



PV PANEL RECYCLING – COSTS AND REVENUES

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TNO innovation
for life

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- Today's practice for processing End-of-Life solar panels
- Future recycling methods
- Future volume of PV waste
- Potential valuable materials recovery (for different material purity levels)
- Balancing costs and revenues
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INTRODUCTION

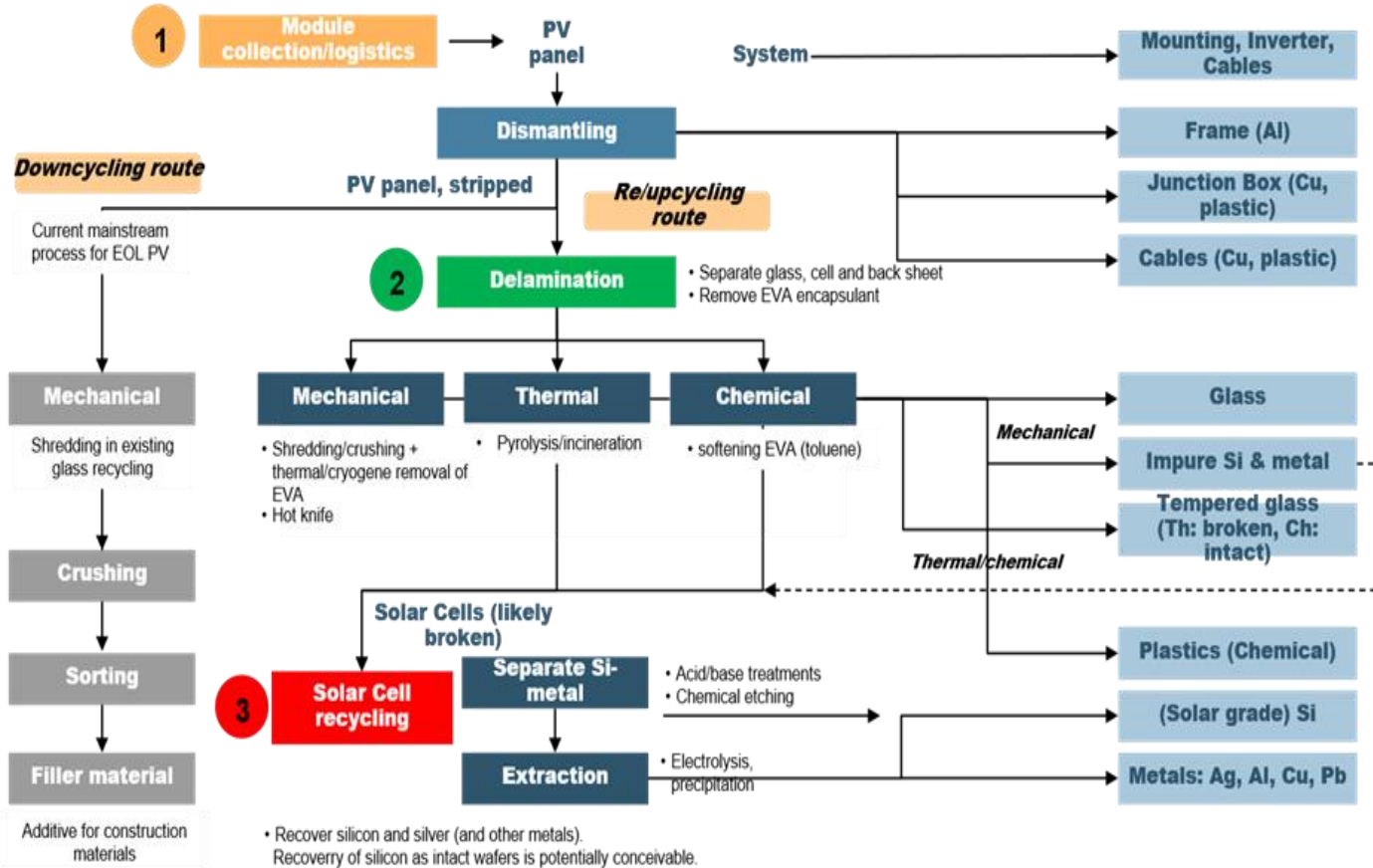
BACKGROUND OF THIS STUDY

- With the current PV installation rate in NL of ~3.5 GW/yr, significant quantities of waste can be expected in future at the End-of-Life (EoL)
- This study comprises an inventory of existing and future technology for processing EoL PV panels
- Processing costs have been compared to potential revenues from secondary material sales
- Stichting OPEN is responsible for collection and processing of electronic waste in The Netherlands and has shown interest in these figures to be able to estimate future costs for processing EoL PV panels

