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OVER- EXPOSED:

Uyghur Region Exposure Assessment for Solar Industry Sourcing

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and a team of anonymous researchers

**Sheffield
Hallam
University** | Helena Kennedy
Centre for
International Justice



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Executive Summary

In the last five years, the government of the People's Republic of China (PRC) has imposed a region-wide, ethnically targeted program of state-imposed forced labor upon the Uyghur community and other minoritized citizens of the Xinjiang Uyghur Autonomous Region (XUAR or Uyghur Region). This oppressive program has been documented in numerous [academic and journalistic books, papers, and reports](#), and the [consequences for global supply chains](#) have been widely demonstrated.

The Uyghur Region produces between one third and one half of the world's solar-grade polysilicon. The Chinese government deliberately located production in region over the last fifteen years, undercutting the price of the essential product, and leading to the shuttering of production in other parts of the world. When news of the human rights crisis emerged, the world was made aware of how reliant our renewable energy future was on that region. As early as October 2020, [representatives of the solar energy industry](#) recognized that the crisis in the Uyghur Region significantly affected solar supply chains. Less discussed by the industry was the fact that the Uyghur Region was also a hub of production for polysilicon's pre-cursor material, metallurgical grade silicon (MGS). The PRC government had capitalized on the availability of cheap coal in the region to make it the epicenter of the world's solar industry.

Since 2021, a series of reports—including one by [Sheffield Hallam University](#)—has underscored the dominance of the Uyghur Region's manufacturing in the solar industry. International outrage, both within the solar industry and among governments, investors, consumers, and affected communities, has fueled significant change in solar industry sourcing, and we have seen significant growth in the sector, mainly within other parts of China but also abroad. A 2021 US ban on the import of the products of one XUAR-based company essential to the solar supply chain and the enactment of the US Uyghur Forced Labor Prevention Act (UFLPA) have likely been significant encouragement for the [solar industry's extraordinarily rapid shifts](#) away from Uyghur Region sourcing, an expansion of manufacturing, and the development of dedicated supply chains that do not include inputs from the region.

Around the world, people are more committed to making the urgently needed shift to renewable energy. And, increasingly, people are committed to ensuring that the transition is a just one. The fate of the planet and human rights go hand-in-hand. We must ensure that the people who are responsible for producing the modules and turbines and batteries that will power our lives are allowed to pursue their own lives in freedom and security. The solar industry has shown that it is indeed possible to shift supply chains in response to egregious human rights violations.

As the crisis in the Uyghur Region has revealed, supply chain transparency is necessary to make the transition to renewable energy a just one. Counter-intuitively, however, information about solar sourcing has become increasingly unavailable following the revelations of the solar industry's reliance on—and resultant complicity in—the oppression in the Uyghur Region. Even as leading companies create new untainted supply chains, the industry's increased opacity means consumers, procurers, investors, and governments find it nearly impossible to identify a solar module that they

can fully trust is not made with Uyghur forced labor. Public trust in the solar industry is extremely low.

This report addresses the lack of transparency by mapping—to the extent that available data and expertise in the field make possible—the supply chains of the solar industry's titans as well as a selection of other solar module manufacturers. Given the data available, the report assesses ten manufacturers' exposure to the Uyghur Region, carefully selecting for size and diversity. We assessed the top five manufacturers (which together manufacture 70% of the world's solar modules) as well as some of the smaller brands; we assess companies operating in China, Southeast Asia, the EU, and the US; we review some that had previously been known to be connected to the Uyghur Region and others that were suspected to be less exposed; and we selected some because they are highly vertically integrated and others that are reliant on external suppliers throughout the value chain.

Because the vast majority of companies are unwilling to make their full supply chains transparent, the report deploys the expertise of a solar industry expert for analysis of certain aspects of the supply chains that remain opaque. Industry expertise provides insight into XUAR-sourcing exposure through the application of historical supply contracts, sourcing trends, and geographical information that would be relevant to sourcing decisions for each individual company. Every company was provided the opportunity to amend or supplement the supply chain maps provided in this report and to respond to our claims. Most companies did not respond or referred to Chinese anti-sanctions and espionage laws as an explanation for not providing detailed information regarding their supply chains. All responses are available in [Annex A—Corporate Responses](#) on the website for this report.

The most significant findings of the report include the following:

- The Uyghur Region now accounts for approximately 35% of the world's polysilicon (down from 45%) and as much as 32% of global metallurgical grade silicon production.
- The vast majority of modules produced globally continues to have exposure to the Uyghur Region. Production in China significantly increases exposure.
- Some of the world's largest module manufacturers appear to have bifurcated their supply chains to create a product line that they claim to be free of XUAR inputs, though evidence of these claims varies by supplier. Most companies have suggested that these supply chains are dedicated to the US market or designed with UFLPA compliance in mind. The portion of modules made by China-based companies on these dedicated supply chains appears to range from 7–14% of the companies' total production capacity globally.
- Companies that have created supply chains purportedly free of XUAR inputs continue to source from suppliers or sub-suppliers that have exposure to the Uyghur Region for other product lines.
- It is sometimes impossible to determine if it is indeed the case that these dedicated product lines are XUAR-input-free because companies do not disclose sufficient supply chain information.

- Despite significant global pressure for increased transparency, information regarding solar industry sourcing is becoming less transparent over time, thwarting the world's ability to source ethically.

Our assessments indicate the extent to which a company or module is exposed to the Uyghur Region. By exposure, we mean the heightened risk that a supply chain includes within it a Uyghur Region input, based on available sourcing disclosures. An assessment of “VERY HIGH” indicates a product line is verified to be made with Uyghur Region inputs, while “NONE (Verified)” indicates that disclosures verify a supply chain to be entirely free of Uyghur Region inputs. The vast majority of companies fall somewhere in the middle because companies do not provide enough information to verify that their supply chain is for certain exposed or free of Uyghur Region sourcing. In those cases, the report applies available data and expertise to assess the exposure of the product.

These assessments make clear that many solar modules being sold into international markets are indeed still very much exposed to Uyghur forced labor.

For each exposure assessment the report provides:

- An overall assessment for the company
- An assessment for individual product lines, where relevant
- A summary of the evidence used in the assessment
- A list of opportunities the company has to improve the assessment
- An analysis of what is known about the company's supply chain(s) and a discussion of the predicates upon which exposure is identified where there are gaps in public sourcing information.

The report also provides a decision tree that details the logic of the assessment process; the decision tree can serve as a tool that can be applied to companies or modules that are not assessed in this report.

This is a point-in-time assessment. Supply chains will change drastically in the coming months and years. Readers should call on independent industry expertise when assessing solar module exposure to ensure that the most up-to-date and reliable information is used in decision making.

In the meantime, however, this report shines a light on what is known and unknown about solar supply chains at this moment and provides some insight into how solar supply chains have shifted in response to global demand for ethical sourcing.

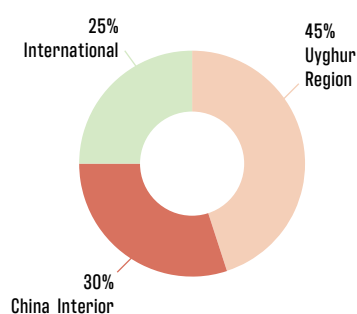
Note: This report was updated in November 2023 to reflect additional evidence provided by Moxeon Solar Technologies that indicated a need for a reassessment. That reassessment has been reflected here and in the Moxeon section of the report.

Exposure	Company
HIGH	Canadian Solar
VERY HIGH	JA Solar—Southeast Asia/US
VERY HIGH	JA Solar—China
HIGH	Jinko Solar—Southeast Asia/US
HIGH	Jinko Solar—China
VERY HIGH	LONGi Solar—Southeast Asia
VERY HIGH	LONGi Solar—China
NONE (UNVERIFIED)	Moxeon 3/5/6 Module / Sunpower X-/A-/M-Series
NONE (UNVERIFIED)	Moxeon / Sunpower Performance Series
NONE (UNVERIFIED)	Meyer Burger Technology
VERY HIGH	QCells
NONE (UNVERIFIED)	REC Group N-Peak and Alpha
VERY HIGH	REC Group TwinPeak 4
HIGH	Tongwei Solar
NONE (UNVERIFIED)	Trina Solar—Southeast Asia
VERY HIGH	Trina Solar—China

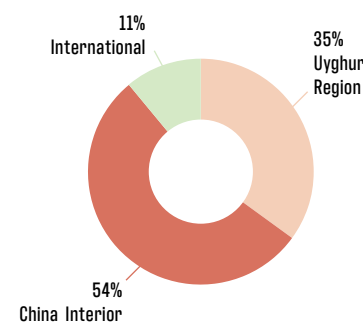
Polysilicon Market Share

Source: Bernreuter Research

2020



2022



Introduction

FORCED LABOR IN THE UYGHUR REGION AND ITS IMPACT ON THE SOLAR INDUSTRY

In early 2021, Sheffield Hallam University's Helena Kennedy Centre for International Justice and [others](#) published reports documenting the use of state-sponsored labor transfers in the Xinjiang Uyghur Autonomous Region (XUAR or Uyghur Region) in the direct production of metallurgical grade silicon (MGS) and solar-grade polysilicon. "[In Broad Daylight](#)" provided evidence that every solar industry-serving company operating in the Uyghur Region either engaged in state-sponsored labor transfers or sourced from a company that did. The report identified labor transfers as an extremely serious problem impacting the ethical commitments of the global silicon-based solar supply chain.

None of the companies that were engaged in state-sponsored labor transfers in 2021 has announced any changes to its recruitment methods or shown any resistance to participation in the PRC government's programs. Indeed, since that time, the PRC government's labor transfer program has only [increased in scale](#) and the pressure on companies to "absorb" the workers the state deemed to be "surplus" remains high. Indeed, Chinese state media have revealed in the last several months alone that at least two companies in the region ([TBEA](#) and [Hoshine](#)) continue to participate in government "surplus labor" and employment "docking" programs.

According to solar industry expert Johannes Bernreuter's most recent calculations, the Uyghur Region accounted for approximately [35% of the world's solar-grade polysilicon](#) in 2022. That's a significant decrease from the approximately 45% that the region was responsible for in 2020. Bernreuter's preliminary calculations predict that the region's global share will decline even further to between 28 and 32% in the coming years.¹ The Uyghur Region's share of production of metallurgical grade silicon (MGS)—the material from which polysilicon is made; see graphic below—also appears to be on the decline. But the most recent public data available from 2020 still suggests that the XUAR produced 44% of China's share of MGS, which amounts to [32% of global MGS production](#). China has added significant polysilicon and MGS capacity since the end of 2021 while very little capacity has been added outside of China. And some new polysilicon production outside the Uyghur Region likely continues to rely at least in part on MGS made in the XUAR.

Despite the decline in the region's share of the world's production, the Uyghur Region's continued dominance in the production of materials essential to the manufacture of [more than 95% of solar modules](#) represents significant exposure to state-imposed forced labor for the industry.

Recent regulations have transformed the solar industry's ethical obligation to exit the Uyghur Region into a legal one. In June 2021, the United States Government issued a [Withhold Release Order](#) against Hoshine Silicon Industry Co., the world's largest producer by capacity of MGS for solar and other applications, asserting that the company employed forced labor in its manufacturing in the Uyghur Region. Since that time, the US enacted the [Uyghur Forced Labor Prevention Act](#), which prohibits the import of all

products made in whole or in part in the Uyghur Region. These US regulations have had a significant effect on solar manufacturers worldwide, as companies work to comply with the law. In addition, US Customs and Border Protection has reported thousands of shipments of solar [panels have been stopped](#) for investigation at US borders since June 2022; while reports indicate that some panels have been released, many of those shipments are still under investigation at the time of publication.

Solar industry resistance to goods made with forced labor extends beyond the US. [Pending and existent due diligence and forced labor legislation](#) (including in Germany and the European Union) will surely also impact the solar industry's ability to source from the Uyghur Region. Alarmed by the [human rights](#) crisis in the region, many manufacturers, developers, municipalities, and government agencies worldwide are working to avoid procuring solar modules that have XUAR inputs, even without a government mandate.

Though there is increasing appetite for ethical sourcing of solar modules on the part of governments, developers, and domestic consumers, there is no way for these stakeholders to easily and accurately determine whether a particular silicon-based solar module contains silicon produced with forced labor in the XUAR. The problem results from the global silicon-based solar industry's almost universal lack of transparency regarding the full supply chains of silicon-based solar modules.

The lack of transparency is amplified by a blind spot in the industry regarding the most upstream segments of the supply chain, which are mining quartz rock for conversion to MGS and producing polysilicon from the MGS (see "The Making of a Solar Module" below). For years, the solar industry has described its supply chain as if it begins with polysilicon, without regard to where or how the polysilicon was produced, so long as the purity/quality was assured. It is not unusual to hear people talk about polysilicon as a "raw material" or even to read of the "mining" of polysilicon, even though that is far from the truth. This is a critical oversight because quartz mining and MGS production segments are the most likely supply chain segments to transfer Uyghur Region exposure to the entire solar supply chain.

This project provides a systematic assessment of solar module exposure to the XUAR for a range of solar modules. The assessment employs publicly disclosed data informed by established knowledge of typical sourcing patterns within the industry.

These assessments are designed to help investors, government agencies, developers, domestic consumers, and other interested stakeholders understand solar supply chains and assess the risk of sourcing products potentially made with forced labor. The assessments also empower stakeholders to advocate for disclosure where gaps in traceability appear. This project provides a model for conducting similar tracing and assessment for other solar manufacturers' modules.

As people grow more committed to the pursuit of a renewable-energy-based future, they also grow increasingly aware of the suffering inflicted upon those who work in our green tech supply chains. This report seeks to move the needle toward a more just transition, as part of the global effort to protect both people and planet.

THE SOLAR SUPPLY CHAIN

1. **quartz** rock that meets specific purity and physical property specifications (also known as quartzite) is mined from the earth;
2. quartz is chemically reacted with carbon sources to produce **metallurgical grade silicon (MGS)** in electric arc furnaces;
3. MGS is converted to **polysilicon** through a series of chemical reactions and purifications;
4. polysilicon is placed in high purity quartz crucibles and melted, and long cylindrical single crystal silicon **ingots** are “pulled” from the melt;
5. ingots are squared and then sliced into very thin **wafers** with diamond wire saws;
6. individual solar **cells** are produced from wafers via a complex series of automated chemical and physical processes; and
7. individual cells are assembled into solar **modules**.

The least visible parts of the solar supply chain are its most upstream segments: quartz mining and conversion of quartz to metallurgical grade silicon (MGS). **These less visible parts of the supply chain and the polysilicon stage are the ones with the highest potential Uyghur Region exposure.**

Production of MGS, polysilicon, and ingots consumes large amounts of electricity. These tiers of the supply chain are optimally located in regions with abundant, low-cost electricity. The XUAR’s abundant coal reserves have encouraged some companies to locate their production in the Uyghur Region, resulting in a very high carbon footprint and very low price. **Every single polysilicon plant in the Uyghur Region is 100% powered by coal.** [The Breakthrough Institute](#) calculated that a polysilicon-based panel made with 100% coal as the energy source installed in California would have 3.76 times the CO2 payback time compared to one made with renewable energy.

Many companies have attempted to “bifurcate” their supply chains to comply with regulations and consumer demand, producing some product lines that include XUAR inputs and others that they claim do not. At the same time, batches of MGS or polysilicon sourced from different locations are often blended, which could introduce XUAR-sourced materials into any batch made by a company sourcing any amount of materials from the region. **Bifurcation of solar module supply chains presents a significant challenge to the wide range of governments, developers, and consumers purchasing modules, as they cannot always be certain whether they are buying the tainted or untainted products.**

This report provides insight into these obscure supply chains at a time when solar manufacturers provide increasingly little information in public records.

The Making of a Solar module



1. Quartz



2. Metallurgical Grade Silicon (MGS)



3. Polysilicon



4. Ingots



5. Wafer



6. Cells



7. Modules

METHODS

This analysis uses two sources of information for its module exposure assessment. This assessment of exposure:

1. deploys publicly available records regarding solar supply chain sourcing, including corporate annual reports, press releases, announced production capacity, customs records, and email exchanges with responsive solar producers, and
2. applies more than thirty years of expertise in auditing the most obscure parts of the solar supply chain (quartz—metallurgical grade silicon—polysilicon) to determine risk where visibility is least possible.

The assessment for each of the seven segments of the supply chain (quartz, MGS, polysilicon, ingot, wafer, cell, module) indicates XUAR exposure introduced to the supply chain through sourcing for that specific segment. Exposure assessments for each segment of the supply chain consider geographic location of the production step (located in the XUAR or not) and geographic source of the silicon input required for each segment (silicon input from proceeding segment produced in the XUAR or not). The final assessment is based on whether any XUAR-produced material is used (or likely to be used) in production at any individual segment of the supply chain.

The assessments rely on the most recent data available. Desk-based research shows companies involved in the silicon-based solar supply chain—from polysilicon through module production—have reduced public disclosures regarding sourcing over the last 12-18 months. While the number of disclosures and details provided has never been adequate to accurately map the full supply chain of most modules, significantly more information could be gleaned about specific parts of the supply chain prior to this observed change.

Where information is not publicly available, industry expertise provides insight into likely sourcing decisions, based on geographical location, production capacity, corporate ownership, or joint ventures in other companies in the supply chain. When multiple likely scenarios are available—when there are multiple suppliers, multiple manufacturing sites, or multiple product lines—all known possibilities are represented in the exposure assessments.

Companies assessed for this project represent a non-random sample of the industry's manufacturers. The companies were chosen to represent a range within the following characteristics: production capacity, manufacturer location, suspected exposure, degree of vertical integration, and consumer interest in Europe and the US. We included in the sample each of the [world's top five module producers](#) for 2022, as they collectively represent 70% of module demand globally.

DEFINING EXPOSURE

Corporate exposure is assessed based on high-risk indicators of supply chain connections to the Uyghur region, as indicated by publicly available sourcing information. In some cases, supply contracts confirm a relationship between the company and a Uyghur Region manufacturer of MGS or polysilicon. In other cases, disclosures reveal sourcing from companies that have elevated risk of sourcing from the Uyghur Region, based on the assumptions described below. Assessments note both and differentiate the

two. The decision tree at the end of this report provides a graphical representation of the assessment logic.

ASSUMPTIONS

The expertise-based assumptions that undergird the determinations of likely sourcing include the following:

Quartz: China-based MGS producers historically use quartz mined in the same province in which they are located. Historical sourcing trends indicate that most quartz is not shipped great distances in China. The overall quality of quartz in the XUAR is poor, but the region's MGS industry has become massive due to the abundance of low-cost coal-based electricity. To address the low quality, some quartz used in the XUAR is shipped from other provinces, including Fujian and Gansu, or possibly from Kazakhstan. Given the poor quality of XUAR-mined quartz, there is no concern that XUAR quartz is being exported internationally or to other provinces of China for MGS production.

MGS: Public and non-fee-based data on MGS sourcing is now practically non-existent. This analysis assumes, based on sourcing behaviors typical of the industry, that polysilicon producers located in a province producing significant and sufficient quantities of MGS use only MGS produced in that province, outside of emergencies. The XUAR, Yunnan, and Sichuan are the top three MGS-producing provinces, in order. Polysilicon manufacturers located in provinces with limited or no MGS production (Inner Mongolia, Qinghai, and Zhejiang, for example), however, can be assumed to use MGS produced in one or more outside provinces (usually at least two). One can assume with reasonable accuracy that all of these MGS consumers purchase at least some MGS from the [top three provinces](#) (the XUAR, Yunnan, and Sichuan) because these three account for the vast majority of China's MGS production. Without sourcing disclosures on which to base a supply chain map, polysilicon producers in low-MGS-producing provinces—which must source from outside provinces—are more likely to source from the XUAR. China and other Asia-based (Japan, Korea, and Malaysia) MGS consumers usually sign three-month supply contracts (US and European consumers usually sign twelve-month MGS supply contracts.). As a result, China-based consumers can use a high number of unique MGS suppliers each calendar year, again increasing potential exposure. MGS production is expected to increase significantly in the coming year, so geography-based assessment indicators will need to be reevaluated as new production comes online. Multiple projects to increase MGS production in Inner Mongolia have been announced to match the rapidly expanding Inner Mongolia polysilicon production, but most of this new capacity remains under construction. Like XUAR, electricity is generated from use of abundant coal reserves in Inner Mongolia.

Polysilicon: All polysilicon from facilities that source any MGS from the XUAR should be considered to contain XUAR inputs. Regardless of how MGS is handled, polysilicon plants are never designed to facilitate total isolation of different sources of MGS. While possible, such designs could increase capital expenditure by approximately two to three times; at the time of publication no known facilities have made this investment.

Multiple Suppliers: When there are multiple inputs for a specific segment of a supply chain, the total XUAR exposure for that supply chain segment is based on the worst-case exposure of the individual suppliers. Whenever disclosures make it possible, assessments differentiate between discernably bifurcated supply chains.

Production Capacity: Most companies only disclose their production capacity and not their realized production. Realized production is always less than production capacity. Due to lack of reliable and consistent information on realized production, the assessments use capacity as a proxy for production. When supply contract volumes do not add up to an amount sufficient to meet production capacity, unmet supply represents elevated risk of XUAR sourcing because suppliers may be unknown.

Lack of Disclosures: When a company discloses that it sources MGS, polysilicon, ingots, wafers, or cells from China but will not disclose its suppliers' names or amounts procured, there remains an elevated risk that the company is sourcing from the XUAR, given the region's dominance in MGS and polysilicon production.

Note: Non-silicon materials required to produce a finished module, such as aluminum (frames), glass (module covers), silver (electrical contacts), copper (electrical contacts), and polymers (back sheet of each module), are not included. Some of these non-silicon parts of the supply chain, notably aluminum, may also have exposure to the XUAR and require additional scrutiny for ethical procurement. Consideration of XUAR exposure in these parts of the module is not within the scope of this report.

VERIFYING THE DATA

Once the expert analysis of the supply chains exhausted all public data, all companies whose modules were assessed were given the opportunity to provide information that could address missing data. Where companies provided data directly, it is noted. Where that data cannot be verified through a source other than the company, that has also been noted.

"Verified public disclosure" is used to describe a module producer's private or public disclosure that can be verified by a separate public disclosure and/or a known disclosure accessed through use of reputable fee-based analysis services. Public disclosures include solar company press releases, annual reports, semi-annual reports, company "road show" reports, and investor presentations.

LIMITATIONS

Data access is the most significant challenge to assessing exposure to the XUAR. With very few exceptions, the global silicon-based solar industry withholds critical data that renders any tracing effort incomplete. Top-tier module producers know for certain where every batch of polysilicon is sourced for every module they manufacture, but they largely will not share this information.

As the available information on sourcing for a module producer decreases, risk of XUAR inputs increases. Most module producers offer several module product lines. Generally, product lines are divided by individual module efficiency (defined as the percentage of sunlight a module converts to electricity) and/or power ratings. There is a good chance that different product lines from the same module producer have different XUAR exposure due specifically to the purity of polysilicon required. However, unless panel manufacturers have revealed sourcing by specific product, it is impossible even for an expert to know for certain which products or even batches of modules present the most risk.

Most companies only publish production capacity without disclosing actual final production. Even for those companies that publish actual production figures, understandings of current sourcing can only be based on the company's capacity, as actual output cannot be predicted from historical data. For this reason, these assessments must rely on corporate disclosures of capacities.

The report is a good faith effort to provide a reasonable assessment, given available data, for the public benefit. Companies may not provide truthful disclosures or may exaggerate or underestimate production capacities, affecting the ability to predict sourcing requirements. Assessments assume companies provide correct information in official filings and press releases, but those sources could still be misleading. The authors of this report rely on this information but cannot guarantee its accuracy.

HOW TO READ THE MODULE ASSESSMENTS

The Risk Assessment for each company—as illustrated by the chart on the following page—is broken into the following sections:

Summary: An overall assessment of the company's product lines' exposure to the XUAR.

Opportunities to Reduce Exposure: A list of steps the company and its suppliers could take to reduce their exposure, either by disclosing more information that would support a finding of lower/no risk or by shifting supply chains. Ethical investors, procurers, and consumers can use these recommendations as a starting point for engagement on XUAR exposure at each stage of the supply chain.

Evidence Base: The sources deployed to come to this finding.

Supply Chain Map: A flow chart representing the known and unknown sources of materials in the products' supply chains. Separate supply chain maps are provided when a company bifurcates its supply chain or creates multiple products that are discernably produced through separate supply chains.

The map present sourcing information that is available in publicly available disclosures and, when sourcing disclosures are not available, include the hypotheses regarding sourcing, based on industry expertise, sourcing trends, production capacity, and historical data. Additional information provided by companies was only included in these maps when it could be corroborated by evidence. When module manufacturers provided their own revisions to the supply chain maps, they are included in the report without color coding. Discussion of some additional evidence supplied by the companies is included within the body of the report, and the full responses of the companies are included in [Annex A – Corporate Responses](#).

Analysis: An analysis of the available information about materials sourcing, broken into two parts: ingot/wafer/cell/module production (which is sometimes vertically integrated and for which the most information is attainable) and the quartz/MGS/polysilicon stages (for which there is typically scant if any information available).

1. Johannes Bernreuter to Laura T. Murphy, personal correspondence with author, 31 May 2023.

XUAR EXPOSURE ASSESSMENT RUBRIC

XUAR Exposure	Polysilicon Sourcing Data Available	Basis of Assessment
VERY HIGH	At least one polysilicon producer is known	Any product in the supply chain (quartz, MGS, polysilicon, ingots, wafers, cells, or modules) is documented to be produced in the XUAR
HIGH	All, some, or none of the polysilicon producers may be known	Any portion of the polysilicon sourcing is unknown, and thus could be from the XUAR. OR Any portion of the polysilicon is sourced from a known producer in China that has high polysilicon production capacity located in a province with low or no MGS production capacity (elevated risk of XUAR sourcing) OR Any portion of the polysilicon is sourced from elsewhere in Asia and the MGS supplier locations are unknown
MEDIUM	None of the known polysilicon producers is in a higher exposure category AND... At least one polysilicon producer is known	Any portion of the polysilicon is sourced from a known producer in China that has low polysilicon production capacity located in a province with low or no MGS production (moderate risk of XUAR sourcing) OR All of the polysilicon is sourced from the EU and the MGS suppliers' locations are unknown (none exists that fit this description at this time, as Wacker Germany is the only EU polysilicon producer)
LOW	At least one polysilicon producer is known	Any portion of the polysilicon is sourced from a known producer in China with any polysilicon production capacity located in a province with high MGS production (the only reason non-provincial or XUAR MGS would be used is due to potential emergency use of alternate suppliers)
NONE (UNVERIFIED)	All polysilicon producers are documented but cannot be independently verified	MGS sourcing locations documented in corporate or other reputable disclosures show none is in the XUAR, but no additional public or official disclosures verify the claim
NONE (VERIFIED)	All polysilicon producers are documented and independently verified	MGS sourcing locations documented in corporate disclosure and show none is in the XUAR, and additional public or official disclosures verify the claim OR All polysilicon is documented to be sourced from the US (due to prohibitive duties on China MGS in the US)

Note: These assessment criteria reflect sourcing trends as of June 2023. As supply chains shift, government regulations change, and new evidence emerges, these assessment criteria would most likely shift. Up-to-date expertise on polysilicon and MGS trends is required. This chart should not be construed as advice or endorsement.

Canadian Solar

All Modules

The overall XUAR exposure for all modules produced by Canadian Solar in China, Thailand, and Vietnam is HIGH.

EVIDENCE BASE

Ranking the XUAR exposure for all modules produced by Canadian Solar in China, Thailand, and Vietnam from purchased polysilicon, ingots, wafers, and cells is a challenge due to a lack of public disclosures. The primary source of information is Canadian Solar annual reports. In its [2021 Annual Report](#), Canadian Solar provided some information about ingot, wafer, and cell suppliers, as well as information about polysilicon suppliers for modules produced for the US market. The company’s most recent [2022 Annual Report](#), however, contains no discussion of ingot, wafer, and cell suppliers, and still only indicates the polysilicon suppliers used for modules produced for the US market. Due to a lack of publicly available information, this assessment relies on information gleaned from both the 2021 and 2022 annual reports, production capacity announcements, and historical sourcing trends.

Canadian Solar appears to have stopped producing modules in Ontario, Canada in 2020 or 2021. There is no available disclosure stating that Canadian production has stopped, but careful analysis of reported capacity data in the 2020, 2021, and 2022 annual reports and the fact that information about the Canadian manufacturing facility was no longer included starting with the [2021 Annual Report](#) suggest this conclusion. For this reason, the assessment does not include the Canadian facility.

The analysis in this document does not include the recently announced [5 GW module production facility](#) to be built in Mesquite, Texas, US.

ANALYSIS

Analysis of XUAR exposure in Canadian Solar supply chains begins with an analysis of global Canadian Solar production capacities. This capacity analysis reflects Canadian Solar’s rapid increase of capacity in China starting in 2021 and extending through 2024 projections. Table 1 shows published Canadian Solar total capacities for the end of 2020, 2021, 2022, estimated end of 2023, and estimated end of 2024. Table 1 shows the rapid progression and the shortfall, at times, in internal ingot, wafer, and cell capacity.

Canadian Solar capacity estimates for mid-2023 are calculated by averaging the published global capacity at the end of 2022 and the estimated global capacity at the end of 2023. The Canadian Solar 2022 Annual Report does not separate Southeast Asian capacity into Thailand and Vietnam; however, disclosures show the total regional capacity (4.2 GW of cells and 4.4 GW of modules) and that Thailand has cell and module capacity while Vietnam only has module capacity.

Table 1 shows that in its 2023 projections, Canadian Solar does not produce enough ingots or wafers internally to meet its 50 GW of module production capacity. It is likely that as the company moves from producing 19.8 GW of cells in 2022 to 50 GW in 2023 there will be an mid-year imbalance in production of cells adequate to manufacture modules. Thus, this analysis assumes that while Canadian Solar is somewhat vertically integrated, the company must purchase polysilicon (to produce ingots), incremental ingots (to produce wafers), incremental wafers (to produce cells), and incremental cells (to produce modules) in 2023. Estimates show that it is Canadian Solar’s ambition to have more balanced production capacities by end of 2024; however, even then, the company will still need to purchase polysil-

Overall Exposure

<div>HIGH</div>	QUARTZ	HIGH
	MGS	HIGH
	POLYSILICON	HIGH
	INGOT	HIGH
	WAFER	NONE (VERIFIED)
	CELL	NONE (VERIFIED)
	MODULE	NONE (VERIFIED)

ASSESSMENT

The HIGH ranking is based on the following factors:

- Incomplete information about all suppliers and their relationships to individual Canadian Solar facilities;
- Lack of metallurgical grade silicon supply disclosures for Chinese polysilicon produced in Henan, Hubei, Inner Mongolia, and Shaanxi provinces, which are claimed to be used for production of modules in Thailand and Vietnam.

OPPORTUNITIES TO REDUCE EXPOSURE

- Verified disclosure of all suppliers of MGS, polysilicon, ingots, wafers, and cells used in all operations
- Verified disclosures that confirm the bifurcation of sourcing across all tiers for the Southeast Asia supply chain and that demonstrate the full separation of dedicated manufacturing lines for different markets

Table 1: Global Canadian Solar capacities for 2021, 2022, estimated 2023 and 2024, estimated mid-2023 capacity for global, China, and Southeast Asia. GW = gigawatts.

CANADIAN SOLAR PRODUCTION CAPACITY BY YEAR	INGOT	WAFER	CELL	MODULE	PERCENT OF TOTAL MODULE CAPACITY
	GW	GW	GW	GW	%
End 2021	5.4	11.5	13.9	23.9	–
End 2022	20.4	20.0	19.8	32.2	–
End 2023 estimate	20.4	35.0	50.0	50.0	–
End 2024 estimate	50.4	50.0	60.0	75.0	–
Mid-2023 estimate	20.4	27.5	34.9	41.1	–
Mid-2023 estimate China Capacity	20.4	27.5	30.7	36.7	89.3
Mid-2023 estimate SE Asia Capacity	0.0	0.0	4.2	4.4	10.7

Note: analysis ignores yield losses for wafer conversion to cells and cells to modules and assumes production equals stated capacities.

icon, wafers, and cells. These significant changes in purchase of incremental inputs on a year-to-year basis introduce significant XUAR sourcing risk to the total Canadian Solar supply chain.

Canadian Solar is currently building a large [vertically integrated facility](#) that will produce metallurgical grade silicon, polysilicon, ingots, wafers, cells, modules, and crucibles in Qinghai with initial Phase-1 startup estimated to be mid-2024. This will significantly improve Canadian Solar's traceability and reduce its reliance on external supplier relationships.

Canadian Solar has no ingot or wafer capacity in Southeast Asia. This almost certainly means that China is the source of wafers used for cell production in Thailand.

At this time, Canadian Solar is not backward integrated to polysilicon, MGS, or quartz.

Ingot/Wafer/Cell/Module Exposure

[Canadian Solar](#) operates its China-based module fabrication facilities in Henan, Inner Mongolia, Jiangsu, and Zhejiang, and its Southeast Asia fabrication facilities in Thailand (at least until April 2023) and Vietnam. The company produces cells in Thailand and in Henan and Jiangsu in China. It produces ingots and wafers in facilities in Henan and Inner Mongolia in China.

As indicated above, Canadian Solar's internal production of inputs is not sufficient for its module production capacity. All along its vertically integrated supply chain, Canadian Solar must (and will for the foreseeable future) purchase ingots, wafers, and cells where the company's own production falls short. Canadian Solar has not disclosed any details about ingot, wafer, or cell suppliers for 2023.

Regarding Canadian Solar's *China-based production*, historical supplier agreements provide some insight into possible current suppliers. [Aiko Solar and Tongwei Solar](#) were listed as the main cell suppliers in 2020, and [Tongwei](#) was listed as the largest cell supplier in 2021. Canadian Solar reported its main wafer suppliers in 2020 as [LONGi and Zhenjiang Ren-de New Energy Science Technology Co., Ltd.](#), and the main wafer supplier in 2021 as [LONGi](#). The company also indicated [LONGi](#) would be a wafer

supplier until the end of 2022 (see [LONGi Solar](#) chapter in this report for more insight into those supply chains). Canadian Solar purchased ingots from Shangji (Hongyuan) from [December 2020](#) to [December 2022](#), and [Shuangliang](#) for an unspecified time, as disclosed in December 2021. However, no disclosures provide useful insight regarding which if any of these companies remain suppliers. This lack of disclosure results in an elevated risk of XUAR inputs entering Canadian Solar's supply chains through one or more of its undisclosed ingot, wafer, or cell suppliers to its China production facilities.

Canadian Solar has a semi-parallel supply chain for its *Southeast Asia-based production* of modules. Cells are produced in Thailand and modules are produced in Thailand and Vietnam. The company stated in a response to Sheffield Hallam University that the Vietnam module facility has been shuttered since April 2023 ([See Annex A – Corporate Responses](#)).

Customs records accessed via Panjiva Market Intelligence show, however, that a Vietnam shipper (whose name has been redacted) shipped upwards of 3 million kilograms of Canadian Solar solar panels to the United States between the beginning of April and the middle of June. A Canadian Solar representative indicated that these shipments were the remaining inventory of that factory.

Canadian Solar does not have ingot or wafer capacity in Thailand or Vietnam. Numerous Thailand wafer supply scenarios exist; it is possible that Thailand receives all wafers via transfer from Canadian Solar's China production. Southeast Asia also has slightly higher module capacity (4.4 GW) versus cell capacity (4.2 GW). Assuming Southeast Asia module production (Thailand and Vietnam combined) is actually at capacity and thus higher than Southeast Asia cell production, incremental cells are required. These incremental cells (0.2 GW) may also be transferred from Canadian Solar China cell production. Due to lack of disclosures, there is no way to know if cell transfer does occur and, if so, the destination of these cells, i.e., Thailand, Vietnam, or both. Because the Southeast Asia supply chain has designated polysilicon suppliers, it is reasonable to assume that Canadian Solar controls the production process across the ingot to module tiers.

Quartz/MGS/Polysilicon Exposure

According to Canadian Solar's annual reports cited above, all polysilicon purchased directly by Canadian Solar is consumed in its *China-based production facilities* to produce ingots in Henan and Inner Mongolia. No public disclosures have been identified that discuss specific polysilicon, MGS, or quartz suppliers used by Canadian Solar and its suppliers for its China module production. Lack of transparency results in elevated risk of XUAR inputs.

Canadian Solar acknowledged the need to avoid XUAR sourcing beginning in its [2021 Annual Report](#). Canadian Solar disclosed that polysilicon used to produce modules for the US market through its *Southeast Asia production facilities* in 2021 was purchased from suppliers in Henan and Inner Mongolia. The names of the polysilicon producers were not provided nor were details about where the ingots and wafers were produced or by whom.

The only polysilicon producer in Henan is China Silicon Company (also known as Sinosico). Sinosico is normally considered a low-capacity plant dedicated to production of semiconductor-grade polysilicon for the Chinese semiconductor industry. Operating polysilicon plants in Inner Mongolia in 2021 were Dongli, Ordos, Risen (formerly Dunan), and Tongwei.

Canadian Solar disclosed in its [2022 Annual Report](#) that polysilicon used to produce modules for the US market that year was purchased from suppliers in Hubei, Inner Mongolia, Shaanxi, and Germany. The names of the polysilicon producers were not provided nor were details about where the ingots and wafers were produced or by whom. The only polysilicon producer in Hubei is China South Glass (CSG). [CSG](#) restarted production in early 2022 after a prolonged shutdown due to market conditions. Operating polysilicon plants in Inner Mongolia in 2022 were Dongli, Ordos, Risen (formerly Dunan), and Tongwei; we cannot know which of these are supplying Canadian Solar, but at least one of them is. TianHong REC is the only polysilicon plant located in Shaanxi. Wacker is the only polysilicon producer located in Germany (with two separate plants: Burghausen and Nünchritz). In response to Sheffield Hallam's inquiries, Canadian Solar asserted that it only sourced polysilicon, MGS, and quartz from Inner Mongolia, Qinghai, Sichuan, and Yunnan (See Annex A). This departs significantly from the disclosures in the 2022 Annual Report. There is no way to verify these claims.

Due to lack of disclosures, it is unknown which of these companies (or others) are supplying Canadian Solar into 2023. However, given historical business relationships, Canadian Solar likely continues to source from at least some of these companies. Based on this, it is possible to gain some insight into where the MGS is likely sourced and where XUAR exposure is highest. There is no MGS production in Henan and very limited in Hubei and Shaanxi. At the time of publication of this report, there remains limited MGS production in Inner Mongolia. As a result, all polysilicon plants operating in these provinces have an elevated risk of sourcing some MGS from the XUAR, especially given the XUAR's global dominance in the production of MGS. These polysilicon plants also have a high probability of sourcing

some MGS from Sichuan and Yunnan, provinces that also produce significant quantities of MGS.

A Wacker executive reports that the company no longer uses any MGS produced in China, though that remains unverifiable through any public domain information.¹ In a response to Sheffield Hallam University, a Wacker representative indicated that the company does not source any products from the Uyghur Region, making this statement regarding the United States Customs and Border Protection (CBP) enforcement of the UFLPA: "Wacker's polysilicon meets CBP's requirements and we have established supply chains to meet CBP's requirements." Wacker further indicated that its German polysilicon is currently made of MGS sourced from Europe, Norway, Canada, Iceland, Brazil, South Africa, and Australia; its US-produced polysilicon is made of MGS sourced from Brazil, US, and Norway. Wacker also provided the country of origin of all of its raw silica. ([See Annex A – Corporate Responses](#))

The XUAR risk for the possible China-based polysilicon suppliers used by Canadian Solar in 2021 and 2022 for the US module market ranges from NONE (UNVERIFIED) (Wacker), LOW (Sinosico), MEDIUM (CSG and Tian-Hong REC) to HIGH (all producers in Inner Mongolia).

Conclusion

Canadian Solar produces most of its modules in China. Modules for the US market are produced by Canadian Solar in Thailand and Vietnam. The overall Canadian Solar supply chain is very complicated due to lack of balance between ingot, wafer, cell, and module capacities, as well as rapid increase in production of all stages of Canadian Solar's vertically integrated supply chain. There are no disclosures by Canadian Solar about specific suppliers of any inputs in 2023 and only extremely limited information about previous years' suppliers. As a result, the XUAR risk for all modules produced by Canadian Solar, including those for the US market, is HIGH.

1. Jörg Hoffman, Wacker Senior Vice President for Investor Relations in Munich Germany to author, personal correspondence, 30 March 2023.

Canadian Solar

China Supply Chain

EXPOSURE KEY

VERY HIGH

HIGH

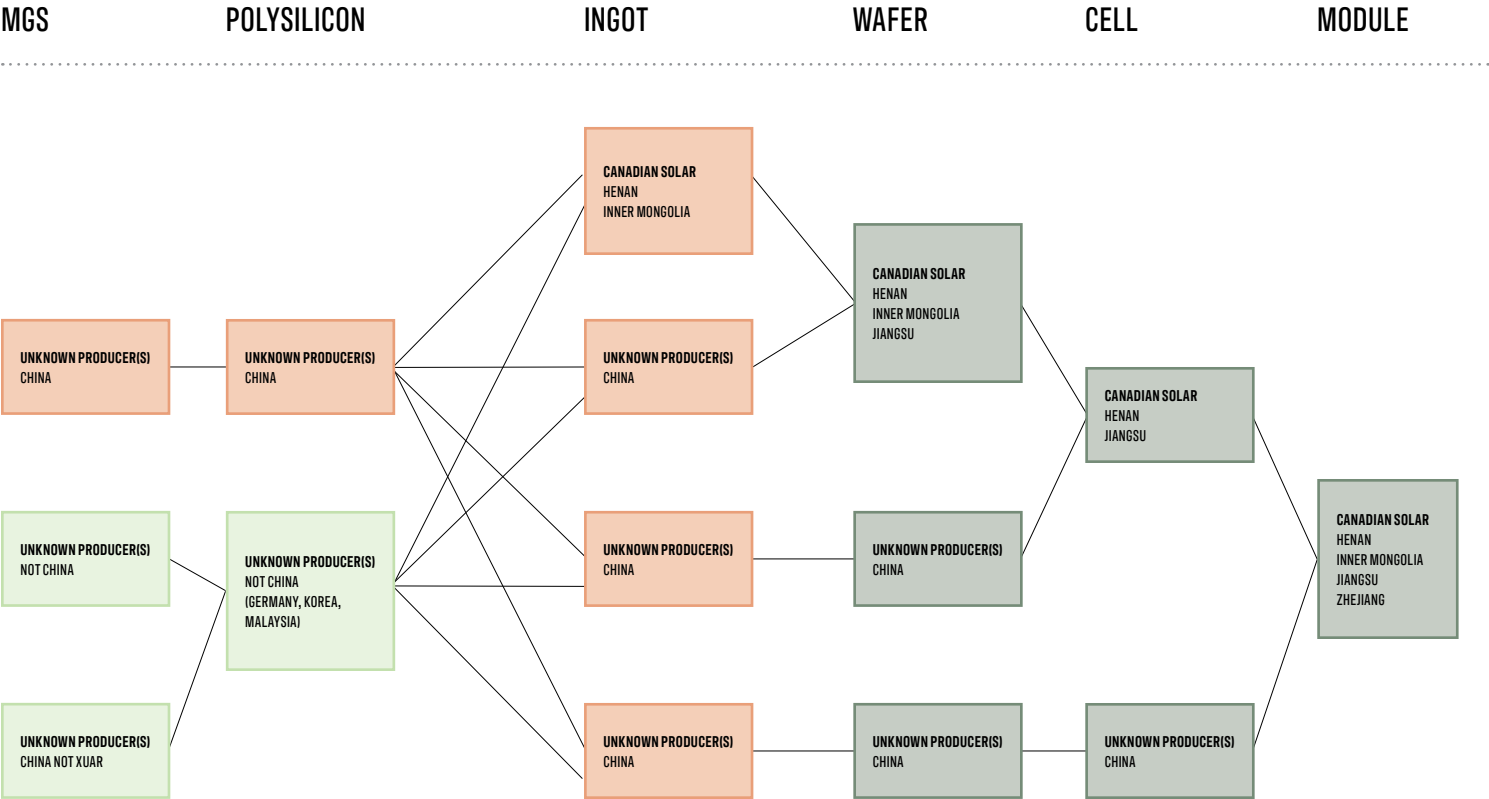
MEDIUM

LOW

NONE (UNVERIFIED)

NONE (VERIFIED)

Solid line = disclosed / known information (verified or unverified)
Dashed line = not disclosed but likely / possible



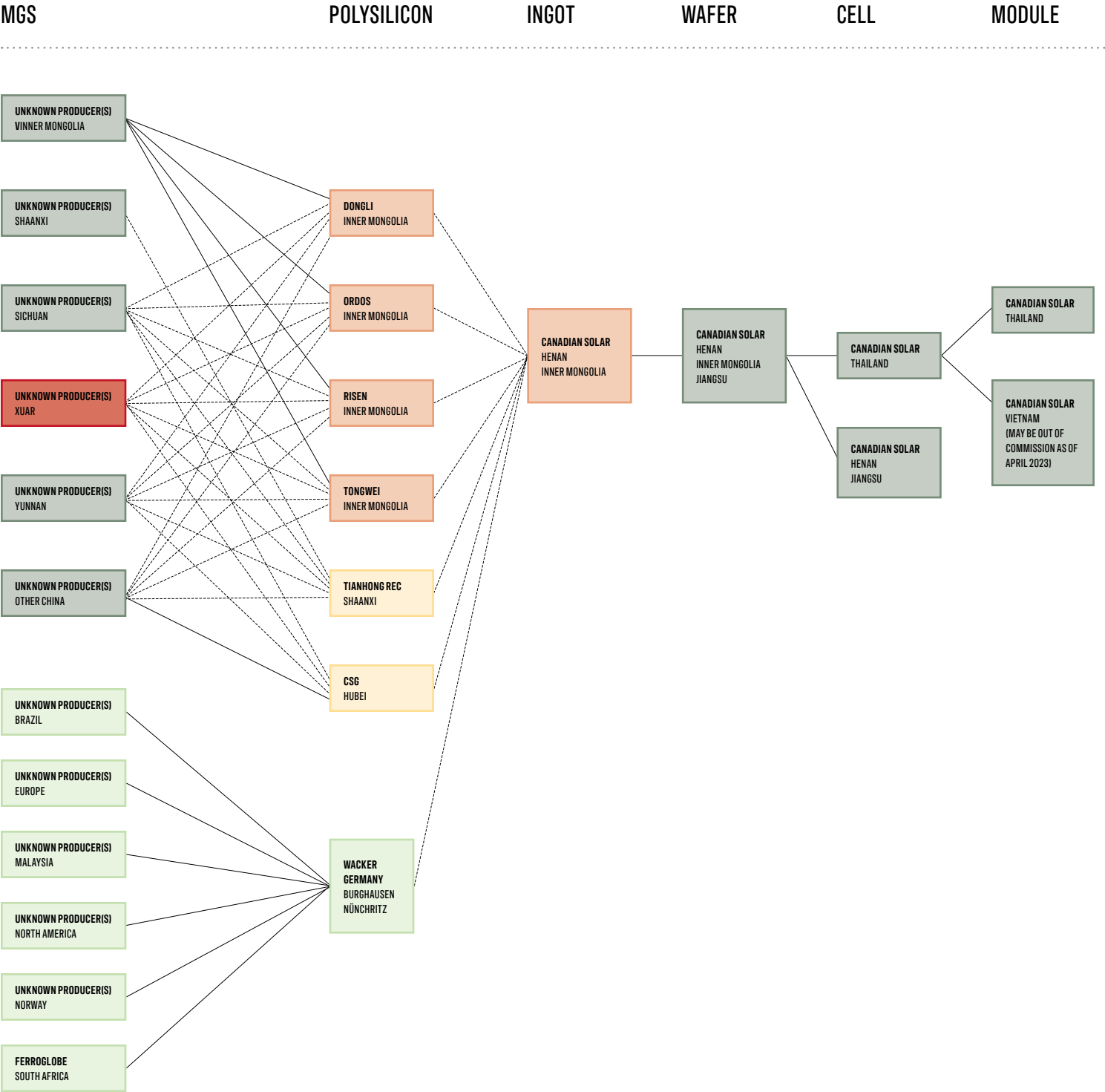
Canadian Solar

Southeast Asia Supply Chain

EXPOSURE KEY



Solid line = disclosed / known information (verified or unverified)
Dashed line = not disclosed but likely / possible



JA Solar

All Modules

The overall XUAR exposure for all modules produced by JA Solar in China, Vietnam, and the US (beginning late 2023) is VERY HIGH.

EVIDENCE BASE

The main source of information about JA Solar is its [Chinese-language corporate website](#), which includes annual reports and investor relations publications. Investor relations information is not found on the JA Solar [English-language website](#).

[JA Solar 2022 Annual Report](#) provides a detailed (though not comprehensive) list of the company's major polysilicon supply contracts listed by supplier name along with total amount (with the exception of Hemlock Semiconductor) and contract duration. Information about suppliers of incremental ingots, wafers, and/or cells is not provided. JA Solar provides general global capacity information in each annual report along with global production data. JA Solar does not publish a comprehensive list of individual manufacturing site capacities.

ANALYSIS

JA Solar operates numerous ingot, wafer, cell, and module production facilities in China. JA Solar operates an integrated facility in Vietnam (ingot, wafer, cell, and module); a cell fab in Malaysia and will produce modules in Arizona, US beginning in late 2023.

There is insufficient supplier and capacity information available to separately assess JA Solar modules produced in China and those produced in Vietnam. Without further disclosures, this will also be the case when US module production begins.

JA Solar is not currently backward integrated to quartz, metallurgical grade silicon, or polysilicon. JA Solar plans to build a [100,000 TPY polysilicon plant](#) in Inner Mongolia, China (along with ingot, wafer, cell, and module production), but JA Solar does not appear to anticipate backward integration to MGS production (or quartz mining) in the future. JA Solar's [2022 Annual Report](#) states that the company sells small amounts of ingots, wafers, and cells. Details of these minor sales are not reported, and they are not incorporated in this analysis, as they do not change the XUAR exposure assessment for JA Solar.

Analysis of XUAR risk of all JA Solar-produced modules begins with an overall analysis of global JA Solar production capacities.

JA Solar provides general global capacity information, as well as actual production, in each annual report. While facility-specific global ingot, wafer, and cell capacity and production data would be better, the approximate values are sufficient to assess XUAR exposure. Data that would link specific suppliers to specific facilities are unavailable, which makes differentiation of China and Southeast Asian supply chains impossible.

Table 1 provides a summary of JA Solar end of 2022 global capacities, as well as a breakdown of China and Southeast Asia (Vietnam and Malaysia) capacities. Table 1 also provides global JA Solar 2022 actual production. Regional production data are not reported by JA Solar. The production data mirror capacities: module production is higher than ingot, wafer, and cell. Table 2 provides the same data for projected end of 2023 capacities. China-only capacities are determined by difference from global and Southeast Asia.

The data in Table 1 show that through the end of 2022, production of ingots, wafers, cells, and modules in Vietnam and Malaysia was significantly out of balance and will remain out

Overall Exposure

VERY HIGH	QUARTZ	VERY HIGH
	MGS	VERY HIGH
	POLYSILICON	VERY HIGH
	INGOT	VERY HIGH
	WAFER	NONE (VERIFIED)
	CELL	NONE (VERIFIED)
	MODULE	NONE (VERIFIED)

ASSESSMENT

The VERY HIGH ranking is based on:

- Significant use by JA Solar of polysilicon produced in the XUAR;
- Incomplete information about the JA Solar polysilicon supply used in its Chinese and Vietnamese ingot/wafer facilities;
- Lack of disclosures regarding wafers and cells purchased for the JA Solar Vietnam and Malaysia facilities.

OPPORTUNITIES TO REDUCE EXPOSURE

- Verified disclosure of annual amount of polysilicon purchased from Hemlock
- Verified disclosure of all polysilicon, ingot, wafer, and cell suppliers and their relationship to specific JA Solar facilities
- JA Solar divestment from Xinte and cessation of purchasing polysilicon from Xinte and Daqo
- End of JA Solar sourcing polysilicon from Daqo XUAR and any additional unnamed XUAR producers

Table 1: JA Solar global, China, and non-China capacities at end of 2022. GW = gigawatts.

CANADIAN SOLAR PRODUCTION CAPACITY BY YEAR	INGOT	WAFER	CELL	MODULE	PERCENT OF TOTAL MODULE CAPACITY
	GW	GW	GW	GW	%
Global capacity 2022	40.0	40.0	40.0	50.0	–
Global 2022 production realized	36.01	35.07	32.16	40.04	–
Global capacity estimate 2023	72.0	72.0	72.0	90.0	–
China capacity 2022	38.5	38.5	35	46.5	93.0
Vietnam capacity 2022	1.5	1.5	3.5	3.5	7.0
Malaysia JA Solar capacity 2022	0.0	0.0	1.5	0.0	0.0

of balance in the coming year, assuming all facilities are operating at capacity. This suggests that, when operating at capacity, the Southeast Asian facilities require inputs from elsewhere. If JA Solar is supplying its own cells to make up the deficiency, those cells would come from China. JA Solar could also be sourcing externally from an unknown supplier. The use of China-produced inputs combined with lack of detailed disclosures means there is no way to create a separate exposure assessment for JA Solar's Southeast Asia operation using publicly available data.

Ingot/Wafer/Cell/Module Exposure

Table 1 shows that globally, JA Solar has higher module capacity than ingot, wafer, and cell capacities. This means that when JA Solar is operating at capacity, cells must be purchased from one or more external suppliers. The data in Table 1 for actual global JA Solar 2022 production show that even when operating below capacity, JA Solar produced more modules (40.04 GW) than cells (32.16 GW) resulting in the need to purchase 7.88 GW of cells. JA Solar provides no disclosures about external cell suppliers. JA Solar appears to continue to plan for routine external cell purchases as estimated 2023 module capacity remains higher than cell capacity.

While the data in Table 1 indicate “balanced” production of 40 GW of ingots, wafers, and cells by JA Solar, JA Solar's 2022 Annual Report shows ingot production capacity did not reach the 50GW necessary for module production and also indicates that JA Solar will only reach “about” 90% of module capacity in 2023. JA Solar's contract to purchase wafers from [Jingyuntong New Material Technology Co., Ltd.](#) (JYT) through the end of 2023 bolsters the inference that that JA Solar's wafer capacity does not equal cell capacity. There may be additional external wafer and/or ingot suppliers.

JA Solar's **China module production** capacity in Anhui, Hebei, Jiangsu, Shanghai, and Zhejiang totaled 46.5 GW in 2022, but its cell production in Hebei, Jiangsu, and Zhejiang only reached 32.16 GW. This left as much as 14.34 GW of cells to be purchased from unnamed supplier(s).

For its **Southeast Asia production**, Vietnam produces 3.5 GW of cells and modules but only produces 1.5 GW of ingots and wafers. The Malaysia facility produces 1.5 GW of cells, but no wafers. The remaining 3.5 GW wafers required

for JA Solar's Southeast Asia operations are likely produced in China by JA Solar and/or by an external Chinese wafer producer, as [China produces more than 98% of wafers globally](#). The wafers could be sourced through the JYT supply agreement described above, but that is uncertain. It does appear that JA Solar produced just under 3GW more wafers than cells in China in 2022, all of which could have been transferred to Southeast Asia. Even in this case, JA Solar's exposure to the XUAR (described below) would be extended to its Southeast Asia operations. As a result, the lack of detailed JA Solar disclosures about wafer purchases and transfers makes an isolated XUAR assessment for Southeast Asia/US JA Solar operations impossible.

While JA Solar Vietnam cell and module capacity is balanced at 3.5 GW each, the 1.5 GW of cells produced in Malaysia have no disclosed final destination. These 1.5 GW of cells produced by JA Solar Malaysia are likely sold to one or more external companies producing modules for the US market, due to demand for XUAR-free products.

Quartz/MGS/Polysilicon Exposure

Table 2 lists the main JA Solar polysilicon suppliers for 2022 along with contract start/stop dates, as stated in the company's 2022 Annual Report. JA Solar provides data on the total amounts of polysilicon purchased from each supplier except Hemlock Semiconductor. In addition to the polysilicon supply contracts listed in Table 2, JA Solar has disclosed that [East Hope \(XUAR\), Tongwei \(Inner Mongolia, Sichuan, Yunnan\) and Wacker \(Germany, US\)](#) supplied polysilicon from 2019-2022. The status of these producers as suppliers in 2023 is not known.

Public domain disclosures about MGS suppliers used by any China-based polysilicon producer do not exist. Nonetheless, XUAR exposure for JA Solar's designated polysilicon suppliers is quite high. Without full disclosures of MGS suppliers, sourcing trends and geographic location can reveal indicators of XUAR sourcing.

XUAR-based polysilicon producers such as Daqo and Xinte almost certainly use 100% XUAR-produced MGS, given the companies' geographical location, sourcing trends, and the dominance of the XUAR in MGS production. Xinte appears to be a primary supplier, providing JA Solar with 46,800

Table 2: Summary of the major JA Solar polysilicon suppliers.

JA SOLAR POLYSILICON SUPPLIER	POLYSILICON PLANT LOCATION	CONTRACT TERM
Asia Silicon	Qinghai, China	September 2020 – August 2025
Daqo XUAR contract-1	XUAR, China	January 2021 – December 2023
Daqo XUAR contract-2	XUAR, China	January 2022 – December 2025
GCL-Poly	Jiangsu, China	July 2021 – June 2026
Hemlock Semiconductor	Michigan, US	October 2016 – September 2027
Xinte XUAR	XUAR, China	September 2020 – December 2025
Xinte Inner Mongolia	Inner Mongolia, China	April 2022 – December 2026
Xinte XUAR	XUAR, China	April 2022 – December 2026

tonnes in 2022, constituting 37.6% of the known polysilicon that JA Solar used. Xinte's Inner Mongolia plant was not open at that time, so this all would have been sourced from the XUAR.

There is no MGS production in Jiangsu; therefore, the risk of GCL-Poly using XUAR-produced MGS is assessed as high. The risk of using XUAR-produced MGS by Xinte Inner Mongolia and Asia Silicon is elevated as well; there is currently limited MGS production in Inner Mongolia and Qinghai, and MGS consumers in those regions likely use MGS from the main producing provinces, with the XUAR at the top. JA Solar's preferred polysilicon supplier appears to be Xinte (parent: TBEA). Xinte operates a polysilicon plant in the XUAR and is developing a new plant located in Inner Mongolia to begin operation in 2023. JA Solar owns a [9% share](#) of the Inner Mongolia Xinte polysilicon plant.

Hemlock, on the other hand, cannot use any China-produced MGS due to a long-standing 139% anti-dumping duty on any Chinese MGS imported to the US.

Hemlock Semiconductor (US) is the only supplier listed in Table 2 that is certain to only be used in the JA Solar Vietnam ingot/wafer fabrication facility. Hemlock solar-grade polysilicon is subject to a [53.3% anti-dumping duty](#) for imports into China. In January 2020, the Chinese Ministry of Commerce (MOFCOM) [extended anti-dumping duties](#) on US-produced solar-grade polysilicon for an additional five years. Thus, it is prohibitively expensive for China-based ingot-wafer companies to source solar-grade polysilicon from the US. Because it is unclear from JA's annual reports how much polysilicon Hemlock supplies to JA Solar, it is not possible to determine if it is sufficient for the full production of the ingots made in Vietnam. Even if it is, however, the lack of disclosures regarding the externally sourced wafers and cells described above still represents exposure for the Southeast Asia supply chain.

JA Solar Future

JA Solar plans to build a [100,000 TPY polysilicon plant](#) in Inner Mongolia, China (along with ingot, wafer, cell and module production); once it is producing at capacity, that integration will reduce JA's reliance on external suppliers. MGS will remain a concern, however, because Inner Mongolia currently has low MGS production, and so MGS sourcing remains a possible exposure.

JA Solar Vietnam plans to add a [2.5 GW wafer facility](#) to bring the total Vietnam capacity to 4.0 GW of wafers but only 3.5 GW of modules in 2023. The "extra" 0.5 GW of wafers produced in Vietnam could be transferred to JA Solar Malaysia. JA Solar Malaysia would still require an additional 1.0 GW of wafers to produce the total 1.5 GW of cells.

A JA Solar [2.0 GW US module fab](#) is projected to begin operation in late 2023. The chances that US module production exceeds 1.5 GW (and uses only the 1.5 GW of cells produced by JA Solar Malaysia) in 2023 are very low. Any new facility takes some time to reach the design capacity. As long as US module production is no greater than 1.5 GW, all cells can be supplied from JA Solar Malaysia. When the facility reaches full production capacity, the additional 0.5 GW of cells will need to be purchased, assuming the facility does not begin cell production.

By the end of 2023, assuming all facilities are operating at capacity, production of ingots, wafers, cells, and modules in Vietnam, Malaysia, and the US will remain out of balance. This continues to indicate elevated risk of XUAR sourcing.

Conclusion

JA Solar has significant ingot, wafer, cell, and module capacity in China and limited capacities in Vietnam and Malaysia. By late 2023, JA Solar plans to add module capacity in the US and polysilicon production in Inner Mongolia. Based on JA's 2022 and 2023 capacity data, neither China-based nor the Southeast Asia-based operations (Vietnam and Malaysia) are balanced in terms of ingot, wafer, cell, and module capacity. As a result, the sources of some inputs (wafers and cells) for these sites are unknown and are most likely produced in China. JA Solar disclosures about polysilicon supply do not provide details about use of specific polysilicon suppliers for specific JA Solar locations and do not add up to the amount required for ingot production. As a result, there is no way to provide separate XUAR risk rankings for modules produced in China and modules produced in Southeast Asia (or those to be produced in the US beginning in late 2023). The XUAR risk for all modules produced by JA Solar is VERY HIGH.

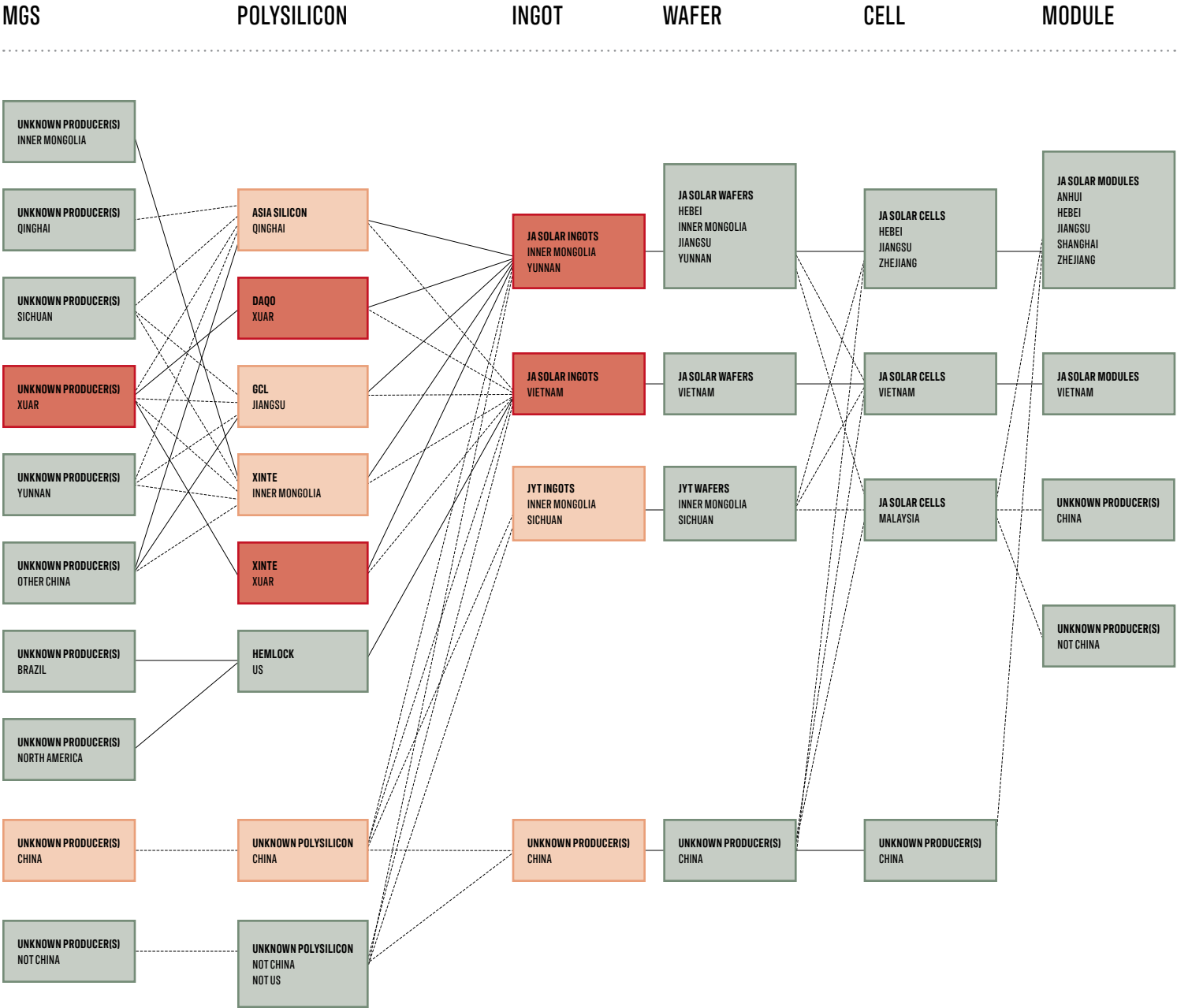
JA Solar

All Modules

EXPOSURE KEY



Solid line = disclosed / known information (verified or unverified)
Dashed line = not disclosed but likely / possible



Jinko Solar

Southeast Asia-Produced Modules and China-Produced Modules

The overall XUAR exposure for all solar modules produced by Jinko Solar is assessed as HIGH.

