RECYCLING PHOTOVOLTAIC SYSTEMS

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Summary

Photovoltaic systems are recycled using well-established standard processes that are also easy to scale. We therefore expect no fundamental difficulties in the quantity of material needing to be recycled from PV systems in relation to the significant growth that is predicted in the coming decades. The disposal and recycling of PV systems is financed in Switzerland through an advance disposal and recycling fee. The take-back and disposal of PV systems are largely state-regulated both on a national and international level. This also means that relevant information on regulations, established work practices and markets is mostly freely available online.

Legal foundations

Within Europe, organizations such as the European association for the recycling of solar panels (PV Cycle) provide a wealth of information [1].

Take-back and recycling of PV systems in Switzerland is regulated by the Ordinance on the Return, Taking Back and Disposal of Electrical and Electronic Equipment of January 14, 1998 (ORDEE; SR 814.620; currently being revised). In general when it comes to PV systems, the buyer has an obligation to return and the seller an obligation to take back. At present, the resources needed for disposal, transportation and recycling are generated through an advance disposal and recycling fee that is currently CHF 40 per ton [2].

The Swiss solar energy industry association (Swissolar) and SENS eRecycling signed a cooperative agreement as of 01.01.2014 regulating the aspects relevant to the take-back and disposal of PV systems in Switzerland [3]. The SENS Foundation (Sustainability Expertise Network Solution) is an independent, neutral and non-profit charitable organization and operates publicly under the SENS eRecycling brand [4]. SENS eRecycling coordinates a sustainable solution for taking back and recycling PV modules and their fittings. This service is for both trade and consumers and is backed up by strict controls.

Methods of recycling

Essentially, PV modules are constructed like car windows (solar cells embedded in protective films and glass panels, surrounded by an aluminum frame) and are therefore recycled as flat glass. Common PV modules contain almost 90% glass, which is chopped up with shredders during the recycling process. Once shredded, the glass shards either go back into sheet glass production or are used to make qualitatively less sophisticated products (fiberglass, etc.).

The non-toxic silicon wafers are not recycled separately but are chopped up together with the glass from the PV modules. Processing silicon wafers with chemicals on an industrial scale has not become established [5]. At 26%, silicon is the second most abundant element in the earth’s crust and is a fundamental component in glass, porcelain, silicon and microelectronics. Crystalline PV modules (approx. 90% market share; [6]) are invariably non-toxic. Thin-film PV modules may, however, contain toxic substances. Examples of these toxins are CdTe, CIS, CIGS. In Switzerland, only very small quantities of PV modules containing toxic substances have been taken back to date. The groundwork for the take-back processes has been laid. The recycling process for PV modules containing toxic substances is not yet in place in Switzerland, but a corresponding research project is underway [5].

The various metals in a PV module are prepared in smelting works ready for further processing. The plastics used in PV modules are usually of inferior quality and are either disposed of in waste incineration plants or used for energy recovery in the cement industry.

Besides the PV modules, disposing of a PV system also involves recycling other system components such as inverters, copper cables, seals and mounting structures. Take-back and recycling of these PV components are also coordinated by SENS eRecycling.

Photovoltaic systems also increasingly feature built-in PV storage systems that also need to be recycled at the end of their service life. Battery recycling is regulated in Switzerland in Annex 2.15 (Battery Annex) of the Ordinance on the Reduction of Risks relating to the Use of Certain Particularly Dangerous Substances, Preparations and Articles (Chemical Risk Reduction Ordinance, ORRChem; SR 814.81). BATREC Industrie AG in Wimmis, canton of Bern, is Switzerland's only battery recycling provider [7]. As with PV systems, battery recycling is also financed through an advance disposal fee (ADF). However, due to the complexity of the battery recycling process, the ADF is also substantially higher for PV storage systems that are lithium-ion based (around 3 CHF/kg; [8]) than for PV systems.

Material flows

337 tons of PV modules were recycled in Switzerland in 2017. This is made up of PV modules (mainly from the 1980s and 90s) that have reached the end of their service life, as well as product guarantee recalls and cases of fire [9].

We can estimate the quantity of PV modules needing to be recycled by the year 2050 based on the current annual increase in PV production in Switzerland of 240 MW_p (2017) and an assumed PV module service life of 33 years [10], assuming that all other parameters remain the same. This quantity will most likely be around 1,000 times higher than the aforementioned 337 tons from the year 2017. Since PV systems are recycled using easily scalable standard processes, the material flows that need managing need not be of concern. All the more when we consider that other sectors in Switzerland manage similar or even greater amounts of materials (e.g. in the automobile industry). Rising quantities of material also do not necessarily need to cause any significant inflation-adjusted change to the advance disposal and recycling fee, currently at 40 CHF/ton. Except, of course, for severe market changes triggered by disruptive technology, legislation, etc.

Energy flows

By their very nature, there is a close correlation between material flows and energy flows, and ultimately also with value flows. What’s more, the determining parameters (essentially the power-to-weight ratio (kg/kW_p) and PV module service life) are the same for energy flows as they are for material flows.

A representative energy-related figure often cited for renewable energy plants is the so-called energy returned on investment (EROI) measure. This shows how many times more energy the system produces over its entire operating life than is required for its manufacture, installation, maintenance and disassembly. Typical EROI figures for a photovoltaic system in Switzerland are in the region of 10, i.e. the system produces around ten times more power over its entire operating life than the energy used for its manufacture, installation, maintenance and disassembly over its life cycle. With a continued reduction in the power-to-weight ratio of PV systems, it can be assumed that the typical EROI for PV systems can be given an even greater boost in the future.

It is important to point out that calculating the EROI along standard procedures as per ISO 14044 [11] can unfortunately be somewhat time consuming. This can, for instance, be surmised from the calculations carried out by Frischknecht et al. while conducting a life-cycle assessment for the Mont-Soleil solar power plant [12]. The difficulties stem primarily from the many questions pertaining to system limitation. These arise when calculating the expenditure of primary energy that accrues in connection with the manufacture, use and removal of the system being reviewed [13]. Unfortunately, these system limitations are not reliably conducted in practice, either out of complacency or – even worse – with the ulterior motive of pushing the result towards a particular outcome. Results where there is any doubt as to the quality of the underlying calculations should therefore be compared with corresponding data from recognized sources as a precaution (for example [14]).

References

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