TODAY'S PRACTICE FOR PROCESSING EOL PV

- Basic: removal of aluminum frame, JB, cables followed by shredding. Largest part ends as filler material (e.g. in concrete or under roads)
 - **Advantages:** Cheap, existing large scale plants not specifically for PV
 - **Disadvantages:** Limited re-use of (valuable) materials, environmental concerns?
 - Up to what volume can this strategy be pursued considering the future “market” for filler materials?
- Slightly more advanced: re-use of front glass for glass wool (building isolation)
 - **Advantages:** Improved re-use of materials
 - **Disadvantages:** Under development, dedicated to PV = far from full scale industrial
 - To justify investment in an industrial plant, volume is required! But still lacking....

FUTURE RECYCLING METHODS



FUTURE VOLUME OF PV WASTE

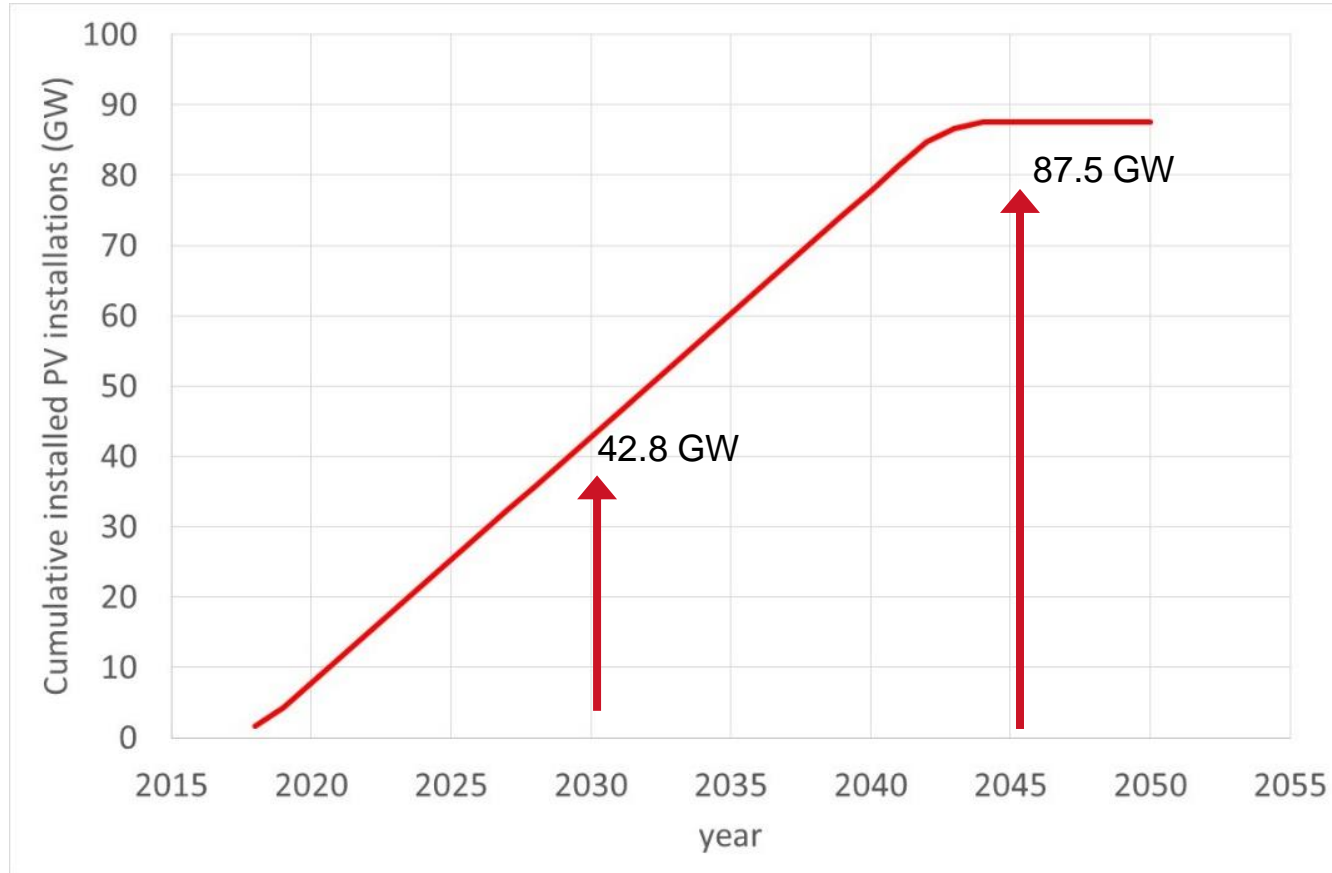
Input data:

- 14 GW PV power installed in 2021 (cumulative, The Netherlands)
- Ambition for 2030: 42 GW wind+PV power installed
- Current growth rate PV: ~3.5 GW/yr (2020 and 2021)

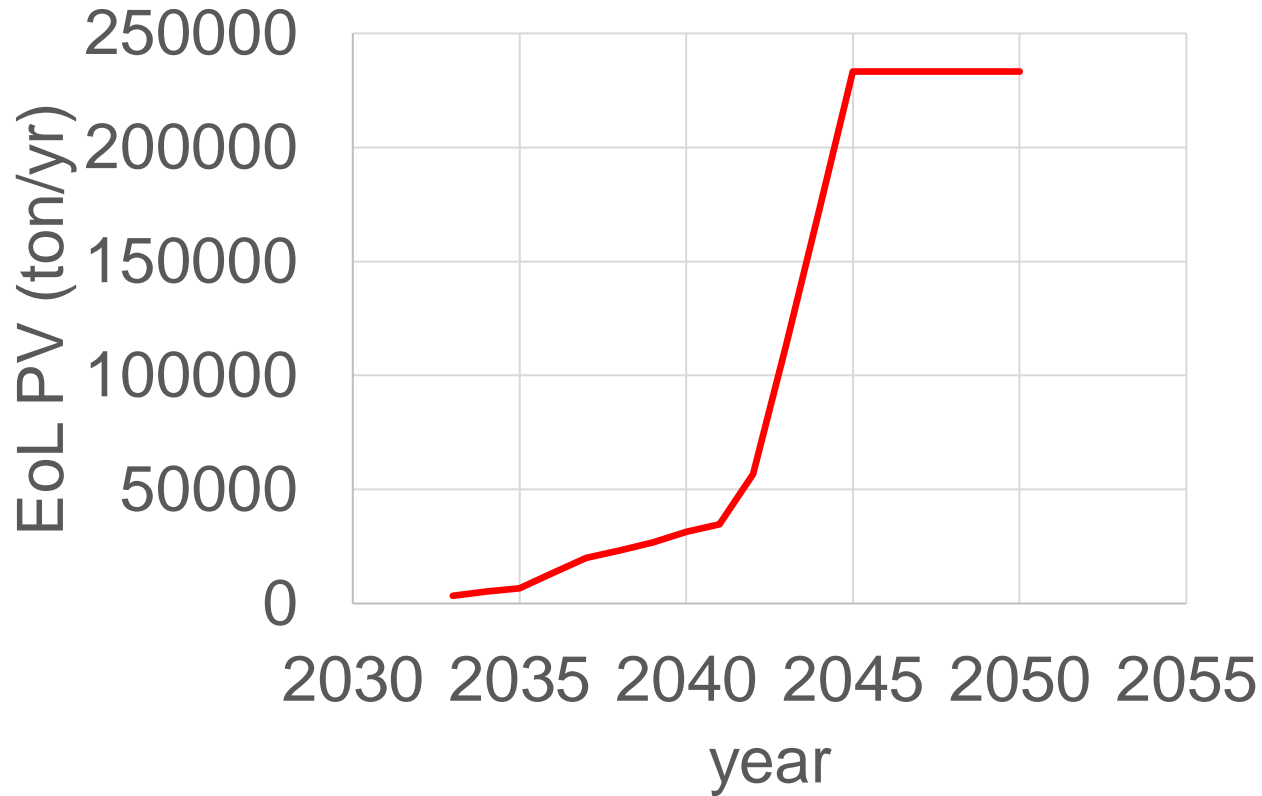
Assumptions for projected volume of PV waste:

- 2020/2021 growth rate PV: ~3.5 GW/yr assumed to remain constant
- Product service lifetime: 25 years

CUMULATIVE VOLUME OF INSTALLED PV



PROJECTED VOLUME OF ANNUAL EOL PV



FUTURE VOLUME OF PV WASTE

Projected waste volume based on input data and assumptions:

Current growth rate PV: ~3.5 GW/yr = large amounts of waste from 2046 onwards

-Would be equal to 230000 tons/yr, 11.5 million panels
-Would justify a dedicated plant for shredding
-Would (in terms of road construction) equal a 4 lane highway strip of 22 km

-Would this be acceptable.....??



- Just recycling the glass saves a large volume....

FUTURE VOLUME OF PV WASTE

Besides the volume to be “stored” or “landfilled” other concerns may be:

- Pb as part of the cell metallisation, currently OK? Future legislation?
- Back sheets contain fluorinated polymers (PFAS), production and use may be prohibited in the near future....what about shedding and landfilling these materials???
- Shortage of silver due to sharp growth of solar cell production or at least a price increase = A motivation for Ag recovery from discarded panels!

POTENTIAL VALUABLE MATERIALS RECOVERY

Ag price development in previous two decades, silver most valuable material

All Data Silver Price in EUR/kg

Last Close: 644.15

High: 1052.34 Low: 122.94 ▲445.33 223.99%



Potential shortage would increase price/value but also drive developments:

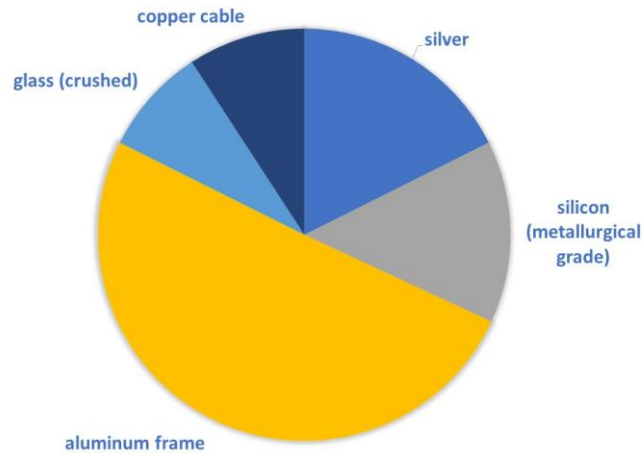
- Ag amount to be halved by 2028
- Alternatives under investigation

Friday, May 13, 2022

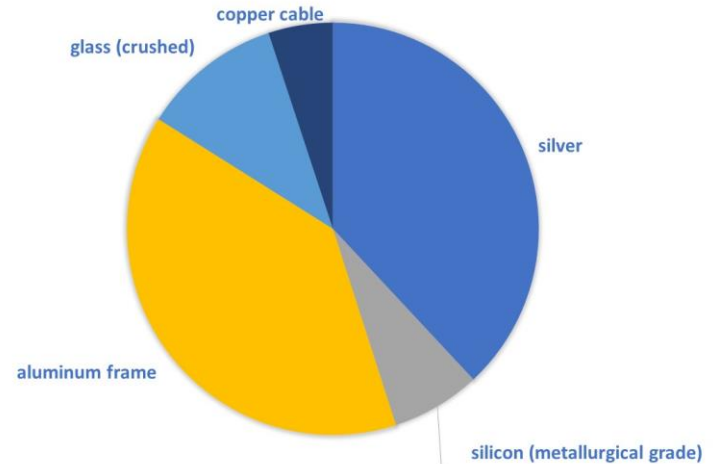
POTENTIAL VALUABLE MATERIALS RECOVERY

....but aluminum wins by mass....