EVIDENCE BASE

Jinko operates (at least) three fairly distinct supply chains, and all are individually assessed at HIGH exposure, based on the evidence below.

Jinko produces most of its modules in China from self-produced ingots, wafers, and cells, which are made of purchased polysilicon. Assessing the XUAR exposure for the majority of modules produced by Jinko Solar in China thus relies on public disclosures about polysilicon suppliers compared against production capacities of Jinko facilities. The Jinko [2022 Annual Report](#) provides limited information about the overall Jinko polysilicon supply. Analysis of public disclosures (see below) regarding Jinko polysilicon supply contracts revealed approximately 60% of the required total Jinko polysilicon supply for 2022 and approximately 90% of the total Jinko polysilicon supply for 2023.

Jinko effectively has a second supply chain involving the Jinko-Tongwei Solar joint venture (JV) based in Sichuan. The Jinko 2022 Annual Report provides insight into the JV but does not provide adequate details regarding sourcing, particularly for incremental cell acquisition.

A third Jinko supply chain operates ingot, wafer, cell, and module production facilities in Vietnam (ingot, wafer), Malaysia (cell, module) and the US (module). Jinko attestations suggest the supply chain is dedicated to US-compliant non-XUAR sourcing and that all polysilicon comes from Germany and the US. Customs records accessed via Panjiva Market Intelligence for 2022 and 2023 inform this analysis and provide some information about cell and module imports into the US by Jinko, and also reveal shipments of polysilicon from Germany, the US, and China to Jinko’s Vietnam ingoting/wafering facility.

Jinko provided fairly extensive responses to Sheffield Hallam’s inquiries ([see Annex A – Corporate Responses](#)), as well as the company’s revision to a draft supply chain map (see below).

ANALYSIS

Analysis of XUAR risk of all Jinko supply chains begins with an overall analysis of global Jinko production capacities. This capacity analysis is for the [end of 2022](#), as that is the most recent published total Jinko capacity data. Jinko does not have (nor are there indications it will have in the future) internal MGS and polysilicon capacity. Jinko does have one polysilicon joint venture and one polysilicon equity investment (see below).

Table 1 summarizes Jinko’s overall and regional capacities as of 31 December 2022.

Ingot/Wafer/Cell/Module Exposure

The data in Table 1 shows that Jinko has two separate China-based module supply chains. The main **China-based module supply chain** produces modules from polysilicon purchased by Jinko and converted to ingots, wafers, cells, and finally modules. This represents 48.0 GW of Jinko’s total 62.6 GW of module capacity in China. Jinko’s [2022 Annual Report](#) indicates that the company operated ingot, wafer, cell, and module fabs in eight Chinese provinces: Anhui, Gansu, Jiangxi, Qinghai, Sichuan, XUAR, Yunnan, and Zhejiang. Jinko announced in May 2023 that it had [sold 100% equity](#) in its XUAR ingot facility. The company further indicated in a response to Sheffield Hallam in July 2023 that the sale agreement for the facility, “has been fully executed and is binding,” and that the new owner has already taken over the

Overall Exposure

<div>HIGH</div>	QUARTZ	HIGH
	MGS	HIGH
	POLYSILICON	HIGH
	INGOT	HIGH
	WAFER	NONE (UNVERIFIED)
	CELL	NONE (VERIFIED)
	MODULE	NONE (VERIFIED)

ASSESSMENT

The HIGH ranking is based on:

- Incomplete disclosure about external cell suppliers;
- Incomplete disclosure about polysilicon suppliers used for the Vietnam – Malaysia – US facilities;
- Consideration of Jinko’s announced sale in May 2023 of its XUAR ingot fabrication.

OPPORTUNITIES TO REDUCE EXPOSURE

- Verified disclosure of precise (rather than “approximate”) production capacity of all Jinko facilities
- Verified disclosure of all suppliers of the 14.6 GW of purchased cells
- Verified disclosure of all suppliers of incremental wafers for the unaccounted for 0.4 GW
- Verified disclosure of all polysilicon suppliers and the Jinko destination facility for all sources
- Public records published to confirm the completion of the Jinko XUAR sale and verified disclosure of the source of ingot production capacity replacement

Table 1: Summary of global Jinko production capacity and additional cells requirement remaining to be purchased as of 31 December 2022. GW = gigawatts.

JINKO LOCATION	INGOT/WAFER CAPACITY	CELL CAPACITY	CELLS REQUIREMENT REMAINING TO BE PURCHASED	MODULE CAPACITY	PERCENT OF TOTAL MODULE PRODUCTION
	GW	GW	GW	GW	%
Total	65.0	55.0	15.0	70.0	–
China	58.0	48.0	14.6	62.6	89.4
Vietnam	7.0	11.0	0	0	0
Malaysia	0	7.0	0	7.0	10.0
US	0	0	0.4	0.4	0.6

Note: analysis ignores yield losses for wafer conversion to cells and cells to modules and assumes production equals stated capacities. Capacities for Vietnam, Malaysia, and the US are confirmed in annual reports. Jinko disclosures regarding capacity always indicate “approximate” capacity. Jinko does not provide any guidance about the capacity range or variation, so the “approximate” values are noted here for lack of more specific data information.

factory and is now producing ingots for self-consumption. Jinko suggested in its statement that Jinko will not be sourcing from the sold XUAR facility as Jinko produces sufficient ingots for its wafer production. The company also indicated that the XUAR facility’s production capacity was small but did not indicate precisely which of its facilities would make up for the loss of XUAR production. ([See Annex A – Corporate Responses](#))

Note: Recent corporate registration information shows that the [XUAR company’s name has been changed](#), but the sale is not yet recorded in any Chinese government registration aggregators available online, and there is no additional registration information for the new entity. The [new owner](#) of the factory is chairman of Shijing Technology, a company that deals in environmental protection for renewables manufacturing and, as far as public records show, has no other direct stakes in ingot, wafer, cell, or module manufacturing. The company does appear to be [expanding into Baotou](#), but it is unclear what it will be doing there.

The remaining 14.6 GW of cells required for Jinko China’s total 62.6 GW module production must be purchased from one or more unidentified cell producers. It is possible that the source of the cells is either the Jinko-Tongwei JV described below or other Tongwei Solar facilities. Tongwei is the largest global polysilicon and cell producer (currently with only limited ingot/wafer capacity). Jinko and Tongwei have a strong business relationship through the JV described below and [a large, long-term Tongwei polysilicon supply contract](#). Nonetheless, since the supplier(s) of the 14.6 GW of cells are not disclosed, there is elevated risk of XUAR sourcing. If Jinko’s China-based module production was running far lower than projected and its cell production was not lower than projected, this gap could be decreased.

What can be thought of as a **second China-based Jinko module supply chain** represents 10.0 GW of cells likely produced via a Jinko-Tongwei joint venture and collaboration. Overall details of the joint venture are not known, but Jinko has preemptive rights to receive [60% of the polysilicon production](#) (or 30,000 TPY). Jinko produces an excess of 10 GW of wafers, and it is possible that those are then transferred to a Tongwei Solar cell fab in Sichuan. It is likely that the wafers would be made in the Jinko ingot/

wafer fab located in Leshan, Sichuan because the [Jinko-Tongwei JV polysilicon plant](#) is located in Leshan, Sichuan. Using public disclosures alone, it is unclear how this collaboration functions, how much of the companies’ products are being transferred between one another, and whether this supply chain serves Jinko’s module manufacturing or if the cells are sold elsewhere. In its response to Sheffield Hallam, Jinko indicated that the company does not buy the cells from the JV.

Regarding Jinko’s **Malaysia/Vietnam/US supply chain**, Table 1 shows the 7 GW of wafers produced by Jinko in Vietnam, and likely transferred for cell and module production in Malaysia, where Jinko has a capacity of 7.0 GW of cells and 7.0 GW of modules. However, sourcing across this supply chain is more complicated due to module production at the US facility that brings the full module capacity of this supply chain higher than the cell production in Malaysia.

Assuming Jinko’s 2022 stated capacities of its facilities in Vietnam, Malaysia, and the US listed in Table 1 are accurate, the total module capacity (7.4 GW) of these facilities exceeds cell capacity (7.0 GW) by 0.4 GW. Thus, an additional 0.4 GW of cells must be purchased or transferred to meet the requirements of Jinko’s US module production. It is possible that the required 0.4 GW of cells for the US facility’s 0.4 GW of module production are produced by Jinko in Malaysia (from wafers produced by Jinko Vietnam). Customs records accessed via Panjiva Market Intelligence for 2022 and 2023 for Jinko US imports seem to indicate that most cells used in US-made modules are imported from Jinko Malaysia. The cells produced in Malaysia and shipped to the US would then need to be “replaced” by 0.4 GW of cells purchased elsewhere and shipped to the Jinko Malaysia fab to meet that facility’s production capacity. Jinko disclosures do not reveal how this shortage is managed.

There were also Jinko US module imports in 2022 from two independent Vietnamese cell/module producers: [HT Solar Vietnam Ltd. Co.](#), [Greenwing Solar Technology](#), as well as a shipper whose name has been redacted. The supply chains of these Vietnamese producers are unknown. There is a significant risk that these producers in Vietnam are using China-produced wafers as there are no identified “merchant” wafer producers located in Vietnam. Jinko’s response to Sheffield Hallam University indicated that the company also produces cells and modules in Vietnam (see Jinko Solar Supply Chain – US, according to Jinko Solar below), but there are no public records that confirm this claim, and there is no mention of this expansion in Jinko’s 2022 Annual Report. Jinko representatives noted that the company had previously used these Vietnam vendors for module assembly, and that it is currently “ramping up its capacity in Vietnam. These companies are not included in the supply chain map for this report because they do not appear to be current suppliers, and Jinko’s Vietnam cell and module production is not included due to lack of any public evidence of its existence.

Another alternative sourcing explanation would result if the Jinko capacity data reported in Table 1 for Vietnam, Malaysia, and the US are “approximate” and not absolute. In that scenario, it could be that Malaysian cell production is actually greater than Malaysian module production with excess cells shipped to the US. This alternate scenario of “balanced” ingot – wafer – cell – module production in Vietnam, Malaysia, and the US may occur but cannot be assumed, given the data made available by Jinko in its official annual reporting.

There is little risk that Jinko exports China-produced cells directly to their US fab due to longstanding anti-dumping duties, so that reduces its exposure to some extent; but polysilicon sourcing (discussed below) remains a concern for any cells that cannot be accounted for in Jinko's own production lines.

In essence, without full disclosure of all wafer and cell providers adequate to the full Jinko production, XUAR exposure cannot be ruled out in the dedicated Vietnam/Malaysia/US supply chain.

Quartz/MGS/Polysilicon Exposure

Jinko only provides information about purchased polysilicon on a global basis, so it is not possible to ascertain where precisely the company's purchased polysilicon is consumed. Disclosures show that Jinko purchased polysilicon in 2022 from [Tongwei](#) (which has polysilicon plants located in Inner Mongolia, Sichuan, and Yunnan), [Wacker](#) (Germany and US), and [Hemlock Semiconductor](#) (US). Of these sources, only the Wacker Germany and Tongwei portions are likely to be used in China. Polysilicon produced by Wacker US is subject to a 57.0% [anti-dumping duty](#) on import to China and Hemlock polysilicon to a 53.3% duty.

Total Jinko 2022 wafer capacity was 65.0 GW (see Table 1). To produce 65 GW of wafers, Jinko would need to purchase 175,500 metric tonnes of polysilicon (metric tonnes are converted to equivalent GW using 2022 metric of 2.7 grams silicon per watt metric). Jinko disclosures cited above indicate that between its 2022 contracts with Tongwei and Wacker (including the Tongwei-Jinko joint venture), the company would have bought a total of 132,069 metric tonnes (13,125 tonnes from Wacker; the rest from Tongwei). This total known polysilicon purchase for 2022 accounts for about 48.9 GW (or 75%) of the Jinko 2022 wafer capacity. The polysilicon purchased from Hemlock in 2022 is not known but cannot fully account for the remaining 43,431 metric tonnes unknown 2022 purchases. As [Hemlock produces 30–35,000](#) metric tonnes of polysilicon total—as little as 35% of which is made for solar applications—we know that Hemlock cannot account for Jinko's remaining polysilicon needs. Hemlock confirmed that it supplies Jinko's Vietnam facility.

Even if Jinko does not run at capacity and does not have a shortage of polysilicon to produce its ingots and wafers, evidence suggests that Jinko still has a HIGH exposure to XUAR sourcing. Jinko claimed in a letter to Sheffield Hallam University that only Hemlock and Wacker (Germany and US) polysilicon is used for its modules produced for the US market ([see Annex A](#)), but there are no public disclosures that verify this information. In fact, customs records show while Wacker and Hemlock may provide the majority of Jinko Vietnam's polysilicon, a significant amount comes from elsewhere, including China. For instance, Jinko's Vietnam facility received tens of millions of dollars worth of polysilicon from Jinko's facility in Sichuan in the last year, accounting for more than 7% of imported polysilicon in 2022. Jinko does not produce polysilicon, so the producer is unknown. The polysilicon could come from Tongwei or from the Jinko-Tongwei JV in Sichuan, but there is no way to be certain based on Jinko's disclosures. Customs records indicate that Jinko Vietnam also received polysilicon from OCI Korea, OCI Malaysia and SinoAmerican in 2022. The total 2022 polysilicon imports accounted for only 3.13 GW, leaving other sources unknown. The use of unnamed Chinese sources for polysilicon as well as one or more additional unidentified sources results in a HIGH XUAR exposure for the overall ingot – wafer – cell – module production in Vietnam and Malaysia.

Based on historical supply relationships, the unknown 2022 polysilicon suppliers to Jinko (globally) could potentially include Daqo (XUAR) and Xinte (XUAR) (neither company's new polysilicon plants in Inner Mongolia were operating in 2022). Jinko has purchased polysilicon from [Daqo](#) in recent years. In 2022, Daqo stopped announcing the names of most customers in press releases. Jinko announced a 9% equity investment in the new [Xinte polysilicon plant](#) located in Inner Mongolia in September 2021 and a [supply contract](#) with Xinte running from 2023 to 2030. The Xinte Inner Mongolia polysilicon plant was expected to begin operation in the first half of 2023 and will certainly change Jinko's exposure to some extent. While the Jinko equity investment is with Xinte Inner Mongolia, Xinte, of course, has been a long-time operator of XUAR based polysilicon. In its response to Sheffield Hallam University, Jinko indicated that all metallurgical grade silicon for the Xinte Inner Mongolia plant would be from Inner Mongolia. However, Inner Mongolia currently has low MGS production relative to polysilicon production, and thus has elevated risk of XUAR sourcing.

Jinko Future

Jinko wrote in its letter to Sheffield Hallam University the following: “By the end of 2023, Jinko Solar anticipates having 75GW of ingot and wafer capacity, matching the 75GW of global solar cell production. Moreover, concurrent to this announcement, Jinko Solar also announced a 56GW vertically integrated ingot-wafer-cell-module facility in Shanxi Province.” These expansions are not covered in this report and will require additional expert supply chain tracing and contract analysis.

Conclusion

Jinko's revised supply US market chain map largely corroborates sourcing relationships that can be gleaned from publicly available disclosures. However, it eliminates the China sourcing that is visible through customs records, and it does not account for the full amount of inputs required for the production capacity of the company's ingots. Without further disclosures, it is not possible to exclude XUAR exposure in any of Jinko's supply chains.

Jinko Solar produces 14.6 GW of modules in China for all markets except the US with purchased cells. The 14.6 GW of modules produced by Jinko in China from purchased cells have a HIGH XUAR ranking due to the 4.6 GW of unidentified cell supplier(s). The XUAR exposure for 10 GW of these modules would be LOW if these modules are produced from 10 GW of cells supplied by the Sichuan-located Jinko-Tongwei joint venture, but Jinko has denied that it purchases these cells.

Jinko Solar produces 7.4 GW of modules for the US market in Vietnam (ingots and wafers), Malaysia (cells and modules) and US (modules). Polysilicon purchased from Hemlock Semiconductor (US) and Wacker (Germany, US) is used in this Jinko supply chain. However, Jinko Vietnam also receives polysilicon from China and elsewhere. There are not sufficient disclosures about the Jinko US-focused supply chain to know all details of polysilicon and cell sources. As a result, the XUAR risk is HIGH due to unknown sourcing.

Supply Chain - China (after Jinko XUAR sale finalized)

VERY HIGH	HIGH	MEDIUM	LOW	NONE (UNVERIFIED)	NONE (VERIFIED)
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The diagram illustrates the supply chain for polysilicon, ingot, wafer, cell, and module stages. The flow is as follows:

- POLYSILICON:**
 - UNKNOWN PRODUCER(S) INNER MONGOLIA
 - UNKNOWN PRODUCER(S) SICHUAN
 - UNKNOWN PRODUCER(S) XUAR
 - UNKNOWN PRODUCER(S) YUNNAN
 - UNKNOWN PRODUCER(S) OTHER CHINA
 - UNKNOWN PRODUCER(S) CHINA
 - UNKNOWN PRODUCER(S) BRAZIL
 - UNKNOWN PRODUCER(S) EUROPE
 - UNKNOWN PRODUCER(S) MALAYSIA
 - UNKNOWN PRODUCER(S) NORTH AMERICA
 - UNKNOWN PRODUCER(S) NORWAY
 - FERROGLOBE SOUTH AFRICA
- INGOT:**
 - TONGWEI INNER MONGOLIA
 - TONGWEI SICHUAN
 - TONGWEI YUNNAN
 - UNKNOWN PRODUCER(S) CHINA
 - JINKO-TONGWEI JOINT VENTURE SICHUAN
 - WACKER GERMANY BURGHAUSEN NÜNCHRITZ
- WAFER:**
 - JINKO ALL CHINA
 - UNKNOWN PRODUCER(S) CHINA
 - JINKO SICHUAN
- CELL:**
 - JINKO ALL CHINA
 - UNKNOWN PRODUCER(S) CHINA
 - JINKO SICHUAN
- MODULE:**
 - JINKO ALL CHINA

The flow is as follows:

- UNKNOWN PRODUCER(S) INNER MONGOLIA, UNKNOWN PRODUCER(S) SICHUAN, UNKNOWN PRODUCER(S) XUAR, UNKNOWN PRODUCER(S) YUNNAN, UNKNOWN PRODUCER(S) OTHER CHINA, and UNKNOWN PRODUCER(S) CHINA all flow into TONGWEI INNER MONGOLIA, TONGWEI SICHUAN, TONGWEI YUNNAN, and UNKNOWN PRODUCER(S) CHINA.
- UNKNOWN PRODUCER(S) CHINA, JINKO-TONGWEI JOINT VENTURE SICHUAN, and WACKER GERMANY BURGHAUSEN NÜNCHRITZ all flow into JINKO ALL CHINA, UNKNOWN PRODUCER(S) CHINA, and JINKO SICHUAN.
- JINKO ALL CHINA, UNKNOWN PRODUCER(S) CHINA, and JINKO SICHUAN all flow into JINKO ALL CHINA, UNKNOWN PRODUCER(S) CHINA, and JINKO SICHUAN.
- JINKO ALL CHINA, UNKNOWN PRODUCER(S) CHINA, and JINKO SICHUAN all flow into JINKO ALL CHINA.

