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OVERVIEW OF SOLAR PANEL RECYCLING FOR INDIGENOUS COMMUNITIES

Exploring the what's, why's and how's of recycling in the solar industry

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THE UNIVERSITY
of NORTH CAROLINA
at CHAPEL HILL

W UNIVERSITY of WASHINGTON



- Background & Motivation
- Solar Panel Recycling Availability and Process
- Pros and Cons of Current-Day Solar Recycling
- Emerging Recycling Technologies
- Conclusion

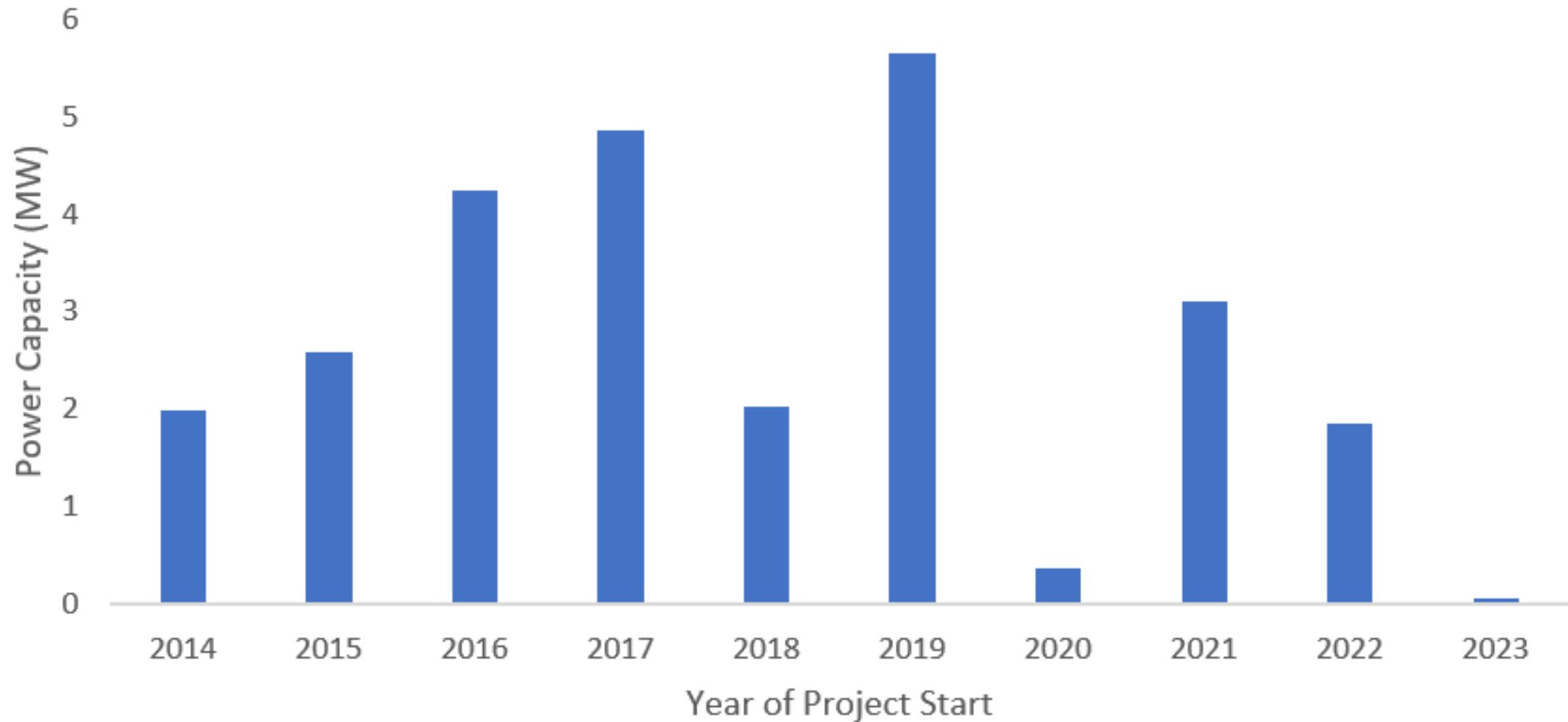


Stock photo

DOE-SPONSORED TRIBAL SOLAR ENERGY IS EXPANDING

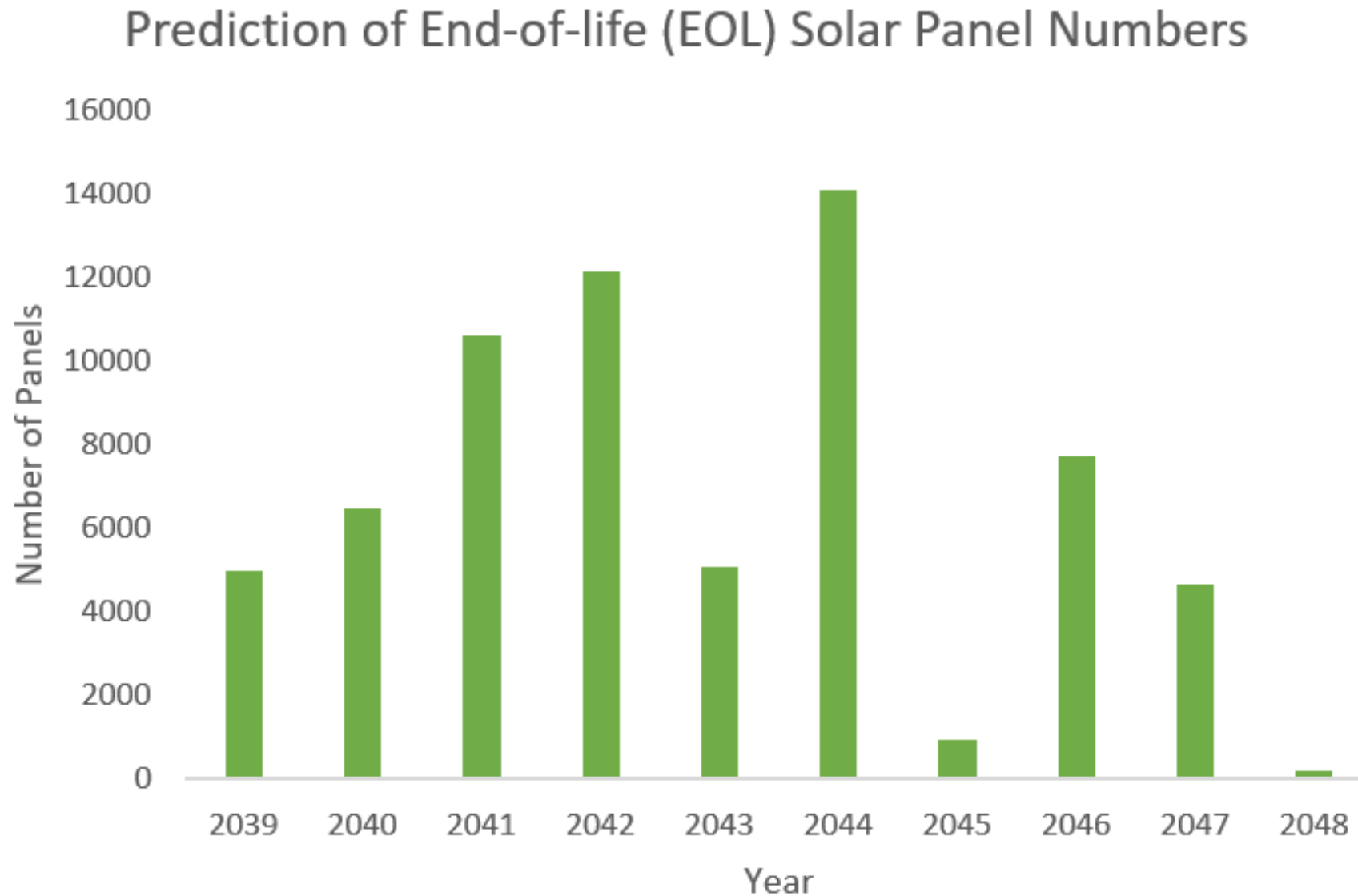


Total Installed Capacities of Solar Projects in Indian Country



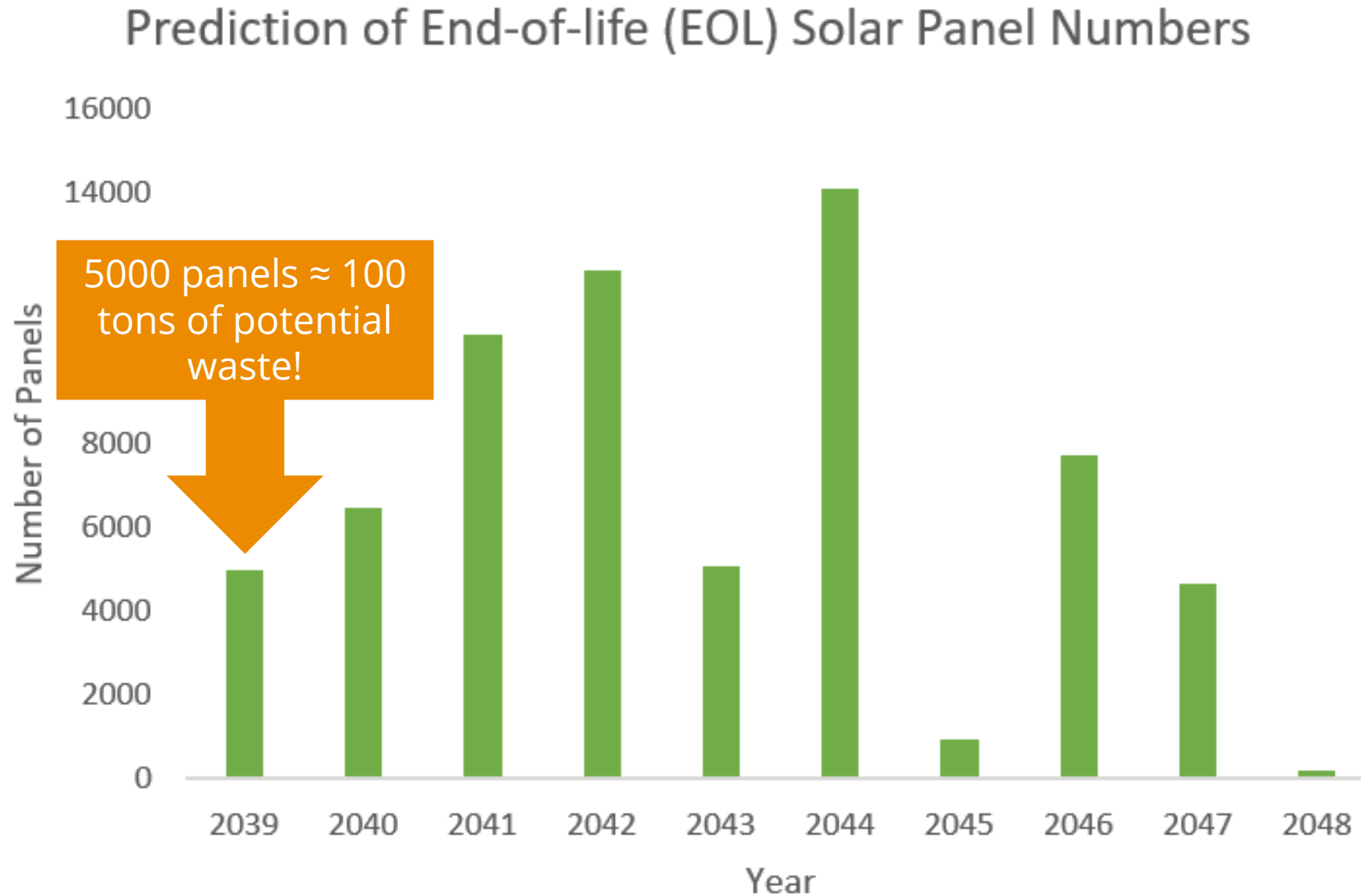
Data estimated from: Indian Energy (IE) Office website; only projects funded by DOE IE

MANAGING SOLAR PANEL WASTE IS AN IMMINENT ISSUE



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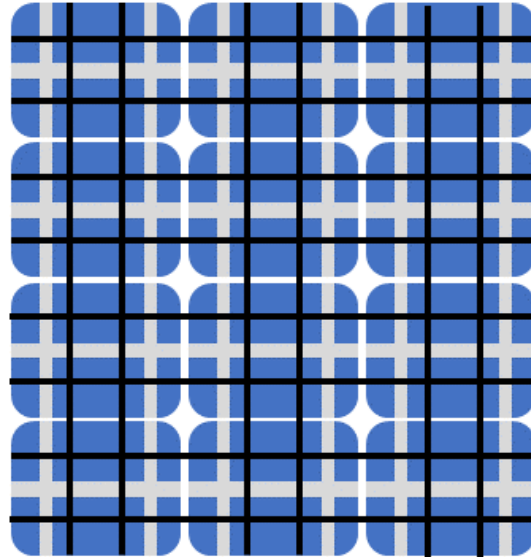
A REVIEW OF SOLAR (TOP-DOWN VIEW)

A solar system is arranged like a beehive:

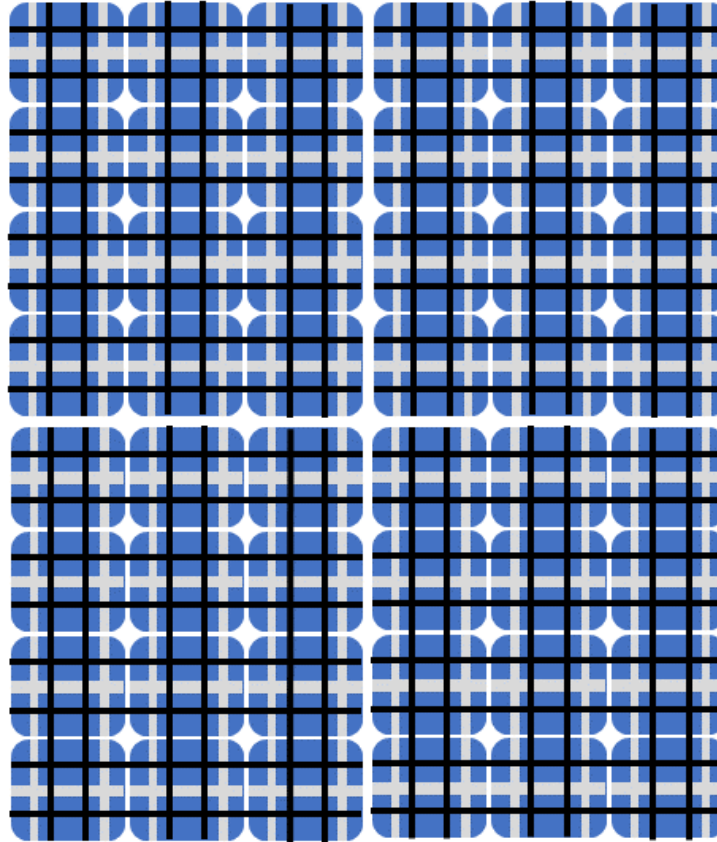
Solar Cell



Solar Module

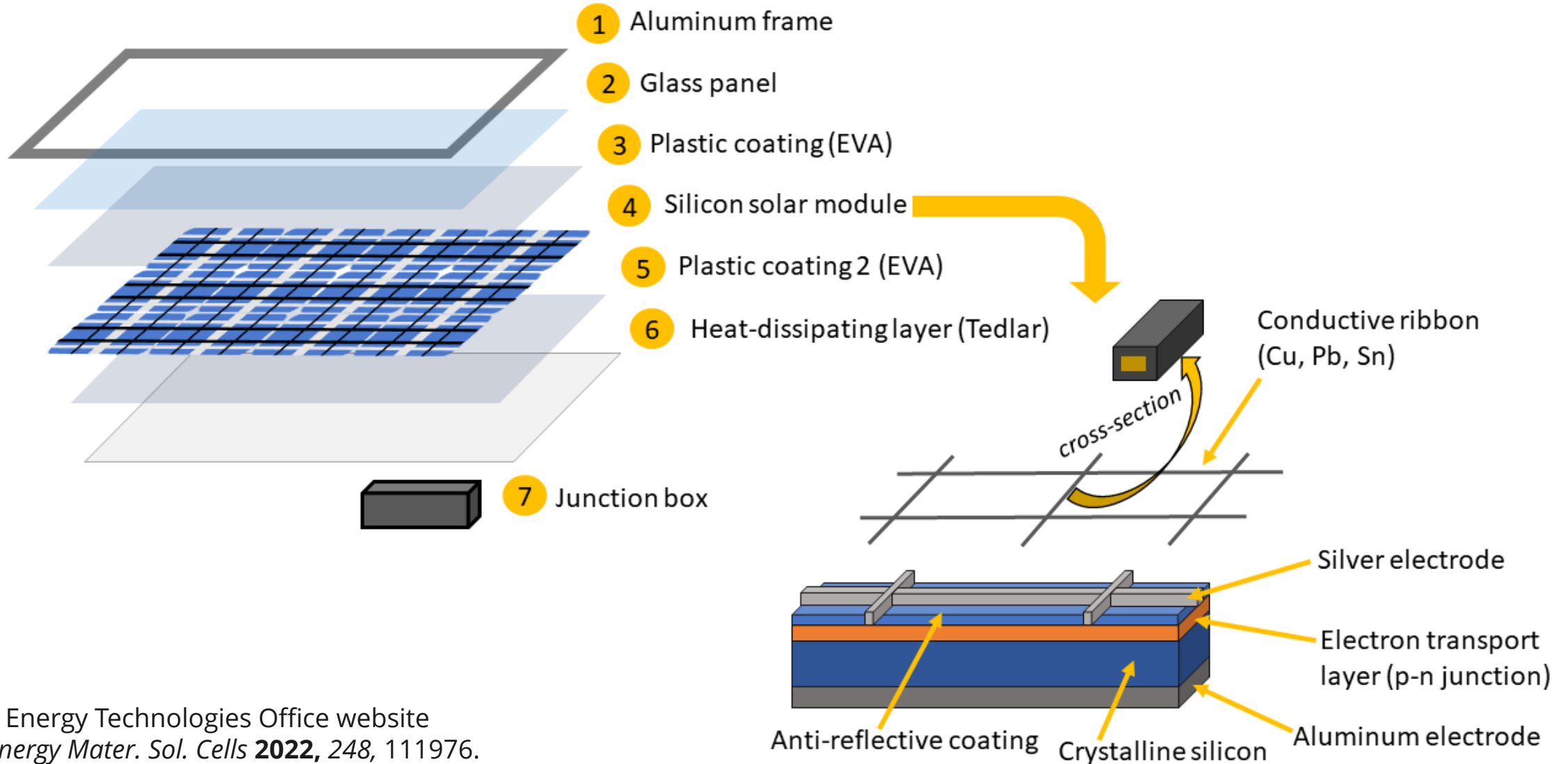


Solar System



A REVIEW OF SOLAR (SIDE VIEW)

A solar panel is constructed like a sandwich:





The United States (US) currently **does not** have any federal regulations for handling