Synthesis of literature describing novel PV recycling technologies

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Overview

Goal

To compliment the review of patents and government R&D recently published by Task 12, a review of the scientific literature was conducted to inform the a detailed techno-economic assessment of crystalline Si PV recycling operations.

Task

Review 50+ literature sources (63 data points) that proposed novel recycling technologies for mono, multi and amorphous silicon PV systems.

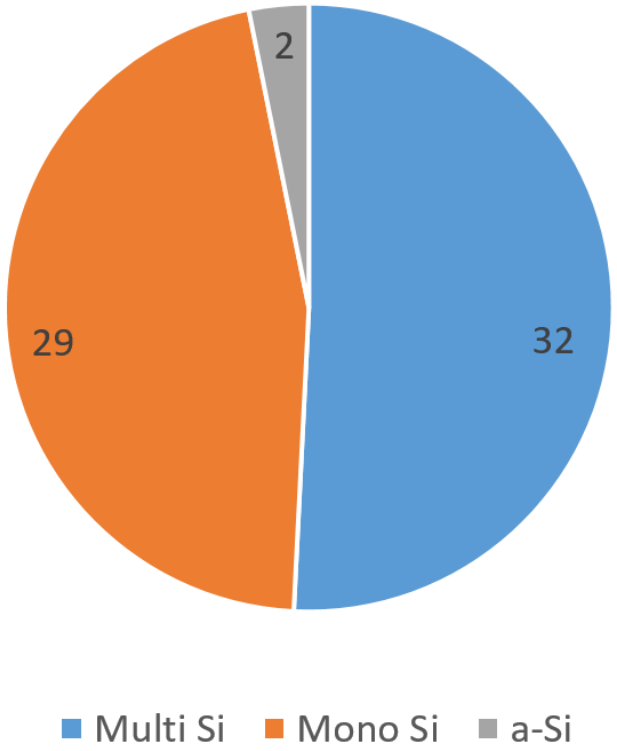
Method

Literature review was organized around 113 techno-economic parameters which included

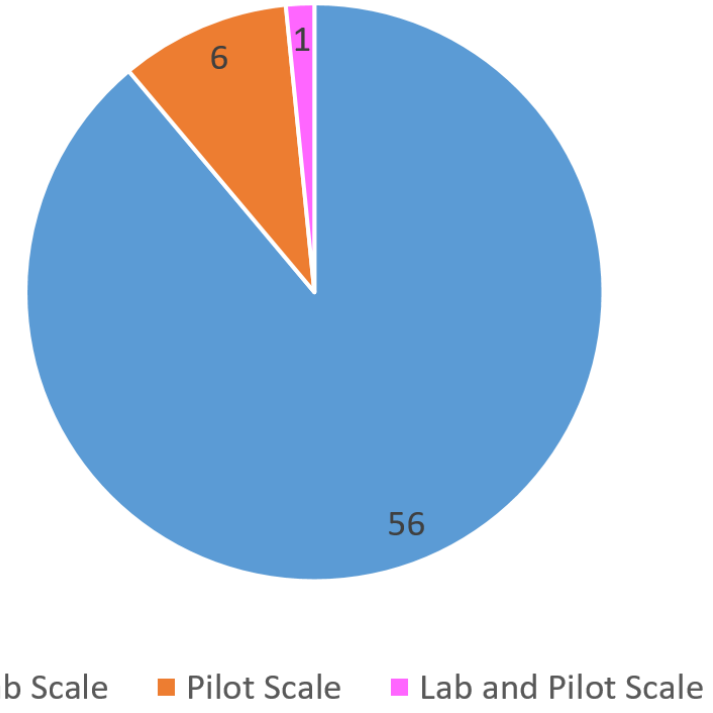
- recycling process,
- module components recycled,
- material and energy requirements,
- material recovery rates,
- value of recovered materials
- material purity, and
- downstream process requirements.

Si PV module type recycled and scale of operations (lab versus pilot)

