

It's time to plan for solar panel recycling in the United States

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By Kelly Pickerel

End-of-life panels might not need recycling for another 15 years, but that doesn't mean we should ignore the growing issue today.

In 2017, the United States installed 10.6 GW of new solar energy. Using rough math (if every panel was 300 W), that's 35.3 million new solar panels installed last year. In about 30 years, a wave of 35.3 million panels may reach the end of their lifespans, not counting the hundreds of millions of panels that flooded the U.S. market in the last decade that may need to be disposed of sooner.

What to do with this future solar waste has been bothering many in the industry, especially Sam Vanderhoof, owner of consulting firm Solar CowboyZ and former president of Schott Solar.



“I’ve been working in solar since 1976. I’ve been doing it a long time, and that’s part of my guilt. I’ve been involved with millions of solar panels going into the field, and now they’re getting old,” he said. “The industry seems to think—myself included—that there isn’t a problem yet. The reality is that there is a problem now, and it’s only going to get larger, rapidly expanding as the PV industry expanded 10 years ago.”

Solar panel disposal and recycling isn’t a huge issue right now in 2018 because there isn’t a big enough volume to cause concern. Solar panels are warrantied to perform more than 25

years, and once the warranty expires, panels will still produce energy, albeit not at their advertised peak. Solar installations in the United States didn't really take off until 2010. Any influx of panels needing replaced today happens after freak weather events or other accidents.

But where are those damaged panels going now? With no dedicated national program or requirement to safely dispose of solar panels, some unfortunately find their way to landfills. If the system owner is green-minded and has the money, panels may get shipped to a recycling facility. Other industry players are warehousing damaged or old panels until a practical recycling program is established.

That's why Vanderhoof and a few colleagues recently started a new recycling program in the United States—Recycle PV—modeled after Europe's successful program. The program is still in its early stages, but Vanderhoof hopes his efforts will start a movement.

"Who is responsible for it? In the U.S., nobody is," he said of solar panel recycling guidelines. "It is important for the industry to step up to address it. Solar is supposed to be renewable and clean energy, but there is this dirty side to it. There is a waste stream after time that hasn't been addressed."

Vanderhoof isn't alone in these concerns. There are many U.S. players trying to get plans in place before safe panel disposal becomes a national issue. Determining guidelines now will make things easier when panels reach the end of their useful lives.

Economics vs. regulations

Cara Libby, senior technical leader of solar energy at the Electric Power Research Institute (EPRI), has been doing solar PV recycling research on behalf of the organization's utility members. Libby said utilities asked for EPRI's help understanding the feasibility of recycling in the United States since many own solar arrays approaching 20 years old. Libby and her research partners have been looking at various recycling technologies, whether modules should be classified as hazardous waste and how other countries have already approached recycling regulations.

"It's still a little premature for dedicated PV recycling facilities [in the United States]," Libby said. "In the future, maybe around 2030, there will be a surge in PV waste volumes. Then we'll have to start thinking about a better way to collect and recycle efficiently."



Photo courtesy of PV Cycle

EPRI found that most panel recycling in Europe through the Waste Electrical and Electronic Equipment (WEEE Directive)—which established rules for solar panel recycling in 2012—happens at glass recyclers. Panels are crushed or shredded and then glass and metals are separated. Other chemical and thermal processes may be used to recover high-value material like silver or copper.

System owners recycle their panels in Europe because they are required to. Panel recycling in an unregulated market (like the United States) will only work if there is value in the product. The International Renewable Energy Agency (IRENA) detailed solar panel compositions in a 2016 report and found that c-Si modules contained about 76% glass, 10% polymer (encapsulant and backsheet), 8% aluminum (mostly the frame), 5% silicon, 1% copper and less than 0.1% of silver, tin and lead. As new technologies are adopted, the percentage of glass is expected to increase while aluminum and polymers will decrease, most likely because of dual-glass bifacial designs and frameless models.

CIGS thin-film modules are composed of 89% glass, 7% aluminum and 4% polymers. The small percentages of semiconductors and other metals include copper, indium, gallium and selenium. CdTe thin-film is about 97% glass and 3% polymer, with other metals including nickel, zinc, tin and cadmium telluride.

There's just not a large amount of money-making salvageable parts on any type of solar panel. That's why regulations have made such a difference in Europe.

“In Europe, we've seen that when it's mandated, it gets done,” Libby said. “Either it becomes economical or it gets mandated. But I've heard that it will have to be mandated because it won't ever be economical.”

There's nothing yet mandated at a national level, but there are a few states trying to get the

required recycling ball moving. In July 2017, Washington became the first state to pass a solar stewardship bill (ESSB 5939), requiring manufacturers selling solar products into the state to have end-of-life recycling programs for their own products. Manufacturers that do not provide a recycling program or outline will not be able to sell solar modules into the state after Jan. 1, 2021. Regional takeback locations will be set up to accept solar panels at no cost to the system owner, and the state may charge manufacturers for the program. Final plans are still being decided.



