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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

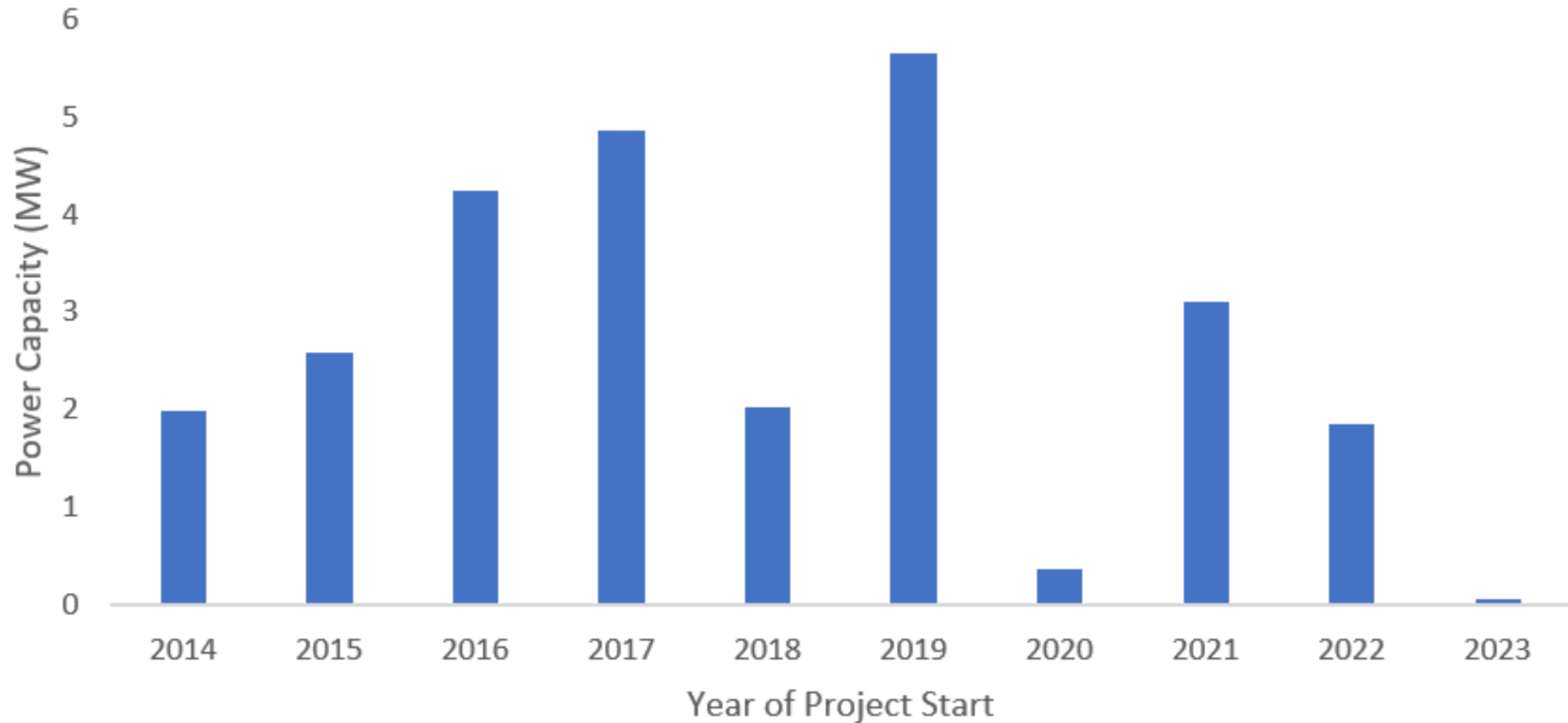


Stock photo

DOE-SPONSORED TRIBAL SOLAR ENERGY IS EXPANDING

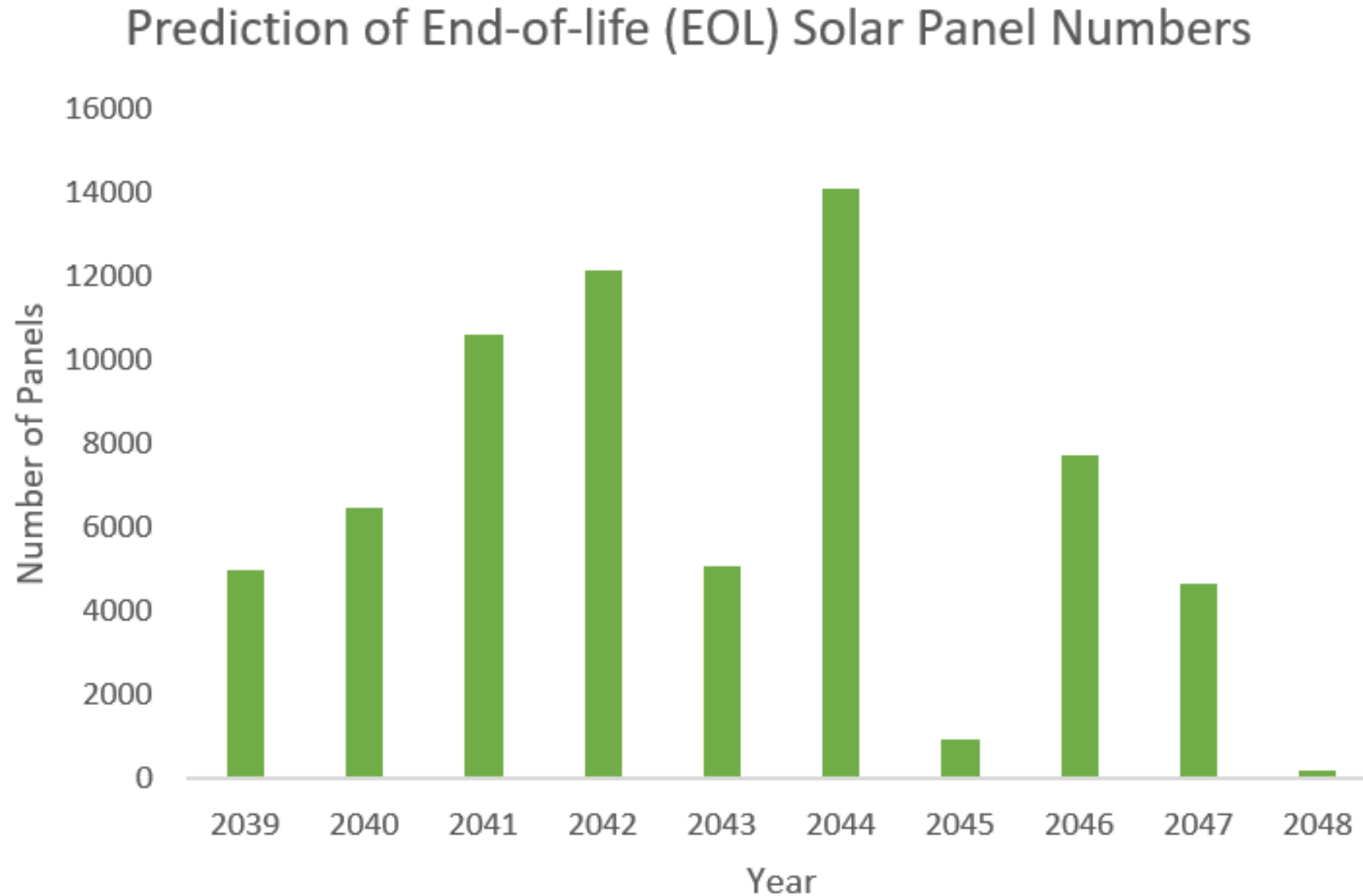


Total Installed Capacities of Solar Projects in Indian Country



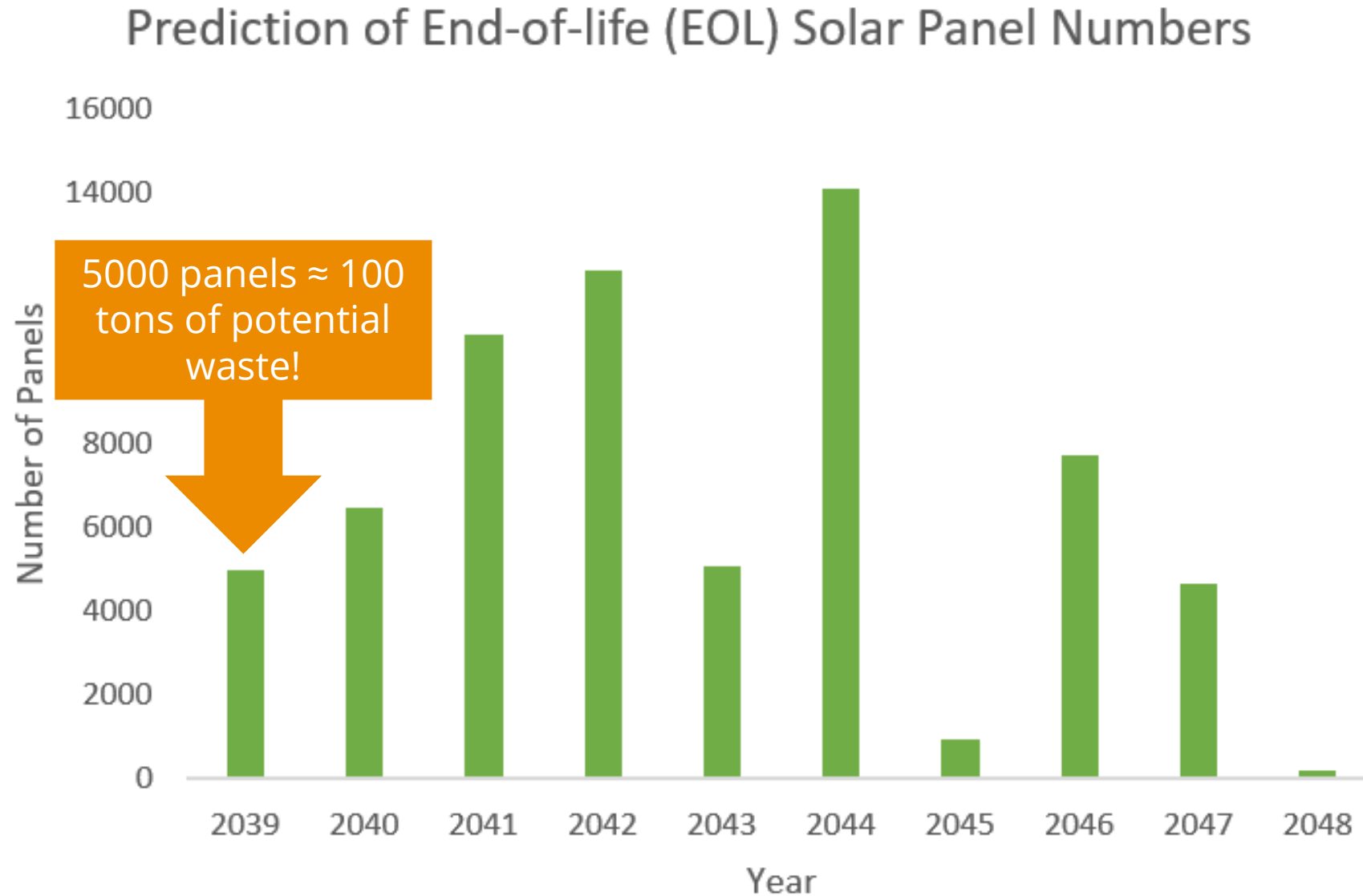
Data estimated from: Indian Energy (IE) Office website; only projects funded by DOE IE

MANAGING SOLAR PANEL WASTE IS AN IMMINENT ISSUE



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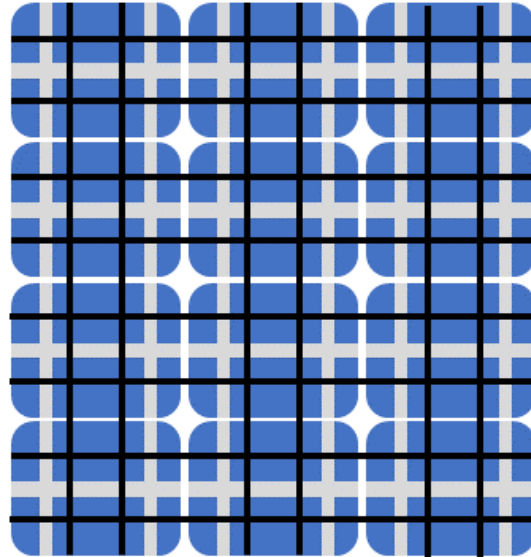
A REVIEW OF SOLAR (TOP-DOWN VIEW)

A solar system is arranged like a beehive:

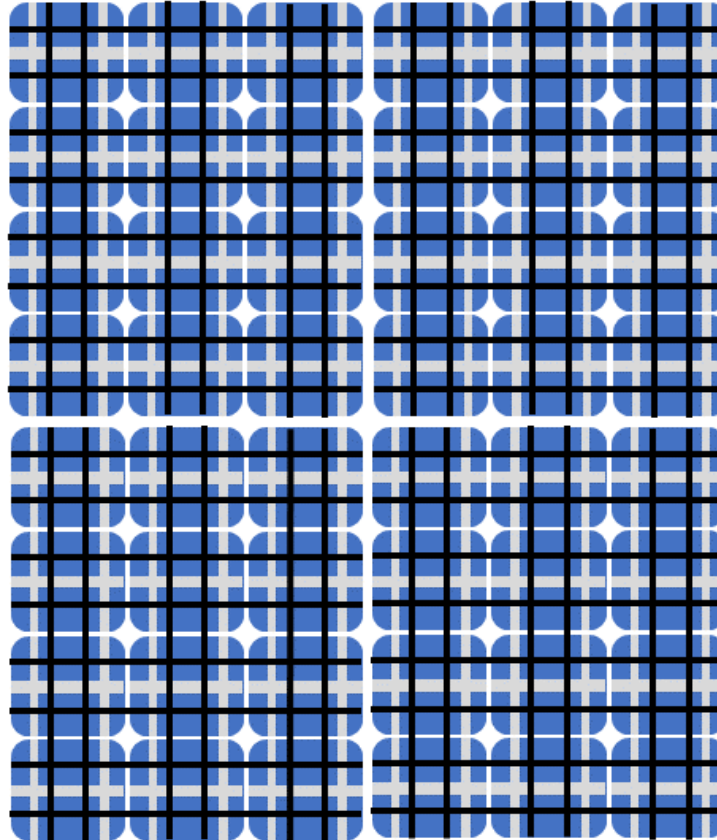
Solar Cell



Solar Module

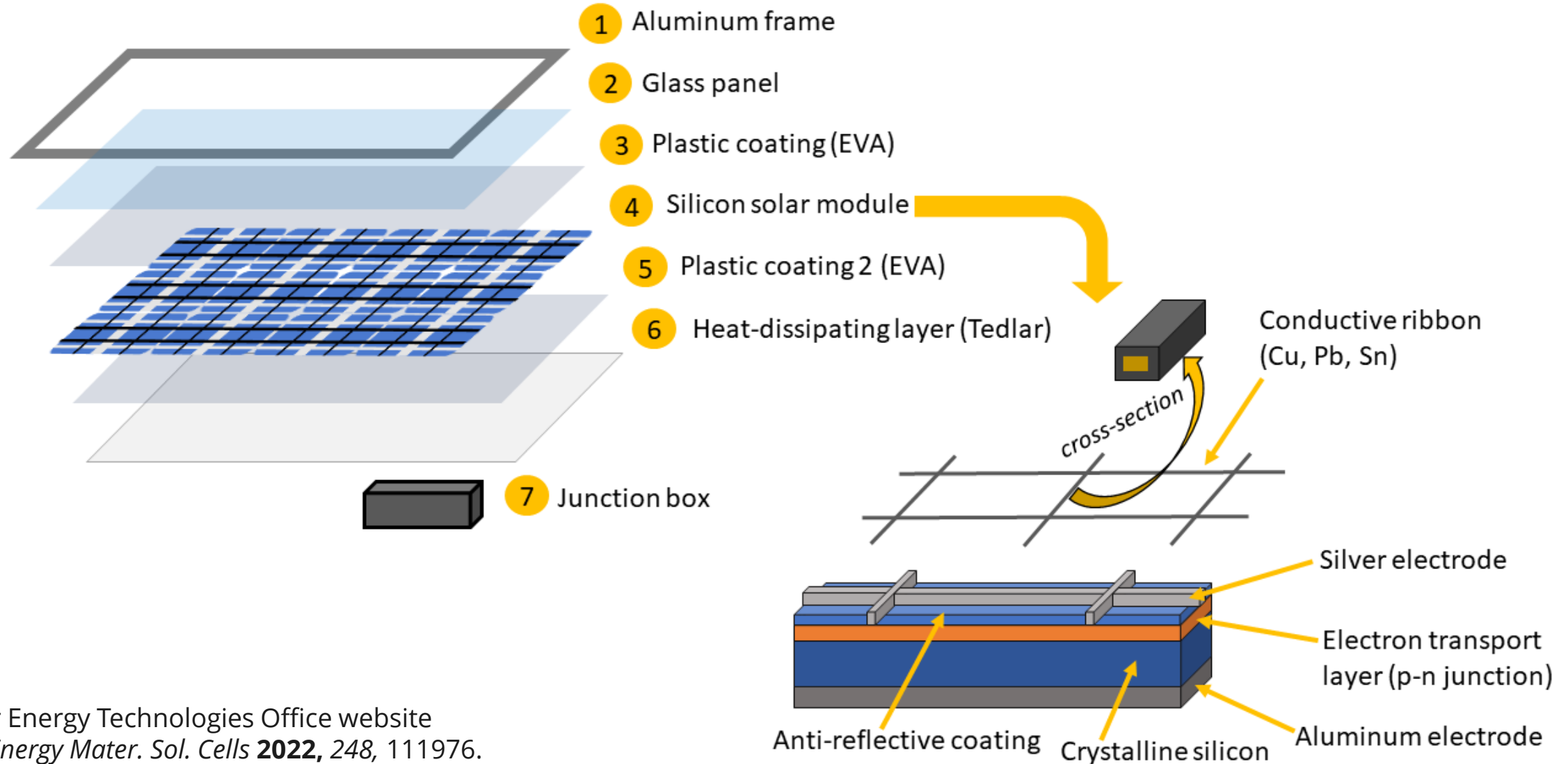


Solar System