DISTRIBUTION MINIMUM MATERIALS VALUE



HISTORICALLY HIGHEST MATERIALS VALUE

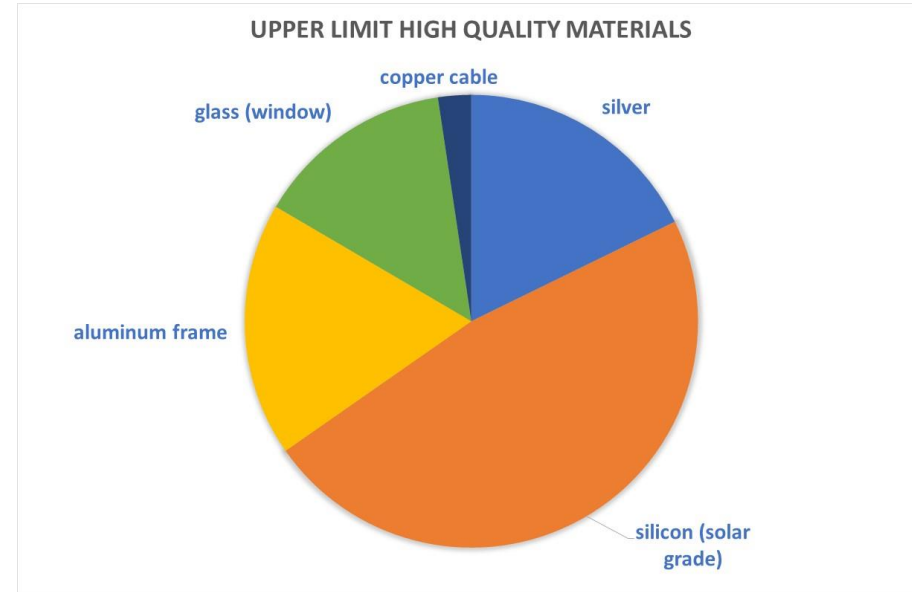
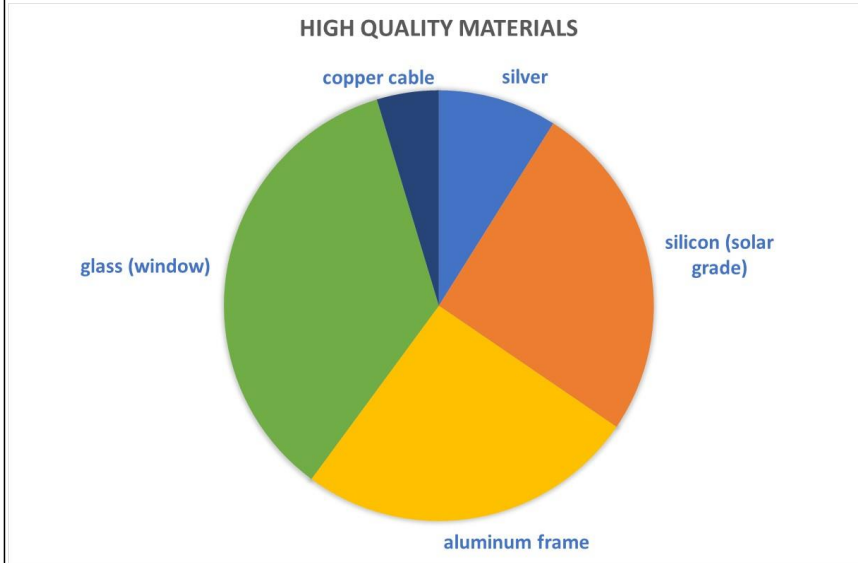


Aluminum is also by far the easiest part to recover

POTENTIAL VALUABLE MATERIALS RECOVERY

....and silicon has potential....

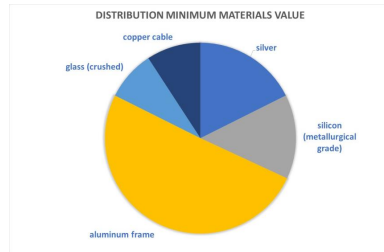
Current solar grade Si price ~ factor 6 higher than in pre-Covid situation



BALANCING COSTS AND REVENUES

Net cost ranges (after subtracting revenues) of transport and processing in € /panel
Net revenues in red (only for lowest costs + highest revenues = high risk, unlikely)

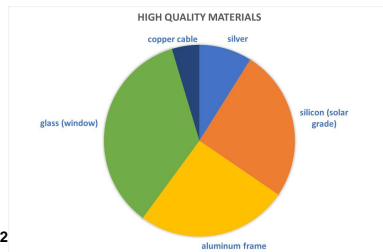
Current costs of transport and processing: 6 €/panel



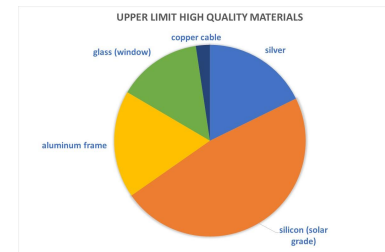
8 / 17 €



-6 / 3 €



10 / 19 €



-4 / 5 €

CONCLUDING REMARKS

- If ambitions for PV come true large volumes of PV waste can be expected in future
- 3-4 GW annually installed now in NL = more than 200000 ton/yr waste from 2047
- Current situation: PV panels contain valuable materials, but recovery of the lower value parts require the highest efforts and costs
- Scaling up to industrial processes currently hindered by low volumes
- Current price of solar grade Si is extraordinary high, sustainable?
- Veolia and Sasil develop test facilities for advanced recycling
- Purely based on market economics today difficult to generate selfsustaining business....

BUT

- Things may change depending on silver price or shortage
- Things may change dramatically and soon due to additional legislation (PFAS)
- Innovations may result in “recycling friendly” designs for PV panels