Jinko Solar

Supply Chain – Southeast Asia/US

EXPOSURE KEY

VERY HIGH

HIGH

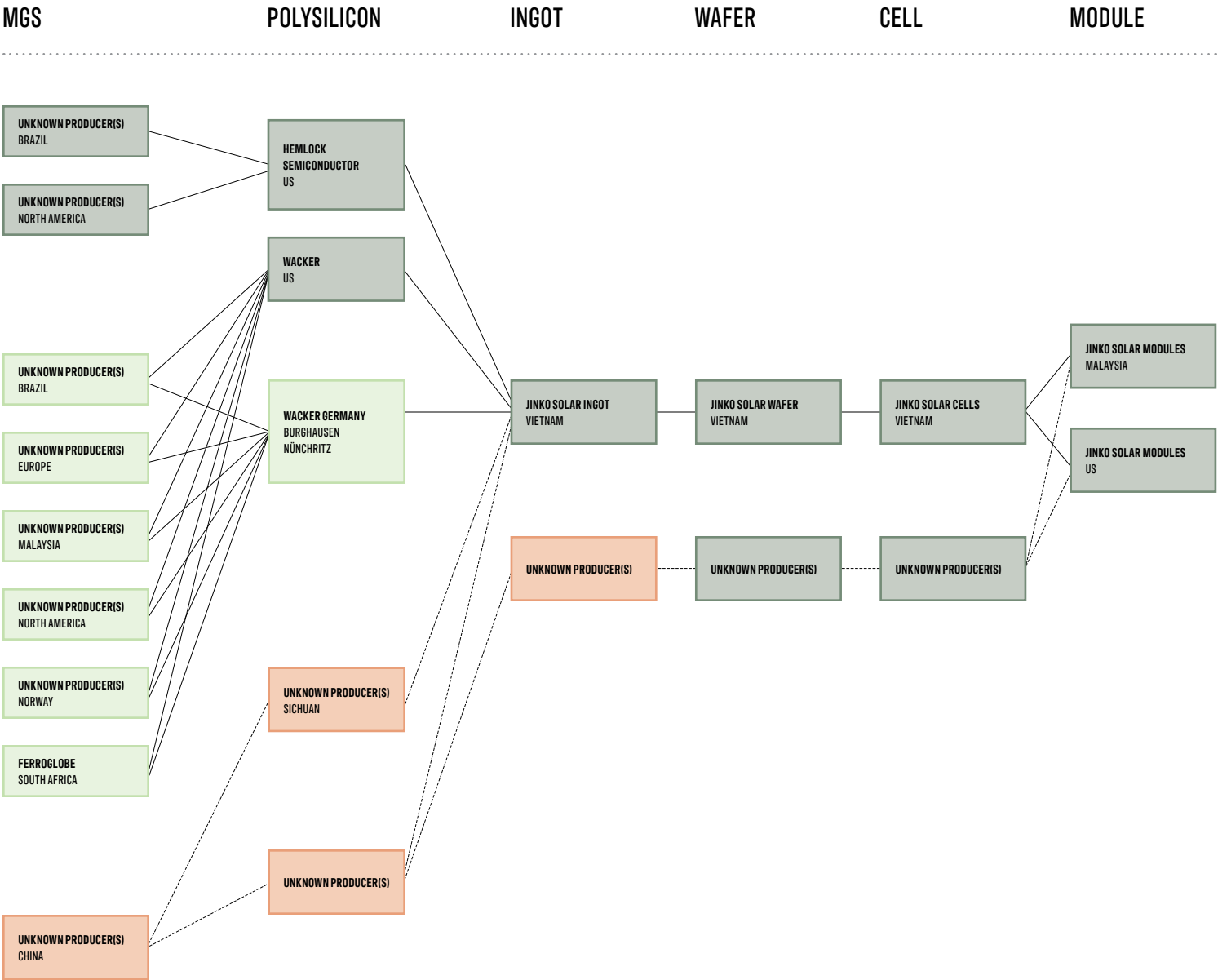
MEDIUM

LOW

NONE (UNVERIFIED)

NONE (VERIFIED)

Solid line = disclosed / known information (verified or unverified)
Dashed line = not disclosed but likely / possible



Jinko Solar

Supply Chain for US Market – According to Jinko

EXPOSURE KEY

VERY HIGH

HIGH

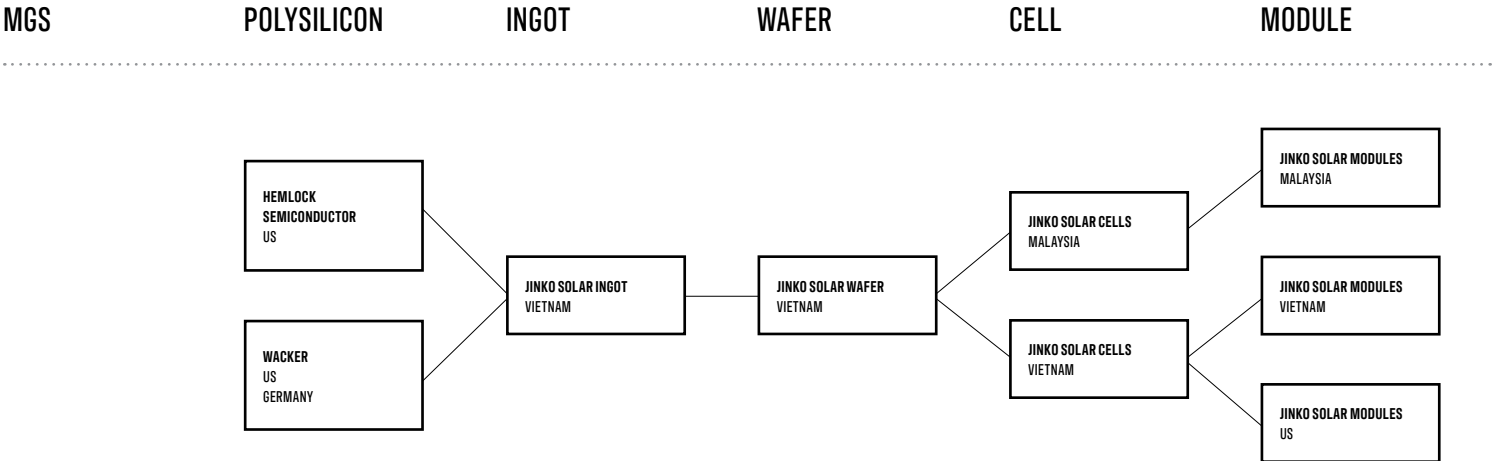
MEDIUM

LOW

NONE (UNVERIFIED)

NONE (VERIFIED)

Solid line = disclosed / known information (verified or unverified)
Dashed line = not disclosed but likely / possible



Note: All companies were given the opportunity to correct or amend draft supply chain maps.
Jinko Solar provided their revision of the supply chain for Vietnam/Malaysia/US as above.
These revised maps cannot be corroborated and, therefore, are presented separately.

LONGi Solar

All Modules

The overall XUAR exposure for all modules produced by LONGi in China, Malaysia, and Vietnam is VERY HIGH.

EVIDENCE BASE

LONGi publishes end of year global ingot, wafer, cell, and module capacity data and end of year actual global production data in its annual reports. LONGi does not publish details of production capacity broken down by region or facility. This lack of regional capacity data makes a more granular analysis impossible which, in turn, prevents a separate XUAR ranking for China-produced modules and modules produced in Malaysia and Vietnam.

LONGi purchases polysilicon from several Chinese producers and OCI Malaysia. LONGi also has a long-term agreement with Tongwei that leads to supply of incremental cells.

Polysilicon supply contracts are included in LONGi [annual reports](#), including in 2022, and significant information is included in LONGi’s investor relations website, though it appears that as of July 2023, the content of the [English-language version](#) and the [Chinese-language version](#) differs. Other companies’ public disclosures also provide insight into LONGi supply chains.

This assessment does not include the recently announced 5 GW module production facility to be built in [Pataskala, Ohio, US](#).

ANALYSIS

LONGi produces most of its LONGi-branded modules in China. The company produces a limited number of modules in Malaysia and Vietnam, predominately for the US market. LONGi is also the [largest global supplier of merchant solar wafers](#), which the company sells to numerous cell producers. As a result, the LONGi XUAR risk is transferred to all of their wafer customers.

All modules produced by LONGi in China (Anhui, Jiangsu, Ningxia, Shanxi, Shaanxi, Zhejiang), Malaysia, and Vietnam are produced from ingots and wafers produced by LONGi in China (Ningxia, Shaanxi, Yunnan) and a very limited amount in Malaysia. LONGi has no backward integration to quartz, metallurgical grade silicon, or polysilicon.

Analysis of XUAR risk of all LONGi produced modules begins with an overall analysis of global LONGi production capacities. This capacity analysis is for the end of 2022 and based on [LONGi’s 2022 Annual Report](#) and previous disclosures. LONGi has likely added capacity in the first half of 2023, but these additions likely do not change sourcing and thus do not necessarily affect the overall XUAR exposure assessment.

LONGi provided a revision to a draft of the supply chain map included below, which informed this assessment.

Table 1 provides a summary of global LONGi capacities and regional capacity estimates for the end of 2022. Regional estimates and LONGi-Tongwei JV production are based on calculations and assumptions described below.

The LONGi [2017 Annual Report](#) shows the original starting capacities of LONGi’s *Malaysia* facility were quite low, but based on information provided by the [CEO of LONGi Malaysia](#) and reported in a local business publication, LONGi Malaysia was expected to have a total cell capacity “over” 8 GW by August 2022. Table 1 estimates/rounds Malaysia cell capacity at 8 GW. Estimates for ingot and wafer capacities are based on 2017 disclosures due to the

Overall Exposure

<div>VERY HIGH</div>	QUARTZ	VERY HIGH
	MGS	VERY HIGH
	POLYSILICON	VERY HIGH
	INGOT	VERY HIGH
	WAFER	NONE (VERIFIED)
	CELL	NONE (VERIFIED)
	MODULE	NONE (VERIFIED)

ASSESSMENT

The VERY HIGH ranking is based on:

- Incomplete information about LONGi individual manufacturing site capacities;
- Incomplete information about LONGi suppliers across the supply chain.

OPPORTUNITIES TO REDUCE EXPOSURE

- Verified disclosure of LONGi regional production capacities
- Verified disclosure of relationships between specific polysilicon suppliers and individual LONGi wafer facilities
- Verified disclosure of all MGS sources for all Chinese polysilicon producers located outside of the XUAR

Table 1: Global LONGi capacities and regional capacity estimates for end of 2022. GW = gigawatts.

LONGI LOCATION	INGOT/WAFER CAPACITY	CELL CAPACITY	CELLS REQUIREMENT REMAINING TO BE PURCHASED	MODULE CAPACITY	PERCENT OF TOTAL MODULE PRODUCTION
	GW	GW	GW	GW	%
LONGi Global , end 2022	133.0/133.0	50.0	35.0	85.0	-
China	132.7/132.0	37.0	36.0	73.0	85.9
Malaysia	0.3/1.0	8.0	0.0	0.0	0.0
Vietnam	0.0/0.0	5.0	0.0	12.0	14.1

Note: analysis ignores yield losses for wafer conversion to cells and cells to modules and assumes production equals stated capacities.

lack of LONGi reports suggesting expansions in those areas. LONGi's response to Sheffield Hallam University inquiries indicated that a LONGi Malaysia module facility has been shuttered, but a new one is in development. ([see Annex A – Corporate Responses](#)).

LONGi acquired [Vina Cell and Vina Solar](#) located in **Vietnam** from Ningbo EZ in 2020. There are no official LONGi disclosures of Vietnam cell and module capacity. A reference updated in January 2023 shows current [Vietnam capacity](#) at 5 GW of cells and 12 GW of modules.

Given these estimates, it appears that the Southeast Asia supply chain could have a production capacity of 13.0 GW of cells, but only 12.0 GW of modules. It is possible that Malaysian cell production operates below capacity to enable cells produced to match modules produced. Or the additional production could be transferred to China. The most likely scenario is that these production capacities are not indicative of the current situation, due to lack of current disclosures.

China capacity estimates are calculated by subtracting the Southeast Asia production estimates from known global totals, but again, these rely on older data.

LONGi supplies wafers to numerous companies that do not have internal wafer production or sufficient internal wafer production. These wafer customers all produce cells, and some also produce modules. Some LONGi wafer customers supply cells to module producers. The result is that any LONGi XUAR exposure is transferred to their direct wafer customers and all modules produced from these direct wafer sales.

Ingot/Wafer/Cell/Module Exposure

LONGi's primary business is producing ingots and wafers. LONGi did not enter direct cell and module production until 2016 with the acquisition of [Lerri Solar](#). And while LONGi has quickly risen to one of the leading module producers in the world, the company's wafer production far exceeds its module requirements, and thus the company sells those wafers on to its international customers.

LONGi's 2022 Annual Report indicates that the company produced 50GW of cells in its own facilities to make its 85 GW of modules. It is possible that the remaining 35GW of cells required for module manufacture are made of LONGi wafers by the LONGi-Tongwei Solar joint venture in Anhui and

Sichuan China, but it is not possible to be certain. Analysis of LONGi annual reports does not show explicit disclosures of information about the Tongwei joint venture. Tongwei is the largest global cell producer and partner in a LONGi-Tongwei joint venture and so is a likely source for the incremental cells LONGi requires.

There is a chance that LONGi built sufficient ingot and wafer capacity in Malaysia to support combined cell capacity in Malaysia and Vietnam (13 GW). If this scenario is true, then a parallel supply chain would exist for the US module market and XUAR risk could be much lower. However, given the lack of granular production capacity data, the exposure remains high because the ingots could come from an undisclosed China-based supplier. LONGi indicated in a followup that the company's Malaysia module facility has been shuttered, but a new [vertically integrated facility](#) is in development in Malaysia.

Quartz/MGS/Polysilicon Exposure

To produce its ingots and wafers, LONGi consumes a significant amount of polysilicon (133 GW of ingots require approximately 333,000 metric tonnes per year assuming the 2023 metric of 2.5 grams polysilicon per watt). LONGi discloses polysilicon purchases in annual reports and other financial disclosures. Table 2 lists all LONGi polysilicon suppliers for 2022 along with contract dates. LONGi purchases all required polysilicon from external suppliers or through a [joint venture agreement](#) with Tongwei Solar.

The combined polysilicon purchases for 2022 (339,282 tonnes) account for approximately 94.5% of the total polysilicon required by LONGi to produce 133 GW of ingots (stated end of 2022 ingot/wafer capacity). Because production capacity is an estimate, it can be assumed for all practical intents that at this rate, LONGi's disclosed polysilicon suppliers likely meet all of the company's needs.

LONGi has purchased polysilicon from two XUAR-based producers. The company had a contract with Daqo through the end of 2022. While the Daqo XUAR contract ended in December 2022, a large contract with Daqo Inner Mongolia started in May 2023, which creates some exposure related to Daqo's own undisclosed sourcing. LONGi has an ongoing supply contract with Xinjiang Xinte through December 2025.

In the company's response to Sheffield Hallam University, LONGi's revision of the draft supply chain map indicated that it has created a dedicated/isolated supply chain for XUAR inputs. The map suggests that its module facilities in Shanxi and Shaanxi source cells from LONGi Ningxia and Sichuan, which are in turn supplied ingots/wafers from LONGi Ningxia. According to LONGi's map, the LONGi Ningxia ingot/wafer facility is the exclusive consumer of the Xinte XUAR polysilicon. There is no way to verify LONGi's claim using publicly available disclosures.

Furthermore, while the Xinte (and the former Daqo) contract represents immediate XUAR exposure, it is also the case that all disclosed 2022 LONGi polysilicon suppliers except for OCI Malaysia have some XUAR exposure based on possible use of metallurgical grade silicon produced in the XUAR. (See Table 2 and LONGi Supply Chain Map below)

There are no public domain disclosures about MGS suppliers used by any Chinese polysilicon producers. Sourcing trends indicate that XUAR-based polysilicon producers such as Daqo and Xinte use 100% XUAR-produced MGS given the amount of MGS produced in XUAR.

Table 2: Summary of 2022 LONGi polysilicon suppliers. Except as noted through hyperlink, all data are from a table in LONGi's [2022 Annual Report](#).

LONGI POLYSILICON SUPPLIER	POLYSILICON PLANT LOCATION	CONTRACT TERM
Asia Silicon	Qinghai, China	Sep. 2020 – Dec. 2024
Daqo IM	Inner Mongolia, China	May 2023 – Dec. 2027
Daqo XUAR	XUAR, China	Jan. 2020 – Dec. 2022
GCL-Poly	Jiangsu, China	Jan. 2021 – Dec. 2025
OCI	Malaysia	Mar. 2021 – Feb. 2024
Tongwei Sichuan	Sichuan, China	Jan. 2022 – Dec. 2023
Xinte	XUAR, China	Jan. 2021 – Dec. 2025
Tongwei – LONGi Inner Mongolia Joint Venture	Inner Mongolia, China	Jan. 2020 – No End Provided
Tongwei – LONGi Yunnan Joint Venture Phase-1	Yunnan, China	Jan. 2022 – No End Provided

The risk of Asia Silicon, Daqo Inner Mongolia, and Tongwei Inner Mongolia using XUAR-produced MGS is HIGH because there is currently limited MGS production in Inner Mongolia and Qinghai. MGS consumers in Inner Mongolia and Qinghai likely use MGS from the main producing provinces, and the XUAR is at the top of the list. GCL-Poly is located in Jiangsu, where there is no MGS production, rendering it highly exposed as well.

Tongwei Solar (TWS) polysilicon plants located in high MGS producing provinces (Sichuan and Yunnan) can be safely assumed to normally use only locally produced MGS from within the province. TWS's (or any company's) polysilicon plants located in lower or no MGS producing provinces can be safely assumed to purchase MGS from more than one high MGS producing province.

LONGi indicated in a response to Sheffield Hallam that OCI Malaysia sources no MGS from China. However, OCI's own correspondence with the authors indicated that the company does continue to source from China. Though OCI sources some MGS from Malaysia and perhaps Brazil and Norway, OCI does source significant MGS produced in China. However, OCI has no apparent XUAR exposure, as they have reportedly stopped purchasing MGS from the region.¹ It is not possible to verify OCI's disclosures about its current global MGS supply, and OCI did not respond to a request for more information.

Polysilicon purchased by LONGi from [OCI Malaysia](#) deserves special discussion. The contracted amount purchased from OCI Malaysia is 77,700 metric tonnes, although the 2022 LONGi annual report says "about" 68,000 tonnes. If the purchased amount is 77,700 tonnes and the OCI deliveries are constant over the duration of the contract, LONGi received 25,900 metric tonnes in 2022. Assuming 2.5 grams Si per Watt (2,500 metric tonnes Si per GW), the OCI Malaysia polysilicon received by LONGi in 2022 is equivalent to 10.36 GW of modules. If LONGi used all of its purchased OCI polysilicon for module production in Malaysia and Vietnam, and if Malaysia and Vietnam produced a combined 12.5 GW modules as stated in LONGi disclosures, then OCI would account for 82.9% of Malaysia and Vietnam

module production. If the purchased amount was closer to the 68,000 tonnes, then OCI would account for even less of that supply chain's requirements. Without verified and precise disclosures of the Malaysia/Vietnam supply chain production capacities, it is not possible to confirm this scenario or to account for the additional polysilicon required.

If accurate, LONGi's revised supply chain could provide insight into the additional polysilicon consumed by the company. The map suggests two dedicated/isolated supply chains for its Malaysia and Vietnam production. The polysilicon providers largely reflect those in the 2022 disclosure, with some variation. The Southeast Asia supply chains purport to originate with Wacker (US and Germany) and OCI (Malaysia) polysilicon for Malaysia ingots/wafers and cells, and with Tongwei-LONGi JV (Yunnan) and Asia Silicon for its Baoshan/Chuxiong/Vietnam ingots, wafers, and cells. Wacker was not listed in the 2022 supply contracts, and no other public records verify this supply relationship. Customs records do not reveal the source of wafers imported by LONGi Vietnam, so those claims cannot be confirmed. Nonetheless, LONGi's sourcing from Asia Silicon represents an exposure in that dedicated supply chain, as described above. LONGi reported that Asia Silicon consumes some MGS produced in Europe and South Africa. There are several MGS producers in Europe (Elkem and FerroGlobe are the largest) but only FerroGlobe in South Africa. There is no way to confirm LONGi's supplied information about Asia Silicon's Europe and South Africa MGS supply. FerroGlobe was contacted and declined to comment on any customer relationships.

LONGi's map suggests that they have entirely isolated the company's XUAR exposure and suggests the regions from which their suppliers purchase MGS to the company's Ningxia China manufacturing base.

Conclusion

Capacity analysis shows that about 85% of LONGi module capacity is in China, and the remaining modules are produced in Malaysia and Vietnam. Modules produced in Malaysia and Vietnam are predominately for the US market. LONGi provides detailed information about all polysilicon suppliers but does not provide granular information about how this polysilicon is distributed in its individual production lines. Because the companies from which LONGi sources polysilicon do not disclose their MGS suppliers, those polysilicon producers have elevated risk of sourcing from the XUAR.

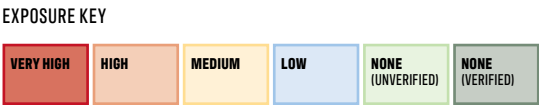
LONGi's revised supply chain map corroborates sourcing relationships that can be gleaned from publicly available disclosures. If the company's revision is correct, what it shows is that certain polysilicon suppliers are dedicated to particular LONGi manufacturing facilities. These particular connections cannot be corroborated through public disclosures and no further evidence was provided by LONGi. Without the ability to verify this bifurcation, it is not possible to exclude XUAR exposure in any of LONGi's supply chains.

LONGi is also the largest global supplier of solar wafers to cell producers. This results in a VERY HIGH XUAR exposure being transferred to all users of LONGi produced wafers, including LONGi's own module manufacturing facilities.

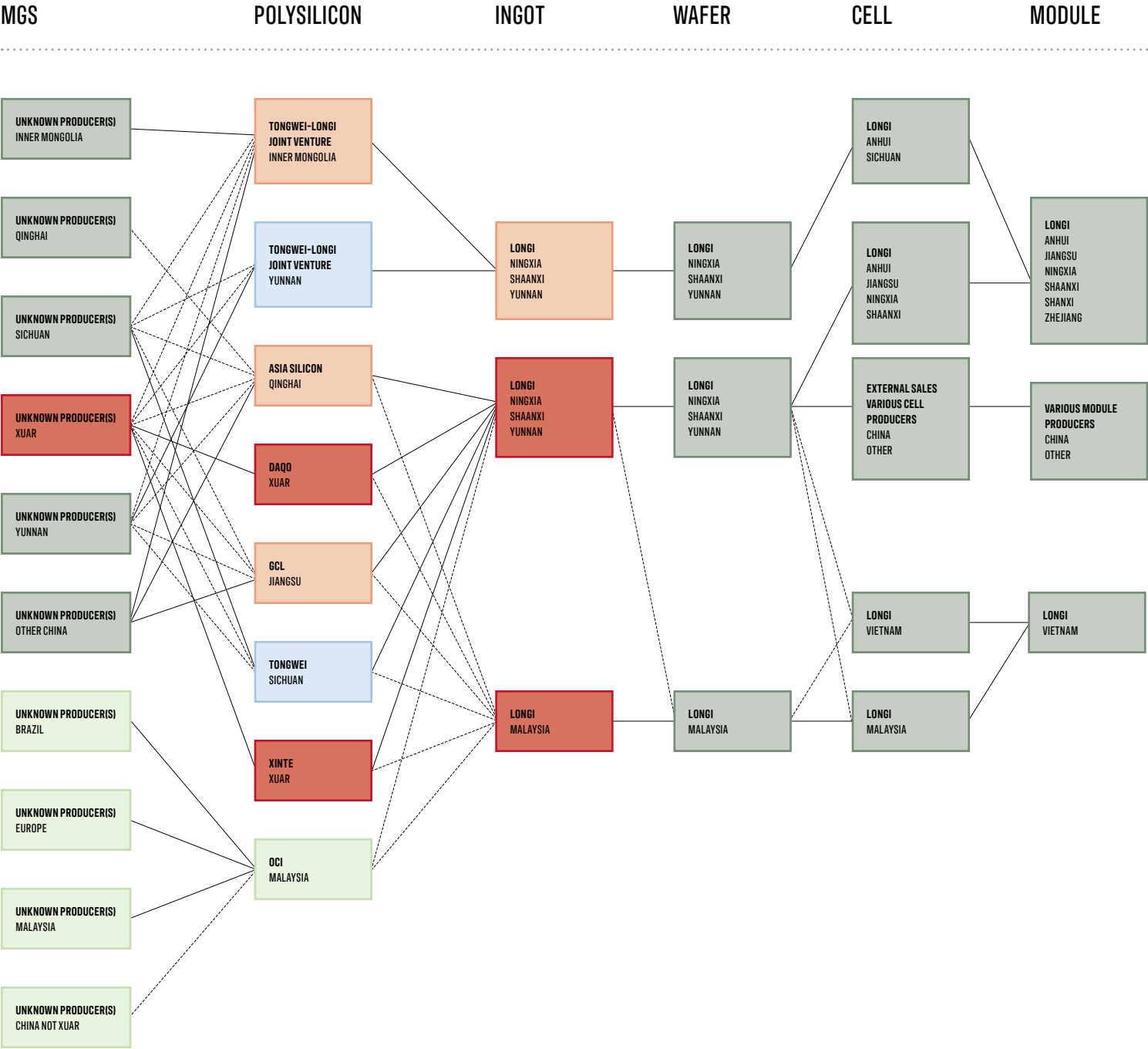
1. OCI Investor Relations to author, personal correspondence, 21 April 2023.