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

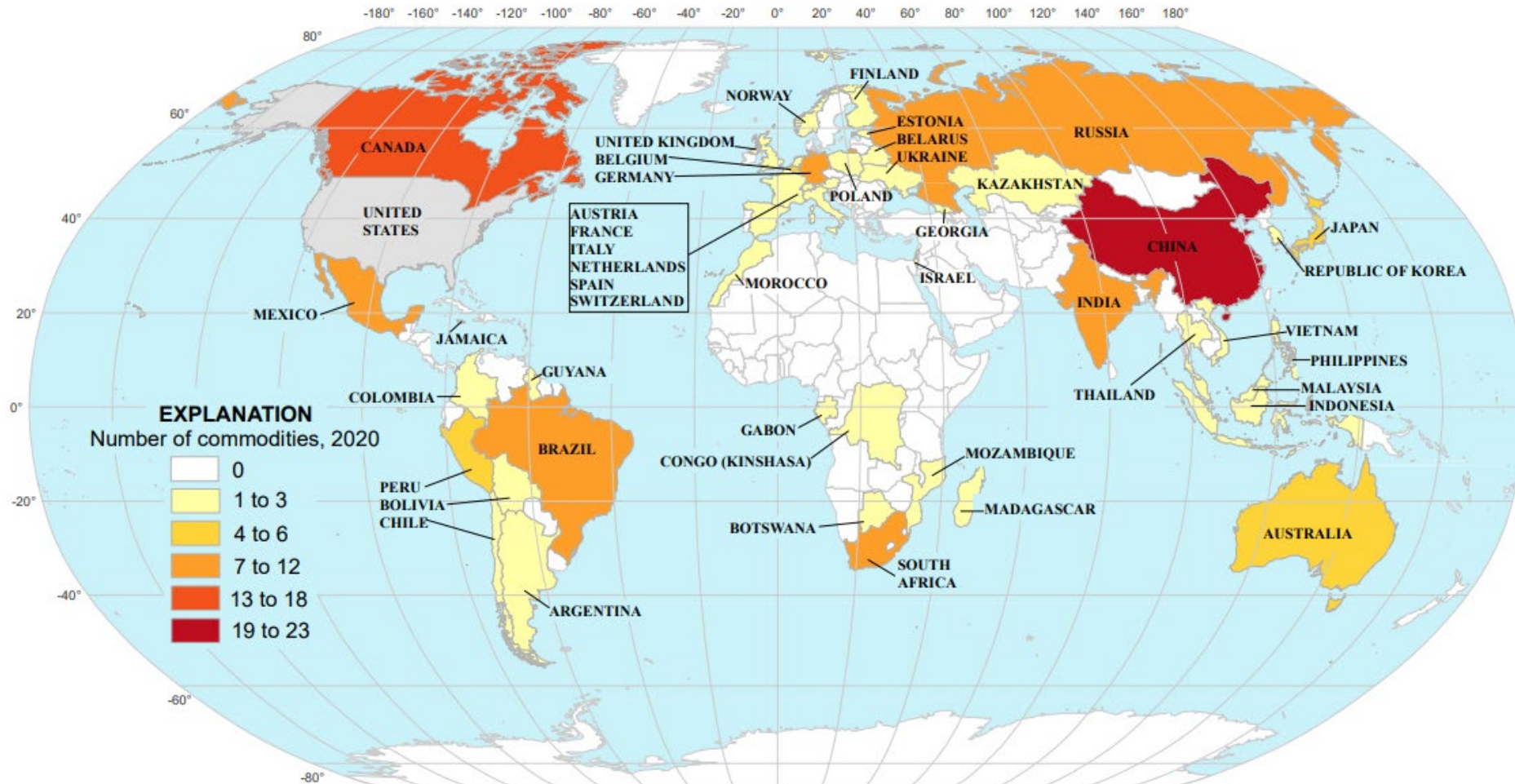
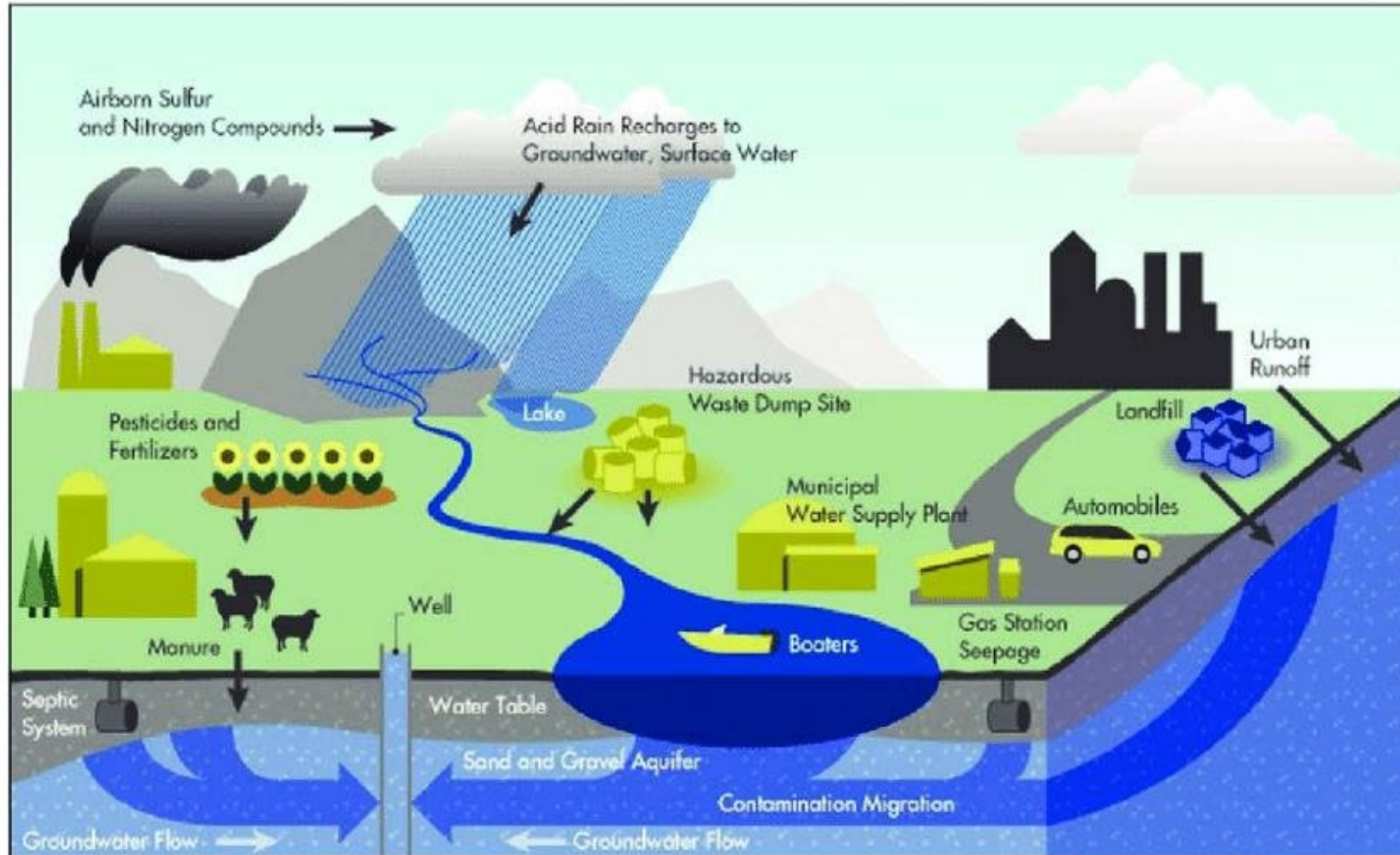


