Scaling up Material Recycling for Solar PV Modules: **Economies of Scale and a European Scrap Market**

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Research Questions

1. What size of recycling facility when and where in the EU is needed to build up a cost-optimal solar PV module recycling industry?

2. What are the implications of economies of scale on a potential solar PV module scrap market in the EU?

Methodology



Preliminary Results

Types and number of recycling facilities

Optimization Model

- The Objective Function minimizes the recycling facility costs and transportation costs.
- Economies of scale considered through different costs of the recycling facility as input parameter.



- Figure 1 illustrates that without a solar PV module scrap market different sizes of recycling facilities are built in each country due to the different quantities of scrap generated.
- The capacity of the recycling facilities reaches from 3.000 to 30.000 [t/y].
- In the Szenario "With Trade", only the largest recycling facilities are constructed, reducing the need for smaller facilities to manage the scrap volume across all EU countries.



Total costs of recycling facilities



• Figure 2 gives insight into the cost drop of -43% if a solar PV module scrap market is developed. The main reason for this significant decrease are the country-specific energy costs determining OPEX and variable costs of the recycling facilities.

• The total costs are a sum of all costs required to construct recycling



sum of all quantities treated in one country in recycling facilities

- quantities transported to another country for recycling there
- transportation costs $t_{y,n,l}$

facilities for establishing a solar PV module recycling industry in the EU in the time horizon 2025-2040.

• If a potential market exists the recycling facilities are built in Finland, Sweden, Denmark, and Poland.

Conclusions

- Trade is beneficial and reduces costs but not the number of facilities.
- Low energy price countries, such as Finland, Sweden, Denmark, and Poland, mainly located in the north, should build recycling facilities.
- Transport and logistics infrastructure to the northern regions of Europe is essential for developing a recycling industry.

Future Work

- Identification of synergies between other recycling sectors.
- Adding scrap market mechanisms, as they are currently only accounted for as a transportation option.



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