Total number of data points = 63

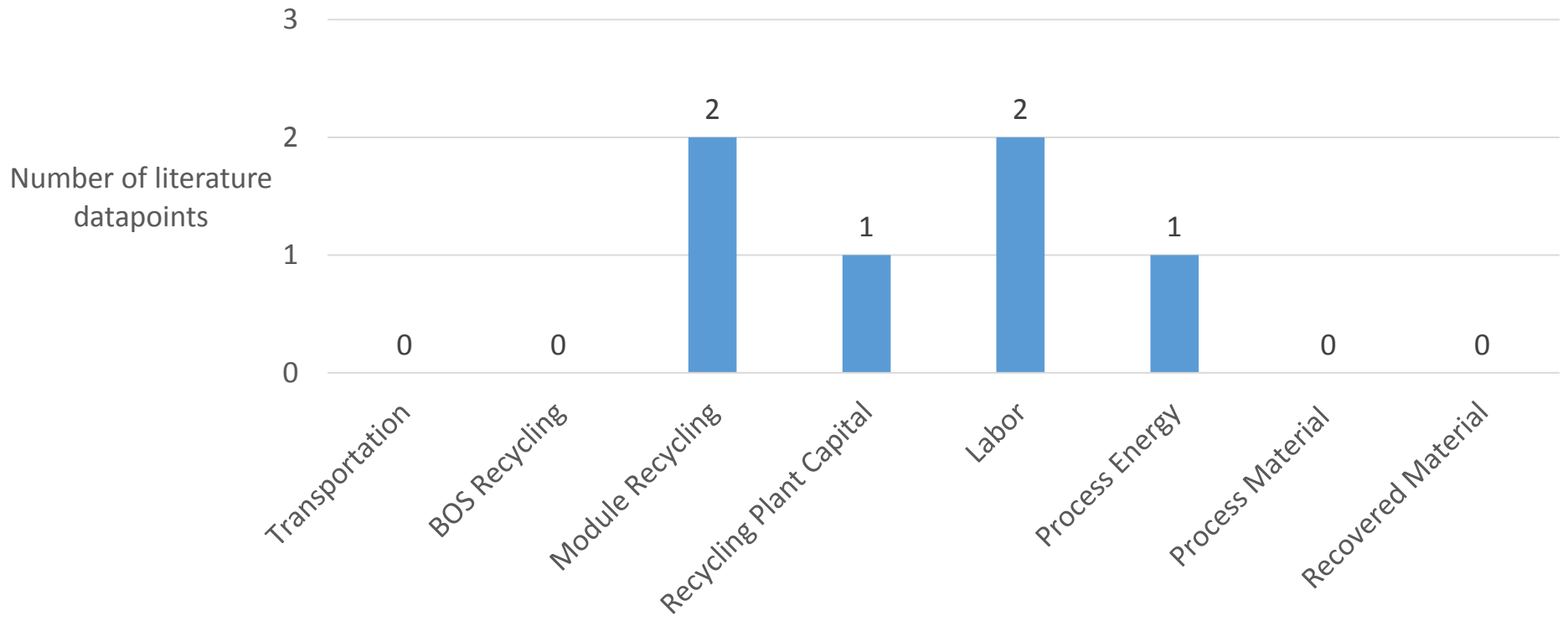


Recycling technologies for multi-Si can be applied to mono-Si



Scaling effect, and inventory data and technology parameter uncertainty should be accounted for given the lack of industrial experience with most proposed processes.

