Managing Used Solar Panels and Components

Guidance for Solar Panel Collection, Storage, Transportation, Recycling and Disposal

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WISCONSIN DEPT. OF NATURAL RESOURCES

Contents

Solar panels and their components can often be refurbished and reused after their original owner is done with them. Solar panels that cannot be reused can be dismantled for recycling, as they contain a variety of recyclable metals, plastics and glass. In some cases, solar panels may also be sent for disposal without recycling. Because many solar panels contain hazardous materials, they require proper end-of-life management to protect workers and the environment.

Hazardous waste testing on solar panels has shown that solar panels may have a variety of potentially hazardous metals present in the semiconductor and solder. Some of these metals, like lead and cadmium, can harm human health and the environment. If these metals are present in high enough concentrations in solar panels, solar panel waste could be classified as hazardous waste. According to the U.S. Environmental Protection Agency, some solar panels at end of life are considered hazardous waste and some are not, even within the same model and manufacturer, because of different concentrations of metals like lead.

This document explains requirements for individuals, governments, businesses or others that collect, store, transport, refurbish, recycle or dispose of solar panels. Some of these activities may need local, state or federal approvals or licenses. For questions about which requirements apply to a specific situation, contact the Department of Natural Resources at DNRWIe-cycling@wisconsin.gov.

Terms used in this document

Facility: Any person, business or organization involved in activities to collect, store, transport, refurbish, recycle or dispose of solar panels.

Generator: The facility that removes all or part of a solar installation and determines the materials are waste.

Inverter: Device that converts direct current electricity received from panels to alternating current electricity that can be used by a home/facility or supplied to the electric grid.

Reuse: Continued use of panels and components for their originally intended purpose by someone else. Examples include donating or selling working solar panels or components and sending solar panels or components to a refurbisher for evaluation, testing or repair.

Recycling: Processing solar panels and components to recover usable materials. Recycling usually begins with dismantling solar panels for recovery of components and metal, glass and plastic. In many cases, those who refurbish solar panels for reuse also recycle some components.

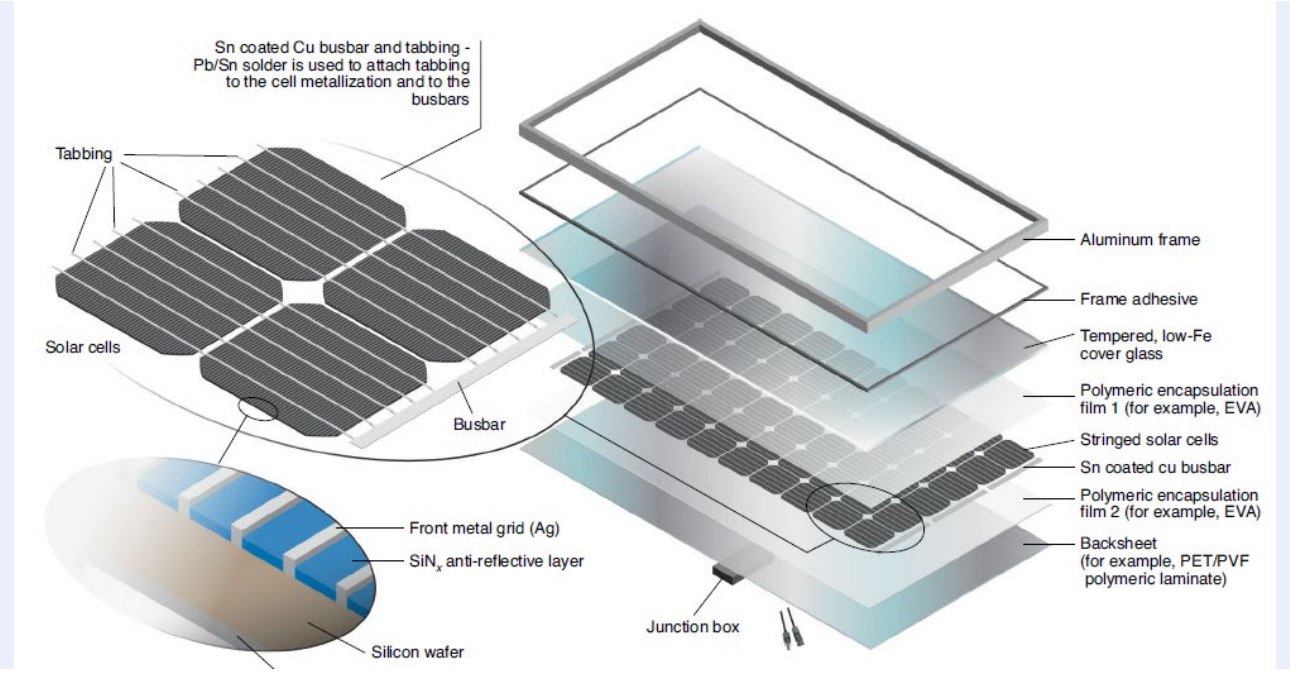
Solar installation: All of the components installed at a given site to generate and use or store solar energy. This may include panels, framing/support structures, cables, wiring, inverters, batteries and other electrical equipment.

Solar panel: A panel of photovoltaic cells that convert the sun's radiant energy into electricity. A solar panel may be called a "photovoltaic module," which is made up of several cells.

Solar installation components and preferred handling

There are several types of solar panels, along with other components that make up a solar installation. Figure 1 shows the general structure and components of the most common solar panel type. Table 1 provides an overview of different panel types and components and the handling options the DNR recommends for each.

Figure 1: Generic structure of crystalline-silicon panels



Source: Heath, G.A., et all, Research and development priorities for silicon photovoltaic module recycling to support a circular economy. Nature Energy 5, 502-510 (2020). https://doi.org/10.1038/s41560-020-0645-2

Table 1: Solar panel types and components

Component	Materials	Potentially hazardous waste?	Legal requirements	Recommended end-of-life options
Framing to mount panels and hold the cells in place	Aluminum	No	Not banned from landfill disposal	Recycle as scrap metal
Wiring/cables	Copper, insulating material	No	Not banned from landfill disposal	Recycle as scrap metal
Inverter	Steel, aluminum, circuit boards, wiring	Yes, toxicity for lead solder if used	Non-household generator should make waste determination; not banned from landfill if non-hazardous	Recycle as scrap metal or electronics
Solar panel: Crystalline silicon (95% of current market)	Glass Silicon Aluminum Copper Lead Silver Tin Plastic	Yes—toxicity; some panels fail Toxicity Characteristic Leaching Procedure (TCLP) Lead solder in junction box and cell connections	Non-household generator must determine whether toxic constituents are above Resource Conservation and Recovery Act levels in s. NR 661.0024, Wis. Adm. Code	Reuse or recycle
Solar panel: Thin Film	Cadmium-telluride (most common for thin-film) Copper indium gallium diselenide	Yes—toxicity; some panels fail TCLP Cadmium in semiconductors	Non-household generator must determine whether toxic constituents are above Resource Conservation and Recovery Act levels in s. NR 661.0024, Wis. Adm. Code	Reuse or recycle
Battery storage	Currently, most likely lithium-ion batteries	Yes	Manage as hazardous waste or as universal waste under ch. NR 673 Follow U.S. Department of Transportation regulations for shipping	Reuse or recycle

When do waste requirements apply?

Solar panels or other components are not a waste if they will be legitimately reused (including if they will undergo repair or refurbishment). If this is the case, neither solid waste nor hazardous waste regulations apply. It is important for an individual or facility to show they are treating the panels or components as a product and not a waste by handling and storing them in a way that avoids damage.

Solar panels or components that are destined for recycling or disposal are a waste, and solid waste and hazardous waste requirements apply.

Keep in mind that solid and hazardous waste requirements apply if a solar installation site, a site with a load of panels/components, or a collection facility has a mix of panels/components both destined for reuse and destined for recycling or disposal. For example, if some panels removed from an installation are damaged beyond repair, they must be managed according to solid and hazardous waste

regulations as soon as they are removed from the installation, even if other removed panels are destined for reuse.