LONGi Solar

Supply Chain



Solid line = disclosed / known information (verified or unverified)
Dashed line = not disclosed but likely / possible



LONGi Solar

Supply Chain – According to LONGi

EXPOSURE KEY

VERY HIGH

HIGH

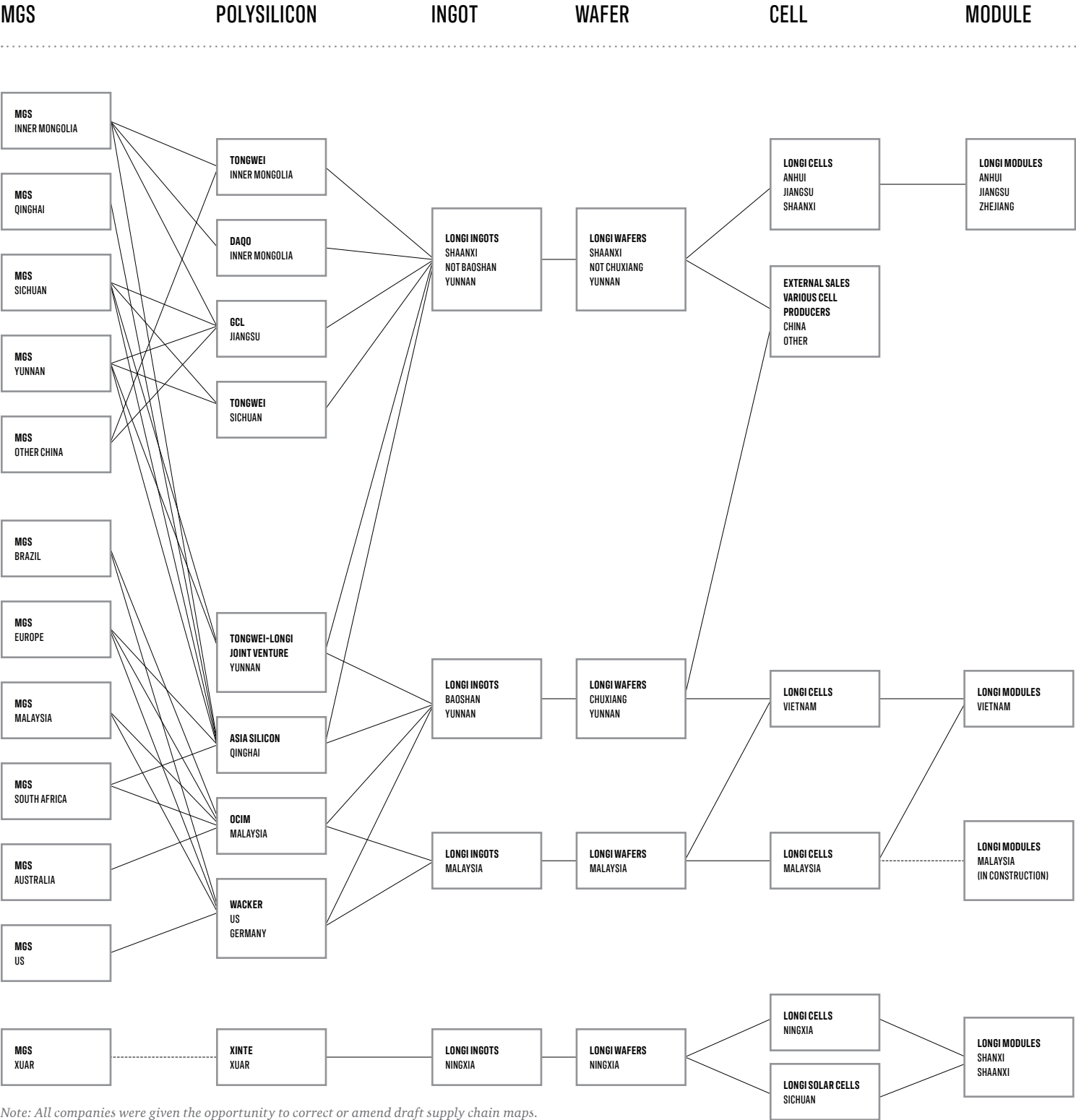
MEDIUM

LOW

NONE (UNVERIFIED)

NONE (VERIFIED)

Solid line = disclosed / known information (verified or unverified)
Dashed line = not disclosed but likely / possible



Note: All companies were given the opportunity to correct or amend draft supply chain maps. Jinko Solar provided their revision of the supply chain for Vietnam/Malaysia/US as above. These revised maps cannot be corroborated and, therefore, are presented separately.

Maxeon Solar Technologies / Sunpower

Maxeon 3/5/6 modules also sold as SunPower X-/A-/M-series and Maxeon/SunPower Performance Series modules

UPDATED NOVEMBER 3 2023

The overall XUAR exposure for all solar modules produced by Maxeon Solar Technologies/SunPower is assessed as NONE (UNVERIFIED).

This chapter includes the original August 2023 assessment of Maxeon Solar Technologies and is followed by a November 2023 Update that includes a re-assessment based on Maxeon disclosures.

EVIDENCE BASE FOR ORIGINAL ASSESSMENT

Maxeon sells modules under its own brand name and model numbers (Maxeon 3/5/6). Maxeon is also the [exclusive producer](#) of all modules sold by SunPower (except the new U-Series). Maxeon 3/5/6 modules are sold as Sunpower X-, A-, and M-Series, respectively. These modules all share the same supply chain. Maxeon also produces an additional Performance Series line that has two separate supply chains, one presumably for the US market and another for the rest of the world. SunPower also sells the Performance Series under its brand name. This report will analyze Maxeon 3/5/6 and the two Performance Series supply chains.

Maxeon no longer discloses sufficient information regarding its [3/5/6/X/A/M](#) series suppliers to trace its supply chain. Potential sourcing relationships are instead related to information on Maxeon's investors. At the time of publication, the top [Maxeon shareholders](#) are Total Energies SE (France), which holds 24.4%, and TCL Zhonghuan Renewable Energy Technology Co. Ltd. (TZS) (China),¹ which holds 24.0%. TZS is the world's second largest global solar wafer producer and has been an [investor in Xinjiang GCL-Poly](#) since 2017.

In 2016, SunPower created Huansheng Photovoltaic (Jiangsu) Co. Ltd. (HSPV), a joint venture (JV) in China to manufacture its *Performance Series*, p-type shingled modules designed primarily for commercial and power plant installations. The original [SunPower JV partners](#) were TZS and Dongfang Electrical Company Ltd. SunPower [transferred its shares of HSPV](#) to Maxeon in August 2020. As of 1 January 2023, TZS has 83.7% [ownership of HSPV](#), while Maxeon has 16.7%. HSPV currently manufactures Maxeon Performance Series modules for the global market.

In 2022, Maxeon [expanded production](#) of the Performance Series of shingled modules in Malaysia (cells) and Mexico (modules) primarily to sell in the US commercial and power plant market. [TZS is the documented primary supplier](#) of p-type G12 wafers to Maxeon for Performance module production.

Maxeon has not responded to author requests to provide wafer supply chain evidence. There is no public domain information from Maxeon, HSPV, or TZS regarding the polysilicon used to produce p-type wafers.

Note: SunPower recently introduced a new budget [U-Series module](#) that appears to be the company's only model that does not use Maxeon cells. The product line may be manufactured by Indian solar manufacturer [Waaree](#). We did not assess this SunPower product line, but customs records accessed via Panjiva Market Intelligence indicate that LONGi is a primary supplier of cells to Waaree (see LONGi chapter of this report for more information on those supply chains). At the time of publication of this report, there is very limited domestic Indian capacity to produce cells and even less domestic Indian capacity to produce ingots

Overall Exposure

NONE
(UNVERIFIED)

QUARTZ	NONE (UNVERIFIED)
MGS	NONE (UNVERIFIED)
POLYSILICON	NONE (UNVERIFIED)
INGOT	NONE (UNVERIFIED)
WAFER	NONE (UNVERIFIED)
CELL	NONE (UNVERIFIED)
MODULE	NONE (UNVERIFIED)

ASSESSMENT (UPDATED)

See update below for the basis of the re-assessment.

OPPORTUNITIES TO REDUCE EXPOSURE

- ✓ Verified disclosure of all wafer, polysilicon, and MGS suppliers used to make Gen 3, Gen 5, and Gen 6 cells starting on 1 January 2023
- ✓ Verified disclosure of all polysilicon, MGS, and quartz suppliers used by TZS to produce the wafers for Performance Series modules
 - End of Maxeon relationship with TZS
- ✓ End of TZS investment in Xinjiang GCL-Poly
 - End of TZS relationship with all suppliers in XUAR

UPDATE KEY

- ✓ Company met or partially met the requirement, but it is unverified
- ✓ Company met the requirement, and it is verified

and wafers. As a result, the wafers and cells used by Waaree are likely purchased from China-based suppliers.

ANALYSIS FOR ORIGINAL ASSESSMENT

Maxeon [assembles modules](#) in its facilities in Malaysia and Mexico, and the company is also a minority shareholder of a joint venture in China that also produces some Maxeon-branded modules. Maxeon exclusively produces n-type IBC Generation 3 and 5 cells in the Philippines and its n-type IBC Generation 6 cells in Malaysia. The company produces its p-type PERC cells in Malaysia and China. Maxeon has no backward integration from wafers, ingots, polysilicon, MGS, or quartz.

Ingot/Wafer Exposure

Before 1 January 2023, *Maxeon 3/5/6 and SunPower X-/A-/M-Series* would have earned a risk assessment rating of NONE (Verified). Until that date, Sunpower/Maxeon fabrication facilities in the Philippines and Malaysia produced all n-type IBC cells using only wafers produced by NorSun, using Hemlock Semiconductor polysilicon. This created no XUAR exposure, as Hemlock cannot use any China-originating MGS due to [139% anti-dumping duties](#) that have been continuously in place since 1991. [NorSun](#) had been the long-term Norway-based producer of wafers for SunPower, and SunPower maintained a polysilicon supply agreement with [Hemlock Semiconductor](#) that began in 2007. SunPower [spun off cell and module production](#) to a new company it named Maxeon in 2020, and the Hemlock agreement was [transferred](#) to Maxeon.

However, Maxeon [ended its long-term agreement](#) with Hemlock Semiconductor on 1 January 2023. Furthermore, NorSun has limited (1 GW) ingot/wafer capacity and is [now listed as a wafer supplier](#) to Meyer Burger, suggesting that it has limited capacity for other customers. Hemlock confirmed in its response to Sheffield Hallam that it has not supplied NorSun or Maxeon since 1 January 2023 ([See Annex A – Corporate Responses](#)).

Without clear supply chain disclosures that would account for wafer sourcing, analysis of the current Maxeon 3/5/6 supply chain depends on analysis of Maxeon's investment and business relationships. Maxeon maintains a long-term [business relationship](#) with TZS, which supplies wafers for the Performance Series (see below), so it is possible that TZS became the main Maxeon 3/5/6 wafer supplier on 1 January 2023. TZS operates [large capacity wafer fabs](#) in Inner Mongolia, Jiangsu, Ningxia, and Tianjin.

The sourcing from TZS for the *Maxeon Performance Series*, on the other hand, is well-documented. [TZS is the primary – and likely only – supplier](#) of p-type G12 wafers used by Maxeon in Malaysia. Maxeon began production of p-type monocrystalline PERC cells in mid-2022 in the existing Alor Gajah, Malaysia fab. The cells are shipped to the Maxeon module fab located in Mexicali, Mexico for assembly into shingled Performance Series modules.

The Maxeon-HSPV joint venture produces p-type PERC cells and shingled modules in a single site located in Yixing, Jiangsu, China. Since TZS is the second largest global solar wafer producer and owns 83.7% of HSPV, one can safely assume that TZS is the supplier of all p-type monocrystalline wafers that HSPV requires.

Quartz/MGS/Polysilicon Exposure

Maxeon has provided no public domain information on its current quartz, MGS, polysilicon, or wafer supply. It has also provided no information on how the company ensures TZS does not use polysilicon from the XUAR in its production of wafers for Maxeon. While TZS does not have physical ingot/wafer production in the XUAR, TZS purchases XUAR-produced polysilicon and MGS, and is a large shareholder of Xinjiang GCL-Poly.

Public domain disclosures provide information about TZS polysilicon supply for only approximately 60 GW wafer production out of its total 140 GW nameplate wafer capacity at the end of 2022. The disclosed TZS polysilicon suppliers are Xinjiang GCL (through the TZS investment), [GCL-Poly](#) (Jiangsu and Sichuan), Daqo ([XUAR](#) and [Inner Mongolia](#)). TZS and GCL are also establishing a joint venture polysilicon plant in [Inner Mongolia](#), where there is elevated risk of XUAR sourcing because of the low production of MGS in the region.

Suppliers of the unknown polysilicon, accounting for 80 GW of TZS's 2022 nameplate, could include companies without XUAR exposure, with lower XUAR exposure (Tongwei Sichuan or Tongwei Yunnan), or even from outside of China (OCI Malaysia, Wacker Chemie). However, these suppliers are not known and are not included in the TZS XUAR exposure assessment.

Maxeon's revised supply chain maps differ significantly from those that can be charted based on publicly available disclosures. Maxeon confirms that the company sources ingots/wafers from Tianjin Zhonghuan for its Performance Line, but Maxeon's map suggests the wafers sourced from TZS do not include XUAR polysilicon, though disclosures show that TZS does indeed source from the XUAR (see below). Furthermore, Maxeon indicated that the company sources wafers from Ferrotec (China), ACC (Japan and Taiwan), and NorSun for its 3 and 6 Generation cells/modules. However, there are no public disclosures that would corroborate any of those three sourcing relationships. Indeed, as stated earlier, the Hemlock – NorSun – Maxeon supply contract is reported to have ended at the beginning of 2023. Maxeon did not respond to a request for more information regarding the Hemlock contract or supporting documentation of any of its wafer suppliers.

A Hemlock representative indicated to Sheffield Hallam that the company does supply a "minimum volume" of polysilicon to AUO Crystal Corporation (ACC) but that he did not know who ACC sells to in turn. The representative further indicated that Hemlock does not currently supply Ferrotec, NorSun, or Maxeon. The representative wrote that he had "many concerns" about Maxeon's representations in its supply chain map and included the production capacity of the wafer suppliers named by Maxeon on the [supply chain](#) it posted to its website on July 26, 2023 (the same as included in this report). The Hemlock representative clarified his concerns after the publication of the report that it appears that the production capacities of the wafer suppliers is sufficient for Maxeon's stated requirements. [See Annex A – Corporate Responses](#).

Update

In response to Sheffield Hallam's request for information (and even prior to), Maxeon Solar Technologies / SunPower has engaged in a process of public disclosure by providing significant documentation of its sourcing and sourcing practices, including but not limited to the company's modern slavery statements, sustainability reports, purchase orders, and supply chain maps. Furthermore, Maxeon has chosen to go on the record, by providing the company's extensive responses to Sheffield Hallam's inquiries to be included in the corporate responses annex of the report's website. In these exchanges, Maxeon has explained in some detail the company's processes for designating suppliers, tracing to the raw materials, monitoring the supply chain, and auditing its suppliers.

Based on the information provided, as of November 1, 2023, Sheffield Hallam is revising Maxeon's XUAR exposure assessment to NONE (UNVERIFIED). We are unable to verify all of the attestations that Maxeon has made about their sourcing and the means by which they ensure that their suppliers—some of whom do source from the XUAR or other unknown suppliers in China—segregate the supply for Maxeon from that which is from XUAR.

Maxeon has two distinct sources of solar modules. The main source is the 100% Maxeon produced modules: Generation 3, Generation 6 and P-Series. Maxeon produces these for their internal sales and for sales as SunPower branded modules. According to Maxeon's statements, the silicon used in these Maxeon produced modules is not from China. A second source of modules sold by Maxeon is a joint venture called Huansheng Photovoltaic (Jiangsu) Co. Ltd (HSPV). This JV is majority owned by TCL Technologies (TZS is the acronym the Over-Exposed report uses for TCL Technologies and TZE is the acronym used by Maxeon) and minority owned by Maxeon. Maxeon receives an allocation of HSPV produced modules. The wafers, cells, and modules used by HSPV are produced in China. Maxeon claims through public disclosure that the portion of the modules produced by HSPV for Maxeon contain no XUAR silicon (MGS or polysilicon).

The following pieces of evidence have contributed to our re-assessment.

1. Disclosure of all wafer, polysilicon, and MGS suppliers used to make Gen 3 and Gen 6 cells starting on 1 January 2023, as evidenced by Maxeon's supply chain map, which was submitted to Sheffield Hallam (and included in the original report) as well as [posted online](#). However, Maxeon does not specify the relationships between individual polysilicon suppliers and the ingot-wafer suppliers. Maxeon Gen 5 is no longer in production.
2. Unverified evidence that Maxeon has explicitly required the exclusion of XUAR inputs from all of its sourcing throughout its supply chain, including
 - Statement in Maxeon's public [Modern Slavery Statement 2022](#) (copyrighted 2023) that the company does "not source any MGSi from China (and in particular anywhere subject to allegations of forced labour), and neither do any of our suppliers' suppliers, to the best of our knowledge following our due diligence processes as described in this document.
 - Statement in Maxeon's public [Modern Slavery Statement 2022](#) (copyrighted 2023) that it requires of all its suppliers to provide "enhanced certifications for China-exposed suppliers

regarding not being (i) in Xinjiang and (ii) on OFAC list of sanctioned entities (which includes the entities alleged to be involved in forced labour)."

- Statement in Maxeon's public [Modern Slavery Statement 2022](#) (copyrighted 2023) that its joint venture "HSPV's operations are located in Yixing city, Jiangsu Province far from the allegations of forced labour that are the subject of scrutiny of the solar industry as are its suppliers which are not located in Xinjiang" (emphasis added).
 - Statement in a corporate blog that Maxeon conducts "site audits of suppliers identified as having potential risk of exposure to Xinjiang either through the manufacturing of products within the province or by benefiting from labor transfers of Uyghurs to other provinces of China."
 - Disclosure in correspondence that "due to the extra risk of polysilicon (and also aluminum) originating from XUAR, we have done extensive and audited traceability to ensure no exposure to XUAR or, in the case of polysilicon, *no exposure to China at all in the sourcing of the raw materials*" (emphasis added). The company confirmed that this was the case for both the Maxeon-produced modules and the HSPV-produced modules made for Maxeon. Note that HSPV is likely still sourcing wafers made with XUAR polysilicon for non-Maxeon cells.
 - Disclosure in correspondence of no co-mingling of sources of wafers, to wit: "The two supply chains are not comingled. Indeed, the Philippines factory does not have any TZE wafers ever enter the factory as it only makes IBC Gen 3 panels. We have two factories in Mexico, one of which is all Gen 3 / 6 using Hemlock / Wacker / OCI and one of which is all P-Series which uses TZS / Wacker-OCI so the wafers aren't even in these same factories to comingle."
 - These claims cannot be verified. Furthermore, this does not amount to full disclosure of the supply chain for the HSPV joint venture made panels. Nonetheless, these attestations do provide sufficient public disclosure of sourcing practices for the purposes of the assessment.
3. The company's explanations of its requirement of its suppliers OCI and TCL Zhonghuan that they only use non-XUAR inputs for the production of Maxeon-bound products, including
 - Descriptions of the designation and the process by which it is traced, monitored, and audited by Maxeon (and its paid third-party consultants)
 - Sample purchase orders

Note on the end of the TZS investment in Xinjiang GCL-Poly: To some extent, [TCL Zhonghuan's \(TZS\) apparent sale](#) of its shares in Xinjiang GCL in September 2023 has a potential effect on the proportion of TZS wafers being made with XUAR inputs; however, this sale is not yet completed, TZS's current and future relationship with Xinjiang GCL will still need to be understood, and TZS continues to have other exposures to the Uyghur Region. However, Maxeon has publicly asserted that it has instructed TZS to source

only Hemlock, OCI, and Wacker for its polysilicon. Note that this information was not relevant to the Sheffield Hallam point-in-time report or to our considerations for revision, as it occurred months after publication.

Public domain disclosures only provide information about TZS polysilicon supply for approximately 60 GW wafer production out of a total 140 GW nameplate wafer capacity at the end of 2022. The unknown polysilicon accounting for 80 GW of TZS 2022 nameplate could include suppliers without XUAR exposure, with lower XUAR exposure (Tongwei Sichuan, Tongwei Yunnan) or even non-Chinese (OCI Malaysia, Wacker Germany). However, these suppliers cannot be known and are not included in the TZS XUAR exposure ranking.

TZS remains the second largest investor in Maxeon.

Information that remains uncertain from the current disclosures include the specific MGS suppliers, the specific relationships between individual polysilicon and ingot/wafer suppliers, and the means by which OCI segregates its China-made inputs from others to satisfy Maxeon requirements.

This revised assessment should not be understood as a recommendation, endorsement, or advice regarding Maxeon or any other manufacturer.

All of Maxeon's correspondence can be reviewed on the report's website in [Annex A – Corporate Responses](#).

