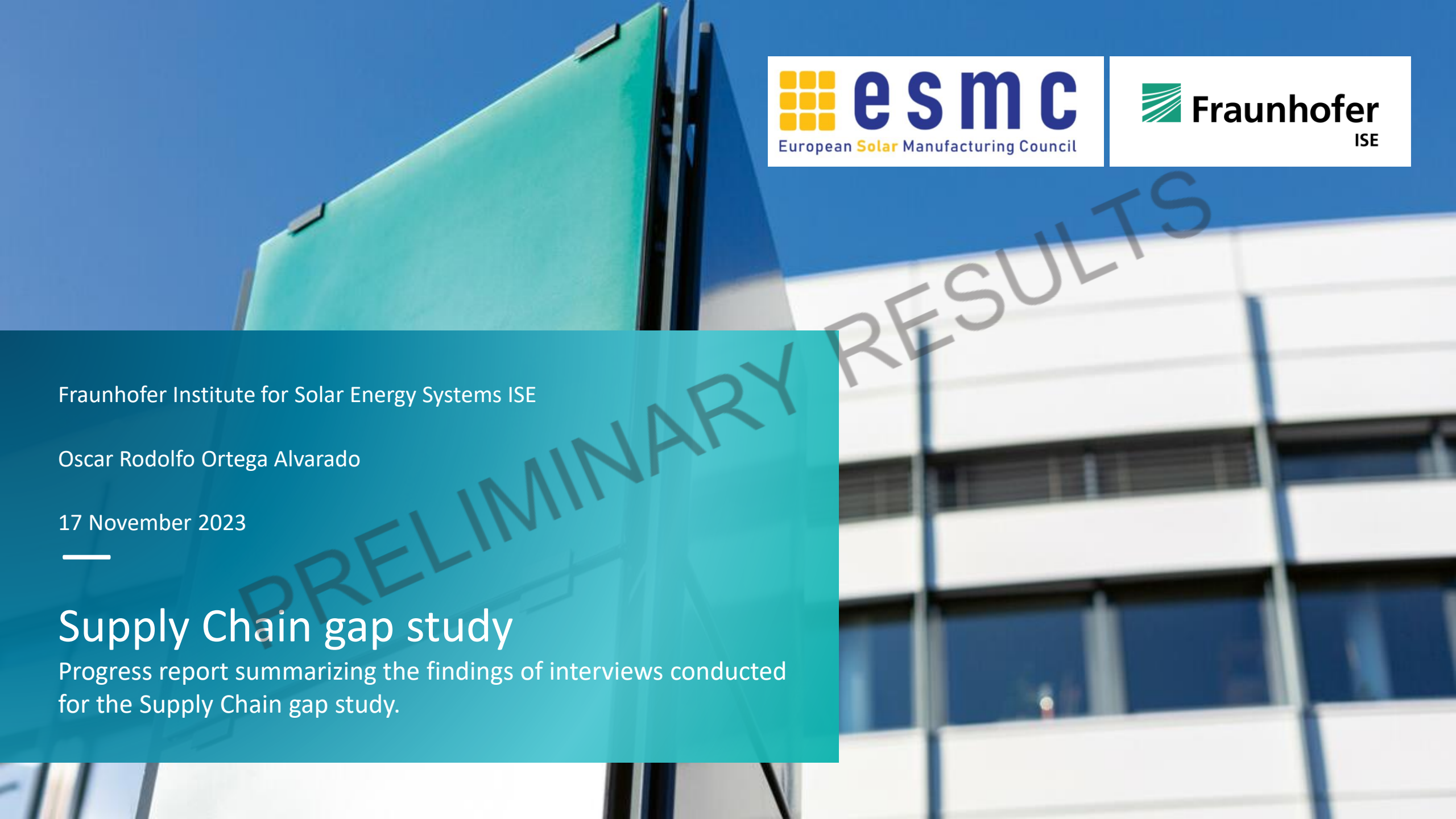

Fraunhofer Institute for Solar Energy Systems ISE

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Supply Chain gap study

Progress report summarizing the findings of interviews conducted for the Supply Chain gap study.

Agenda

1 Scope and Objectives of the Study

1.1 Motivation
1.2 Semi-structured Interviews

2 Data Gathering

2.1 Overview of the Interview Process
2.2 Data Analysis of the gathered information

3 Preliminary Results

3.1 Key Takeaways
3.2 Vulnerabilities & Investment needed

Scope and Objectives of the Study

Motivation

The high concentration of ingot-wafer production in China raises concerns about reaching the EU's reshoring objective.

Ingot-wafer production is highly concentrated

– Today, production is highly concentrated in one country, China controls nearly 97% of the world's production[1].