Reduced requirements for household solar installations

If a solar panel or installation removed from a home is not destined for reuse, and if the household manages/disposes of the panels, the solar panel or installation is a household waste and would be exempt from hazardous waste regulations under s. NR 661.0004 (2) (a), Wis. Adm. Code. The DNR encourages households to recycle panels and other components, but the materials could go to a solid waste landfill if the landfill is willing to accept them.

The household waste exemption applies regardless of whether an owner, renter or contractor does the removal, unless the panels are collected and consolidated at another site before recycling or disposal.

If a contractor or other business or organization removes **only** household solar panels and takes them directly to a disposal or recycling facility, the household exemption would apply. If they take solar panels back to a collection point (including its own warehouse or office), then the exemption above would not apply. In this case, the contractor would need to operate under the household hazardous waste collection rules found in ch. NR 666, subch. HH, Wis. Adm. Code, and should also follow the requirements described in the next few sections.

Making a waste determination

The generator of the solar installation wastes (that is, the person who determines solar panels or other components will not be refurbished or reused) must determine whether they are hazardous waste. The generator must make this determination at the point of generation as follows:

- For panels or components removed from homes or other buildings that qualify for the household hazardous waste collection rules, the determination can be made at the first consolidation point, such as a contractor's warehouse or office.
- For panels or components removed at a site that do not qualify for the household hazardous waste collection rules (e.g., a commercial building or utility solar installation), the generator must make the determination on-site, before shipping panels and components to another location.

To make a waste determination, a generator may use information provided by the panel/component manufacturer, or conduct testing of representative samples. For more information, refer to Waste Determinations and Recordkeeping (WA-1152) or contact DNR staff.

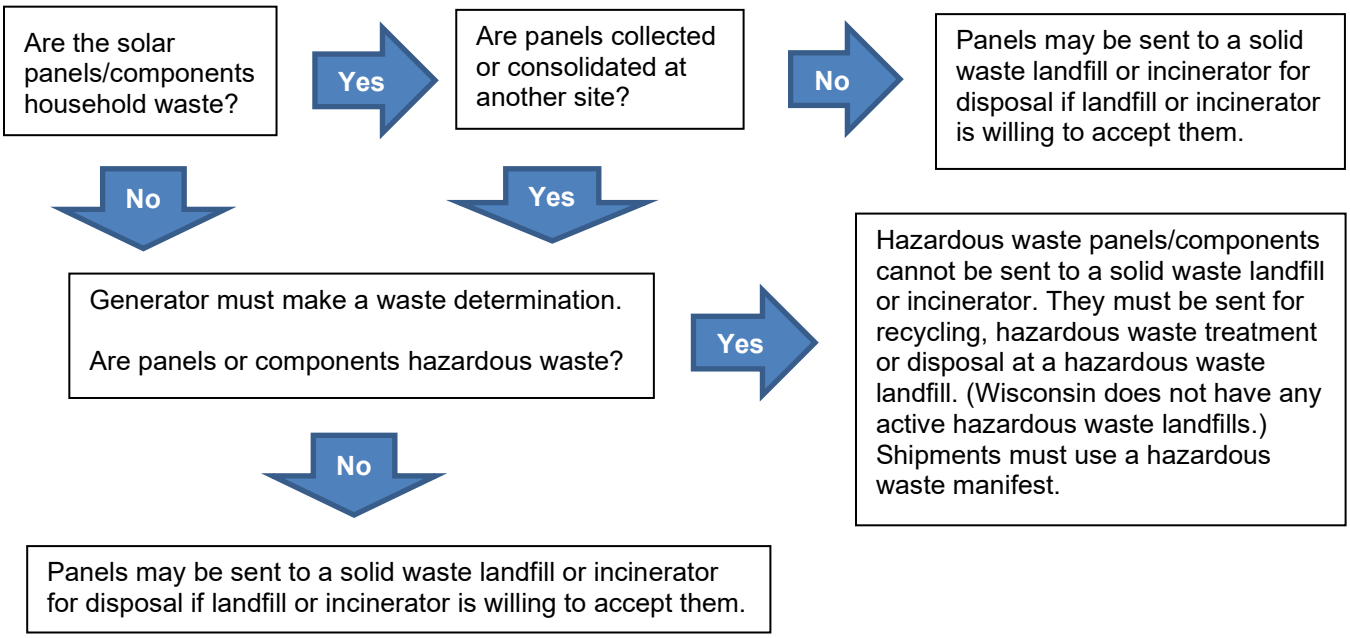
The American Society for Testing and Materials has established a standard for sampling and testing solar panels for toxicity, which is one method a generator may choose to use.