Figure 3.—Major Import Sources of Nonfuel Mineral Commodities for which the United States was greater than 50% Net Import Reliant in 2020

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



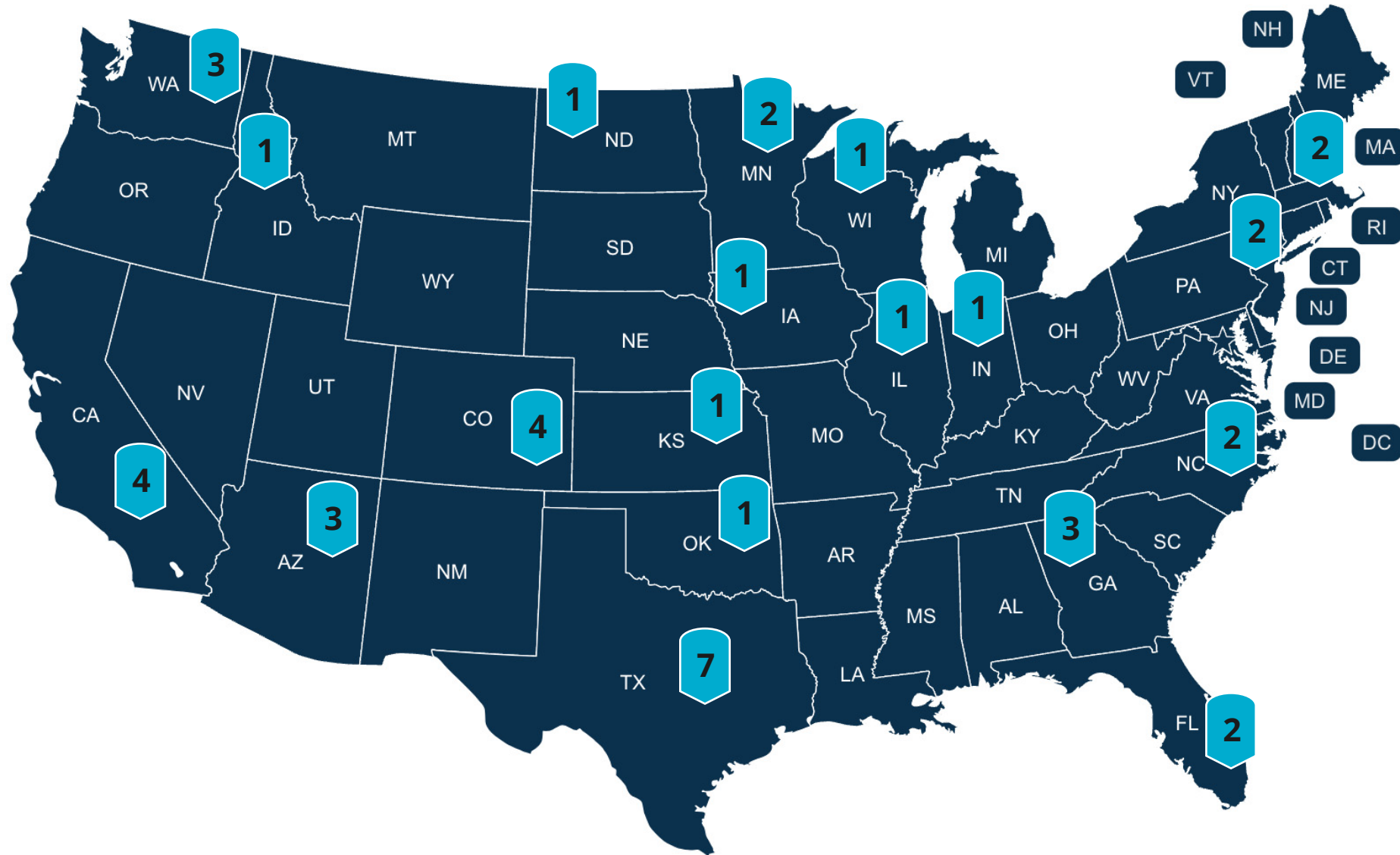


AN OPTION FOR EOL PANELS: RECYCLING

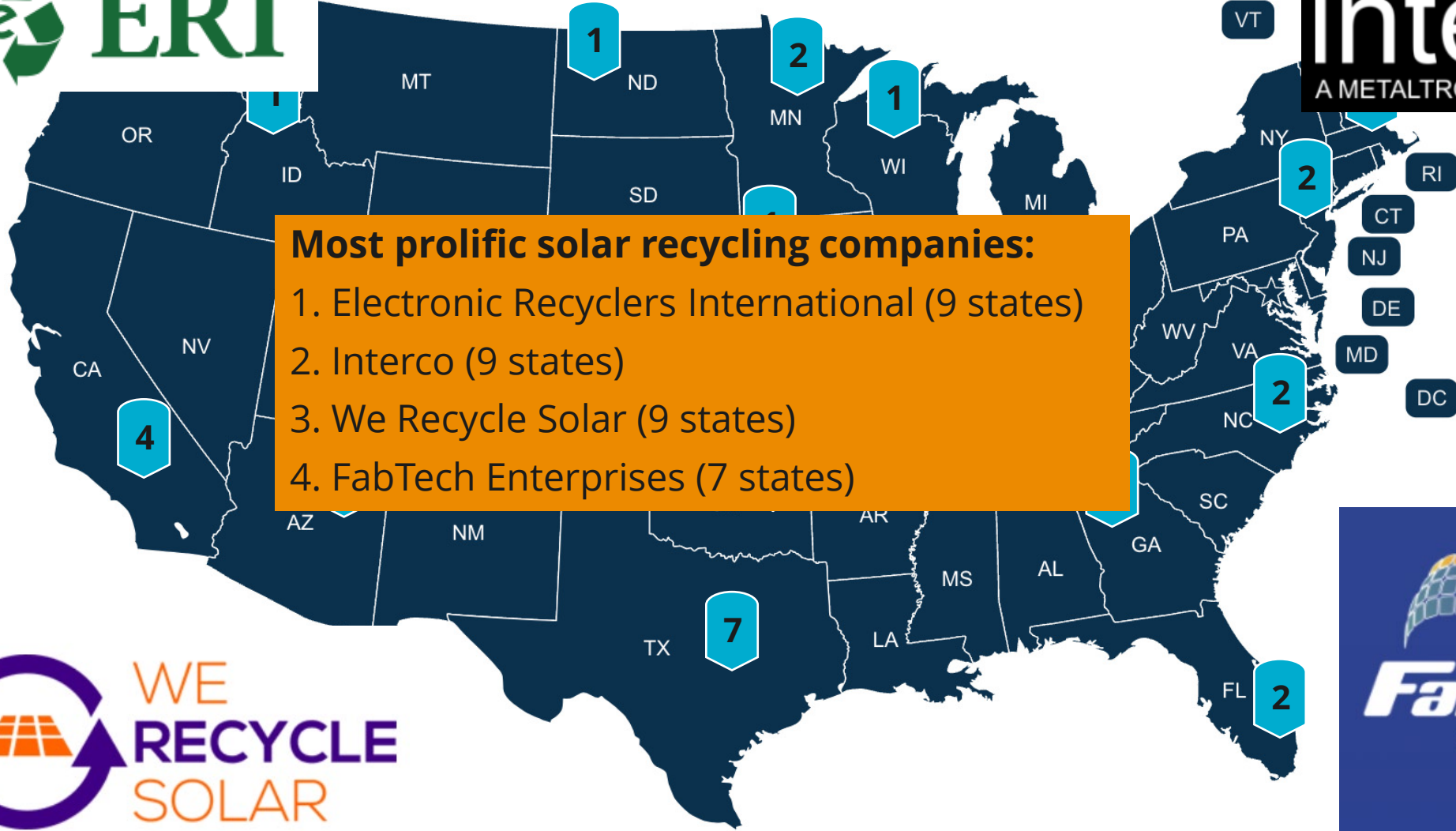
Most materials in a solar panel are readily recyclable:

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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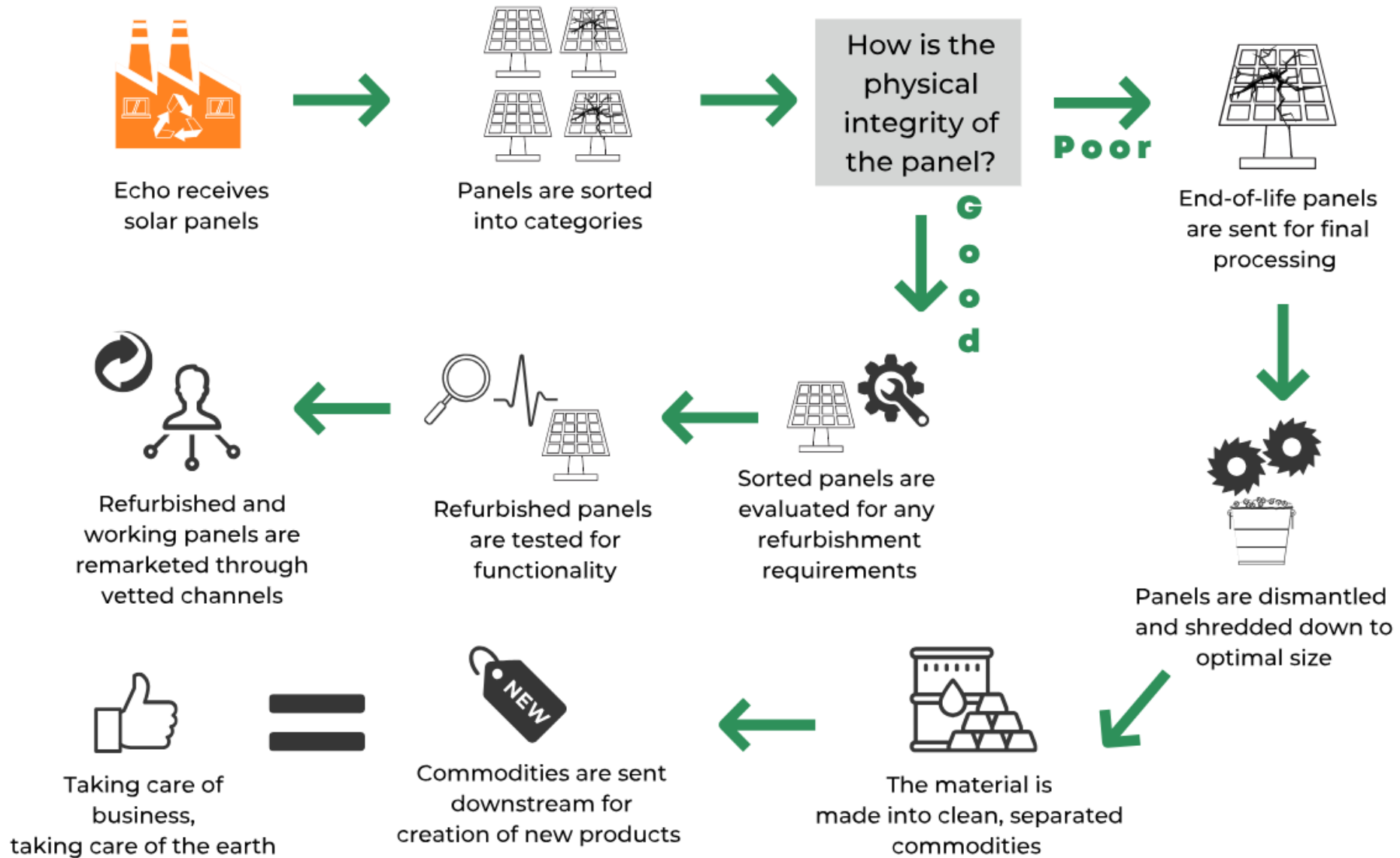


Most prolific solar recycling companies:

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

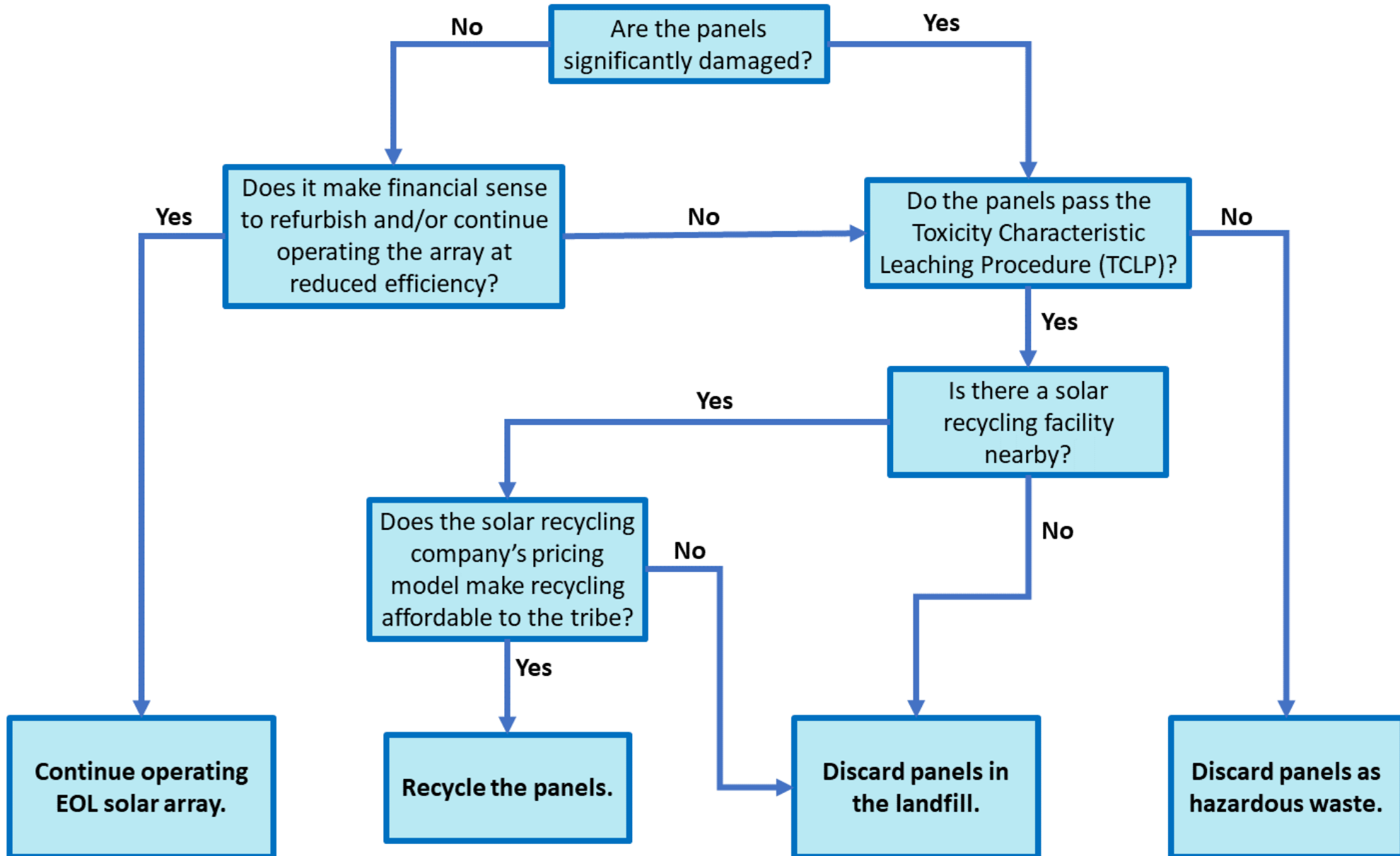
- Most companies will charge for panel palletizing, loading, and shipping
 - Save money by dismounting and palletizing panels yourself
 - Find a company located close to you to minimize shipping costs



Stock photo – palletized solar panels



Evaluating Options for EOL Solar

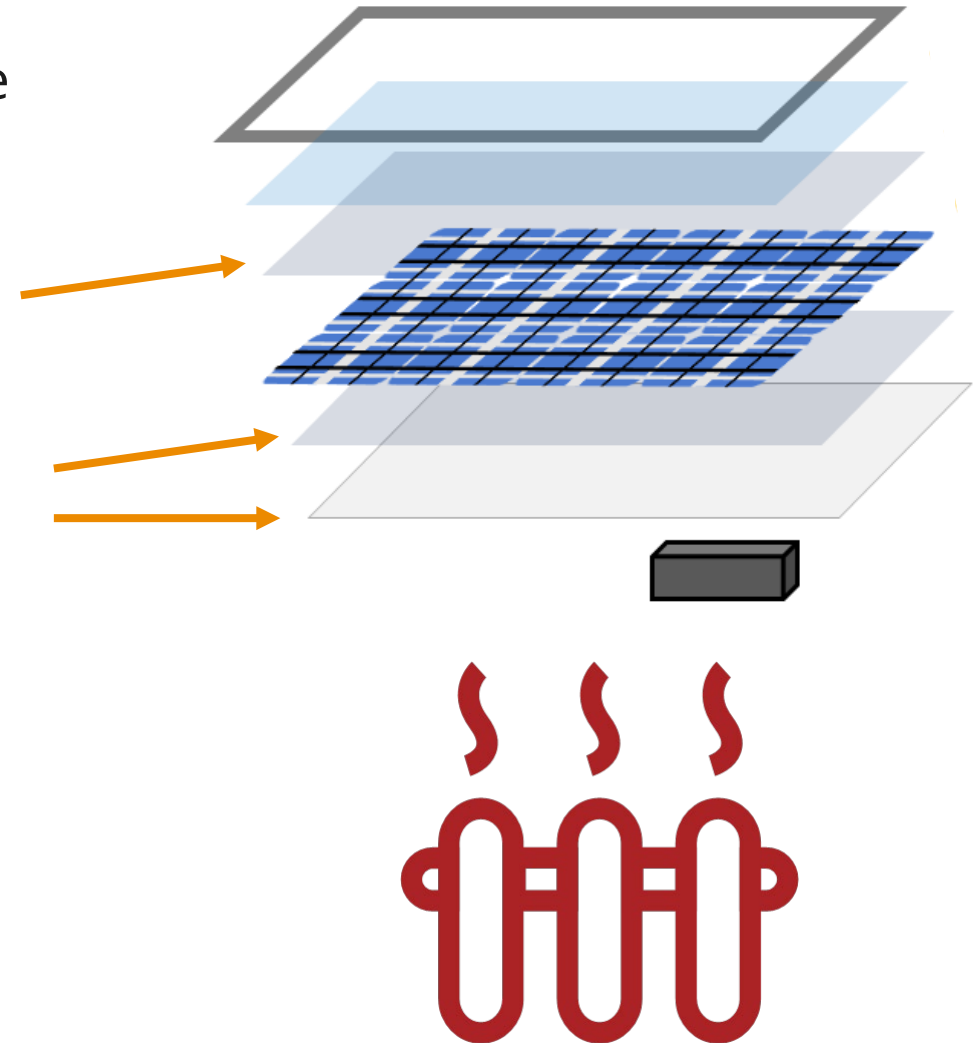


CURRENT SOLAR PANEL RECYCLING METHODS ARE UNSUSTAINABLE AND HAZARDOUS



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:

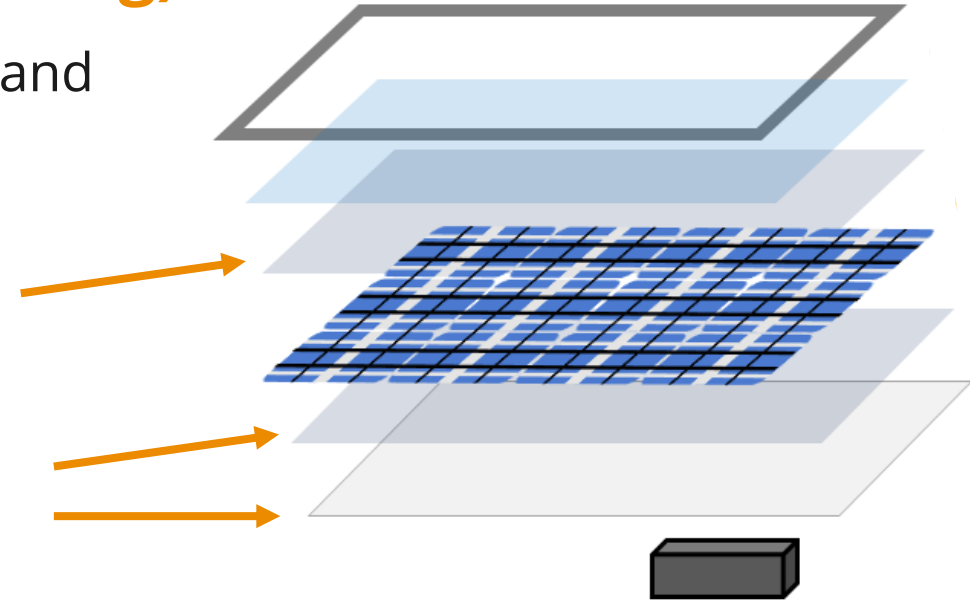
- Toluene



- Hexane



- Environmentally friendly alternative: ethanol/potassium hydroxide



CURRENT SOLAR PANEL RECYCLING METHODS ARE UNSUSTAINABLE AND HAZARDOUS

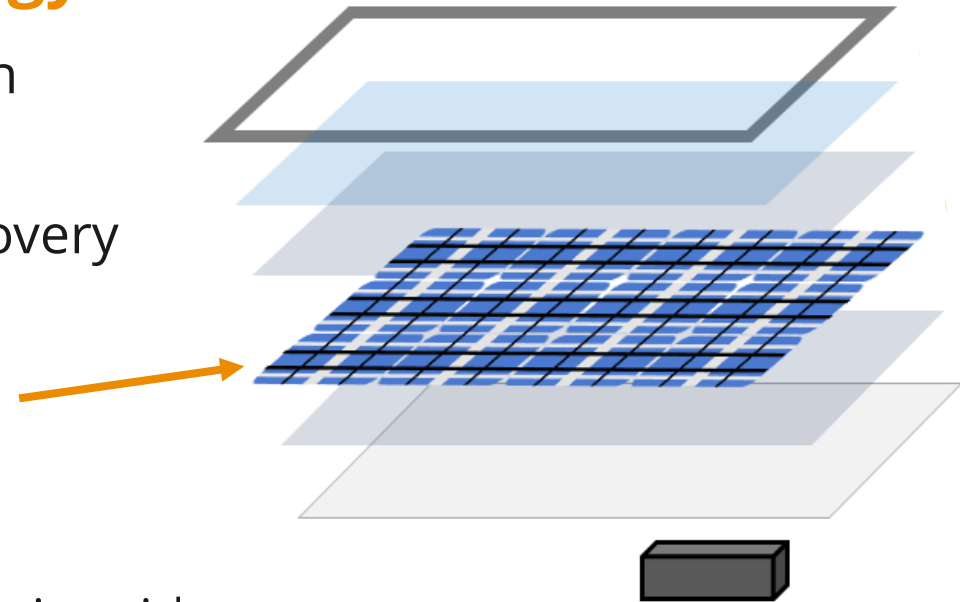


Chemical etching and hydrometallurgy

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



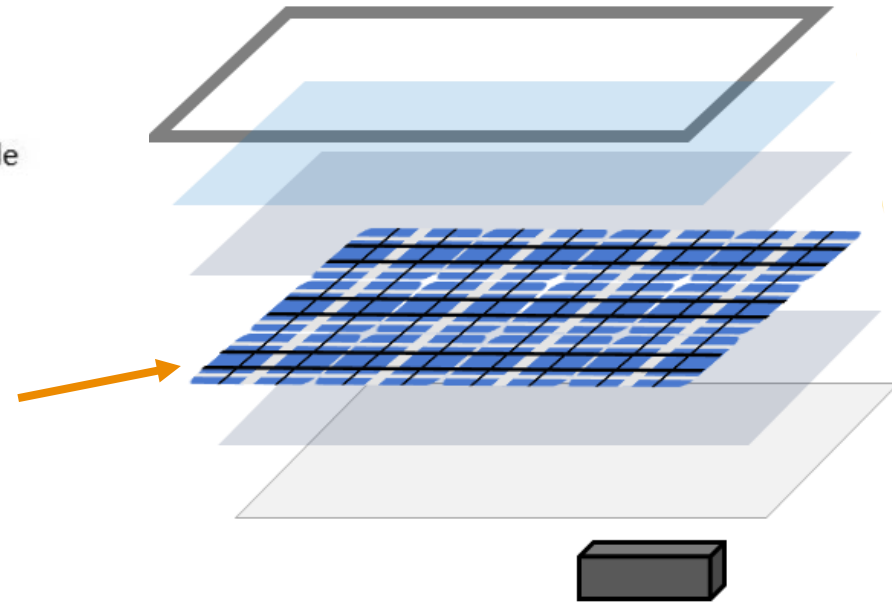
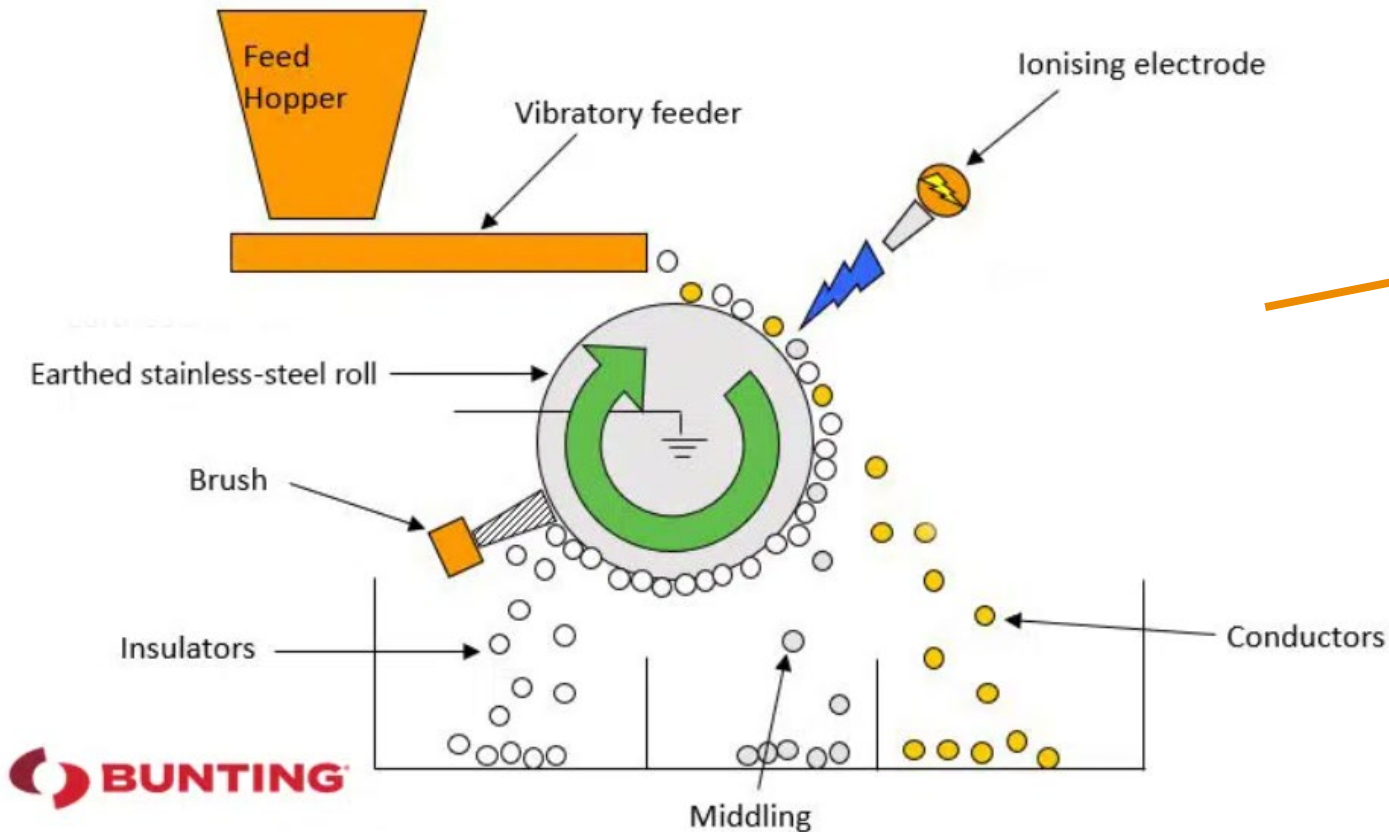
- Hydrometallurgy is used to recover silver ions
 - uses nitric acid, sodium chloride, hydrochloric acid, and sodium hydroxide