Conclusion

As Maxeon has provided significant (and publicly available) information regarding its sourcing, monitoring, and assurance practices, all Maxeon modules have been re-assessed as NONE (UNVERIFIED).

1. Note: Despite the name change to TCL Technologies, many in the industry still refer to this company as TZS.

Maxeon Solar Technologies

3/5/6 and SunPower X-/A-/M-Series Supply Chain
After 1 January 2023

ORIGINAL ASSESSMENT. SEE UPDATED SUPPLY CHAIN MAPS BELOW.

EXPOSURE KEY

VERY HIGH

HIGH

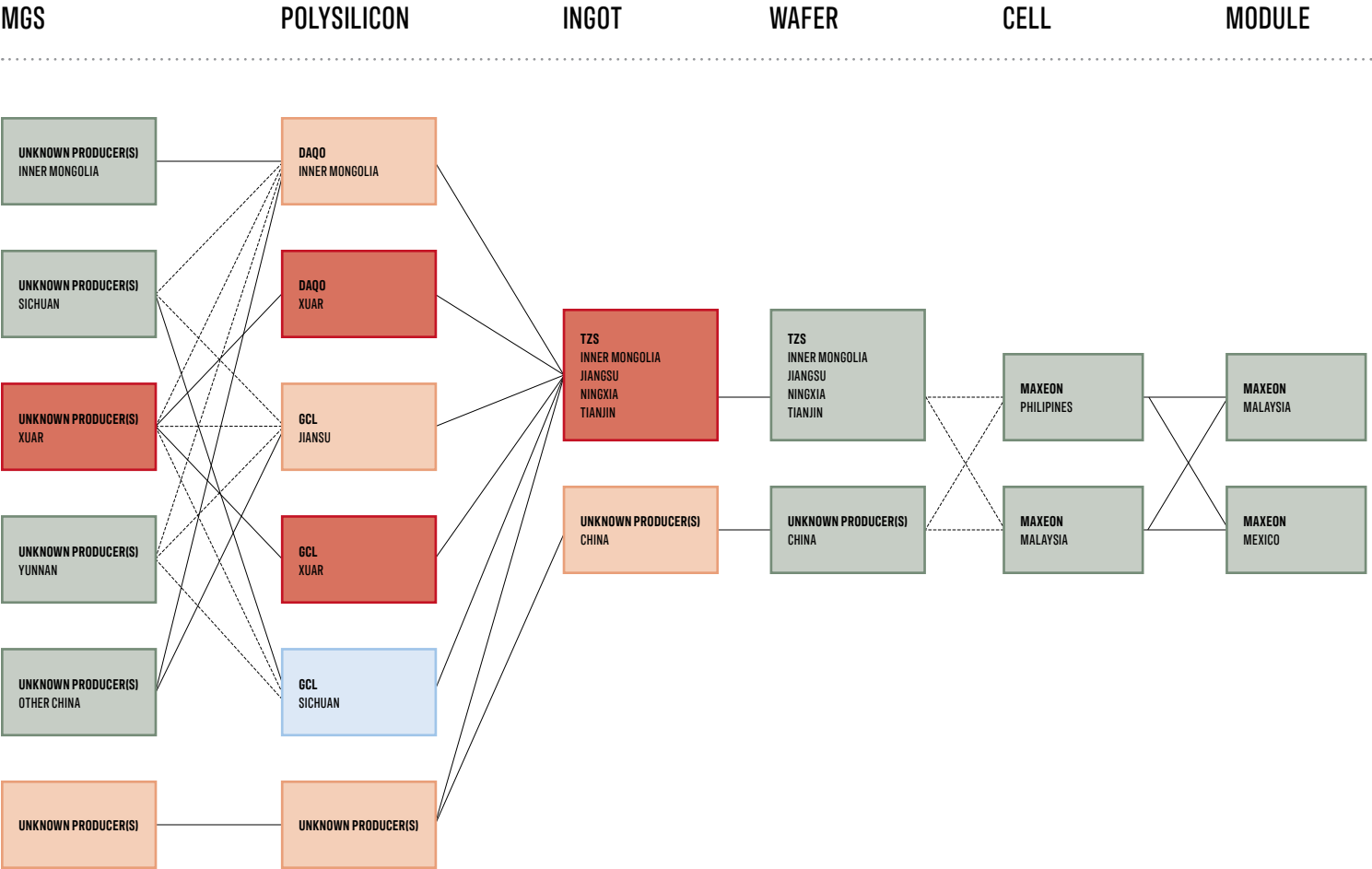
MEDIUM

LOW

NONE (UNVERIFIED)

NONE (VERIFIED)

Solid line = disclosed / known information (verified or unverified)
Dashed line = not disclosed but likely / possible



Maxeon Solar Technologies

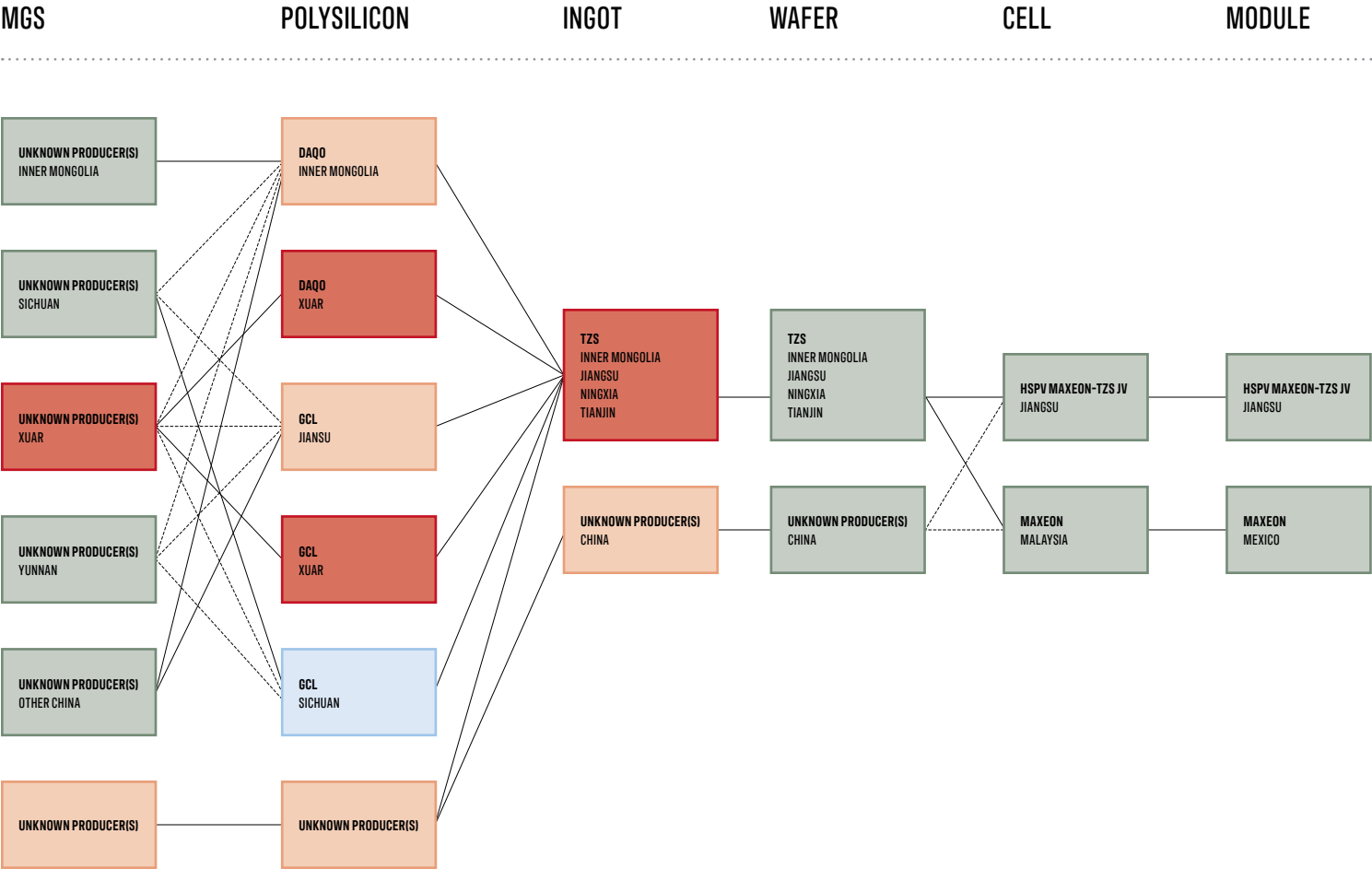
Performance Series Supply Chain

ORIGINAL ASSESSMENT. SEE UPDATED SUPPLY CHAIN MAPS BELOW.

EXPOSURE KEY



Solid line = disclosed / known information (verified or unverified)
Dashed line = not disclosed but likely / possible



Maxeon Solar Technologies

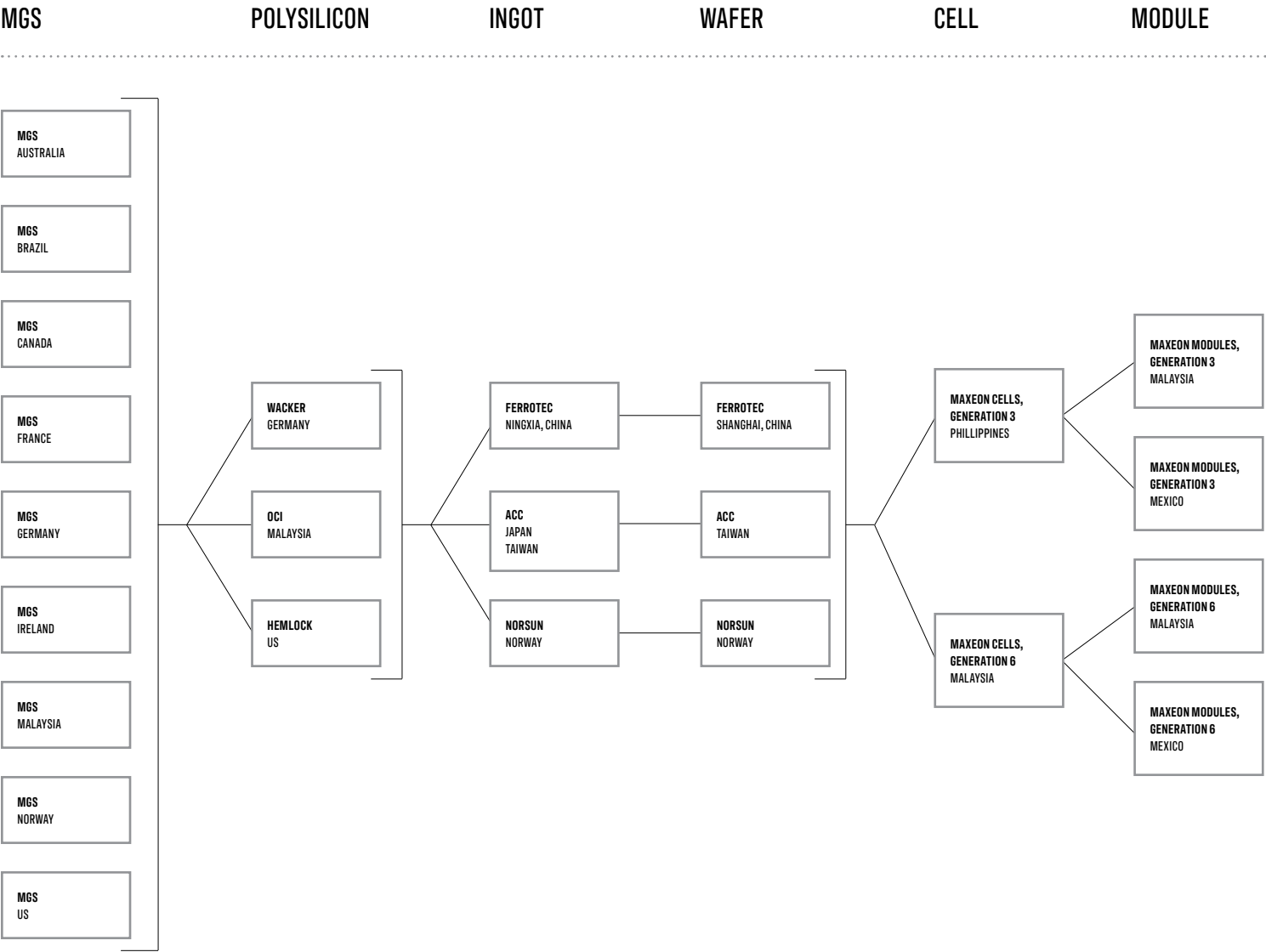
Generation 3 and 6 Manufacturing Supply Chain – According to Maxeon

ORIGINAL ASSESSMENT. SEE UPDATED SUPPLY CHAIN MAPS BELOW.

EXPOSURE KEY



Solid line = disclosed / known information (verified or unverified)
Dashed line = not disclosed but likely / possible



Note: Maxeon provided their revision to the supply chains for both the 3 and 6 models, as well as the Performance models.

Maxeon Solar Technologies

Performance Line Manufacturing Supply Chain – According to Maxeon

ORIGINAL ASSESSMENT. SEE UPDATED SUPPLY CHAIN MAPS BELOW.

EXPOSURE KEY

VERY HIGH

HIGH

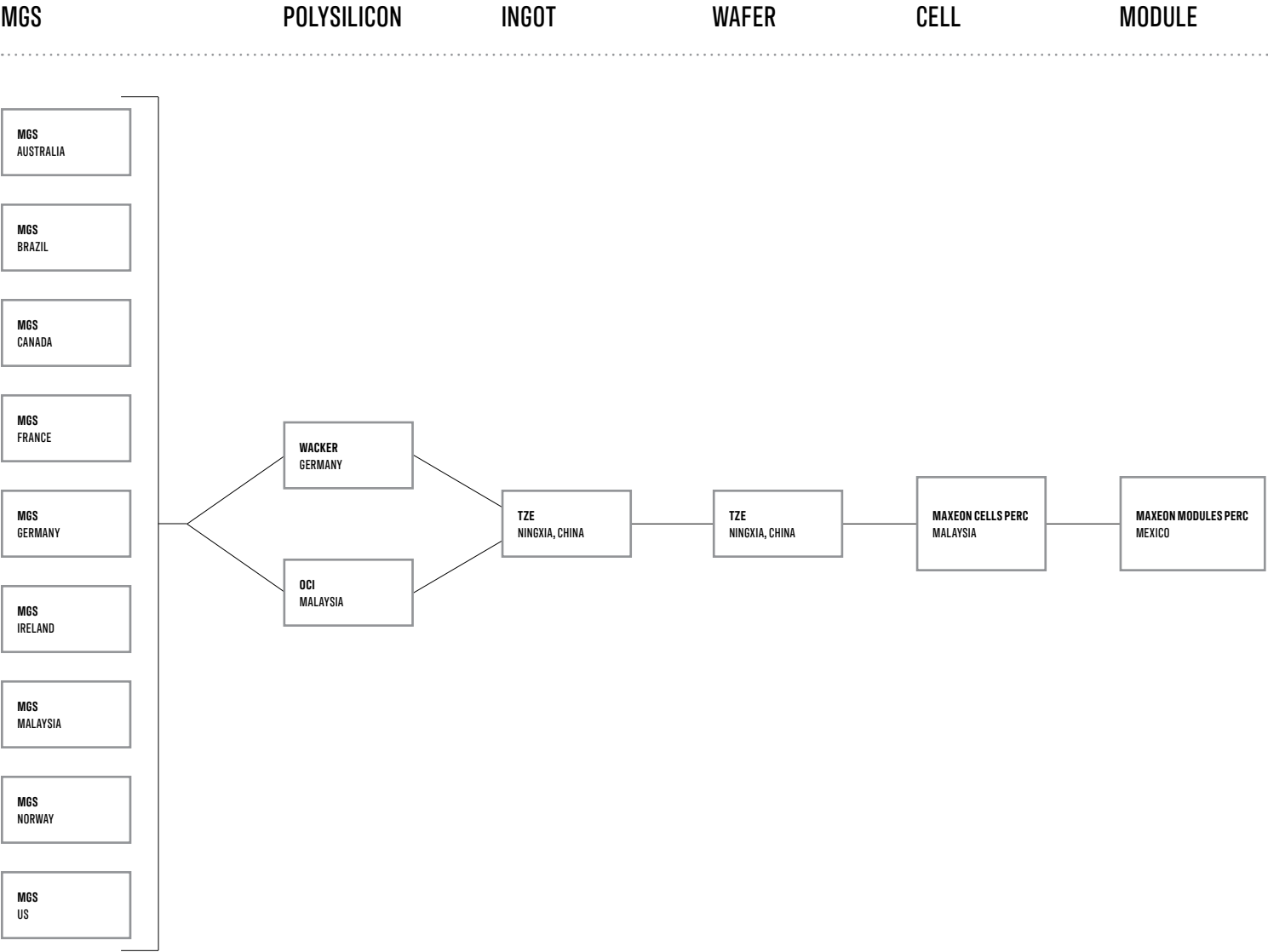
MEDIUM

LOW

NONE (UNVERIFIED)

NONE (VERIFIED)

Solid line = disclosed / known information (verified or unverified)
Dashed line = not disclosed but likely / possible



Note: Maxeon provided their revision to the supply chains for both the 3 and 6 models, as well as the Performance models.

Maxeon Solar Technologies

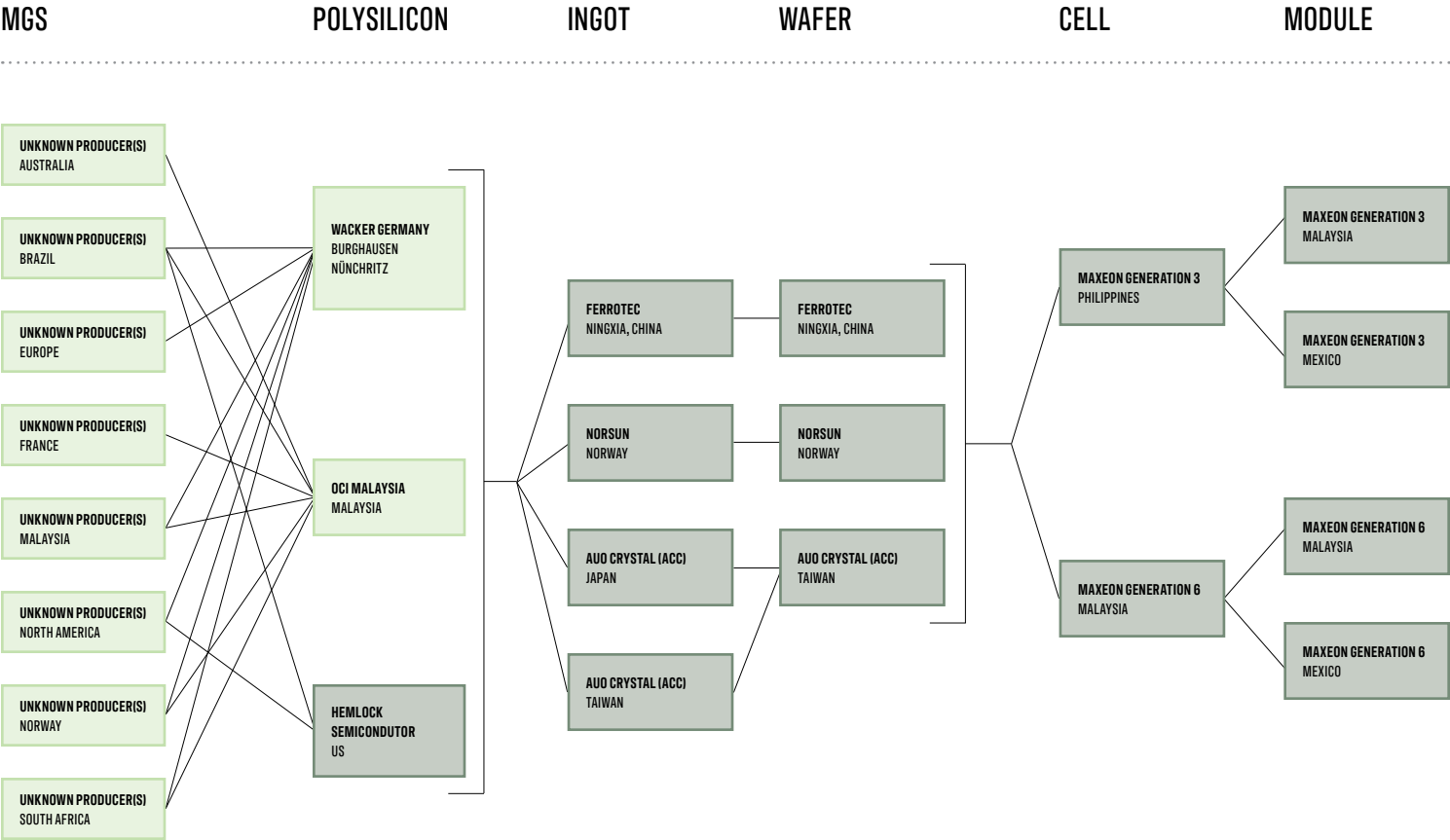
3 / 6 and SunPower Series X / M Series Supply Chain

Update November 2023

EXPOSURE KEY



Solid line = disclosed / known information (verified or unverified)
Dashed line = not disclosed but likely / possible



Maxeon Solar Technologies

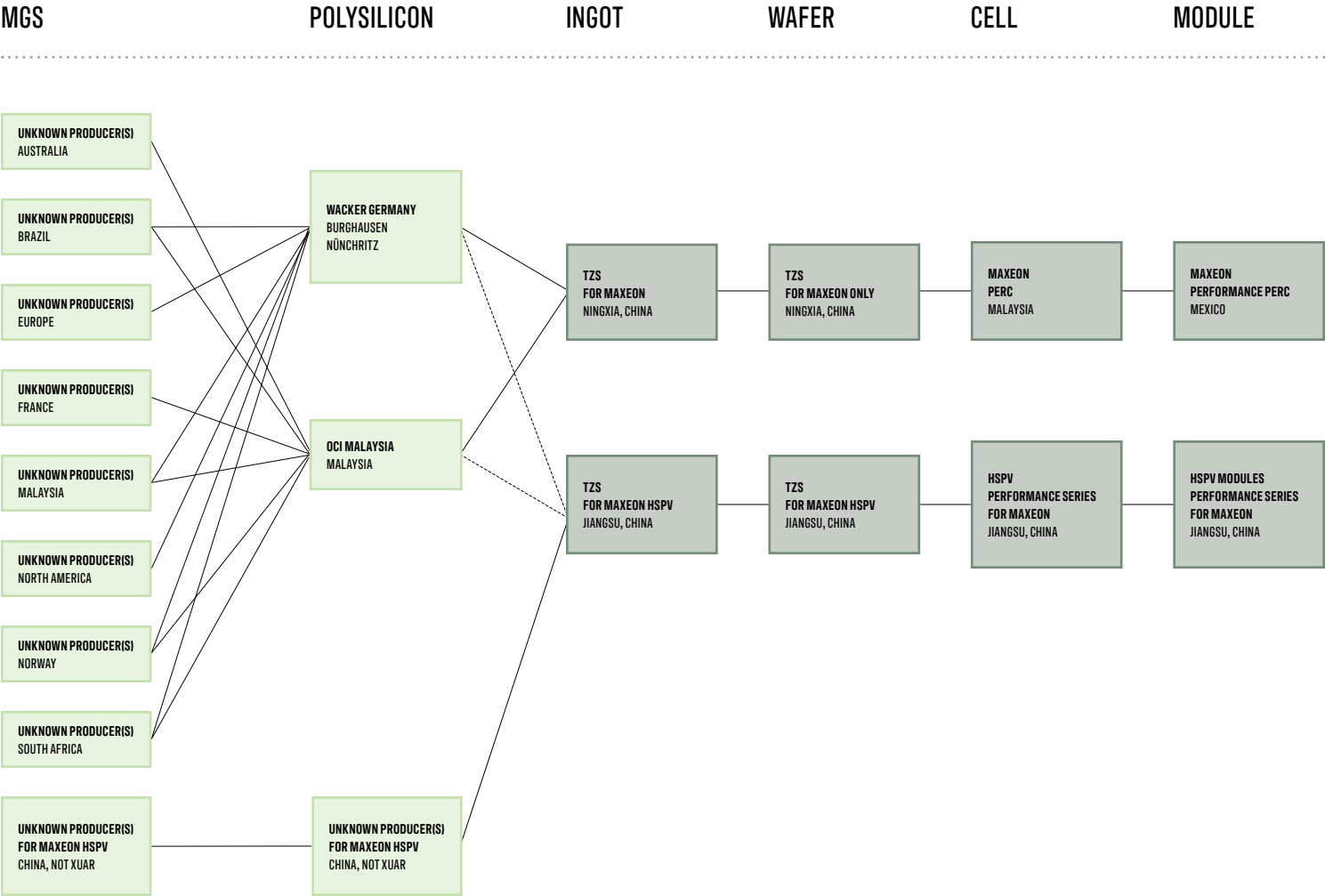
Performance Series Supply Chain – Maxeon and HSPV Produced

Update November 2023

EXPOSURE KEY



Solid line = disclosed / known information (verified or unverified)
Dashed line = not disclosed but likely / possible



Meyer Burger Technology AG

All Modules

The overall XUAR exposure for all solar modules produced and sold by Meyer Burger Technology AG is assessed as NONE (Unverified).