- ASTM E3325-21, Standard Practice for Sampling of Solar Photovoltaic Modules for Toxicity Testing

Solar panel disposal limitations and requirements

The DNR recommends reusing or recycling solar panels or components when possible. Figure 2 provides a guide to when and where generators may send solar panels or components for disposal in a landfill or incinerator if recycling is not an option. Solar panels that are hazardous waste cannot be sent to a solid waste landfill or incinerator.

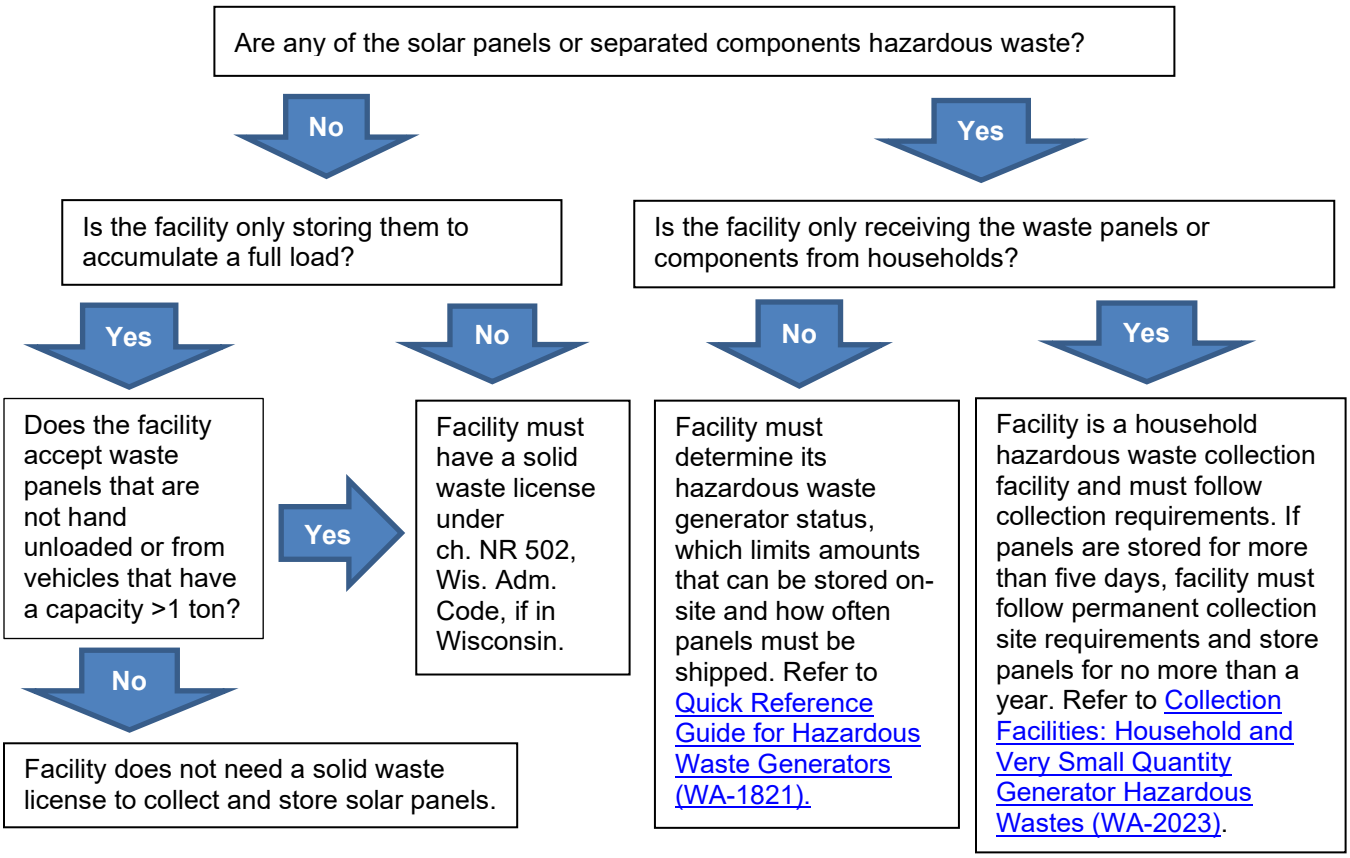
Figure 2: Determining where solar panels/components can be sent for disposal



