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SOLAR PANEL RECYCLING IN THE CAROLINAS

Solar energy use in the Carolinas is rising, increasing the need to manage end-of-life (EOL) solar panels. Silicon-based photovoltaic panels last 25–30 years, and many from the 1990s–2000s are now being decommissioned, adding to waste from damaged units. Recycling can recover glass, silicon, aluminum, plastics, and metals such as copper and silver. This resource outlines EOL management options, panel materials, and the solar recycling industry.

KEY TAKEAWAYS

- **Solar panels can be recycled**, and up to 95% of the materials in solar panels are recyclable.
- Even though the solar recycling industry is in its early stages in the U.S., it already has several **facilities based in the Carolinas**, and the industry is predicted to grow in the future.

WHAT HAPPENS TO SOLAR PANELS WHEN THEY REACH THE END OF THEIR USEFUL LIFE?

Solar panels typically last 25 years or more before their performance declines. At the end of their useful life, panels that are still functional can be reused, while those needing repairs may be refurbished, recycled, or disposed of in a landfill. In the U.S., relatively few panels have reached this stage, so the reuse, refurbishment, and recycling industries are still emerging. According to the North Carolina Department of Environmental Quality (NCDEQ), reuse and refurbishment are often economically advantageous, though the costs and benefits vary on a case-by-case basis.[1]

Recycling solar panels helps reduce waste and the need to extract new raw materials, providing net environmental benefits.[2,3] However, the process can be complex and costly compared to disposal. On average, landfilling a solar panel costs about $1.38, while recycling can range from $8 to $16 per panel, excluding transportation fees, which depend on distance and volume.[4,5,6] As of 2023, fewer than 10% of solar panels in the U.S. are recycled, primarily due to high costs. However, recycling frequency is expected to increase as more panels reach the end of their lifespan and as recycling technologies improve and become more cost-effective.[7,8]

Beginning November 1, 2025, North Carolina requires NCDEQ-approved decommissioning plans for utility-scale solar projects (2 MW or larger).[9] By December 1, 2026, solar panels that cannot be recycled must be disposed of in lined landfills that meet environmental protection standards. Panels classified as hazardous must follow hazardous waste requirements for recycling and disposal.[10] In South Carolina, decommissioning plans must identify components for recycling or disposal, but recycling is not yet mandatory.[11]

HOW ARE SOLAR PANELS RECYCLED?

About 95% of solar panel materials are recyclable, based on usual recovery rates for silicon-based panels (the main solar panel technology installed).[12,13] The remaining 5% that is not recycled is in plastics, adhesives, sealants, and breakage/debris.

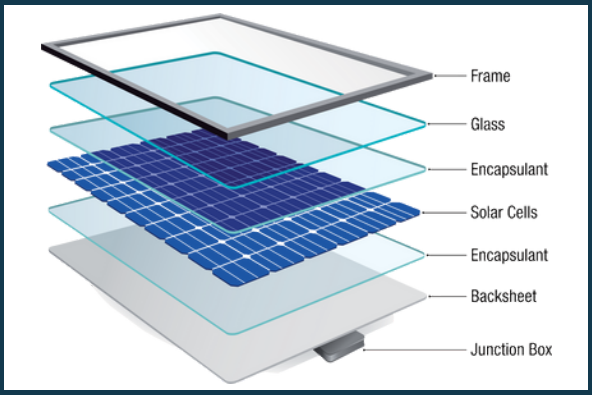

Figure 1 (above). Labeled Components of a Silicon Solar Module

Silicon solar panels are the most common type, typically made of a metal frame, glass, silicon cells, copper wiring, and plastic components such as the encapsulant, back sheet, and junction box. Thin-film cadmium telluride panels are less common and consist of metal, thin photovoltaic layers, and glass.[14] They require different recycling methods and are not yet widely recycled, though several U.S. facilities handle them.

RECYCLING PROCESS

Solar panel recycling methods vary depending on the panel type and manufacturer, and can include:

MECHANICAL

Breaks, separates, sorts, and further processes materials.[15]

THERMAL

Removes the plastic encapsulant layers from solar panels using heat. Helps recover silicon wafers intact, allowing them to be reused or further processed.

METALLURGICAL

Chemical and electrochemical methods extract valuable metals like silver and copper. Purifies the metals for reuse in manufacturing and other applications.

