

## Recycling for the solar life cycle: Why the recycling of a solar module is important and how it can be done

Creating clean and green energy through solar panels would only be half as successful in creating a more environmentally-friendly world if the panels could not be disposed of properly and their components recycled at the end of their working life. REC makes a concerted effort to ensure its panels are durable and fully recyclable, however, as recycling guidelines differ across the world and treat all components differently, this paper looks at what can be done when a panel reaches its end of life.

### Why recycle a solar module?

When we recycle, used materials are converted into new products, reducing the need to consume fresh natural resources. This helps conserve raw materials which means the extraction of new ones through mining and forestry for example, can be reduced, saving energy as well as protecting the environment and natural habitats for the future. Indeed, the mechanical processing and conversion of the individual material components into high quality secondary raw materials leads to a clear reduction in carbon dioxide (CO<sub>2</sub>) emissions compared to the extraction of primary raw materials.

By generating clean energy over a period of time, often in excess of 25 years, solar modules contribute greatly to environmental protection and a cleaner future. But in order to live out a lifetime of several decades, the energy generation components, i.e., the cells and connections, need to be protected from whatever challenges Mother Nature throws at them. They are therefore encased in an encapsulating layer which is permanently bonded around the cells and connections and to the glass, before being framed for extra strength. The recycling of a solar module returns these components back into the manufacturing chain, providing a ready-made source of raw materials without the need for further extraction.



Img. 2: Glass powder from solar module recycling (Butenhoff Werbeagentur & Verlag).



Img. 3: The aluminum frame can be fully recycled avoiding the fresh extraction of raw material (credit: Butenhoff Werbeagentur & Verlag).



Img. 1: End of life solar modules can be recycled and the components sorted at specialist recycling facilities.

### What components of a solar module can be recycled?

While the permanent bonding of the individual module components ensures a quality and long-lasting product, when it comes to recycling, this conflicts with the recycling industry's desire for ease of disassembly. REC's cooperation with our recycling partners has however shown that practically every component of our solar modules can be recycled on a daily basis on an industrial scale. An REC solar panel primarily consists of the following components:

#### *Glass:*

An ultra-pure and low-iron solar glass is used by REC. During recycling, it is ground down to small shards or to a fine powder and processed into foam glass for use in the construction industry for example.

#### *Frame:*

The frame, as well as the corner pieces which hold it together, are made exclusively from aluminum. 100% of this metal is recovered after the shredding process by means of electromagnetic and mechanical procedures and can then be re-utilized in the metal industry.

#### *Cells:*

The cells consist of silicon which can be melted down and re-used, but as pure silicon is one of the most common elements on earth, the recovering of silicon from solar cells is not always the most efficient method and each jurisdiction will deal with this in its own way.

#### *Ribbons and Conductors:*

REC uses copper ribbons with silver plating. REC's recycling partners use the appropriate processes to recover as high a share of the metals from each component and treat as required.

#### *Cables:*

The cables contain a copper conductor which is separated in the recycling process from the insulating plastics and added to the other plastics from the panel. Methods of recovering copper from cables have been used in the recycling industry for a long time with the latest methods and processes being used by our recycling partners.

#### *Plastics:*

A solar module uses embedding materials such as EVA which is not thermoplastic meaning it cannot be re-melted; the backsheet consists of several layers of various high-quality plastics which cannot be separated from each other, and the junction box which is made of thermoplastics filled with curing silicone to safely insulate the diodes

within. The separation of the plastic components of a solar module is possible but not always economically feasible and each region will deal with this as best suits their recycling infrastructure.



Img. 5: Recovered metal from the copper cabling, ready for re-working in the metal industry.



Img. 6: Recovered plastics from a solar module, including backsheet, ready for recycling (Butenhoff Werbeagentur & Verlag).

### Recycling of harmful materials

REC solar modules do not contain highly toxic substances such as gallium or cadmium telluride, which are found in thin-film panels and make the recycling of these especially difficult and cost-intensive. However, crystalline solar modules do contain tiny amounts of lead in the solder alloy used for the inter-connections, but this is a known process in the recycling industry, who are experienced in dealing with lead and are able to treat this in an appropriate and protective way.