There is no good quality, publicly available costing data for Si PV recycling

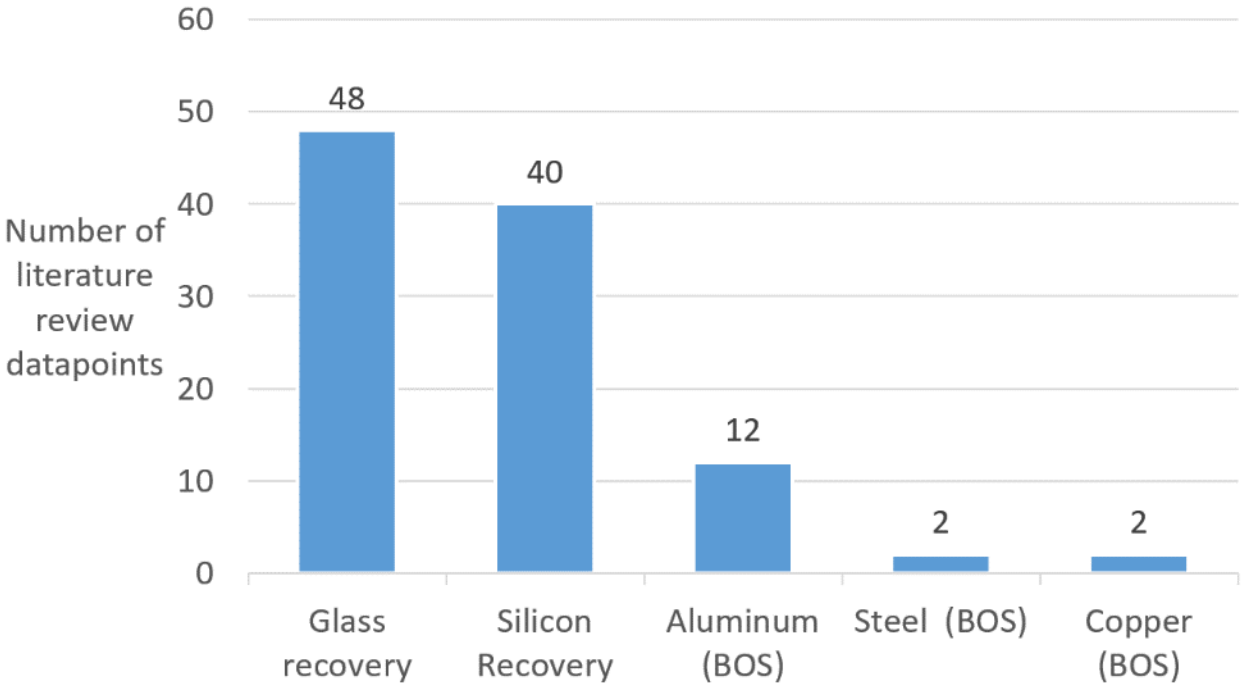


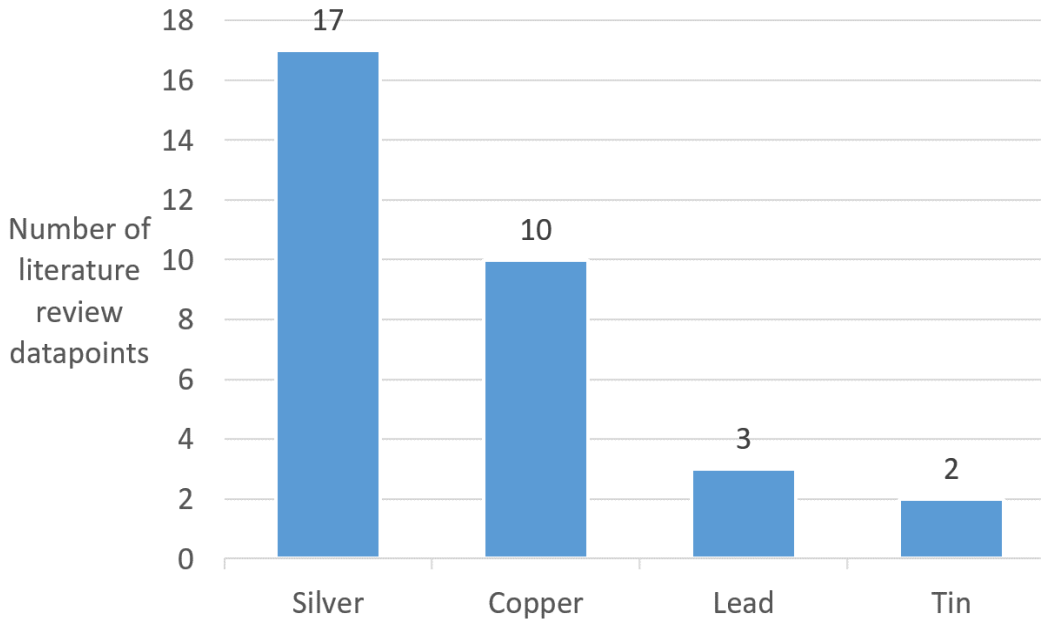
Total of 63 data points

Lack of data for multiple aspects of Si PV recycling process

Paucity in data for an integrated Si PV recycling process

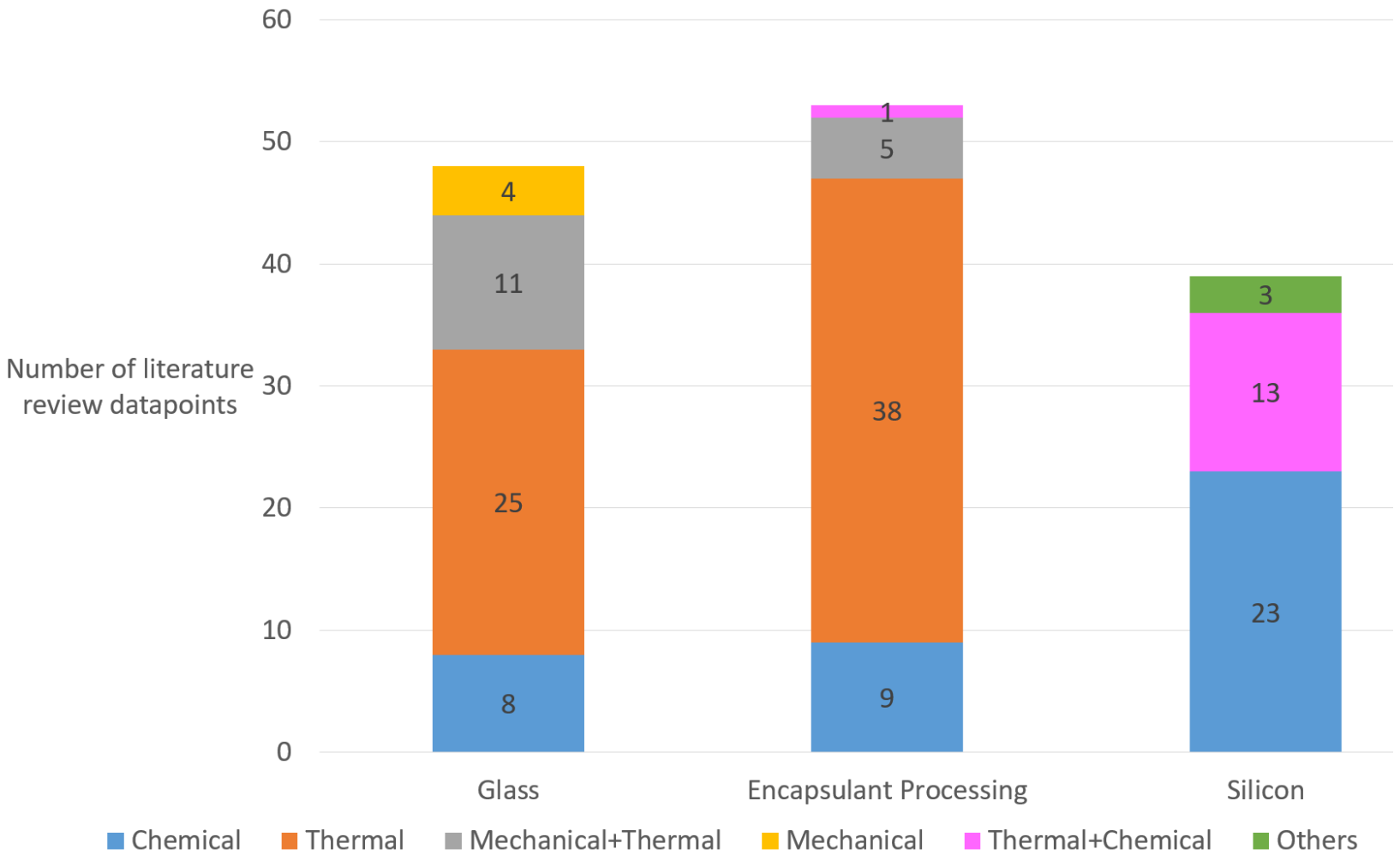