end-of-life (EOL) solar panels. Today, tribes can make their **own** decisions for disposal . . .

AN OPTION FOR EOL PANELS: RECYCLING



Solar panel manufacturing relies on import of metals from adversarial countries

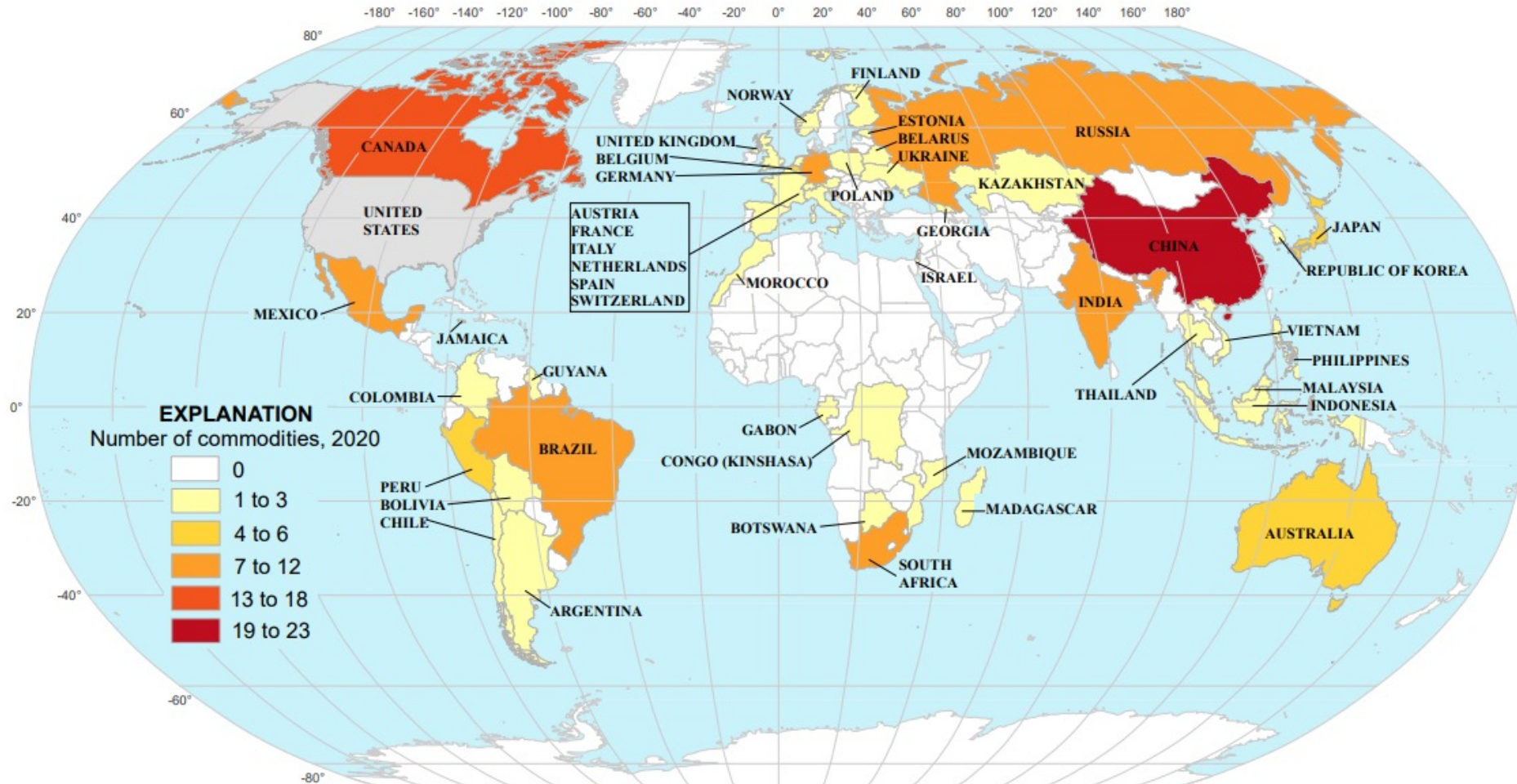
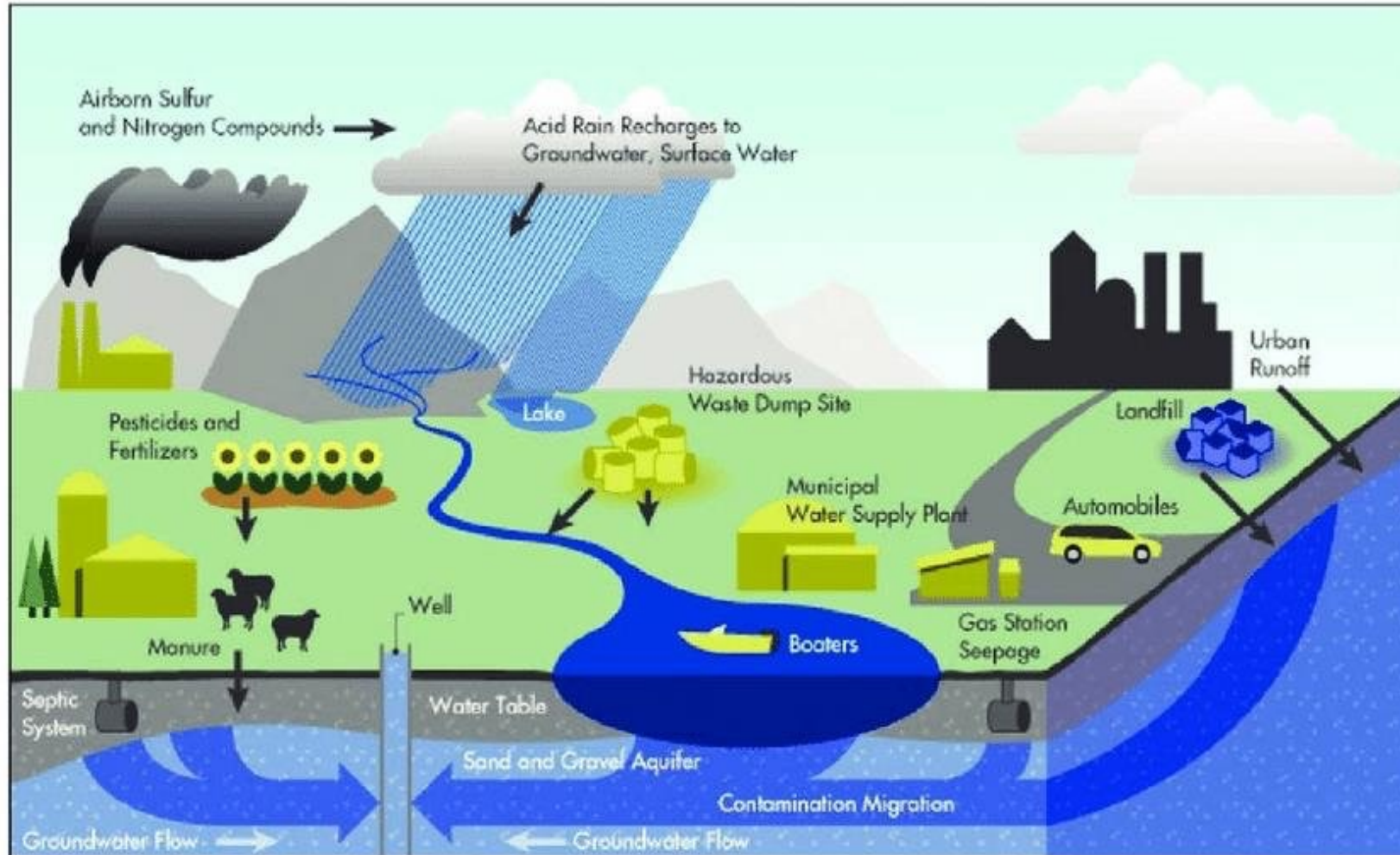