Collection and storage

Individuals or organizations that collect, consolidate or store used solar panels destined for disposal or recycling must follow solid and hazardous waste requirements. Figure 3 highlights key requirements.

Figure 3: Determining which collection and storage requirements apply to solar panels



Speculative accumulation limits

Hazardous waste may not be stored indefinitely. To meet the speculative accumulation limit under s. NR 661.0001 (3) (h), Wis. Adm. Code, materials transferred from the collection facility to a recycling or disposal facility during each calendar year must equal at least 75% by weight or volume (e.g., filled containers, number of units) of the amount of solar panels accumulated on-site as of Jan. 1 that year.

Moving the solar panels from one site to a second site owned by the same individual or company for purposes of storing at the second site would not reset the timeline for speculative accumulation.

Under s. NR 661.0001(3) (h), Wis. Adm. Code, the individual or facility accumulating the solar panels must also show that the material is potentially recyclable and has a feasible means of being recycled. In general, a material has a feasible means of being recycled if there is a known market for the material and an identified recycler that will accept and recycle the material.

To demonstrate compliance with the speculative accumulation limit, sites handling solar panels must label all containers/pallets or similar storage units with the date when the first panel was placed there. If the site is not able to label the storage unit, it must use an inventory log or other appropriate method to demonstrate compliance with accumulation limit requirements.

The DNR also recommends sites maintain records, such as contracts and bills of lading or other shipment details, to show panels are going to legitimate recycling activities within the appropriate timeframe and to show compliance with speculative accumulation limits.

For questions about meeting speculative accumulation limits, contact DNRWIe-cycling@wisconsin.gov.

Best management practices

The DNR also recommends the following best management practices to ensure solar panels and components remain recyclable and therefore avoid more stringent requirements:

- Protect solar panels from the elements as much as possible—store indoors or in covered containers, or move off-site frequently if stored outdoors.
- Whenever possible, have a contract with a recycler, or other documentation, confirming the solar panels will be recycled or reused.

Transportation

Shipping waste solar panels or components for recycling or disposal will likely require a solid or hazardous waste transporter license from the DNR.

Any individual or organization hauling **non-hazardous waste panels**, if hauling more than 20 tons of all waste in a calendar year, would need a solid waste/recyclables transporter license to haul to a disposal or recycling facility.

Any individual or organization hauling **any hazardous waste panels**, would need a hazardous waste transporter license to haul to a disposal or recycling facility and follow hazardous waste manifest requirements. For more on manifests, go to https://dnr.wi.gov/topic/waste/manifest.html.

For more information on transporter licenses, go to https://dnr.wi.gov/topic/waste/licenses.

Dismantling, sorting and processing

Any processing (e.g., crushing, shredding, dismantling, sorting) of solar panels will likely require a solid or hazardous waste approval and license from the DNR. Contact DNR staff at DNRWIe-cycling@wisconsin.gov before starting to process solar panels for recycling.

More information

The U.S. EPA's End-of-Life Solar Panels: Regulations and Management webpage provides additional background and information about how the Resource Conservation and Recovery Act may apply to solar panels.

For more information on this subject, including other publications, staff contacts and administrative codes and statutes, go to dnr.wi.gov and search "hazardous waste resources." For more information about managing universal waste, go to **dnr.wi.gov** search "universal waste."

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