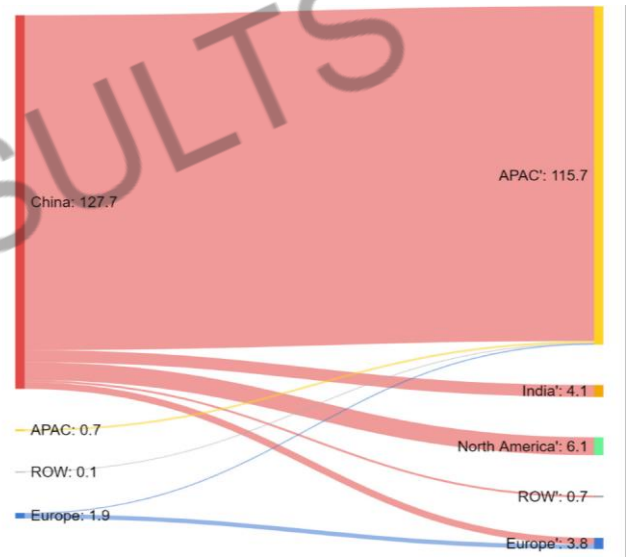
Potential Chinese export restriction

– Chinese Ministry of Commerce's *"Catalogue of Technologies Prohibited or Restricted from Export" includes: "large scale solar wafer technologies, ultra-high efficient ingot casting mono/multi crystalline technology, black silicon preparation technology and „others"* [2].

Reshoring Goal of 30 GW

– The ESIA's objective is to achieve a yearly PV production capacity of 30 GW throughout the value chain. However, the export restriction announcement made by the Chinese has sparked concerns about achieving this target.

Sankey Diagram Wafer flows [1]



China Bans Export Restrictions [2]

2. Category Restricted from Export	a. Agricultural: i. Crop hybrid dominance utilization technology b. Mining and processing of non-ferrous metals: i. Mining engineering technology c. Non-metallic mineral products industry: i. Photovoltaic silicon wafer preparation technology d. General equipment manufacturing: i. Bulk material handling and conveying technology e. Manufacturing of communication equipment, computers and other electronic equipment: i. Lidar system f. Research and experimental development: i. CRISPR gene editing technology ii. Synthetic biology technology

[1] IEA Special Report on Solar PV Global Supply Chains (2022)
[2] Ministry of Commerce of the People's Republic of China (2022)

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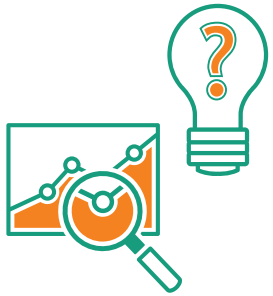
Scope and Objectives of the Study

Semi-structured Interviews



Primary data source Interviews

Publicly available data on ingot-wafer manufacturing is scarce. Due to the lack of data at the level of understanding required, we interviewed specialists from companies in the field.

Semi-structured interview format

The semi-structured interview method proves to be the most beneficial for this type of study as it is a better approach when faced with a substantial number of questions to address, questions that are intricate or open-ended; and instances where the order and logic of questioning may require flexibility (Easterby-Smith et al. 2008; Jankowicz 2005).