Solar recycling companies may use a combination of different processes for their recycling techniques, and processes may be adjusted based on the size, design, and condition of the solar panels being processed. The steps below show silicon panels going through a mechanical recycling process at SPR in North Carolina.

Figure 2 (left): Removal of Aluminum Frame and Electronics from a Solar Panel

STEP 1 — Remove Frame & Electronics

The aluminum frame, junction box, and electronic components are separated from the panel. These materials are collected for recycling.

STEP 2 — Remove Adhesives

Adhesive materials around the edges of the panel are removed. This allows access to the interior layers for further processing.

STEP 3 — Separate the Glass

The glass layer is ground into small chips using specialized equipment. The glass chips are collected for reuse.

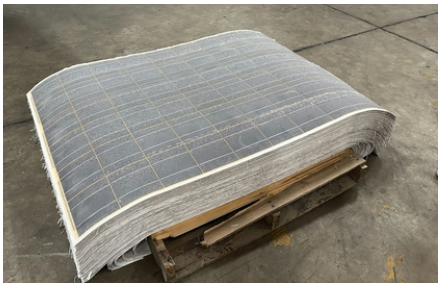

Figure 3 (right): Remaining layered materials after Step 3

STEP 4 — Crush Materials & Separate into Powders

The remaining layered materials are crushed and separated into powder-like forms of copper, a silver-silicon mixture, and plastics for recycling.

Figure 4: Copper powder (left) and Silver-Silicon mixture powder (right) after Step 4

MATERIAL COMPOSITION AND RECYCLABILITY OF SOLAR PANELS

MATERIALS	APPROX. % OF PANEL[16]	RECYCLABLE?	SOLAR PANEL PART AND USE	HOW IS IT RECYCLED, AND WHAT IS IT USED FOR?[17]
Glass	76%	Yes	Protective layer.	Cleaned and reused in concrete, fiberglass, paints, and containers. Widely used glass processing techniques in the U.S. are incompatible with reuse in new glass.
Silicon	5%	Yes	Core material that generates electricity in the solar cell.	Reused in the technology industry, specifically in batteries and semiconductors.
Aluminum	8%	Yes	Forms the panel frame, offering lightweight structural support and durability.	Products include new solar panel frames, building construction components, automotive components, and consumer products such as bicycle components.
Plastic	10%	Partially	Used to seal and protect silicon cells.	Most difficult component to find a market for to be reused. When recycled, typically used for shoe soles and sandals.
Other Metals (Silver, Copper, etc.)	1%	Yes	Used in parts of the panel that carry electricity, like wires and metal strips.	Recovered and refined for use in electronics, wiring, and industrial applications.

WHAT DOES THE SOLAR PANEL RECYCLING INDUSTRY LOOK LIKE IN THE CAROLINAS AND AT LARGE?

Even though the solar panel recycling industry is young and recycling frequencies are currently fairly low, it is predicted to grow. The U.S. solar panel recycling industry has predicted an average annual growth rate of investment of 12.98% from 2023 to 2030 and is set to reach a revenue of $90.13 million by 2030.[18] The value of materials recovered from EOL solar panels could be more than $15 billion by 2050 globally, and the materials could even be used to produce 2 billion new solar panels.[19]

There are three solar panel recycling facilities in the Carolinas already (see map to the left). This map uses information from North Carolina's Recycling Markets Directory.[20] SPR in Salisbury, for example, employs over 200 people in its solar panel and general recycling operations.[21]

FOR MORE INFORMATION OR TO REQUEST TECHNICAL ASSISTANCE, VISIT CAROLINAS-DASH.ORG.

RESOURCES USED IN THE CREATION OF THIS FACT SHEET

[1]North Carolina Department of Environmental Quality and the Environmental Management Commission. (2021, January). *Final Report on the Activities Conducted to Establish a Regulatory Program for the Management and Decommissioning of Renewable Energy Equipment.* [Review of *Final Report on the Activities Conducted to Establish a Regulatory Program for the Management and Decommissioning of Renewable Energy Equipment*. https://files.nc.gov/ncdeq/documents/files/DEQ_H329%20FINAL%20REPORT_2021-01-01.PDF

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[9]N.C. S.L. § 2023-58

[10]N.C. S.L. § 2023-137

[11]S.C. Code Regs. § 61-107.20.E

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