Total of 63 data points



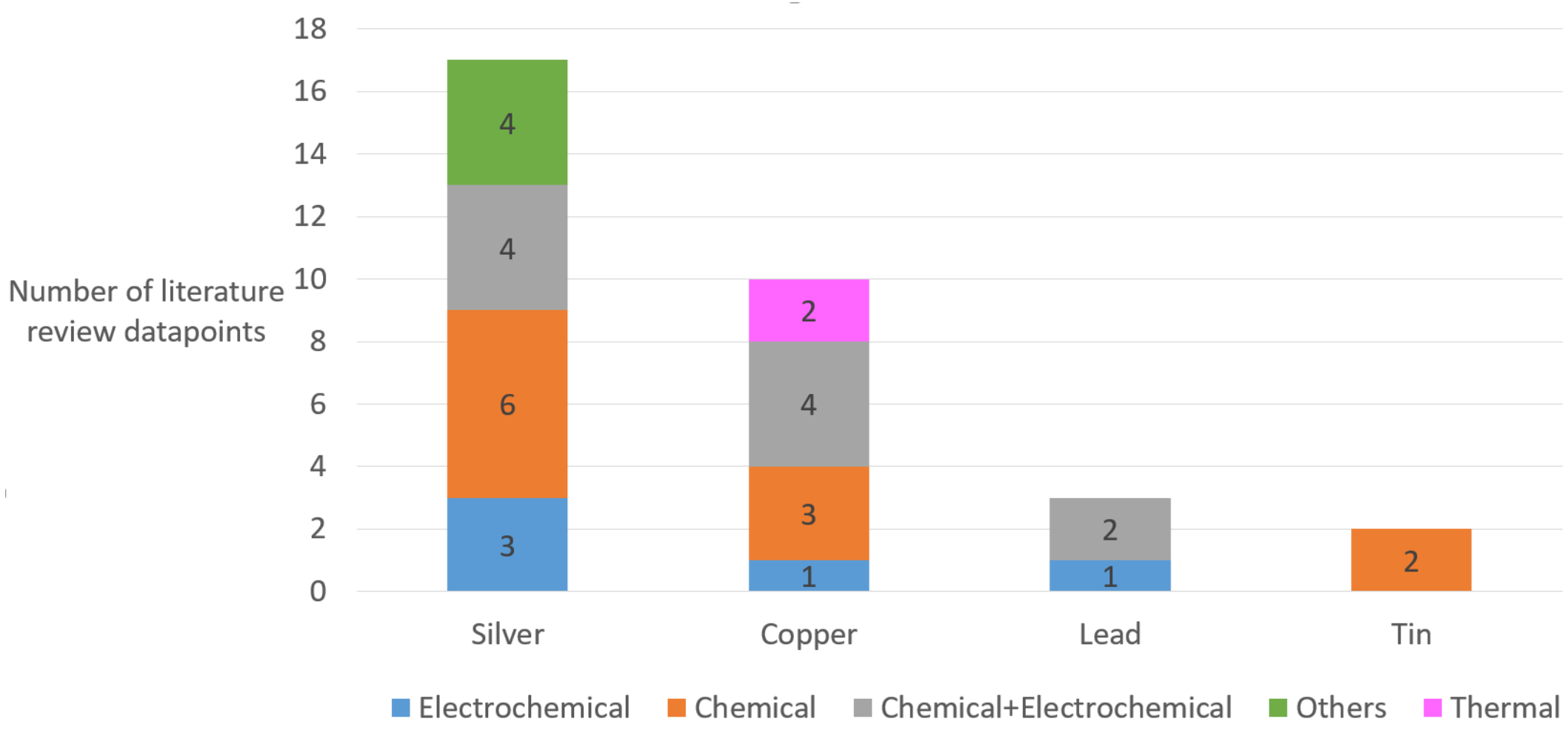


Only two studies include recycling of all the bulk AND specialty materials

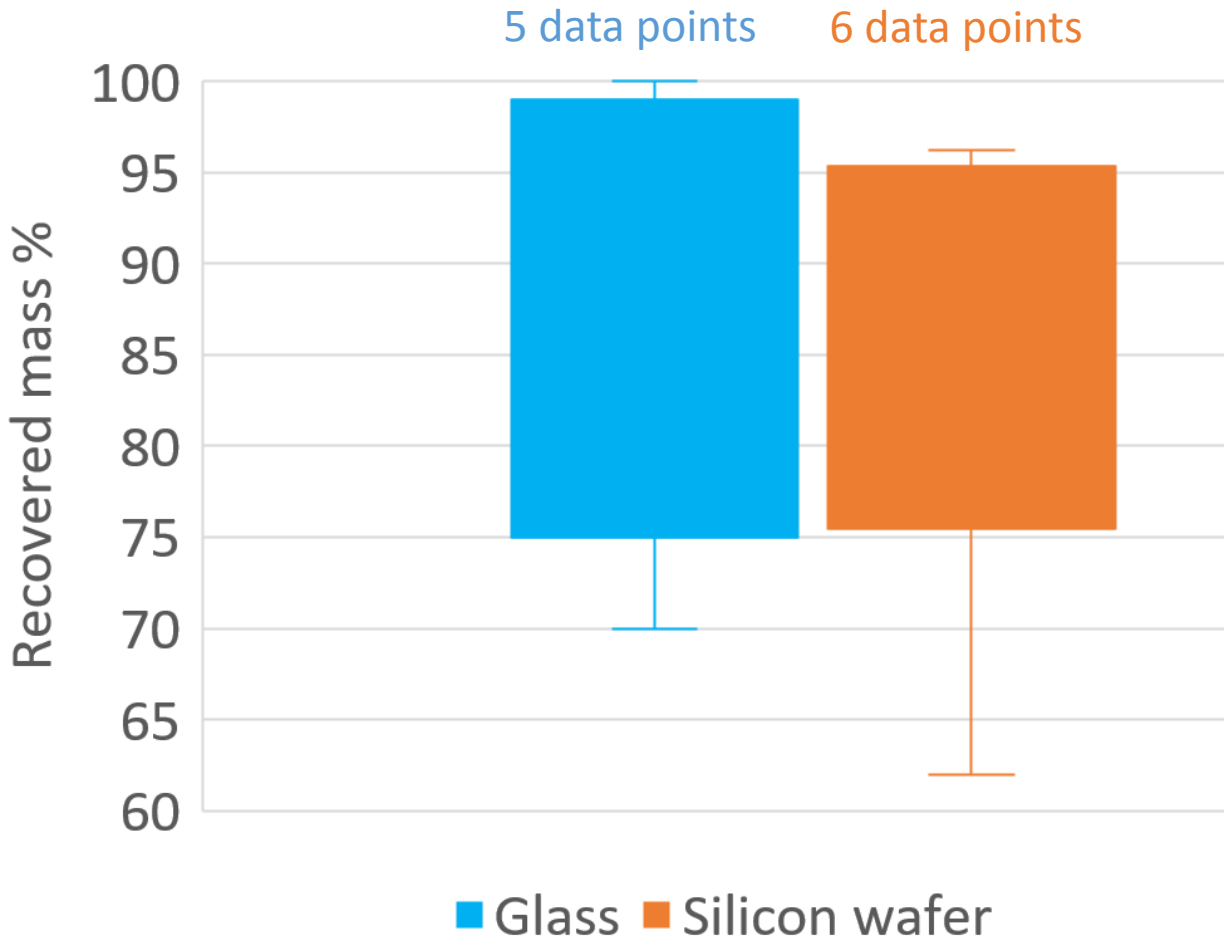
Recycling processes for bulk materials



Recycling processes for specialty materials



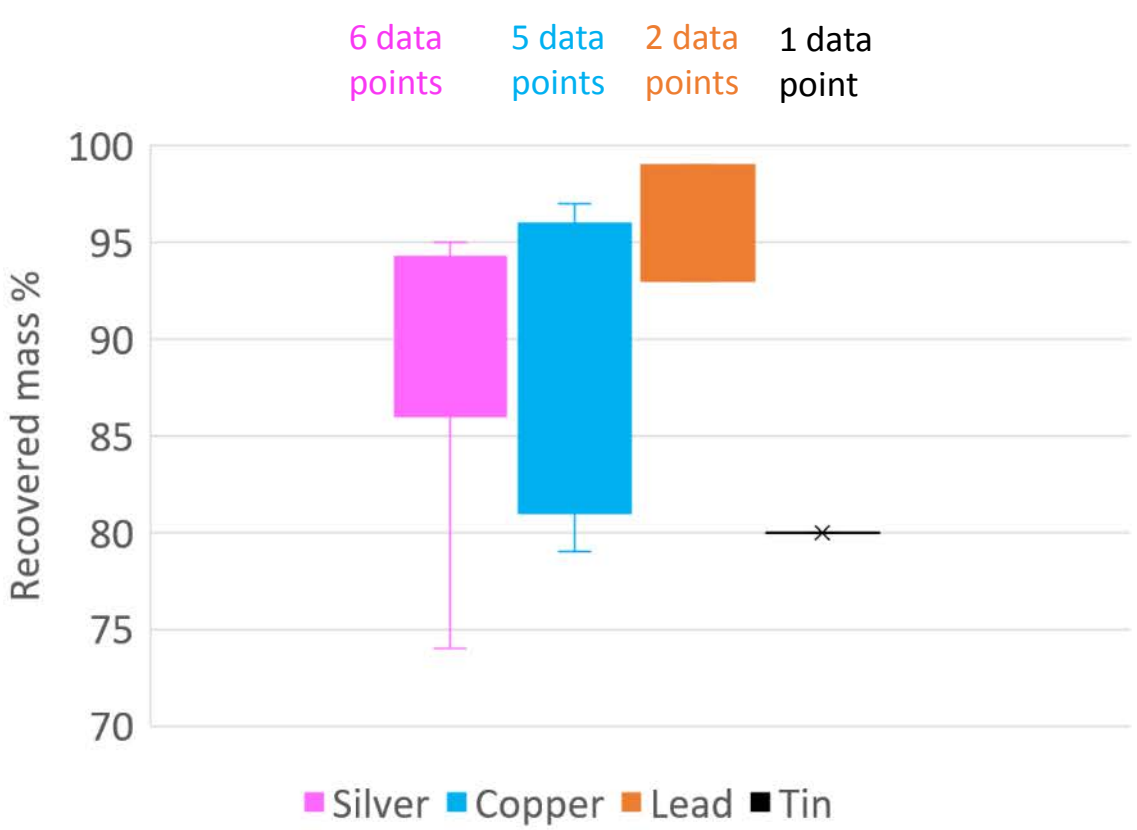
