissioned PV panels is emerging as a serious concern, globally. It is projected that by the end of 2050, a cumulative 70~80 million tonnes of EoL-PV waste will be generated worldwide, with 4.5~7.5 million tonnes envisaged in India. Such enormous PV waste heading into landfills severely threatens the environment and human health. The current study explores a novel, hitherto untried, approach of upcycling EoL-PV panels as a building material. EoL-PV also carries potential for application in housing, alleviating the pressure on conventional building materials. Further, upcycling PV panels could extend the use-phase by a few decades, buying time till recovery and recycling options become economically viable.

For application as a building material, EoL-PV panels need to be examined for their solar and thermal transmittance. PV panels, before they reach end of functional life (EoL), undergo degradation subject to various field (environmental) and operating conditions. The impact of degradation on the solar and thermal transmittance of EoL-PV panels has not been examined thus far. About 33 decommissioned EoL-PV panels with various degradation modes have been visually and electrically examined. EoL-PV panels are non-opaque materials, and hence solar transmittance measurements would provide crucial insight into their climatic performance. Further, the impact of degradation on solar and thermal transmittance has been examined, comparing EoL-PV panels and new (unused) PV panels. The measurement approach adopted (under natural sunlight) has been a maiden attempt in examining PV panels. ASTM E1084-86:2015 stipulations for such measurements have been complied with. Compared with new PV panels, a drop in solar transmittance of 11 % ~ 37.6 % has been observed in EoL-PV panels. Both EoL-PV and new PV panels have also been tested for their thermal transmittance in a state-of-the-art HotBox facility. No significant changes between EoL-PV and new PV in their thermal transmittance were observed. The absolute U-values were in the range of 11.7 W/m^2K ~ 12.5 W/m^2K, with their thermal conductivity in the range of 0.55 ~ 0.7 W/mK. The climate responsiveness on EoL-PV building has been examined for various climate zones in India. This has involved a real-time monitoring of a case study building (building integrated with EoL-PV as façade), supported by whole-building simulation models. Time lag and decrement factors are parameters to examine the climatic-response of a building envelope. The time lag for the EoL PV case was observed to be very low (< 1 hour), and the decrement factor around 1. The thermal damping was found to be negative, indicating that the indoor air temperature is higher than outdoor ambient temperatures. For tropical conditions such as India, this would imply a large heat gain, which is not favourable. Suitable interventions need to be devised to improve the thermal performance of the EoL-PV envelope. Four interventions have been proposed and tested through whole building simulations. Significant improvement in the decrement factor (0.4 ~ 0.7) and time lag (6~8 hrs) have been achieved for favourable adoption in tropical conditions.

Given the huge demand in housing, the current study has examined the applicability of EoL-PV for housing and in alleviating the demand for conventional building materials. Conventional building materials are process intensive and carry a huge carbon footprint. There is an emerging paradigm shift in the adoption of novel building materials with low embodied energy. EoL-PV is an affordable and durable material with an inherent low embodied energy. The current study also examines the energy, cost and carbon-emission benefits accruing through the adoption of EoL-PV buildings in comparison with conventional buildings. EoL-PV panels carry inconsistent degradation, which depends on the age of PV, climate zone and other factors. An approach has been developed to determine the probability of degradation modes for a given climate zone, including the impact of climate-change. Based on this, state-wise projections on the number of EoL-PV panels likely to be generated in India, and the minimum number of houses adopting EoL-PV has been estimated as part of this study.

The result from the study strongly favours the application of EoL-PV as a building material with appropriate interventions customised to achieve indoor thermal comfort in response to the prevalent climatic conditions. This makes EoL-PV a valuable decentralized resource with potential to support Net-zero buildings.