Washington-based solar panel manufacturer [Itek Energy](#) assisted with the bill's writing.

“Most of us here at the company feel strongly about being strong environmental stewards,” said Evan Bush, special programs coordinator at Itek. “It’s important to spearhead these efforts before there’s a big volume that will need to be disposed. With this in place, we’ll be more prepared.”

Itek’s modules are already in compliance with the new bill; the company uses a recycling partner in Idaho to take damaged panels and manufacturing scrap. Itek has been accepting back other brands of modules just to keep them out of landfills.

“There are reasons beyond just doing the right thing that should encourage others to [recycle panels],” Bush said. “Given the value of the component materials in modules, this shouldn’t be a burden to us or other participants.”

New York has a similar bill on the Senate calendar this year. Bill S2837A would require solar panel manufacturers to collect end-of-life panels for recycling. Critics argue that panel manufacturers should not bear the burden of recycling panels alone, although that is how the WEEE Directive works in Europe.

California SB 489 passed in 2015 and encourages safe disposition of old panels. California designates end-of-life solar panels as universal waste, a type of hazardous waste that is widely used in homes and businesses (like TVs or batteries). By California law, universal waste cannot be trashed or landfilled, but no guidelines are given on the proper way to recycle solar panels.

A U.S. recycling veteran

One U.S. company that has recycling figured out is CdTe thin-film module manufacturer First Solar. In 2005, the company made a commitment to extended producer responsibility. First Solar execs understood that in order for a renewable energy technology to truly be green, it was important to consider its end-of-life management. First Solar's recycling program was established at the beginning of production to responsibly recycle manufacturing scrap, warranty returns and end-of-life panels. This environmental decision also had a financial perspective—tellurium doesn't just grow on trees.



First Solar's current recycling line

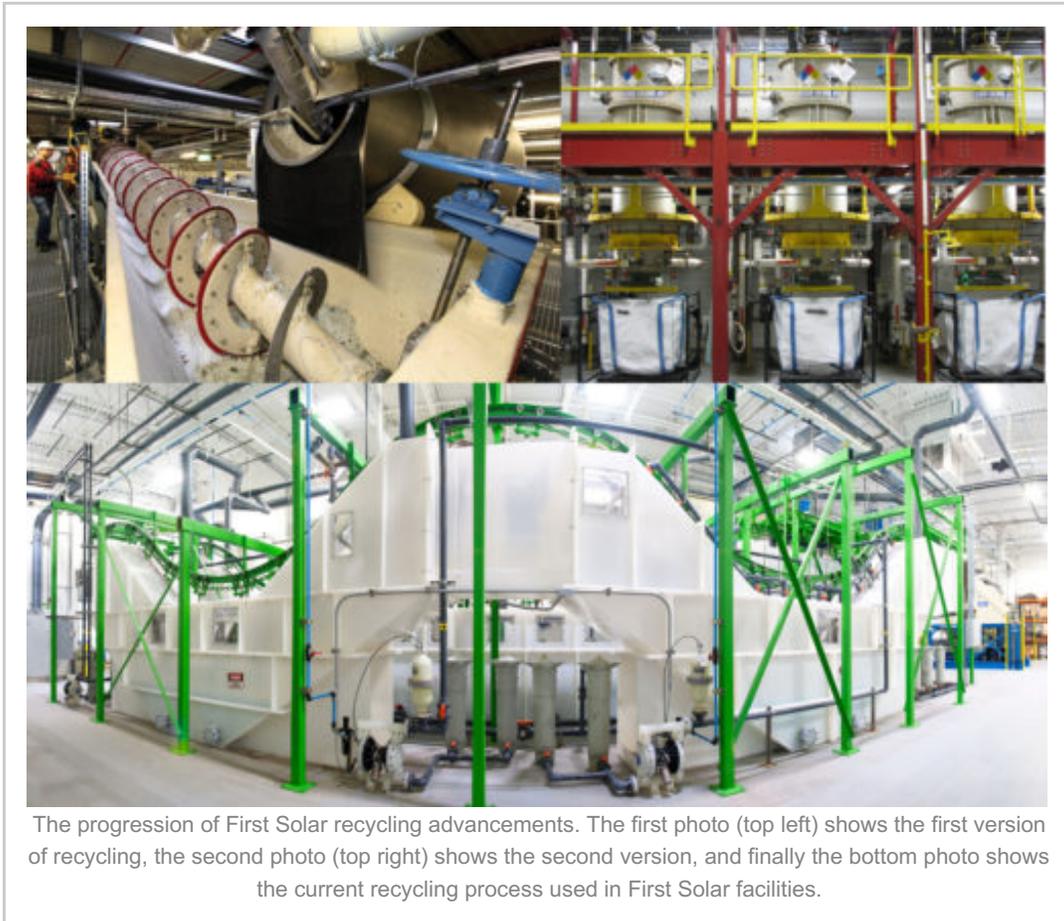
“There is a finite amount of tellurium,” said First Solar global recycling director Sukhwant Raju. “They wanted to make sure there was a way to recover the valuable stuff so it becomes sustainable growth for First Solar. It's not just about being green, but how do we stay sustainable in the long term?”