Data gathering

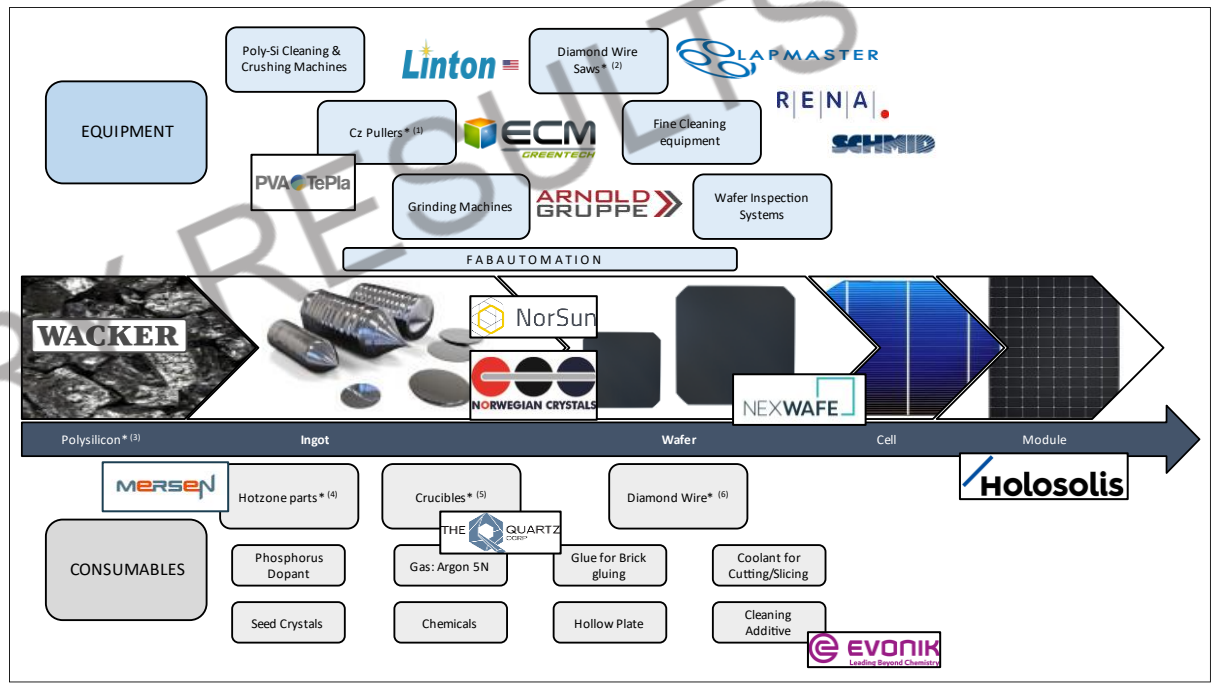
Overview of the Interview Process

Companies studied

- The focus of this study is on European companies in the ingot-wafer stage of the PV value chain, but other companies outside of China were also included in the analysis.
- Firstly, we reached out to individuals who are members to the ESCM and the ESIA.
- One of the outcomes of this effort is a comprehensive mapping of the existing supply scene for this crucial stage of the value chain. Diagram 1 provides examples of companies discussed during the interviews.

Interview Questions

- Interviewees answered a set of +20 questions related to the research objectives.



Diag. 1 EU PV ingot-wafer value chain

Data gathering

Data Analysis of the gathered information

Analysis of responses

- The answers were grouped into 5 categories:

General Information, Supply Chain Mapping, Supply Risks, Market Analysis, Export Ban, Research & Innovation, and Other information

Key components mapped

- Based on expert responses, we developed a list of *'Key components' which include the following:*

✓ *Equipment: Cz Pullers, Diamond Wire Saw*

✓ *Raw Material: Polysilicon*

✓ *Consumables: Quartz Crucibles, Hot Zone parts, and Diamond Wire.*

General Information	HQ and Mfg. Locations	Production Capacity	No. of Employees	
Supply Chain Mapping	EU players in the ingot-wafer value chain	Inputs needed for ingot-wafer production	Supplier selection criteria	
Supply Chain Risks	Main Strengths in the European PV Supply Chain	Main Weaknesses in the European PV Supply Chain	Logistics / Transportation	Other risks
Market Analysis	Competitive landscape	Relevance of European PV Market	Expansion plans	Collaborations or partnerships
Export Ban	Point of View on the potential export ban	Support needed from the EU policy makers		
Research & Innovation	R&D support	R&D initiatives		
Other	Other relevant information			

Table 1. Categories of interview responses

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Preliminary results

Key Takeaways: Cz puller

Current Market situation

- Chinese suppliers provide **the most advanced technology**, **the best quality**, and **the lowest prices**.
- In Europe there is a **lack of know-how** and **industrial capacity** for manufacturing the required pullers.

Challenges for (re) - entering

- First **upgrade** their **technology** to be competitive.
- Real challenge: **matching low** equipment **prices** from China.
- Expanding capacity requires a **sizeable market**.
- Cz pullers are the **most expensive piece** of equipment in the process.

A double-edged sword

Semiconductor Cz puller manufacturers leaders in the sector **could convert**

Low-cost and **high-volume** nature of PV could **adversely affect** their core business

Linton has an **approved plan** for a new plant in the US

Expansion is **on hold** due to geopolitical tensions.

Seeds of optimism

- European consultancy firms have **acquired process knowledge**.
- Focus on **long-term operational consistency** and flexibility would favor European options.

Vulnerability of supply

- China has the **power to change** wafers sizes or formats. This creates **nervousness** in European **investors**.
- Current **market conditions** for equipment manufacturers in Europe are **unfavorable** due to the shortage of ingot producers.

Investment needed

- Companies **need help** filling the **technology and cost gaps** before they can successfully enter the industry.

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Preliminary results

Key Takeaways: Diamond wire saws

Current Market situation

- Currently, Chinese technology is leading. In Europe (Germany), Lapmaster Wolters is **developing equipment** with **first prototypes** scheduled for **January 2024**. **Ready** for delivery by the end of **June next year.**

Challenges for (re) - entering

- High energy prices, could hinder competitiveness in this **highly automated**, **energy-intensive** process.
- **Managing** the resultant **wastewater** of wafer cutting operations.

A double-edged sword

Although **saws** are being **developed**

↓

No player is currently **visible** in diamond wire production outside of China

↓

Threatening the **independence** of the whole process.

Seeds of optimism

- Opportunity to **transfer know-how of** semiconductor to the PV sector in the use of **artificial intelligence (AI).**
- **Developing** and adapting **technology** to match Chinese current leading equipment standards is **expected** to be feasible **within the next 2-3 years**.

Vulnerability of supply

- Northern European countries with access to clean and affordable energy and vast amounts of water have an advantage to perform this process.

Investment needed

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Preliminary results

Key Takeaways: Polysilicon

Current Market situation

Challenges for (re) - entering

A double-edged sword

Seeds of optimism

Vulnerability of supply

Investment needed

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Preliminary results

Key Takeaways: Quartz Crucibles

Current Market situation

Challenges for (re) - entering

A double-edged sword

Seeds of optimism

Vulnerability of supply

Investment needed

Preliminary results

Key Takeaways: Hotzone materials

Current Market situation

Challenges for (re) - entering

A double-edged sword

Seeds of optimism

Vulnerability of supply

Investment needed

Preliminary results

Key Takeaways: Diamond Wire

Current Market situation

Challenges for (re) - entering

A double-edged sword

Seeds of optimism

Vulnerability of supply

Investment needed

Preliminary results

Vulnerabilities & Investment needed in the ingot-wafer value chain

Thank you for your attention!

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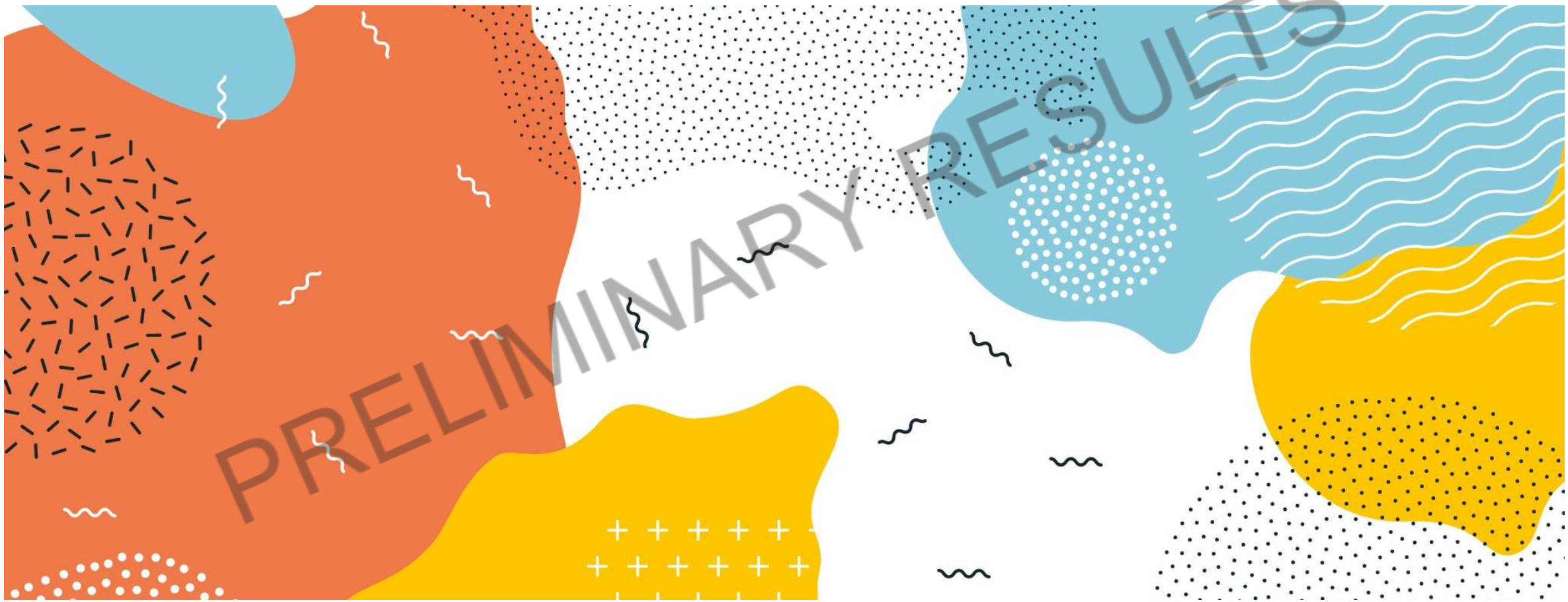
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