European Commission

Science for Environment Policy

Closed-loop recycling of photovoltaic panel materials could mitigate up to 0.2% of Flanders' annual environmental impact

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Source: Peeters, J.R., Altamirano, D., Dewulf, W. *et al*. (2017). Forecasting the composition of emerging waste streams with sensitivity analysis: A case study for photovoltaic (PV) panels in Flanders. *Resources, Conservation and Recycling*. 120: 14-26. DOI: 10.1016/j.resconrec.2017.01.001.

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The development of future recycling technologies must be informed by data about products and materials that will enter the waste stream, but such forecasts are subject to a high level of uncertainty. In this study, researchers have proposed a methodology for predicting emerging waste materials, applying it to silicon-based photovoltaic (PV) panels. The findings show that closed-loop recycling — when post-consumer waste is recycled to make new products — of PV panel materials could mitigate up to 0.2% of the annual environmental impact of Flanders[1], Belgium, if suitable technology was developed.

Europe's PV capacity is currently 70 GW — enough to power 20 million households — and rapid advances in technology coupled with the decreasing price of PV panels means that solar power in Europe is predicted to grow more than any other energy source in the near future[2]. The volume of PV panels collected by the European collection scheme PV CYCLE[3] is currently low, but it will grow as panels installed in the past decades come to the end of their life. In addition, the Directive 2012/19/EU[4] on waste electrical and electronic equipment which also covers PV panels provides for WEEE collection targets increasing over time.

Allowing for uncertainty, the researchers predicted the amount of PV waste that will be discarded in the future using a 'distribution delay' forecasting method, drawing on data including figures from the Flanders energy administration on PV panels installed between 1998 and 2015, plus volumes of waste collected by PV CYCLE. The average lifetime of a PV panel was determined based on the 'bathtub curve' theory used in engineering to represent large data uncertainties. This takes into account the large number of early failures of PV panels, due to their complex installation requirements. For example, a small peak in discarded panels was predicted in 2014, following a rise in sales in 2011.

In the case study area of Flanders, the study estimates that up to 22 000 tons of PV panels per year — equivalent to 3.4 kg per capita — will be sent for recycling in the next 20 years. To improve the sustainability of solar energy, solutions are needed for the emerging problem of recycling these end-of-life PV panels, composed chiefly of glass, aluminium, silicon, silver and polyethylene (PET). For example, under current recycling methods, impurities in separated glass mean it is not suitable for re-use in PV panels, neither can silicon be extracted in a sufficiently cost-efficient way for closed-loop recycling.

The data modelled in the study, together with estimates of recycling efficiencies and costs, can indicate whether sufficient value might be recovered from PV panel materials in future to pay off the development of innovative recycling technologies. Yet the study stresses that uncertainty over product lifetimes, and over materials that will be used in future, mean that a range of scenarios are possible. For example, the researchers acknowledge that manufacturers are reducing the amount of silver in PV panels, so three silver content scenarios (low, average and high) are described in their forecast, with silver content ranging from 0.14–0.2% in panels discarded in 2003 to 0.07–0.16% in 2023.

Continued on next page.

1. The 0.2% environmental impact was calculated by multiplying the total mass of materials (glass, aluminium, silicon, silver and polyethylene) that will be annually discarded, with the single score end-points impact for the production and recycling of every material. Total annual environmental impact for each material considered was based on the Life Cycle Assessment database Ecoinvent 3 and the ReCiPE method.

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2. European Photovoltaic Industry Association (now Solar Power Europe) (2012). *Global Market Outlook for Solar Power 2015-2019*. Report available from: http://resources.solarbusinesshub.com/solar-industry-reports/item/global-market-outlook-for-solar-power-2015-2019

3. PV CYCLE is one of several producers' responsibility organisations which is active in several Member States providing a system for producers in order to comply with the requirements of the Directive 2012/19/EU on waste electrical and electronic equipment. (http://www.pvcycle.org/)

4. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32012L0019

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Silver content is important as the economic viability of separating metals from PV panels currently depends on the amount of silver that can be recovered, as this is the most valuable component (although subject to fluctuations in price). The waste stream before 2040 will be dominated by panels produced before 2017, with a relatively high silver content, but beyond this, panels will mainly consist of glass and aluminium, which are less valuable than silver. The study notes that copper is expected to gradually replace silver in future production, so technology will need to evolve to reflect this.

In contrast, from an environmental perspective, the study notes that recycling plastics and silicon will be of key importance. The main components requiring recycling, by volume, will be glass and aluminium, so efficient technologies will also be needed to deal with these. The study suggests that future research should focus on the fine tuning of existing technology and innovative processes for separating these materials so they can replace virgin resources.

Importantly, as more reliable data on waste from PV panels becomes available, this can be fed into the model to update the forecasts. The methodology can also be applied to other waste streams for which there is no complete data on product lifetime. The results from this analysis can guide policymakers looking to stimulate economically and environmentally viable recycling technologies.