First Solar recycling plants are attached to its manufacturing facilities—in Ohio, Malaysia and under construction in Vietnam. There's also a stand-alone recycling plant in Germany.

“We have the capacity to recycle 2 million panels globally on an annual basis,” Raju said. “As more panels start reaching the end of their 25-year lifetimes, recycling will increase drastically.”

The company only recycles CdTe panels currently, even if the panels are not manufactured by First Solar (other CdTe panel manufacturers include Calyxo of Germany and Advanced Solar Power (ASP) of China). Raju said the company may develop techniques to handle crystalline silicon panels.

“We have a decade’s worth of experience in recycling, and we want to utilize that to broaden our efforts,” he said.



As with the decommissioning of other energy technologies, there’s still a financial obligation on behalf of the system owner. The company’s initial recycling program was pre-funded. When a First Solar panel was sold, a portion of that money went into a fund that could only be used for end-of-life recycling. In 2012, the company switched gears but continues to honor historical commitments under the prefunded module collection and recycling program.

“We realized we were not doing anyone any favors by charging customers 20 to 30 years in advance for end of life recycling,” Raju said. “The better approach was to do pay-as-you-go since it is more cost-efficient to finance PV recycling through later-year project cash flows instead of upfront funding. Now when we sell our panels, we offer a global recycling services agreement. Customers have the option to use our services when the panels get to the end of life stage. We’ll do the recycling, and they’ll pay the price at that time.”

This customer-funded recycling effort is dependent on system owners willing to pay the price to do the right thing. Raju thinks that as volume increases, recycling costs will come down and the greener option will be more attractive than just throwing panels away. First Solar is also taking steps to reduce recycling costs to ensure recycling becomes the preferred end-of-life management approach.

“Limited land availability and regulatory requirements will only increase the costs of landfilling,” he said. “Meanwhile, recycling costs will continue to go down. While customers may only be sending 100 panels today for recycling, by the time most of their panels get to end of life, our cost ratio will be way lower. They see the value in getting on the recycling bandwagon.

“But at the end of the day,” Raju continued, “there is nothing to force them, other than in places where there are regulations.”

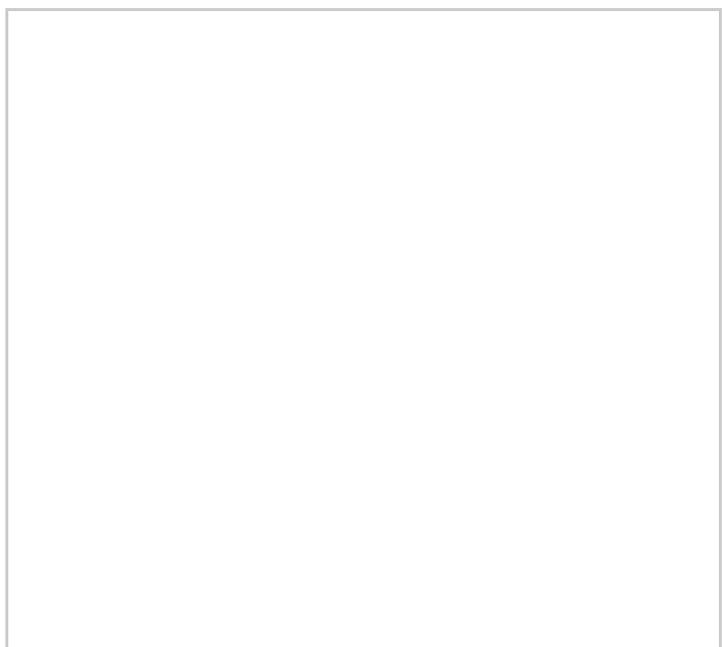
The need for crystalline recycling

For c-Si modules needing recycling now in the United States, there are a few scattered options. Various glass and electronics recyclers have taken on solar panel recycling, but usually not on dedicated lines or on a grand scale. Industry advocacy group SEIA has begun organizing recycling efforts through its [PV Recycling Working Group](#). SEIA will choose preferred recycling partners that offer benefits to SEIA members. [ECS Refining](#) and [Cleanlites Recycling](#) have recently been approved as SEIA recycling partners.