Glass and Si wafer recovery

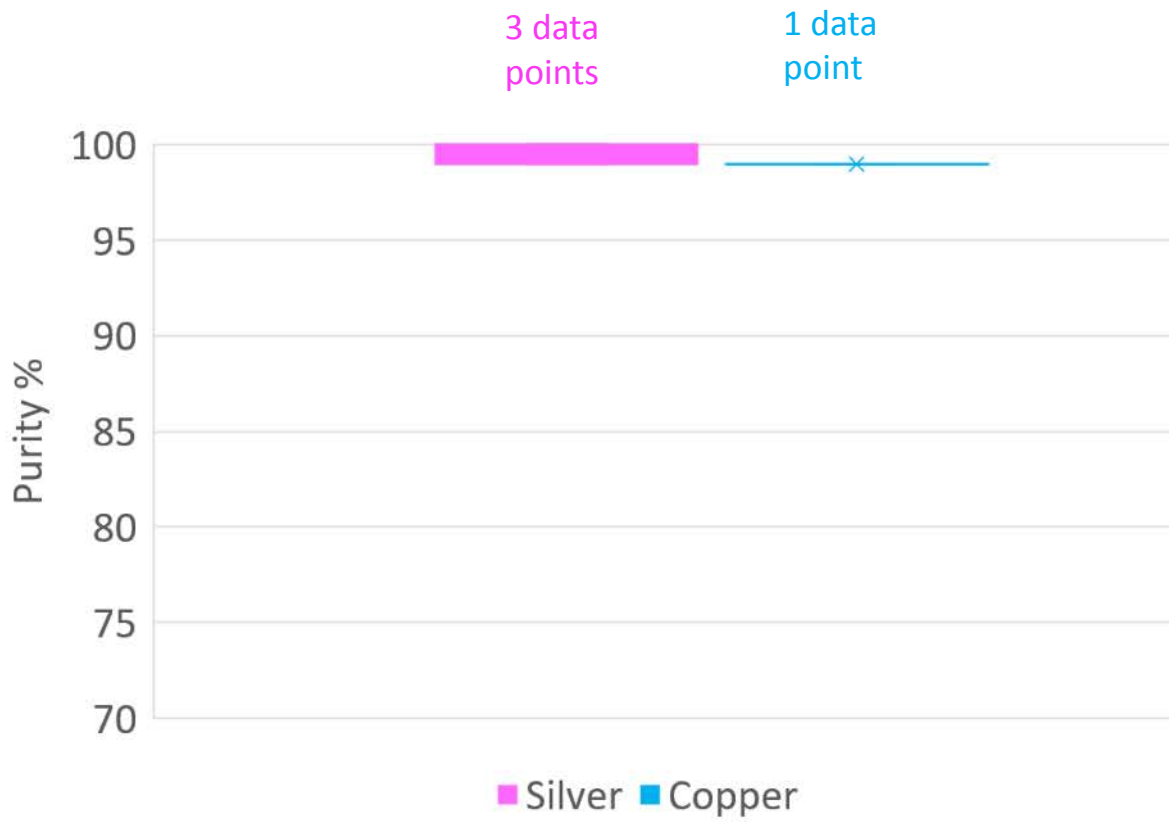


The 4 studies that recovered 100% of the glass used the thermal+chemical process. One of these studies recovered glass in an intact form.

Among the 5 studies that recovered greater than 90% of the Silicon wafer, 3 used a chemical process and 2 used a thermal+chemical process

Recovery efficiency and purity of metals recovered from Si PV recycling

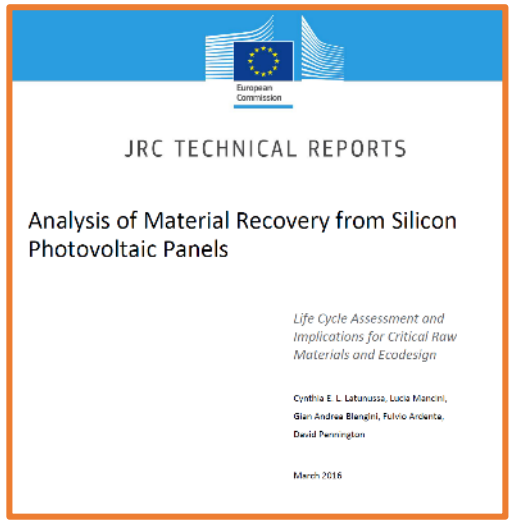




Studies that reported silver and copper recovery efficiencies greater than 90% with purities higher than 99% used an electrochemical process.

No publicly available data on purity of lead and tin that is recovered.

Promising Studies for Techno- economic assessment


European Commission

JRC TECHNICAL REPORTS

Analysis of Material Recovery from Silicon Photovoltaic Panels

Life Cycle Assessment and Implications for Critical Raw Materials and Ecodesign

Cynthia E. L. Latunussa, Lucia Mancini, Gian Andrea Blengini, Fulvio Ardente, David Pennington

March 2016

Advantages

- Energy and material data for recovery of bulk materials, and silver and copper

Disadvantages

- No data for tin and lead recovery
- Silicon is downgraded to metal grade
- Potential leaching of lead since not recovered


Contents lists available at ScienceDirect

Solar Energy

journal homepage: www.elsevier.com/locate/solener

ELSEVIER

Strategy and technology to recycle wafer-silicon solar modules

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[a] School for Engineering of Matter, Transport and Energy, Arizona State University, Tempe, AZ 85287, USA
[b] School of Electrical, Computer and Energy Engineering, Arizona State University, Tempe, AZ 85287, USA

Advantages

- Recycling process recovers all the bulk materials, as well as silver, lead, copper and tin

Disadvantages

- Specialty material recovery processes was developed based on an exogenous mixture of metallic compounds, not from actual modules, so applicability of results to modules has not yet been validated
- Use of platinum electrodes may make this process commercially infeasible
- No material and energy inventory data reported

Thank you!

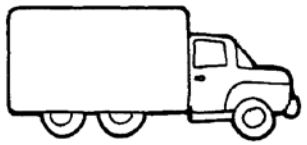
Questions?

PV recycling literature review - system boundary

Energy
Labor
Material

Disassembly

Balance of Systems



Transport

Energy
Labor
Material

crystalline Si
PV panel

Energy
Labor
Material

Delamination

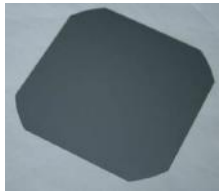
Process type?

Glass

Delaminated
wafer

Energy
Labor
Material

Process
type?



Si wafer

Silver?

Lead?

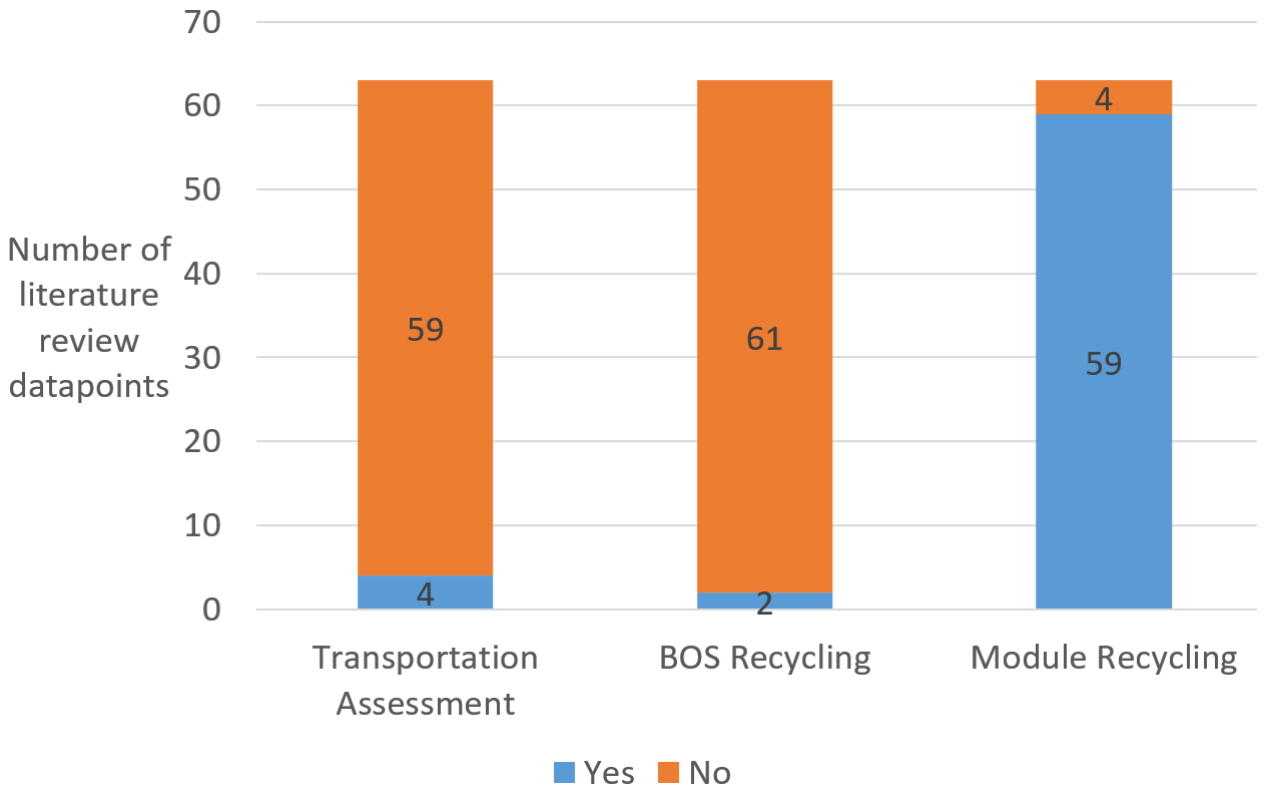
Tin?

