Reuse of Deconstructed PV Glass Modules

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As per researchers at the University of South Australia with the data provided by the Clean Energy Regulator (CER) by 2035, approximately 1,00,000 tonnes of PV module waste would be generated. A major problem with existing PV module (post end-of-life (EoL)) waste arose after anti waste movement by countries including China, Malaysia, Philippines and Thailand banned imports of recyclable wastes from other nations $(\text{in } 2018)$[1], thereby resulting in global waste stockpiling. Also, resource loss and shortage problem for the global photovoltaics (PV) manufacturing boom and need to grow even faster to supply massive amounts of "green" elecricity[2]. There are currently no economically and environmentally satisfactory end-of-life (EoL) treatments that retain high value of the components of a deconstructed silicon-cell PV module[3]. It is challenging to find valuable markets for the resulting materials and parts.

For example, even if a tempered low-iron glass front cover glass sheet (and rear glass in a glass-glass module), that comprises a large share of the module weight and volume, can be recovered clean and intact there are only a few viable reuse opportunities in Australia or in most parts of the world. Also, since tempered glass cannot be re-sized and the EoL modules are of many different dimensions and manufacturers are often changing dimensions, particularly to make larger ones. As a result, recovered glass re-use in new modules is unlikely, even in countries where module production is high and it is impossible in remote parts of the world, where PV may, nevertheless, be used. We seek to retain the energy content in a manufactured glass sheets after module's EoL by finding secondary markets.

Currently, most of the decommissioned Si-cell PV modules go into landfill mixed crushed together with Construction and Demolition (C&D) waste that has been categorised in e-waste whose direct landfilling, depending on jurisdiction, has been banned or taxed heavily, thereby promoting market for alternative secondary life purposes.

We carried out a literature review into the viability of recovered glass sheets use in greenhouses, balustrades, and canopies. We propose to use recovered glass sheets from PV (76-89% of module by weight and transmittance 89-91%) in greenhouse (glasshouse) frames, whose construction techniques allow for variation or adjustability in the glass sheet sizes and aspect ratios. In other words, the greenhouse frame can be adjusted to suit glass sheet sizes as they become available from the EoL PV waste stream. The glass sheets in any given greenhouse would normally be similar but another greenhouse might have the frame adjusted or re-sized to suit another available glass size.

Also, the future market for greenhouses and indoor controlled growth structures is likely to grow as traditional agriculture and horticulture for human food production is challenged by climate change, population pressure and land use conflicts, motivating food production on poor quality land or in less suitable environments and greenhouse market is becoming trending and popular.

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The recovery of glass from the PV module can be processed with the help of, for example, $\text{hot} - \text{knife}$[4] or Delaminating Resources[5] methods. Thus, it allows for an efficient low-cost disassembly of PV Modules into its original components glass, Al/Steel frames, Cu-connecters, solar cells. The recovered glasses may then be sorted according to their size. The different loadings for glass structures particularly greenhouse was considered while forming prototype such as dead load, live load, snow load, wind load and the upward lift created by wind and was found to be suitable for the use of delaminated PV glass module in greenhouse etc.

However, during the critical situations, since the recovered PV glass is tempered glass that is four to six times more shatter-resistant than annealed glass, and even if it breaks it breaks into small pieces, making it less likely to break and less likely to cause any injury if it does.

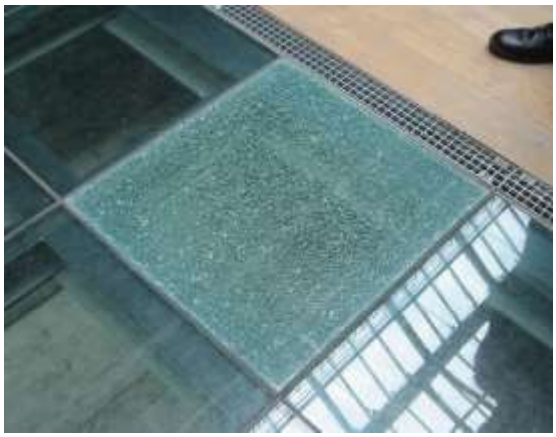

Figure 1: A floor element in laminated glass with the upper ply[5] .

Figure 2: When broken, toughened glass fractures into small granules. [AS 1288]

Below are different views of conceptual usage of PV module glasses in greenhouses. Since the glass used in PV vary differently in sizes but it was found that the thickness of glass used was between 3.2mm-4.0mm. An exemplar greenhouse was built categorically by taking a typical existing glass module size “1823×1029×3.2mm” and was found to be in accordance with the IS 14462 (Indian standards) and AS 1288. Also, it was found that one of the largest greenhouse glass suppliers, for 3.2mm thick low iron toughened glass used standard size “1800*1200mm"[6].Hence, the use of PV module recovered glass was found to be in accordance with the standards and market conditions too.

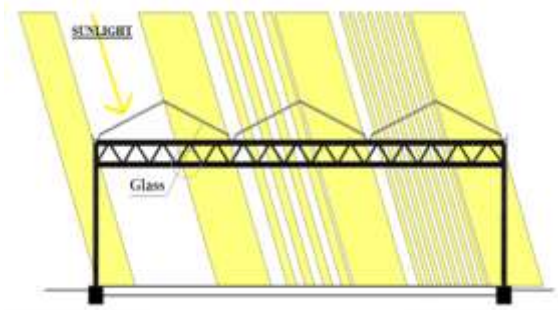

Figure 3: Prototype for Glasshouse (Front View) Yellow shaded portions[7]: - Direct solar radiation at Mediterranean latitudes. [21 June, 12:00 pm]

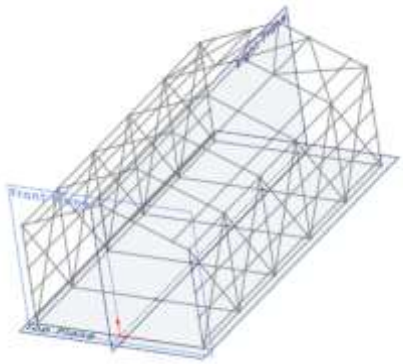

Figure 4: Modified Greenhouse Structure

The construction costs have been reduced through use of extruded glazing bars, bar caps and strip caulking. Double and triple glazing can be used to reduce heat loss. To overcome the anomaly of size disparity two or more glass panel maybe overlapped over each other and laminated or held together with S clips firmly without negatively disturbing transmission.

Our literature study also suggests that it will be feasible to reuse delaminated glass from PV modules in various sizes of architectural canopies and balustrades with the help of spider clips, over panel side panel connecting patches, or firm magnetic clamps, glass clips that do not require any holes in the glass, to avoid shattering due to the high tension in surfaces of tempered glass.

We conclude since that there are different viable re-use possibilities for delaminated glass from PV modules in economic and environmentally satisfactory ways after EoL and provide a circular recycle process for high value addition instead of landfilling as e-waste or low valued “down-cycling chains”.

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