Figure 3.—Major Import Sources of Nonfuel Mineral Commodities for which the United States was greater than 50% Net Import Reliant in 2020

AN OPTION FOR EOL PANELS: RECYCLING

Dumping EOL panels in the landfill could lead to leaching of toxic and/or environmentally harmful metals, including cadmium, lead, chromium, and nickel



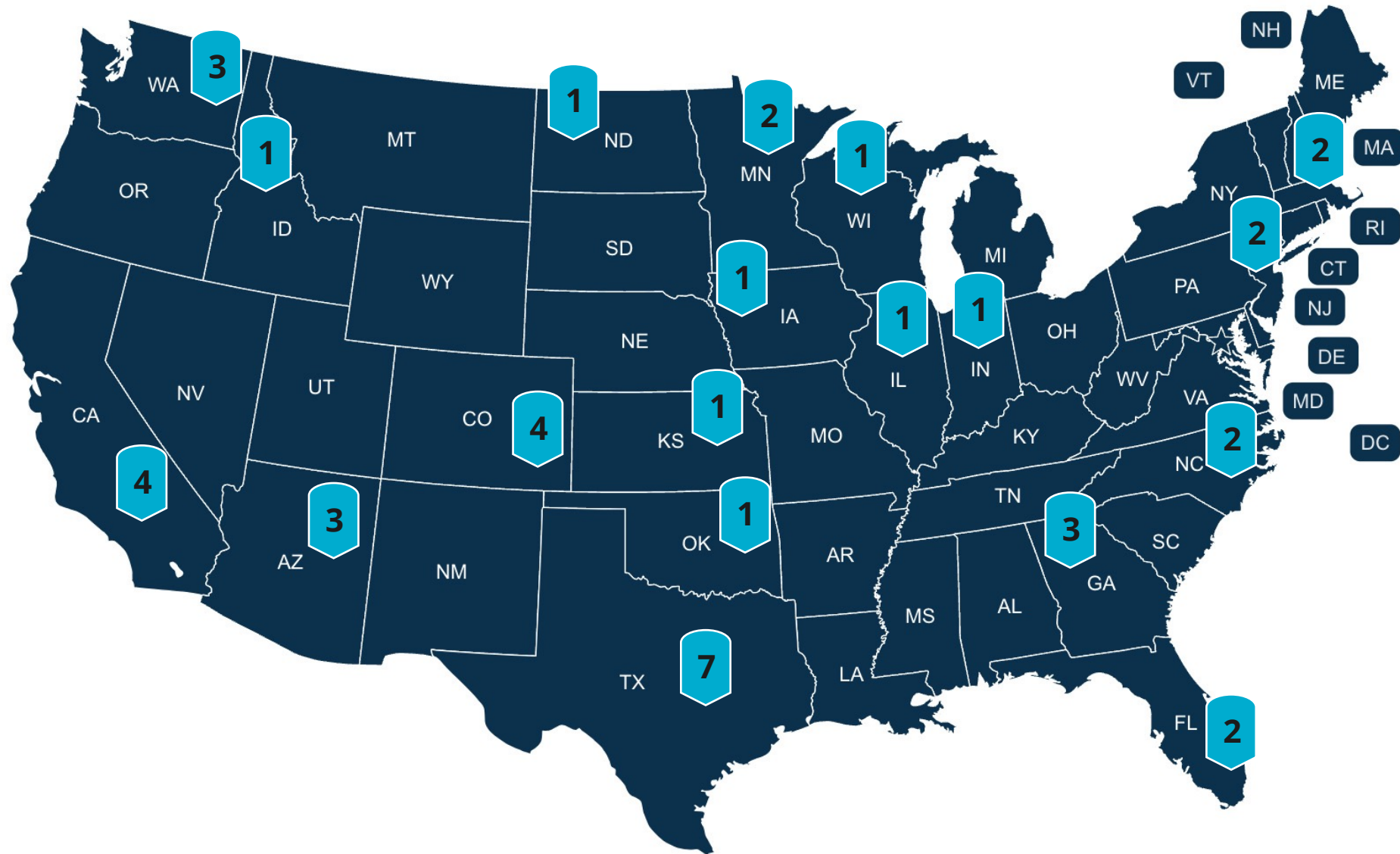


AN OPTION FOR EOL PANELS: RECYCLING

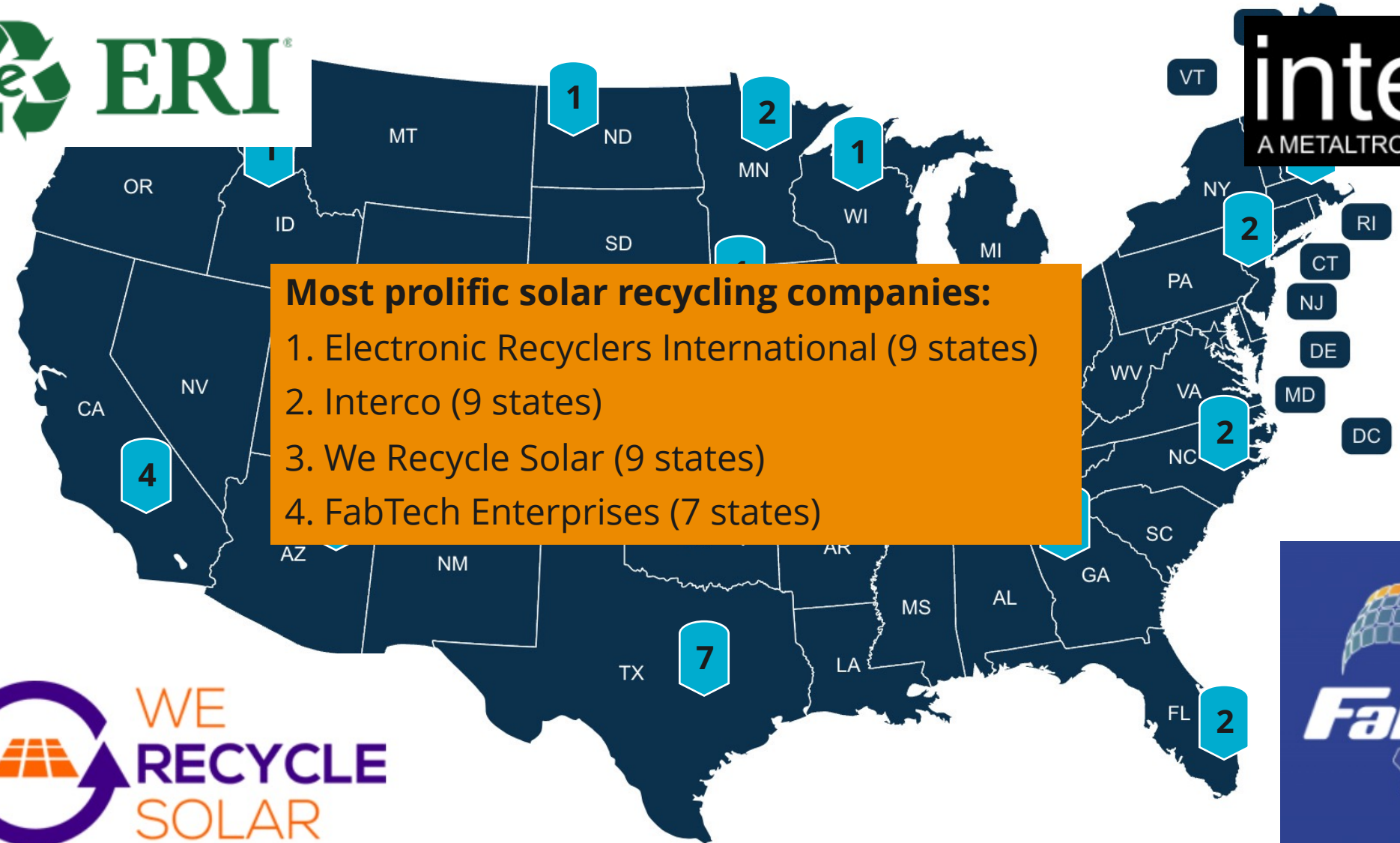
Most materials in a solar panel are readily recyclable:

Material	Weight percentage in a module (%)	Relative economic value	Of interest to recycling?
Silicon	2–3	High	Yes
Silver	0.006 ~ 0.08	High	Yes
Copper	4.4–7	High	Yes
Aluminium	10 ~ 20	Medium	Yes
Glass	69 ~ 75	Low	Yes
Junction box	2	Low	Yes

MANY COMPANIES NATIONWIDE ARE CAPITALIZING ON SOLAR RECYCLING



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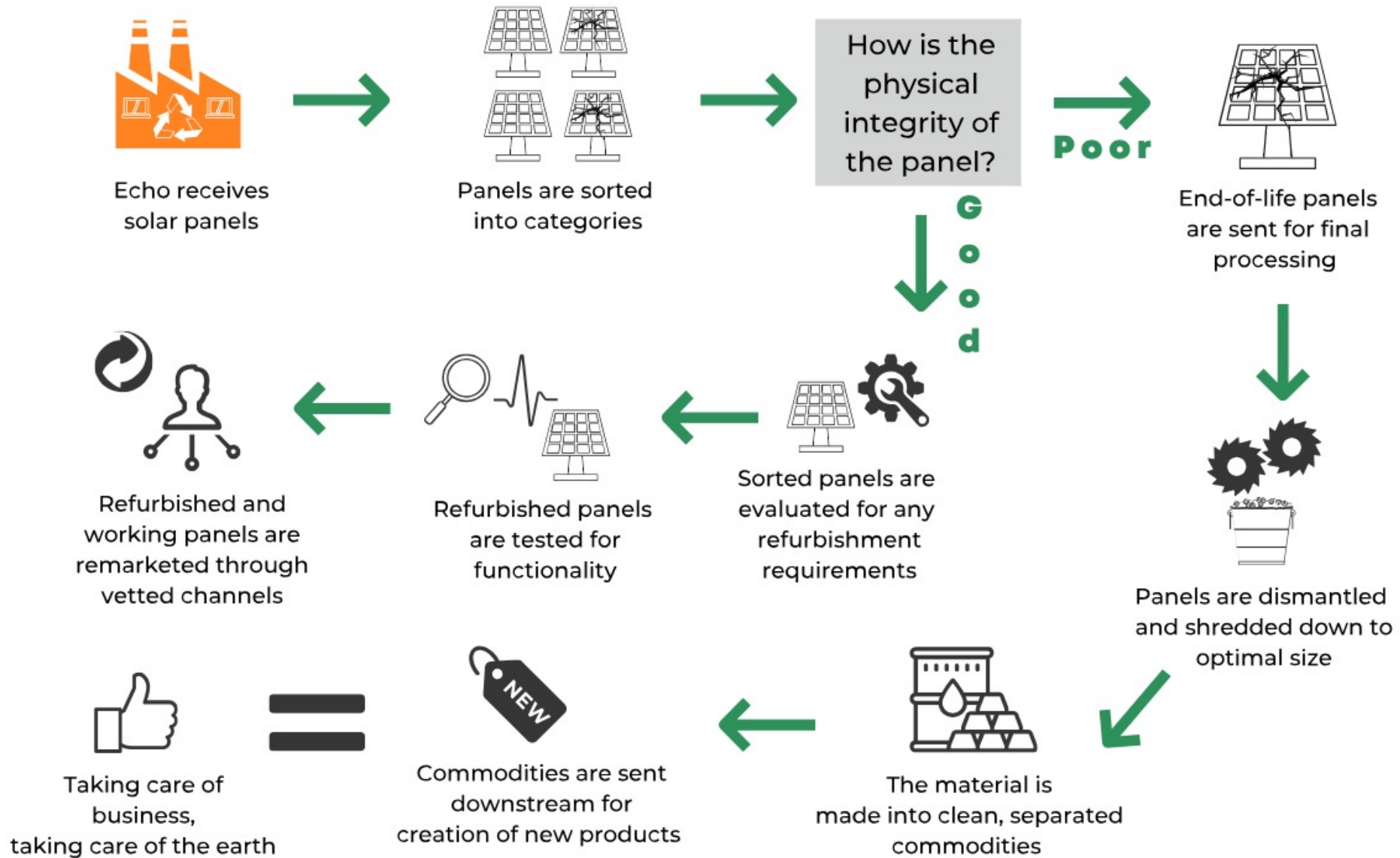


Most prolific solar recycling companies:

- 1. Electronic Recyclers International (9 states)
- 2. Interco (9 states)
- 3. We Recycle Solar (9 states)
- 4. FabTech Enterprises (7 states)



WHAT IS THE PROCESS FOR RECYCLING SOLAR PANELS?



CONSTRAINTS FOR SOLAR PANEL RECYCLING



1. Hazardous Waste Regulations

- Damaged solar panels can expose recyclers to toxic metals, which can result in serious health problems
- To mitigate this risk, all damaged panels must be tested for exposed toxic, leachable metals using the Toxicity Characteristic Leaching Procedure (TCLP)
 - If the test shows leachable toxic metal levels are above the allowed threshold, those damaged panels *cannot* be recycled
- Consult with a hazardous waste professional to determine the number of non-recyclable solar panels in your solar array



EPA website



Caspian Environmental Laboratory website

CONSTRAINTS FOR SOLAR PANEL RECYCLING



2. Limitations on solar recycling (minimums)

- Some companies only recycle utility-scale panels (i.e. **We Recycle Solar**)
- Other companies place have wattage/weight minimums
 - **SolarCycle**: 500 panel minimum (~200 kW solar capacity)
 - **First America**: 5,000 lbs minimum (~125 panels or 50 kW solar capacity)



Field visit to Picuris Pueblo



Children of the Sun solar initiative

CONSTRAINTS FOR SOLAR PANEL RECYCLING



3. Price of recycling

- Recycling costs money, BUT selling panels suitable for reuse gives you a discount