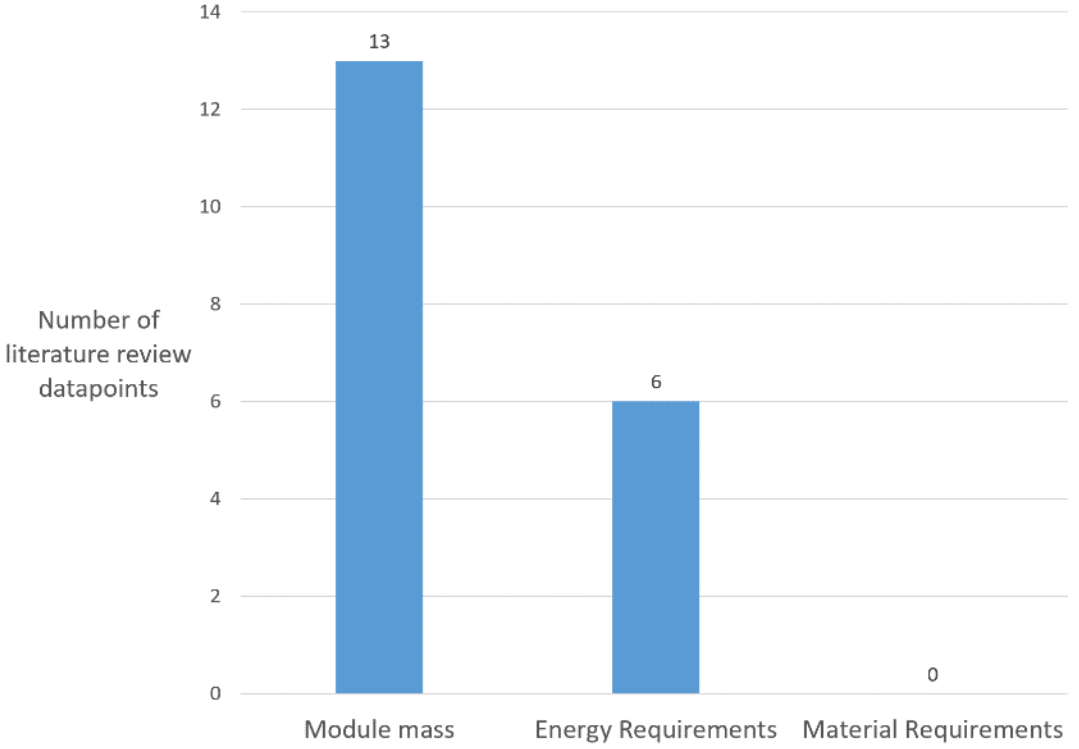
Purity?
Mass?
Market value?

Copper?

Downstream
Processing

Data Availability for transportation, BOS recycling, and energy and material requirement



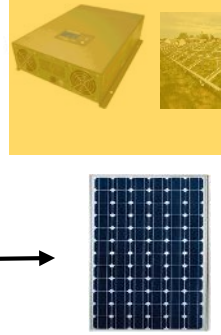


Recommendations

Disassembly

Transport

Balance of Systems



crystalline Si
PV panel

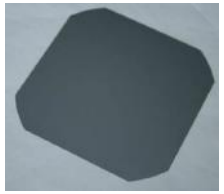
Delamination

Process type?

Glass

Delaminated
wafer

Process
type?



Si wafer

Silver?

Lead?

Tin?

Copper?

Downstream
Processing

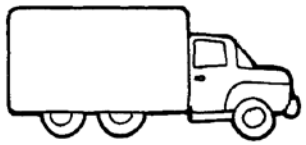
First Solar's process
with suitable
modifications

Recommendations

Disassembly

Balance of Systems

Transport



crystalline Si PV panel

Thermal delamination

Delamination

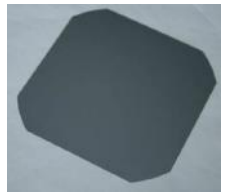
Process type?

Glass

Delaminated wafer

Process type?

Si wafer



Silver?

Lead?

Tin?

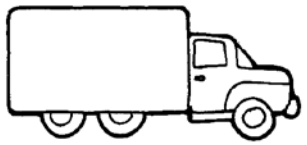
Copper?

Downstream Processing

Recommendations

Disassembly

Balance of Systems



Transport

crystalline Si
PV panel

Delamination

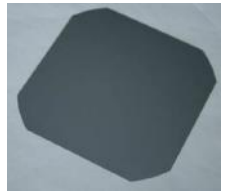
Process type?

Glass

Delaminated
wafer

Chemical etching

Process
type?



Si wafer

Silver?

Lead?

Tin?

Copper?

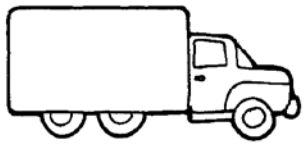
Downstream
Processing

Recommendations

Disassembly

Balance of Systems

Transport



crystalline Si PV panel

Delamination

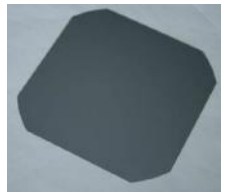
Process type?

Glass

Delaminated wafer

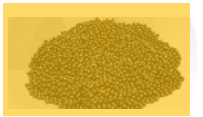
Process type?

Si wafer



Silver? Electrochemical

Lead? Electrochemical



Tin? Chemical

Copper? Electrochemical

Downstream Processing