PEER REVIEWED
ASIA-PACIFIC
SOLAR RESEARCH CONFERENCE

A Reverse Logistics Model for End-of-Life Solar Modules Using Existing Transport Processes.

David Leyton, Nathan Chang, Richard Corkish

Australian Centre for Advanced Photovoltaics, UNSW Sydney, 2052 Sydney, Australia

One of the largest costs, and greatest impediments to, recycling any good is that of logistics and transport. Collection, sorting, storage, materials recognition, sampling, pathways, pickups, packaging, manual handling, robotic handling, distances, secure passage, fuel costs, etc. are all components of the heavy logistics burden any recycling system must espouse to be successful.

In a study conducted by Cutting and Gietman (2019) for the Victorian Government in Australia, the authors concluded that the economic value of a recycled solar module was $3.41 in reclaimed materials, which may be compared to the price of a new module being between $100 and $300.

To alleviate this problem the locations of permanent recycling centres have been researched (Choi & Fthenakis 2014) but the mathematical model developed by those authors require a minimum of 19,000 tons of waste modules per site per annum to make them begin to be economically viable.

Furthermore, in a paper introducing an innovative mobile device for recycling silicon modules, Del Pero et. al. (2019) noted that, while the operation of their proposed device was not economically viable, given the glass and other materials recovered from the process, the fact that their device was mobile was a great benefit in the overall economics of recycling solar modules. But while mobile recycling centres can show an improvement in the economics of recycling solar modules, the processes for recycling solar panels are still not a viable economic activity by up to two orders of magnitude.

In some countries it may never be possible to assemble 19,000 tons of module recycling in one city and so the above model would mean that those countries may never have a functioning solar module recycling system.

In practice, it often falls to the installers to remove and deal with end of life (EoL) solar modules. A practice which delivers varying results such as dumping in landfill, removing the aluminium frames and dumping the remains in landfill, or just warehousing the modules whilst waiting for an industry-wide solution, or formal directions from the Clean Energy Regulator (2021a) or Clean Energy Council (2021), to be made clear.

Our model is to make use of the very efficient and secure methods and logistics currently in existence in the solar and electrical industry for the transfer of solar panels from the manufacturer to the end-use site (Clean Energy Regulator 2021b) and to use some stages of this process in reverse.

It is a fact that the same class of solar installers who instal solar modules are the ones who remove them from current use. We propose that these electricians would return EoL solar modules to a limited number of solar wholesalers in a city, who would, in turn, return them to a city-wide central logistics centre for processing.

Currently all installers must either call or visit wholesalers to get stock for their new jobs on a daily or weekly basis. They have to make this trip, and either go back to the warehouses empty handed, or just take their cardboard and packaging back to the wholesalers for recycling when they collect new stock for their next jobs. We propose that they also take back end-of-life solar modules to the wholesalers, also for recycling, at a nil or small incremental cost. Indeed, the incremental cost may be negative relative to alternatives, if installers were to be removing the EoL modules in any case.

Furthermore, we propose that the same information and compliance systems currently in use for installing solar modules, often mandated by the Clean Energy Regulation Offices, through the use of barcodes, serial numbers, geotagged pictures, and mobile phone portals, be used for the verification of collection and processing of EoL solar modules (Clean Energy Regulator 2021b). Then the same system of accountability and information reporting as exists for the installation of new solar systems could also apply for the removal and processing of EoL solar modules.

We envisage that this system could be formalised by the Clean Energy authorities and their existing detailed and extensive processes could be enforced on each installer to account for each solar module. The marginal cost to each installer for returning modules to wholesalers is very low as they must return to wholesalers to pick up new stock regularly. Likewise, for the wholesalers, the marginal cost of returning modules from their facilities to a central aggregation centre is minimal as delivery trucks must come from central distribution centres to deliver new modules anyway.

Furthermore, by participating in this scheme, the module manufacturers would ensure that their EoL modules would return to just one place in any city and this would streamline and reduce the costs of their warranty processes. In the Victorian context, at least, this scheme should work well as a voluntary scheme where installers, wholesalers, and manufacturers cooperate to provide a cost effective and efficient EoL solution.

By using the existing regulated and efficient processes in the electrical and solar industry, with its more than 169,000 nationwide network of electricians and thousands of wholesalers and huge fleets of trucks in Australia alone, the Australian photovoltaics industry could become an even greater facilitator of the clean and circular economy we need (Guterres 2021).

Choi, J.-K. & Fthenakis, V. (2014). Crystalline silicon photovoltaic recycling planning: macro and micro perspectives. *Journal of Cleaner Production* **66**, 443-449.

Clean Energy Council. (2021). https://www.cleanenergycouncil.org.au/. Melbourne: Clean Energy Council. [Accessed 29 August 2021].

Clean Energy Regulator. (2021a). Solar panel serial number ledger, http://www.cleanenergyregulator.gov.au/RET/Scheme-participants-and-industry/solar-panel-serial-number-ledger. Clean Energy Regulator. [Accessed 29 August 2021].

Clean Energy Regulator. (2021b). http://cleanenergyregulator.gov.au/. Canberra: Clean Energy Regulator. [Accessed 29 August 2021].

Cutting, J. & Gietman, A. (2019). PV Panel Reprocessing: Research into Silicon-Based Photovoltaic Cell Solar Panel Processing Methods, Viable Materials Recovery and Potential End Market Applications. HRL Technology Group Pty Ltd.

Del Pero, F., Delogu, M., Berzi, L. & Escamilla, M. (2019). Innovative device for mechanical treatment of End-of-Life photovoltaic panels: Technical and environmental analysis. *Waste Management* **95**, 535- 548.

Guterres, A. (2021). Secretary-General's statement on the IPCC Working Group 1 Report on the Physical Science Basis of the Sixth Assessment. New York: United Nations.