### How can a solar panel be recycled?

There is no single or simple answer to give on how a solar panel can be recycled as laws, guidelines and recycling infrastructure varies so greatly across the world. Indeed, given the long lifespan of solar modules and their relative, though growing, newness to the waste industry, the volume of solar module recycling has not yet reached high enough levels to concern many governments. Most law-makers are preoccupied with consumer goods such as televisions, refrigerators, mobile phones, etc. and have not yet considered the addition of solar modules to such legislation, in which case the disposal of such modules falls under the prevailing general waste mechanism.

Since 2012, however, the European Union – as the sole mover on this topic globally – has included photovoltaic solar modules in its Waste Electrical and Electronic Equipment Directive 2012/19/EU (WEEE) which regulates the correct recycling of electronic and electrical waste in all member states of the European Union.

Products affected by the WEEE Directive can be identified by the use of a crossed-out wheelie bin icon on the product. This logo signifies that the product must not be disposed of with normal household waste and the black line is simply an indication that the product was placed on the market after 2005.

For end-customers, this directive means the recycling of a solar module is a free of charge disposal system, financed by the manufacturers and importers who are legally responsible for the end-of-life management no matter where their manufacturing sites are located. Modules can be brought to a local recycling depot, or in the case of larger numbers, can be picked up from site.

Within the WEEE Directive, there are extensive process steps for proper disposal which are strictly regulated by the authorities and place no further obligation on the owner. However, as this is only a Directive, each individual country is free to put in place a system of its own choosing which meets the Directive requirements. For this reason, the best source of information on the recycling of REC solar modules is by contacting your local recycling authority or recycling center.



Img. 7: The WEEE logo used in the European Union to identify products subject to the specific waste and recycling regulations regarding electrical and electronic goods.

In Asia, it is also worth mentioning that, although solar modules are currently not included in the Japanese Environment Ministry guidelines on the recycling of electrical and electronic waste, with IRENA reporting in 2017 that “Japan has no specific regulation for end-of-life PV panels, which therefore must be treated under the general regulatory framework for waste management,” the Japan Photovoltaic Energy Association has published voluntary guidelines on how to properly dispose of end-of-life solar modules.<sup>1</sup> Included in these guidelines are important notes about the content of different substances and the reference rates permitted for various components. These guidelines are currently without enforceability, but what they do achieve is to lay the groundwork for future implementation of any recovery and recycling laws in Japan.

In the US, the situation is similar in that there are currently no federal laws governing the recycling of used PV modules, and no regulations mandating the collection and recycling of them at their end-of-life. This means that modules must be disposed of in line within the general regulatory framework of the Resource Conservation and Recovery Act, the legal framework for managing hazardous and non-hazardous solid waste. Some states are beginning to move on this issue though, and can use additional leaching procedures for waste classification, e.g., in California, where the process to develop regulations for end-of-life PV modules has begun, however, several steps remain before this regulation is implemented.

### Conclusion:

In summary, the complete recycling of REC panels can be achieved and the recovered materials can be easily and safely returned to the industrial and economic cycles. REC works closely with its recycling partners to ensure state of the art processes are followed and as much material as possible is easily and efficiently recycled.

Globally, it is only Europe that has introduced concrete measures to deal with the recycling of end-of-life solar modules. All other countries are behind on this, some overlooking the topic, some with a lack of recycling infrastructure and others concentrating more on household appliances. However, given the rise of renewable energy sources and the widening use of solar PV, each country will need to begin thinking about how to deal with this problem in the future. In the meantime, REC is doing all it can to ensure that its products are recyclable and ready for whatever mechanisms each country puts in place, from the customer side, pressure can of course also be put on local government representatives to ensure that provisions are made to ensure the recycling of end-of-life solar modules.

<sup>1</sup> Japan Photovoltaic Energy Association, December 2017, Guidelines for Appropriate Processing of Used PV Modules