An In-Depth Look at the European PV Ingot-Wafer Supply Chain

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Motivation

- PV ingot and wafer production highly concentrated: China controls over 97% of the world's PV ingot and wafer production capacity [1].
- Potential Chinese export restriction: Chinese Ministry of Commerce's "Catalogue of Technologies Prohibited or Restricted from Export" 2022 communication included solar ingot & wafer manufacturing equipment [2].
- Goal of 30 GWp: The ESIA's European reshore objective to achieve a yearly production capacity of 30 GWp throughout the PV value chain [3], including ingot & wafer.

Potential export restriction sparked concerns about achieving the ESIA's target. This work aims to identify key equipment, materials, and consumables, i.e., polysilicon, quartz crucibles, hotzone parts, graphite, Cz pullers, diamond wire, and wire saws, needed to reshore this segment of the value chain.

Methodology

This research integrates qualitative insights from semi-structured interviews with quantitative analysis using MFA models used to calculate material quantities of equipment, polysilicon, quartz crucibles, and hotzone parts made of graphite.

Semi-structured interviews

Fifteen industry experts were interviewed from selected companies in Fig 1. Interviewed experts answered a set of +20 questions.

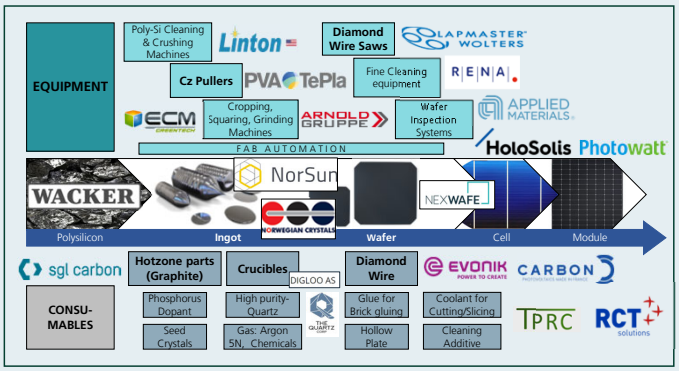

Fig 1. Companies interviewed in the EU PV ingot-wafer supply chain

Material Flow Analysis (MFA)

MFA models were constructed for key components. An export restriction was simulated to examine the impact on the availability of these components.

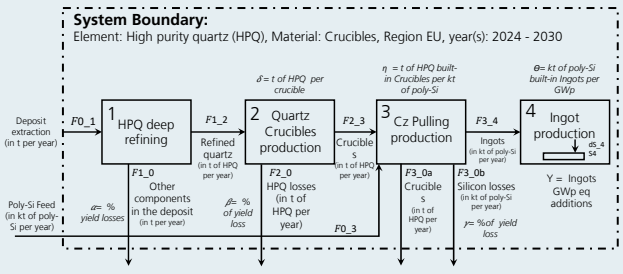

Fig 2. MFA modeling for the required Quartz Crucibles quantities

Conclusions

- European quartz crucible production (demand nearly 50,000 units/a) would be feasible due to available quartz and crucibles-fab construction lead-times.
- Hotzone parts, there is uncertainty over the willingness of existing European graphite producers to meet the demand of 3,000 t/a due to their focus on the semiconductor sector.
- Cz pullers proved to be the most vulnerable component. If an export ban were implemented, it would take until year 2037 to reach 30 GWp/a of puller capacity (demand ~1950 pullers).
- Reshoring ingot-wafer manufacturing requires a holistic approach that incentivizes investments across all key components. The network's success depends on a synchronized start of production.

Results

- Table I summarizes supply vulnerabilities and necessary policy support per key component in PV Ingot-wafer manufacturing.
- Table II shows material demand per year assuming an exponential growth to reach reshoring goal of 30 GWp by 2030.

Table I. Results from interview responses per key component

Key Components		Vulnerability of supply	Support needed
Equipment	Cz pullers	- **China has the power** to change wafer sizes, formats, or standards. This creates uncertainty for European investors. - Shortage of ingot producers creates **unfavorable market conditions**.	- Suppliers **need support to close technology & cost gaps.** - **Finding investors is challenging** due to the PV market's history of volatility, uncertainty, and **lack of clarity on government support.** - Financial support to build **Ingot-Wafer production capacity in Europe** required.
	Diamond wire saws	- **No equipment readily available**, just development in their prototype phase. - These developments are still **relying on Chinese diamond wire**.	
Raw Materials	Polysilicon	- **Competition** with other industries could led to European poly-Si unavailability. - **Global overcapacity** creates low margin market **hindering investments** in European production capacity.	- Need to create a **market with carbon footprint and forced labor criteria** allowing producers the opportunity to sell their supply. - **Low energy prices** are essential.
Consu-mables	Quartz Crucibles	- **No crucible production** in Europe, but potential supplier is interested to start. - US with large western high-purity quartz supply, being purified in Norway.	- More important than financial support, the main issue is **the lack of European customers** (ingot producers).
	Hotzone parts (Graphite)	- Graphite components are **crucial in** the production of **semiconductors** and other expanding industries. - **High demand and competition** expected.	- Graphite producers are **focused on semiconductor, not in PV.** - Support is needed in **design of hotzone for PV equipment.**

Table II. Material requirements per year (from MFA calculations)

Year (Capacity in GWp)		Polysilicon (kt)	Quartz Crucibles (No.)	Hotzone Parts (t of Graphite)	Cz pullers (No.)
2024	(0.0)	-	-	-	-
2025	(0.8)	2.0	1,287	77	50
2026	(2.1)	5.7	3,569	214	139
2027	(4.6)	12.2	7,613	457	297
2028	(8.9)	23.6	14,780	887	576
2029	(16.5)	43.9	27,484	1,649	1072
2030	(30.0)	80.0	50,000	3,000	1950

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[1] IEA Special Report on Solar PV Global Supply Chains (2022)
[2] Ministry of Commerce of the People's Republic of China (2022)
[3] ETIP Photovoltaics. PV Manufacturing in Europe: understanding the value chain for a successful industrial policy (2023)

For those interested in exploring the report further, please refer to the ESIA publication linked here: