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Summary Paper: An Initial Heliostat Supply Chain Analysis

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Abstract. This paper summarizes the prior analysis, key findings, and recommendations from the published report titled "Initial Heliostat Supply Chain Analysis" [1]. Globally, the growing demand for concentrating solar power (CSP) technologies, primarily for electricity generation plants has been met with supply chains primarily composed of plentiful commodity materials such as steel, aluminum, and glass. Often the commodity materials can be sourced in the domestic market where power plant will be constructed. Although specialty components are required for CSP solar fields —including mirror panels used for heliostat applications—these specialty components constitute about 30-50% of total system installed costs [2]. Only a few companies and countries, including the United States, have developed the capacity to supply such specialty components. The U.S. heliostat supply chain at present is comprised of few companies (e.g., CSP developers), component suppliers, and is its infancy.

By 2035, with current and aggressive solar photovoltaic (PV) capacity expansions, there is the potential for 500,000–1,500,000 direct and indirect jobs in the areas of manufacturing, installation and development, and operations and maintenance (O&M) [3]. Utilizing the CSP capacity estimations the recent NREL report [4], the construction of 39 gigawatts (GW) of CSP (assuming mainly power tower) in the U.S. could lead to approximately 195,000 manufacturing, construction, and O&M jobs. This does not include the longer-term jobs and economic impact (e.g., taxes from plant operations staff) from operating the plants once constructed. It is recommended that further CSP component and system supply chain analysis and modelling be undertaken.

Keywords: Concentrating Solar Power, CSP, Heliostat, Supply Chain, HelioCon

1. Introduction

Local manufacturing and the associated supply chains for renewable energy technologies are key economic drivers for increasing a region's ability to uptake and develop industries that support both the domestic and global growing renewable energy markets [5]. In the Middle East North Africa (MENA) region for example, to increase the deployment of CSP, several key factors were identified which included the local manufacturing, existing supply chains and the investments to then reduce costs and increase regional strength [5]. This investment then drives innovation, significant local jobs both during construction and CSP plant operation, and value creation along the supply chains.

The supply chain for CSP is primarily composed of commodity materials such as steel, aluminum, and glass [6,7]. These materials are readily produced in domestic markets like the U.S. For CSP projects, even with local supply capabilities, CSP projects tend to use foreign steel unless there are local content requirements. This is unlike the key components of the crystalline silicon (c-Si) PV supply chain which are more complex in nature [8]. The CSP supply chain with growth and development could provide further significant economic benefits in the U.S., as it has done in other regions such as Spain which is globally dominant e.g., for CSP technology developers, expertise, and deployments [9].

This paper has briefly highlighted an initial heliostat supply chain. This paper highlights the current large heliostat glass suppliers which is considered valuable and timely for the heliostat industry. The full report covers in depth the supply chain, key components, and U.S. domestic content implications for material production and jobs [1]. For brevity, the main Challenges and Opportunities for the heliostat supply chain follow. The potential jobs from meeting the 39 GW of CSP capacity are shown, and the recommendations from this work are summarized. This work has been undertaken alongside the HelioCon Roadmap [2].

2. Heliostat Supply Chain

The general CSP heliostat supply chain is shown in Figure 1. Full details can be found in the report [1]. For this paper, the focus is given to the heliostat glass suppliers. Further companies and elements along the supply chain are reported in the full report.

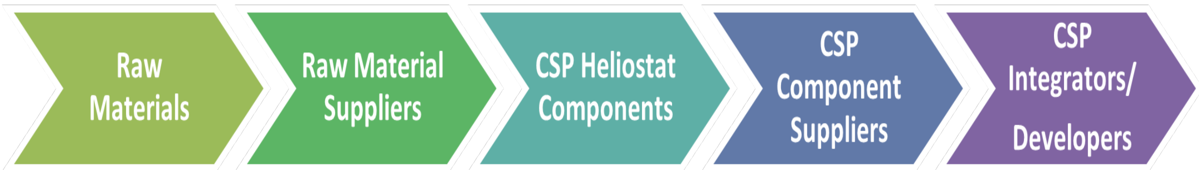

Figure 1. Heliostat supply chain overview.

2.1 Heliostat Glass Suppliers

Relatively few comprehensive datasets exist regarding the CSP supply chain, especially with respect to producers of specialty CSP components (e.g., parabolic trough receiver tubes, heliostat mirrors, and drives). At present, a comprehensive heliostat supply chain and model (e.g., flat glass producers, frame manufacturers, and drives) is not readily available. This work, along with recent World Bank work aims to begin developing the basis for future heliostat supply chain models.

For CSP heliostat mirror glass, the main suppliers are AGC Glass, Cosin Solar, Flabeg Solar, Guardian Glass, and Rioglass. Table 1 shows the main heliostat suppliers as known today, with the countries of Germany, Spain and China being the biggest global suppliers. Table 1 has been developed with detailed work from the World Bank [10], and further NREL research. The table is not exhaustive but looks to mention the biggest heliostat mirror providers. Saint-Gobain, which is a very large CSP glass manufacturer particularly for parabolic troughs, has few current references for heliostat installation. For this paper Saint-Gobain has been removed from Table 1. At present, while Guardian Glass has supplied heliostat mirrors for plants such as Gemasolar (installed in Spain) and Ivanpah (installed in the U.S.), it is unclear the state of their heliostat manufacturing capacity, as such China is considered a larger global heliostat supplier than the U.S.

Table 1. Key global mirror glass suppliers for heliostats.

Key Suppliers	Country where manufacturing is located	Heliostat project references	Power Tower Type	Sources
AGC Glass Europe	Europe e.g., Germany and Spain	Ashalim Plot B/ Megalim (Israel)	Direct steam	[11–13]
Cosin Solar/ Damin Glass	China	Supcon Solar (China)	Molten salt	[14,15]
		Gonghe (China)	Molten salt	[16,17]
Flabeg Solar	Germany (and U.S. prior*)	Crescent Dunes (U.S.)	Molten salt	[10]
		Sierra Sun (U.S.) Tower	Direct steam	[10]
		Hami (China)	Molten salt	[18]
		Redstone (South Africa)	Molten salt	[10,19]
Guardian	Unites States	Gemasolar (Spain)	Molten salt	[10]
		Ivanpah (U.S.)	Direct steam	[10]
Rioglass Solar	Belgium, Spain, and South Africa (and U.S. prior*)	Noor III (Morocco)	Molten Salt	[10]
		Noor Energy 1 (United Arab Emirates, UAE)	Molten salt	[20]
		Khi Solar 1 (South Africa)	Direct steam	[21]
		Atacama 1 (Chile)	Molten salt	[21,22]

3. Challenges in Manufacturing and the Heliostat Supply Chain

CSP manufacturing faces challenges globally and in the United States. When compared with PV, CSP systems are much more complex, require a longer lead time for development to construction, require much higher total CAPEX requirements for system construction, and have higher levelized costs of electricity (LCOE) at this time. These CSP characteristics also favor large, well-funded vertically integrated developers and manufacturers, and can bar new disruptive startup companies. The lack of a consistent global pipeline for power tower project development and projects ready to utilize heliostats is a key challenge in developing a strong heliostat manufacturing base and supply chain. The global supply chain disruption is also highlighted as a near term challenge.

3.1 Inconsistent Annual Demand and Pipeline

For specialty manufacturers serving the sector, the high minimum scale for generating systems creates key challenges. Demand can be volatile owing to the small size of the global CSP industry (~6 GW in total installed capacity [10]), the lengthy development cycles, and the large project sizes relative to total market size. From 2009 to 2017 for the CSP market in general, the annual year-on-year global installed capacity growth decreased significantly, with a large resurgence of installations in 2018, with a further subsequent drop in 2019 and 2020 [1]. The CSP industry, especially for power towers and heliostat fields, installs small numbers of large-capacity projects on an inconsistent basis, making manufacturing capacity planning, scale-up, and efficient operation difficult.

From present day to 2030, the International Energy Agency (IEA) estimates that about 67 GW of new installed capacity is needed by the end of the decade to keep on track with the IEA Net Zero scenario [23]. In 2020 and 2021, a total of approximately 0.3 GW was installed [23], instead of the needed 13.4 GW. In 2020 there was nearly 0.3 GW of power tower systems being constructed [24]. This type of low annual global demand, and an inconsistent pipeline makes it very difficult to build and operate manufacturing facilities, which are best suited to consistent demand to then utilize the facility fully.

3.2 Global Supply Chain Disruptions

Global events, the interconnectedness of today's economies and supply chains can have had significant near-term impacts on the costs of commodities, access to materials, and deployment of renewable energy technologies such as wind, PV and CSP. The emergence of the COVID-19 virus and the ensuing pandemic in 2020, did lead to construction delays of renewable energy plants in construction [24]. While supply chains were disrupted in many countries, globally, solar PV in 2020 still had the largest capacity increase of an additional 139 GW [24]. CSP was negatively affected, as very few plants were finished in 2020 e.g., only 100 megawatts (MW) [24].

The COVID-19 supply chain impacts and labor restrictions, led to labor shortfalls in countries such as China, South Africa, and UAE [24], where CSP plants were in construction in 2020. In Chile, while delayed by the pandemic, the Cerro Dominador 110 MW power tower plant with 17hrs of thermal energy storage (TES), eventually continued construction in 2020 [25]. Discussions with CSP suppliers in 2021 highlighted that the price of shipping transport in 2020 and 2021 went up 4 times to nearly $8,000 per 40-foot (ft) container. In 2021, similarly other sources also highlighted a 40ft container was approximately $8,400 and had quadrupled in price compared to 2020 [26]. Depending on the location of origin, that increased to approximately $12,000 for containers coming from China in 2021. In 2021, the container price to the U.S. from China, was nearly at $20,000 [27]. At present, shipping container costs to the U.S. have decreased to more reasonable ranges of $2,700-4,200 per 40ft container [28].

4. Opportunities

Several opportunities exist for CSP heliostat manufacturing to meet global demands. CSP deployment is expected to grow in regions like China, Africa, MENA, and the Middle East over the next 3-5 years [10]. Combining CSP with TES underpins the potential for more rapid CSP growth beyond 2022, when increasing penetration of PV and other variable renewable generation sources will place a greater emphasis and value on dispatchability. One study suggests that by 2030, potentially 22.4 GW of CSP could be installed, with the key near-term markets being China, Chile, and the MENA area [29].

Significant additional research, innovation, commercialization efforts, and market development are needed for CSP (both parabolic troughs and power towers) to become globally competitive with other generating technologies. Further, development of TES and industrial process-heat (IPH) applications could enhance CSP's unique benefits. Established U.S. R&D centers can contribute to a strong CSP-specific innovative capacity and knowledge base, which could confer advantage to U.S.-based firms should domestic demand markets recover.

5. Jobs

In addition to the potential 500,000 – 1,500,000 direct solar jobs by 2035 for PV [3], CSP plants may have significant additional effects on several commodity industries. This is because of the commodity-intensive nature of CSP plants [3]. Utilizing the CSP capacity estimations from the 'Solar Futures' Study', recent work from NREL highlights the construction of 39 GW of CSP by 2050 (assuming mainly power tower) in the U.S. under some scenarios [4]. Based on prior analysis from Turchi et al., it was found that the construction of a 100MW molten salt power tower plant with 6 hours of TES in the U.S., could need 500 direct and indirect jobs [30]. As such, the construction of 39 GW of CSP could utilize 390 plants, each of 100MW. If each of these 390 CSP plants needed approximately 500 direct and indirect jobs, it can be estimated that 195,000 jobs are associated with the 39 GW of CSP potential in the U.S. by 2050. This does not include the longer-term jobs and economic impact (e.g., taxes from plant operations staff) from operating the plants once constructed.

6. Recommendations

Three main recommendations have been identified from the work.

6.1 Future Detailed Market, Manufacturing Capacities, and Economic Impact Analysis

An important next step will be to undertake further detailed analysis of the U.S. and global markets for heliostat components, manufacturers, and developers. This includes heliostat components, but also the power tower supply chain. The future work would also consider aspects such as commodity price tracking e.g., steel and glass, to help determine factors that drive heliostat and other component costs in the U.S. This type of detailed analysis would help form the basis for a heliostat component, manufacturer, and developer database.

6.2 Development of a Heliostat and Power Tower Supply Chain Model

At present there is no heliostat supply chain model, that directly models the material flow model for heliostats. It is recommended a heliostat and power tower supply chain model is built, that can at first incorporate at least one commercial heliostat recipe. The bottom-up heliostat analysis [31] can form the basis for a generic Commercial heliostat. Understanding the power tower supply chain will also improve the visibility of the heliostat supply chain.

6.3 Future CSP Supply Chain Modelling and Development Efforts

As future supply chain tools and models are built, it is important that CSP components (e.g., heliostats and drives) and CSP supply chain models are also incorporated. It is proposed once heliostat and CSP system supply chain models are built, that these would then integrate with existing or developing supply chain models that include PV, steam turbines, and other related clean energy technologies. This will highlight the interconnected nature between elements of certain supply chains, and the establishment of robust supply chains.

Heliostats are a good candidate for future addition to such an integrated supply chain model due to the potential for having mass produced components such as steel structures and mirrors to understand:

- Near term manufacturing opportunities in meeting the global market, mid and long-term opportunities for domestic markets.
- Relatively simple supply chain and components.
- Job and economic impact in states like California, Arizona, and Nevada where CSP (both tower and trough) has already been developed and constructed.

Data availability statement

The sources from which the data for this paper are from public sources and can also be found from the References section.

Underlying and related material

This paper has summarized a full report titled “An Initial Heliostat Supply Chain Analysis“ [1]. Some of the analysis undertaken as part of the underlying material is based on sensitive and restricted data provided by CSP developers to NREL. Most of the data and sources are publicly available.

Author contributions

Parthiv Kurup has led the preparation, creation, and presentation of the work for this paper, specifically writing the initial draft. Chad Augustine has been involved in the preparation and review. Sertaç Akar and David Feldman have provided analysis and some of the data used.

Competing interests

The authors declare no competing interests.

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