Electrostatic separation

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



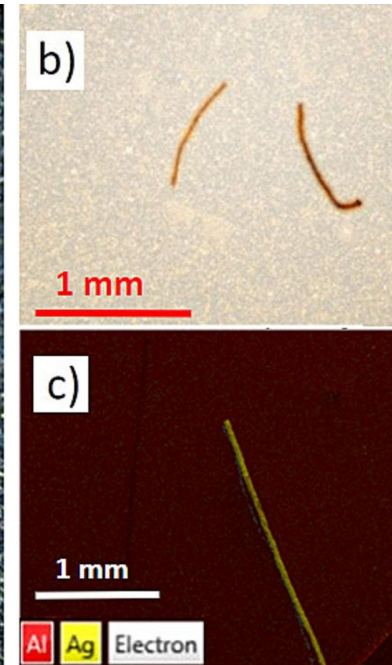
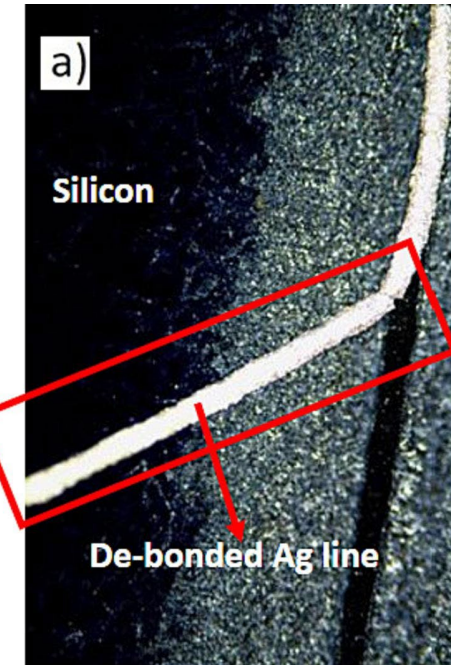
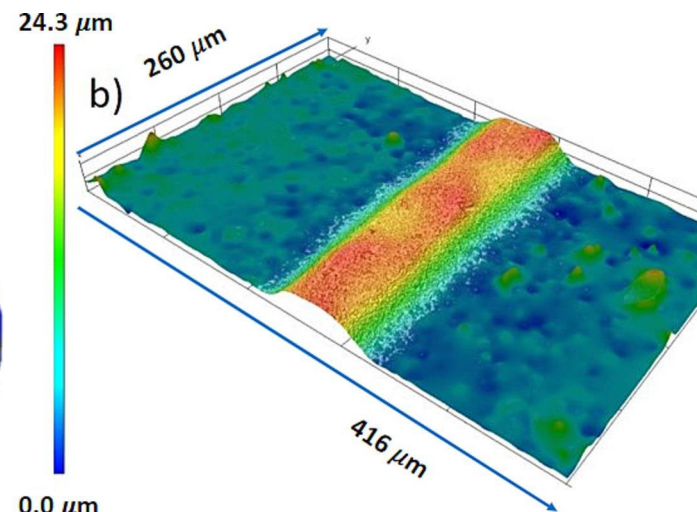
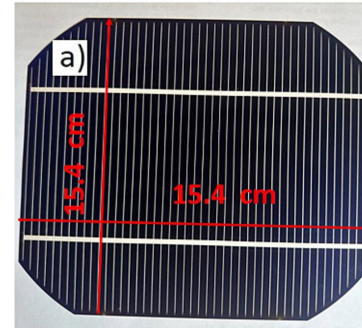
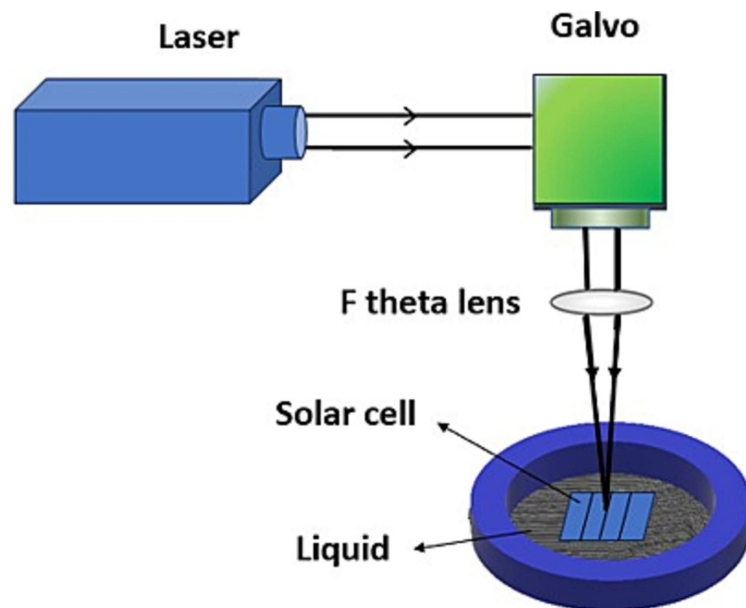
EMERGING ECO-FRIENDLY RECYCLING METHODS

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

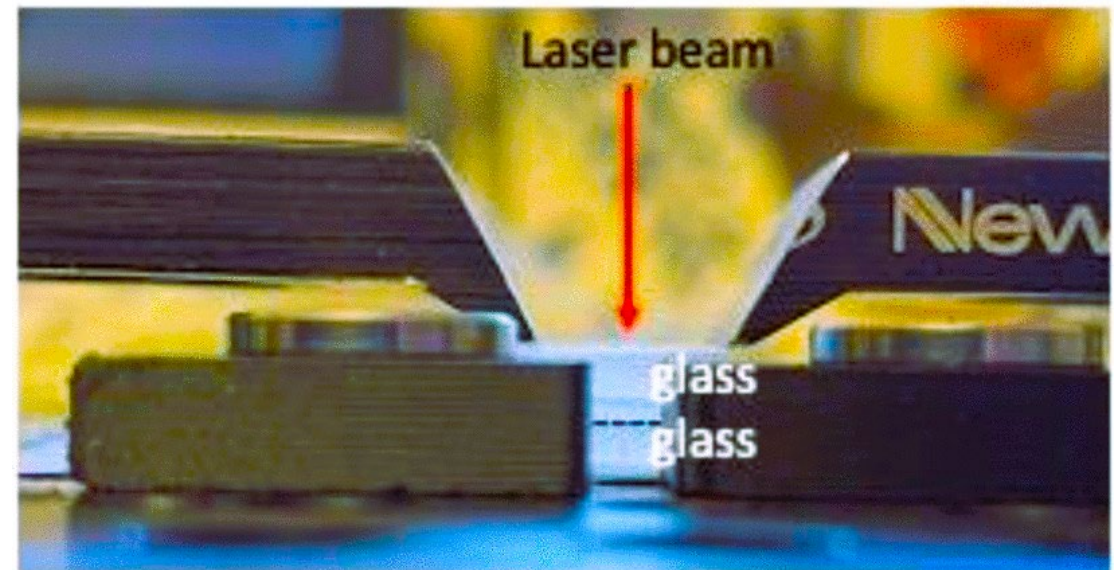
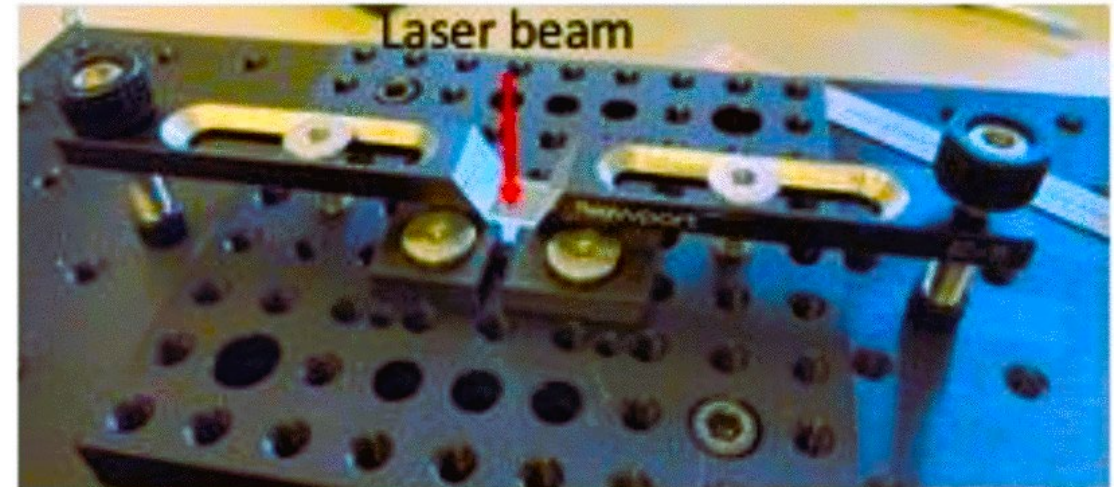




Laser welding for glass/glass solar modules

- 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?