damaged/unusable panels: \$0.15-\$0.45/lb

panels suitable for reuse: sold for \$0.05/W



damaged/unusable panels: \$0.30-\$0.60/W

panels in good condition: \$0.08-\$0.12/W

CONSTRAINTS FOR SOLAR PANEL RECYCLING



4. Extra costs

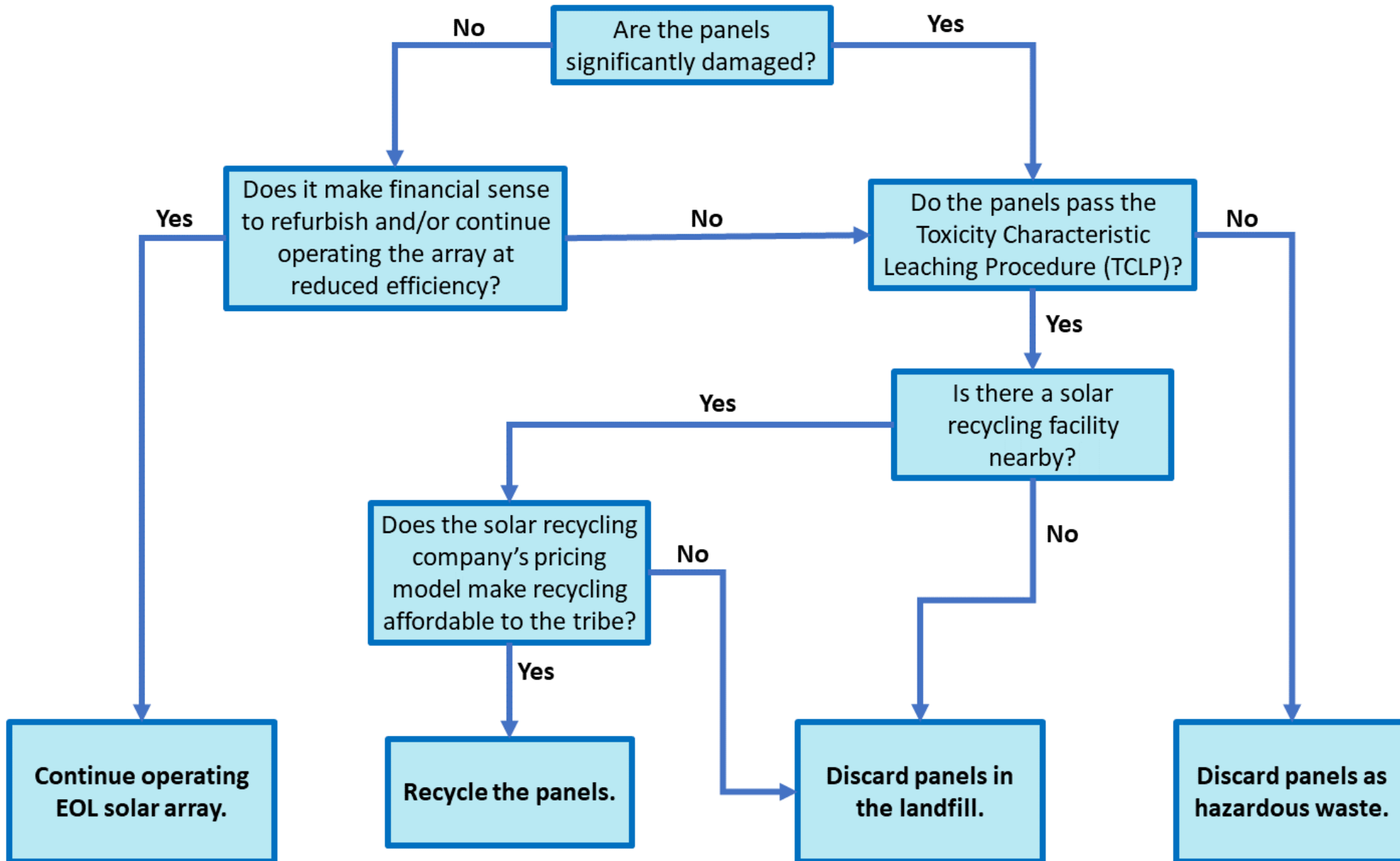
- Most companies will charge for panel palletizing, loading, and shipping
 - Save money by dismantling and palletizing panels yourself
 - Find a company located close to you to minimize shipping costs



Stock photo – palletized solar panels



Evaluating Options for EOL Solar

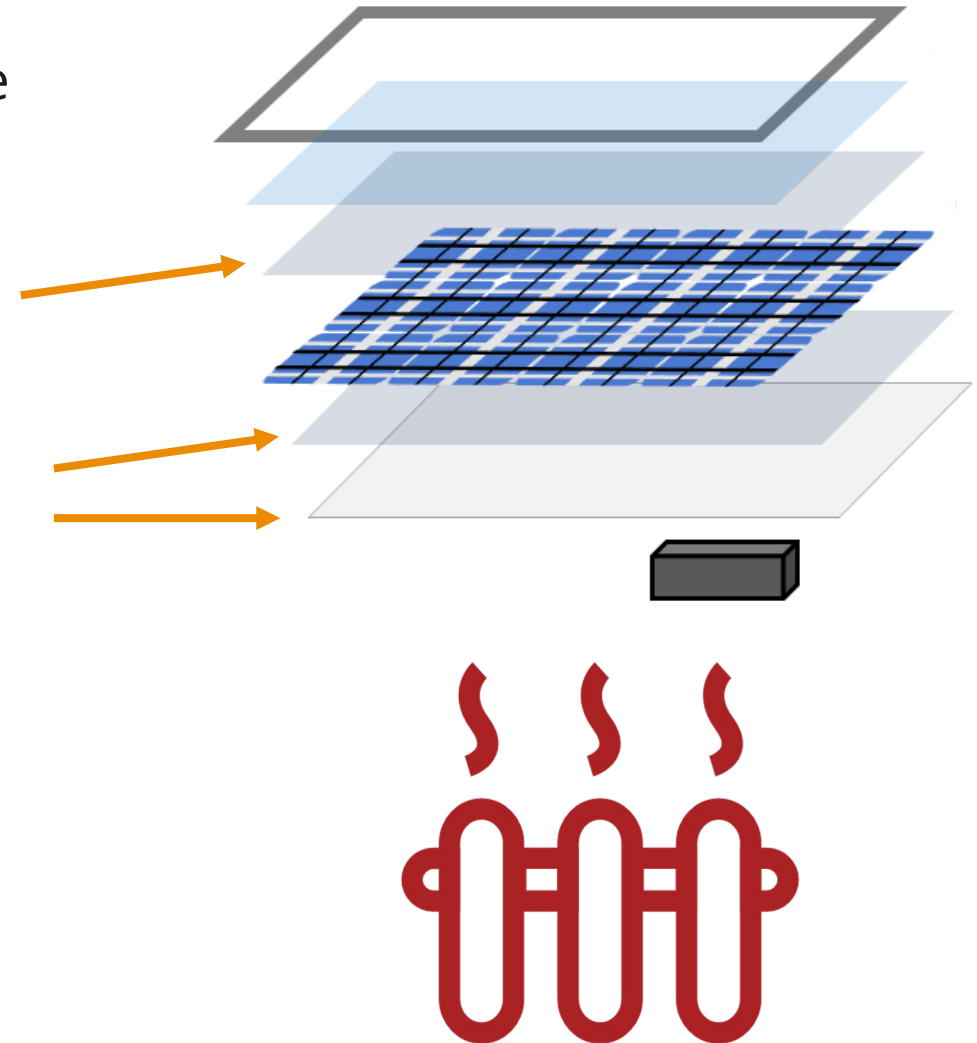


CURRENT SOLAR PANEL RECYCLING METHODS ARE UNSUSTAINABLE AND HAZARDOUS



Thermal Delamination

- Uses heat in the absence of oxygen to remove the polymer and backsheet layers
 - Called **pyrolysis**
 - Requires a lot of energy
 - Requires 2 phases of 15-minute heating sessions per batch



CURRENT SOLAR PANEL RECYCLING METHODS ARE UNSUSTAINABLE AND HAZARDOUS



Chemical delamination (chemical swelling)

- An alternative to pyrolysis, can remove polymer and backsheet layers by dissolving them in solvents:

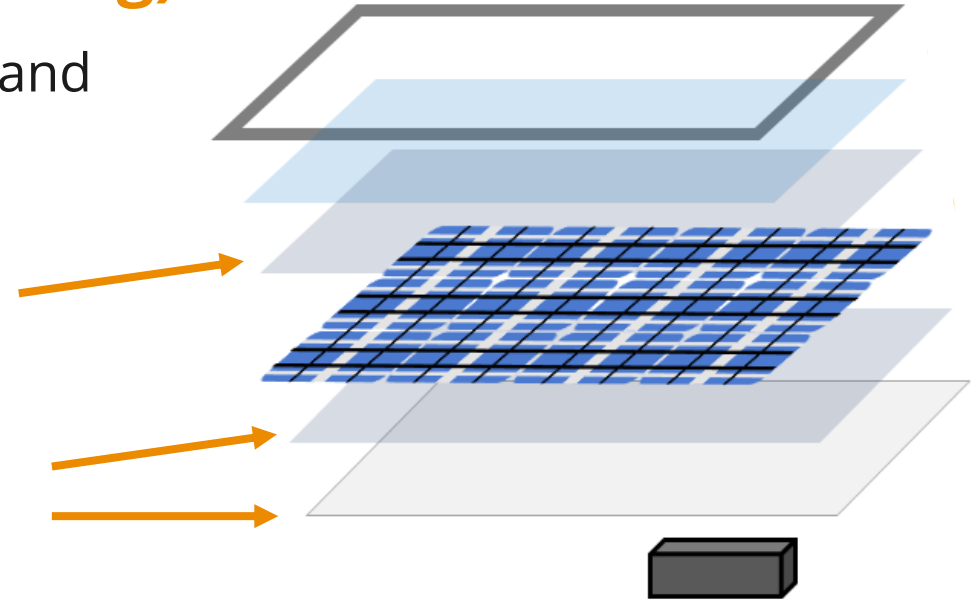
- Toluene



- Hexane



- Environmentally friendly alternative: ethanol/potassium hydroxide



CURRENT SOLAR PANEL RECYCLING METHODS ARE UNSUSTAINABLE AND HAZARDOUS

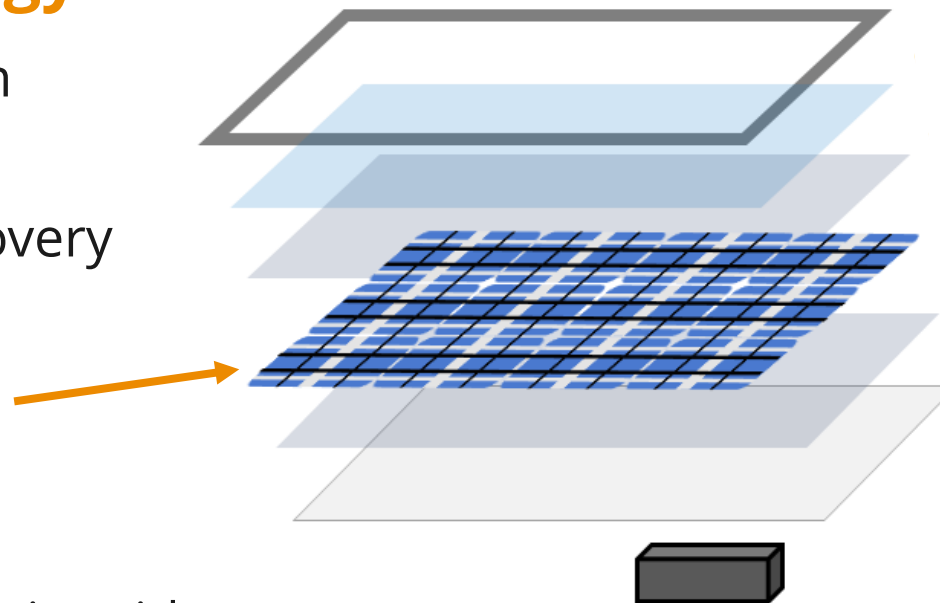


Chemical etching and hydrometallurgy

- Chemical etching is used to recover pure silicon
 - hydrofluoric acid, nitric acid, and sodium hydroxide are required to achieve 90% recovery



- Hydrometallurgy is used to recover silver ions
 - uses nitric acid, sodium chloride, hydrochloric acid, and sodium hydroxide

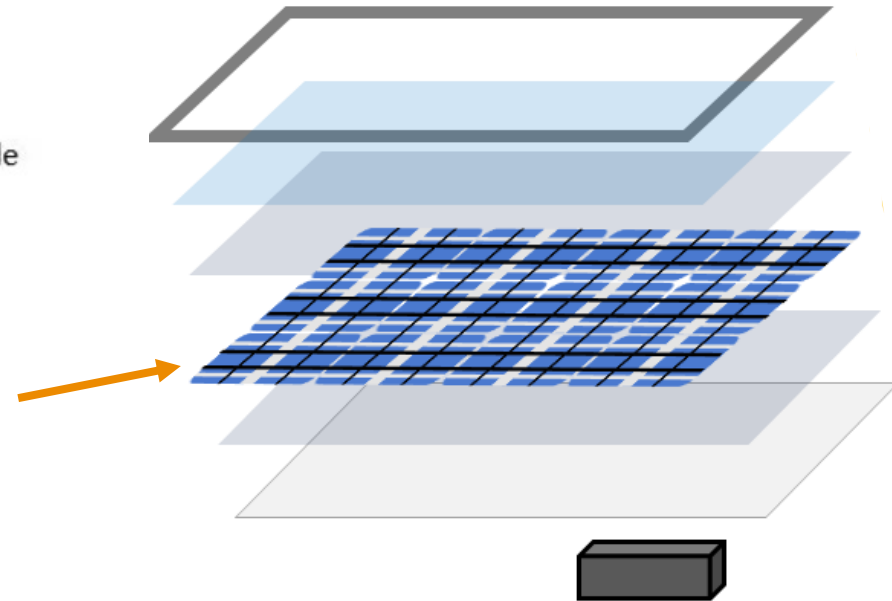
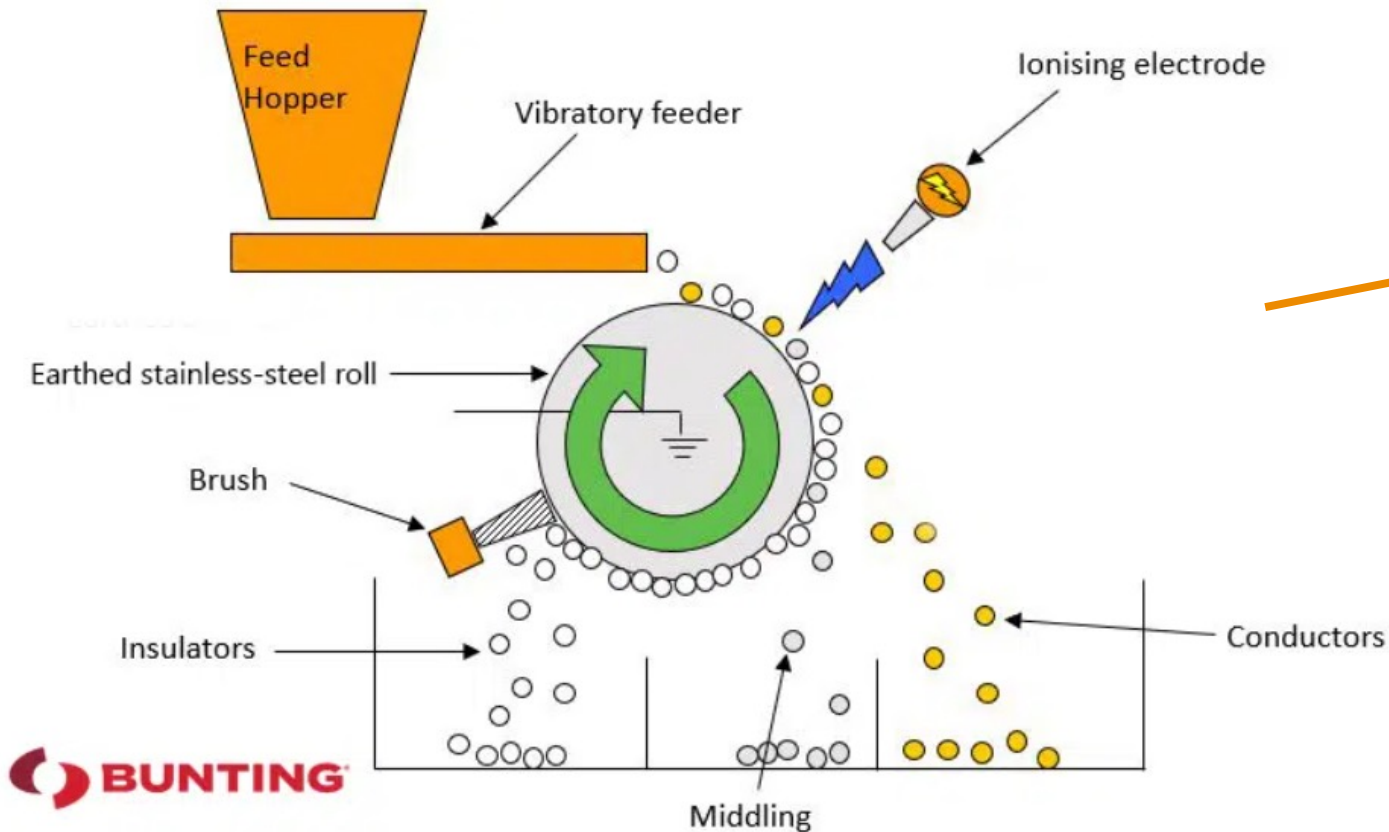


EMERGING ECO-FRIENDLY RECYCLING METHODS



Electrostatic separation

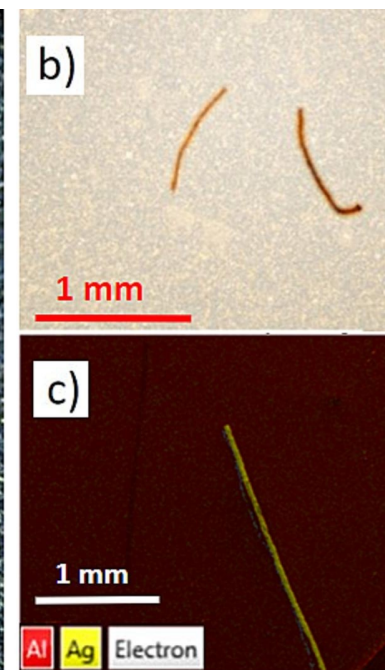
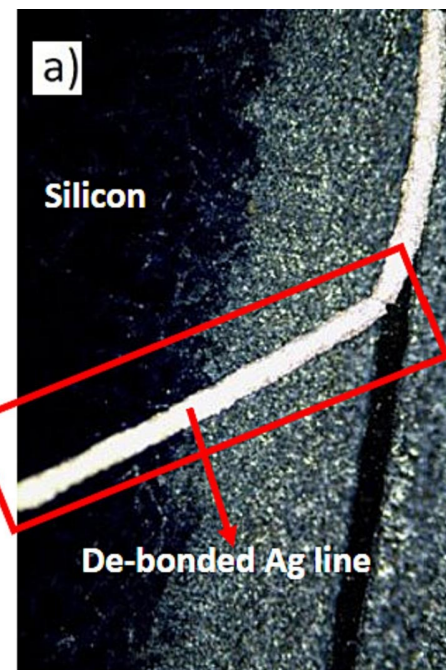
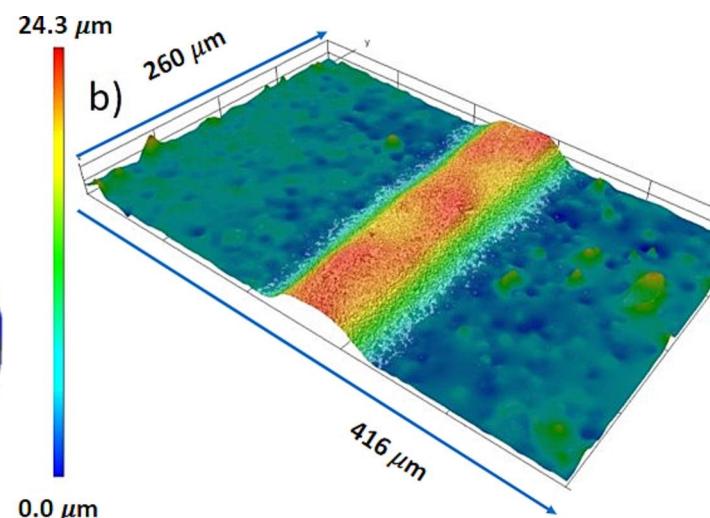
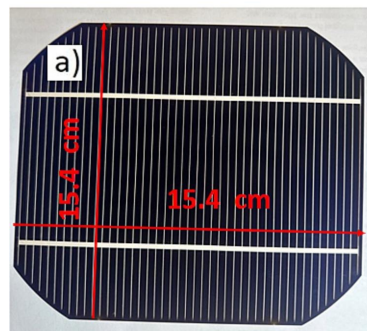
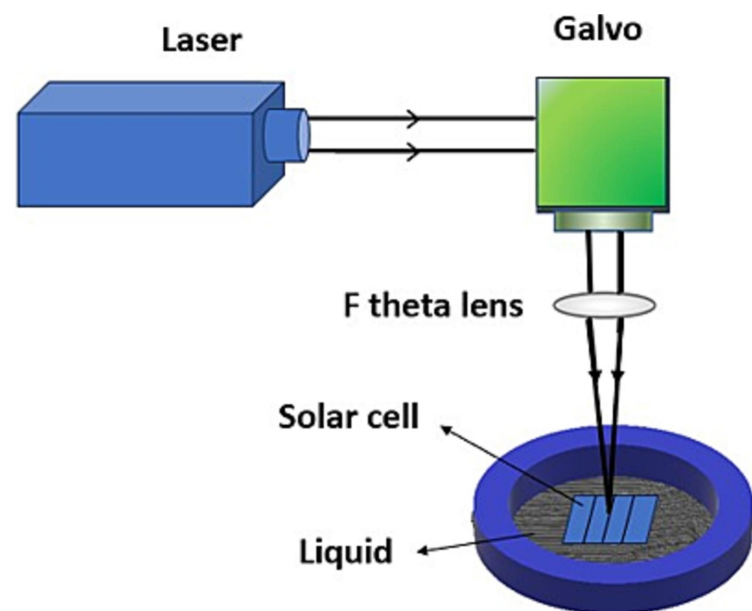
- Technique used in electronics recycling
- Already used by some solar recycling companies
- Separates materials based on conductivity



EMERGING ECO-FRIENDLY RECYCLING METHODS

Laser debonding

- Laser radiation is a localized heat source
- Materials are melted and separated based on differences in thermal expansion
 - In this paper: Silicon (Si), silver (Ag)
- Process can be automated



Prof. Mool Gupta

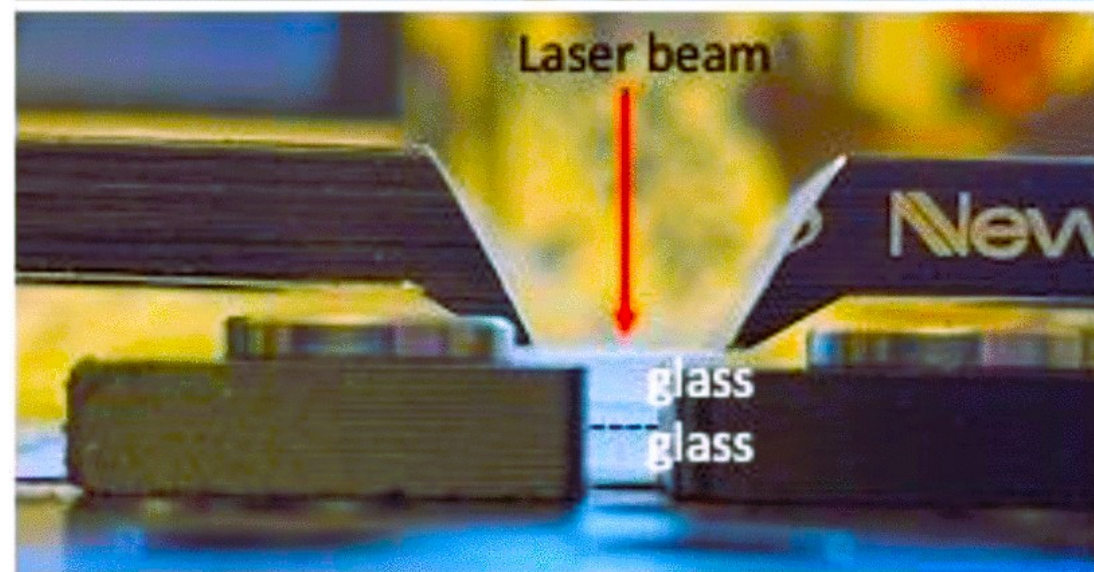
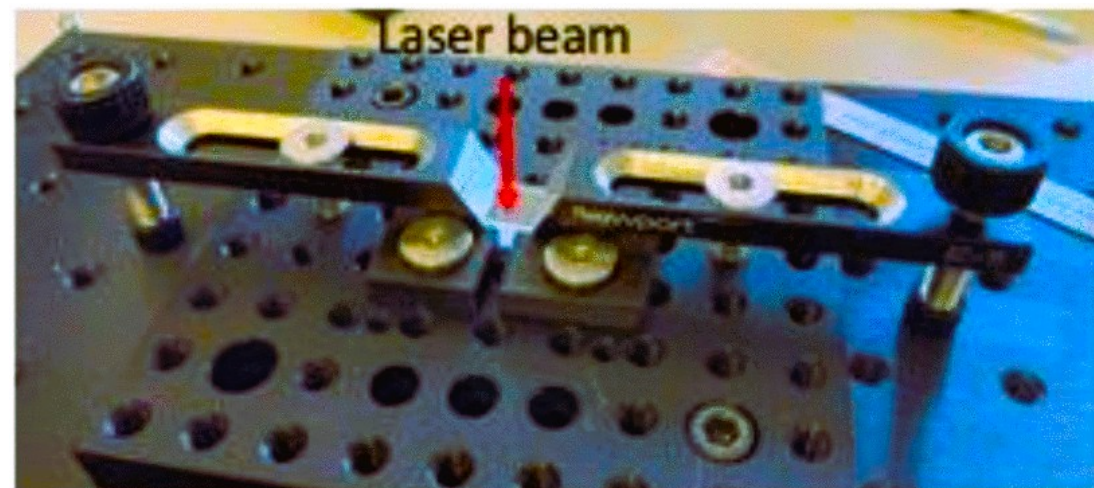




Laser welding for glass/glass solar modules

- Eliminates the need for polymer encapsulant
 - the hazardous procedures required to remove polymers in solar panels become obsolete
- Preliminary results show glass/glass welding provides better environmental protection for the module and enhanced insulation from heat

Next Steps: apply laser welding to full-scale solar module



CONCLUSIONS



Field visit to Picuris Pueblo, NM



- Tribal solar energy is rapidly expanding—soon many tribes will have to figure out what to do with end of life (EOL) panels
- A hazardous waste expert should assess the damaged panels for leaching toxic metals prior to recycling or disposal
- There are many solar panel recycling companies nationwide, but costs for services vary greatly
- Though current methods of recycling panels are not fully sustainable, research into “greener” recycling processes are ongoing

THANK YOU FOR
LISTENING!

ANY QUESTIONS?