Cleanlites began in the early 1990s as a light bulb recycler, taking on other items like batteries and electronics, until it found a niche with “difficult to recycle” items. It has been catering to a solar crowd for the last few years and recycled 1.5 million lbs of solar panels last year (again, using rough math of 50 lbs per panel, that’s 30,000 panels).

“I saw the impending need for solar panel [recycling]. Those coming out of commission from now to the next 10 years is astronomical,” said Tim Kimmel, Cleanlites vice president.

Cleanlites uses optical, magnetic and hand sorting to separate aluminum, other metals and electronics from c-Si solar panels at its Cincinnati-based facility. The company is hesitant to accept other types of panels right now until it can determine safe processes. The leftover glass and silicon wafers (which may also have copper and silver mixed in) are sent to a smelter for further extraction. The process works for now, but it could be improved.



“We’re looking to put a new process line in that will be able to separate all the components and recover the silicon wafers and recycle the units 100%,” Kimmel said. “The goal is to avoid landfilling all these units, which is going to be a vast number here shortly.”

As solar panels are processed on the current lines, Cleanlites collects the scrap and sends 45,000-lb loads out at a time.

“At times, we get thousands of panels in a month, and on those times, we process twice a week, making the material and sending to the smelter on a consistent basis,” Kimmel said. “Other times, they come in slowly and we build them up until we are able to process a whole shipment.”

It costs money to send “solar scrap” to a smelter, and Cleanlites incorporates that cost and the cost of transportation into its recycling prices.

“There is a cost, so you have to weigh... do you want to be an environmentally sustainable company, or do you want to landfill thousands of pounds of material and have that show up?” Kimmel said. “The benefit of sending it to us, we’re able to receive it, ensure that the metals are recovered, and we recycle it. You’re not creating any waste or hazardous waste.”

A solar panel’s level of hazardous waste is up for debate. If panels are just old, there are usually no reasons to worry. EPRI research found the chance of chemical leaching grows if panels are damaged.

“We’ve conducted some toxicity testing on modules, and we have seen results showing that the presence of lead is higher than the threshold allowed by the TCLP (toxicity characteristic leaching procedure). There is a lot of variation between module types,” Libby said. “There is a potential for leaching of toxic materials such as lead in landfill environments. If modules are intact, it’s a low risk, but as soon as they’re broken or crushed, then the potential for leaching is increased.”

Recycling panels is the safest way to dispose of them, and SEIA and recycling centers are trying to make it easy to do the right thing.



Photo courtesy of PV Cycle

Planning for future volume

There are clearly recycling options available now to U.S. solar owners, but their fragmented nature is what led Vanderhoof to form Recycle PV.

“There’s a little effort for sure, but it’s not concentrated. The information isn’t out there,” he said. “There’s not a good, simple flow of information and processes and procedures to deal with the waste stream.”

Recycle PV went straight to the pros, partnering with [PV Cycle](#) (the successful non-profit organization that offers waste management help to solar companies in Europe) and German panel refurbisher [Rinovasol](#) for the U.S. market. Slightly damaged or underperforming panels can find a second life on the refurbished market. Rinovasol will take care of those, and PV Cycle sets up memberships to get recyclable panels to partner facilities. Thus far, Recycle PV has shipped two containers of panels to Germany for recycling, which is expensive but the only way to fully take advantage of the PV Cycle process right now.

The plan for Recycle PV is to get volumes large enough to build a dedicated solar recycling plant in the United States. Vanderhoof said once Recycle PV is processing 10,000 panels a month, a U.S. facility will make more sense.

“It’s not an outrageous goal,” he said. “Right now in Europe, they can recycle that much a day, but it’s been going on for a long time already.”

It’s a lofty goal for Vanderhoof and his partners to start a brand new operation, but he felt he had to do something.

“We’ve gone to a lot of waste management and EPA meetings. You look around the room and it’s all waste management people, not solar people,” he said. “Those guys are in there trying to work on the policies that affect all of us, and they’d like it to be a more expensive policy because they make more money off it. The solar guys aren’t as engaged as they could be.”

The most promising solution for the United States is if SEIA can successfully tap into the PV Cycle model and pick up recycling plants across the nation willing to invest in solar processing. If more states adopt Washington’s requirements to have all panels backed by recycling programs, national recycling plans might automatically form. A big solar name may be willing to forgo Washington sales, but it’d have a harder time losing out on California sales just because it doesn’t have a recycling plan in place.

Time is ticking. The United States has about 15 years before solar panel recycling becomes a major issue. Plenty of time to figure out the best course of action, but also plenty of time to procrastinate. Here’s hoping we set early deadlines.