EVIDENCE BASE

Meyer Burger has not disclosed its supply chain in its entirety. Nonetheless, Meyer Burger’s known polysilicon suppliers provide insight into its upstream suppliers. Meyer Burger CEO [Gunter Erfurt](#) disclosed in an interview published in February 2023 that Meyer Burger purchases wafers that use no China-produced polysilicon. Erfurt stated, “As our customers are pretty sensitive to the Xinjiang issue, the polysilicon is entirely sourced from non-Chinese companies. The vast majority comes from German multinational chemicals company Wacker. On wafers, we get around a fifth of our wafers from Norway-based companies Nor-Sun and Norwegian Crystals, and the rest from China. But the vast majority of the polysilicon—and that’s the interesting part for many of our customers—is made in Germany.”

ANALYSIS

Meyer Burger produces n-type HJT cells in Bitterfeld-Wolfen, Germany. All modules are produced from these cells in Freiberg, Germany. Meyer Burger has no backward integration from wafers, ingots, polysilicon, MGS, or quartz. Meyer Burger is planning cell and module expansions in Germany and is building a new module fabrication facility (that will use German-produced cells) in Goodyear, Arizona, US. Meyer Burger has explicitly stated that it sources wafers from China.

Ingots/Wafer Exposure

Meyer Burger modules use self-produced n-type HJT cells. Meyer Burger produces the HJT cells in Bitterfeld-Wolfen, Germany, using n-type monocrystalline wafers purchased from two Norwegian wafer producers, [NorSun](#) and [Norwegian Crystals](#), and at least one unnamed China-based wafer producer. The Norwegian companies supply about [20% of the wafers](#) Meyer Burger uses, and the remaining 80% are from China.

If Meyer Burger’s claim is correct, and there is no China-originating polysilicon in the wafers it uses, the China-based wafer supplier is likely either LONGi or Yuze Semiconductor. Both companies have produced n-type wafers with non-China polysilicon (from Wacker and OCI) for REC Solar (see REC chapter of this report). Neither LONGi nor Yuze has any production facilities in the XUAR, though LONGi at least does source China-produced polysilicon for other customers’ products (see LONGi chapter of this report).

Quartz/MGS/Polysilicon Exposure

Meyer Burger’s CEO reported in February 2023 (see above) that “the vast majority” of polysilicon used by the company’s wafer suppliers is produced by Wacker Chemie. Wacker (Germany) polysilicon has no XUAR exposure based on their 2023 MGS supply. A Wacker executive reports that the company no longer uses any MGS produced in China, though that remains unverifiable through any public domain information.¹ In a response to Sheffield Hallam University, a Wacker representative indicated that the company does not source any products from the Uyghur Region making this statement regarding the United States Customs and Border Protection (CBP) enforcement of the UFLPA: “Wacker’s polysilicon meets CBP’s requirements and we have established supply chains to meet CBP’s requirements.” Wacker further indicated that its German polysilicon is currently made of MGS sourced

Overall Exposure

NONE (UNVERIFIED)	QUARTZ	NONE (UNVERIFIED)
	MGS	NONE (UNVERIFIED)
	POLYSILICON	NONE (UNVERIFIED)
	INGOT	NONE (UNVERIFIED)
	WAFER	NONE (UNVERIFIED)
	CELL	NONE (UNVERIFIED)
	MODULE	NONE (UNVERIFIED)

ASSESSMENT

The NONE (Unverified) exposure assessment is based on the following factors:

- Meyer Burger disclosed that no China-produced polysilicon is used to manufacture any wafers purchased by Meyer Burger;
- OCI and Wacker Chemie (Germany) have disclosed that no metallurgical grade silicon (MGS) produced in the XUAR is used in their polysilicon;
- However, there is no way to independently verify these disclosures.

OPPORTUNITIES TO REDUCE EXPOSURE

- Public disclosure or other independent verification of Meyer Burger CEO’s February 2023 claims of zero China-produced polysilicon used in wafers purchased by Meyer Burger
- Public disclosure or other independent verification of MGS suppliers used by OCI and Wacker

from Europe, Norway, Canada, Iceland, Brazil, South Africa, and Australia; its US-produced polysilicon is made of MGS sourced from Brazil, US, and Norway. Wacker also provided the country of origin of all of its raw silica, none of which is from the Uyghur Region. ([See Annex A – Corporate Responses](#))

Meyer Burger indicates that the remaining polysilicon used to make the company's wafers is produced outside China, though that is also unverifiable through public domain information. Outside of Wacker (Germany), the only polysilicon suppliers outside China are Wacker (US), Hemlock (US), and OCI (Malaysia). Given that Meyer Burger does not mention Wacker (US) as a supplier in its above-quoted comments about sourcing from Wacker (Germany), sourcing from Wacker (US) is unlikely. It is possible that NorSun and Norwegian Crystals source any polysilicon beyond what Wacker (Germany) provides from Hemlock (US) and/or OCI (Malaysia). As Hemlock (US) sources its MGS from outside China because of the [139% anti-dumping duties](#) attached to importing China-originating MGS, it would be entirely XUAR-free.

OCI (Malaysia) is almost certainly the source of the non-China polysilicon used by the unnamed China-based wafer suppliers. We can confidently exclude Wacker (US) and Hemlock (US) because any China wafer producer would very likely avoid any US supplier due to the 59% anti-dumping duty on US-produced polysilicon imported to China. OCI (Malaysia) primarily sources its MGS from China, but has no XUAR exposure, as they have reportedly stopped purchasing MGS from the region.² OCI (Malaysia) sources its remaining MGS from Malaysia, and perhaps Brazil and Norway. It is not possible to verify OCI's disclosures about its current global MGS supply and OCI did not respond to a request for more information.

Conclusion

The XUAR exposure for all Meyer Burger modules is NONE (Unverifiable). According to corporate reports, all Meyer Burger modules produced in Germany use zero China-produced polysilicon and zero XUAR-produced MGS. Most of the polysilicon used in the wafers purchased by Meyer Burger is produced by Wacker (Germany).

1. Jörg Hoffman, Wacker Senior Vice President for Investor Relations in Munich Germany to author, personal correspondence, 30 March 2023.

2. OCI Investor Relations to author, personal correspondence, 21 April 2023.

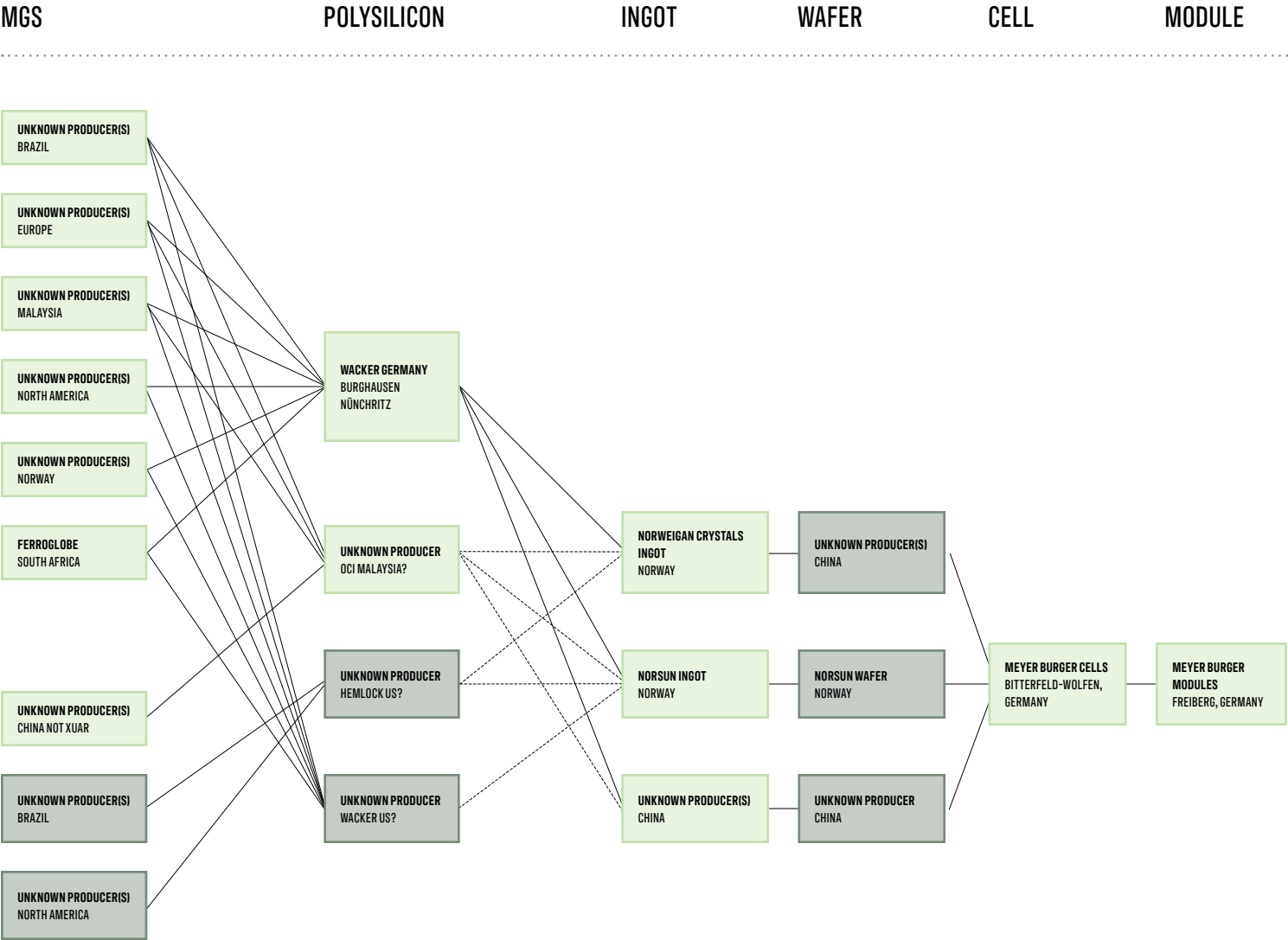
Meyer Burger Technology AG

Supply Chain

EXPOSURE KEY



Solid line = disclosed / known information (verified or unverified)
Dashed line = not disclosed but likely / possible



Qcells

All Modules

The overall XUAR exposure for all solar modules produced by Qcells in China, Korea, Malaysia, and the US is assessed as VERY HIGH.

EVIDENCE BASE

Qcells is a Korea-based cell and module producer. Qcells does not provide clear data for its total cell and module capacities. Qcells permanently [stopped producing ingots](#) in 2018 and focused on cells and modules. Qcells' parent company, Hanwha, [stopped polysilicon production](#) in Korea in 2020.

Qcells CEO [Justin Lee](#) stated in May 2022 that about 95% of the ingots and wafers Qcells purchased in 2022 were produced in China. Lee stated, "Currently, we are still sourcing around 95% our ingots and wafers from China, but this will change soon, as we have also recently signed a \$1.2 billion deal with Korean manufacturer OCI, which is increasing its manufacturing capacity in Malaysia...We are not planning, however, to restart our own polysilicon production in Korea."

QCells has made no public domain disclosures that provide details about the silicon supply chain associated with wafers purchased for use in China, Korea, and Malaysia, nor about cells purchased for use in Korea, Malaysia, and the US. Official corporate documents of wafer suppliers were reviewed to identify 2022 Qcells supply chain relationships.

Customs records accessed via Panjiva Market Intelligence provide some information regarding exports of Qcells' cells.

ANALYSIS

Qcells produces cells in China, Korea, and Malaysia, and modules in China, Korea, Malaysia, and the US. Analysis of the Qcells supply chain is focused on an overall capacity analysis for all Qcells operations. The capacity analysis assumes all fabs are operating at reported capacities and does not take into account actual operating rates. Table 1 shows a summary of global Qcells capacity for the end of 2022, with China capacity calculated by subtracting production capacity of other facilities from the announced total production capacity, due to lack of explicit public disclosures regarding China capacity.

Qcells' reported total production capacity of modules across all of the company's manufacturing sites is 12.4 GW, but the company only produces 10 GW of cells. The data in Table 1 depicts the imbalance of cell and modules production; module capacity is 2.4 GW greater than cell capacity which means that Qcells must purchase 2.4 GW of incremental cells to cover the shortfall. The data shows the cell imbalance is in China and the US, while Korean and Malaysian cell and module production is balanced. While the Table 1 data implies incremental cells are purchased from external supplier(s) for China (0.7 GW of incremental cells) and US (1.7 GW of incremental cells), actual cell supply is more complicated (see below).

Qcells has no current backward integration from wafers, ingots, polysilicon, MGS, or quartz. Qcells does plan backward integration (though not for quartz or MGS) to support its production for the US market (see below). There are no references suggesting a change with its production in China.

Overall Exposure

VERY HIGH	QUARTZ	VERY HIGH
	MGS	VERY HIGH
	POLYSILICON	VERY HIGH
	INGOT	VERY HIGH
	WAFER	NONE (VERIFIED)
	CELL	NONE (VERIFIED)
	MODULE	NONE (VERIFIED)

ASSESSMENT

The VERY HIGH exposure assessment is based on the following factors:

- Lack of public domain information about Qcells' cell and wafer supply chain or about how the company's cell and wafer suppliers sourced metallurgical grade silicon (MGS) and polysilicon;
- The assessment is VERY HIGH because it appears from Meike corporate reports that Qcells was sourcing from Meike until at least the middle of 2022, though Qcells denies the accuracy of this official disclosure.

OPPORTUNITIES TO REDUCE EXPOSURE

- Verified disclosures regarding the wafer and cell supply chain used by Korean, Malaysian, US, and China operations
- Verified disclosure of end of Meike sourcing contract

Table 1: Qcells global cell and module capacity for end of 2022. GW = gigawatts.

QCELLS LOCATION	CELLS PRODUCED	CELLS REMAINING TO BE PURCHASED	MODULE PRODUCED	PERCENT OF TOTAL PRODUCTION
	GW	GW	GW	%
Total	10.0	2.4	12.4	-
China	3.2	0.7	3.9	31.5
Korea	4.5	0.0	4.5	36.3
Malaysia	2.3	0.0	2.3	18.5
US	0.0	1.7	1.7	13.7

Note: analysis ignores yield losses for wafer conversion to cells and cells to modules and assumes production equals stated capacities.

Ingot/Wafer/Cell Exposure

Qcells produces both cells and modules at two Korean fabrication facilities located in Eumseong and Jincheon and at a Malaysian facility located in Cyberjaya. The company produces sufficient cells to meet its production capacity in both Korea and Malaysia (2.3 GW). However, the Korean and Malaysian facilities likely produce cells for the US module fabrication facility (see below), and thus the three facilities in Asia may require purchases to make up for what they transfer to the US facility.

Qcells' Dalton, Georgia, US facility produces modules only. We can be sure that cells supplied to Qcells' US module fab are not purchased directly from external China-based cell producers. Longstanding [anti-dumping duties](#) imposed by the US government prevent import of solar cells from China. Customs records accessed via Panjiva Market Intelligence provide some information regarding exports of Qcells' cells. The US module fab appears to be supplied with cells from Qcells' Korean and Malaysian cell fabs. Table 1 shows that each of these regions have "balanced" cell and module capacity. Available customs records do not reveal the import of cells to the Korean and Malaysian fabs.

Qcells also produces cells and modules in a fabrication facility located in Qidong, Jiangsu, China. Customs records accessed via Panjiva Market Intelligence for 2021, 2022, and 2023 indicate India, Vietnam, Indonesia, and Sri Lanka are the primary Qcells markets served by the Qidong fab. Because the total capacity of that plant is higher than the amount being imported elsewhere, it is likely that the cells are also consumed domestically in China. Given China's dominance in cell production, the incremental 0.7 GW of cells required for China-based module production are likely supplied by one or more China-based cell producers. China-based cell producers are thus likely to supply a total of 1.7 GW of cells to Qcells' Korean and Malaysian module fabs to make up for the supply of 1.7 GW of cells from Korea and Malaysia to the US module fab.

Qcells does not disclose its global wafer suppliers. The only relevant public domain information is the above referenced quote from Qcells CEO Justin Lee that about 95% of wafers currently used are produced in China.

Meike Solar Technology announced in its [2022 IPO documentation](#) that Hanwha Group (and its affiliates) was Meike's second largest wafer cus-

tomers in 2019, 2020, and 2021. By [mid-2022](#), it appears Hanwha remained an important customer but had fallen to Meike's fourth largest. However, a Qcells representative indicated to Sheffield Hallam that the company ceased sourcing from Meike in mid-2021, but the company provided no documentation to support this information. Meike sources from [Tongwei Solar](#) and [Daqo \(XUAR\)](#). This represents elevated risk of XUAR inputs in Qcells' supply chain.

Quartz/MGS/Polysilicon Exposure

As a result of the lack of disclosed wafer suppliers, there is no data about sources of polysilicon or MGS used by the Qcells' wafer and cell suppliers. Given that the vast majority of the wafers used in Qcells modules are made in China, it is highly likely that most of the polysilicon used to produce those wafers is produced in China with China-produced MGS. There is a chance that some wafers are produced in China with OCI (Malaysia) and/or Wacker Chemie (Germany) polysilicon. Without transparency, Qcells' XUAR exposure remains VERY HIGH. In addition to Meike's relationship to XUAR polysilicon producers, because of the XUAR's dominance in the production of MGS and the fact that it is used by polysilicon manufacturers around the world, the highest risk of XUAR exposure in the Qcells supply chain is at the MGS stage.

Qcells' non-disclosure of current supply chain information makes it impossible to confidently determine that the company's cell production in Korea and Malaysia, or its module production in Korea, Malaysia, and the US, is free of XUAR inputs.

Qcells Future

Qcells sourcing is poised to change significantly in the coming years. Hanwha, QCells' parent company, became the [majority shareholder of US-based REC Silicon](#) in March 2022. REC Silicon plans to [restart the Moses Lake, Washington, US](#), solar-grade polysilicon plant in 2023 and will supply all of its production to Qcells. Qcells plans to build an [integrated ingot, wafer, cell, and module fab](#) in the US state of Georgia.

In another shift, Qcells announced a [10-year polysilicon supply contract](#) with OCI (Malaysia) that begins in July 2024 and ends in June 2034. The approximate annual OCI (Malaysia) polysilicon supply to Qcells will be equivalent to that needed for production of 1.5 to 2.0 GW. QCells provided no information about what company it will use to convert the OCI (Malaysia) polysilicon into wafers. Qcells may intend to use the OCI (Malaysia) polysilicon in their planned US ingot fab for blending with lower purity granular polysilicon that will be produced when REC Silicon's Moses Lake, Washington, US plant restarts.

Conclusion

All Qcells modules produced in Korea, Malaysia, and the US have a VERY HIGH XUAR exposure through quartz, MGS, and polysilicon. This VERY HIGH exposure assessment is assigned due to the lack of public domain information about Qcells' silicon supply chain and the reported supply relationship with Meike Solar.

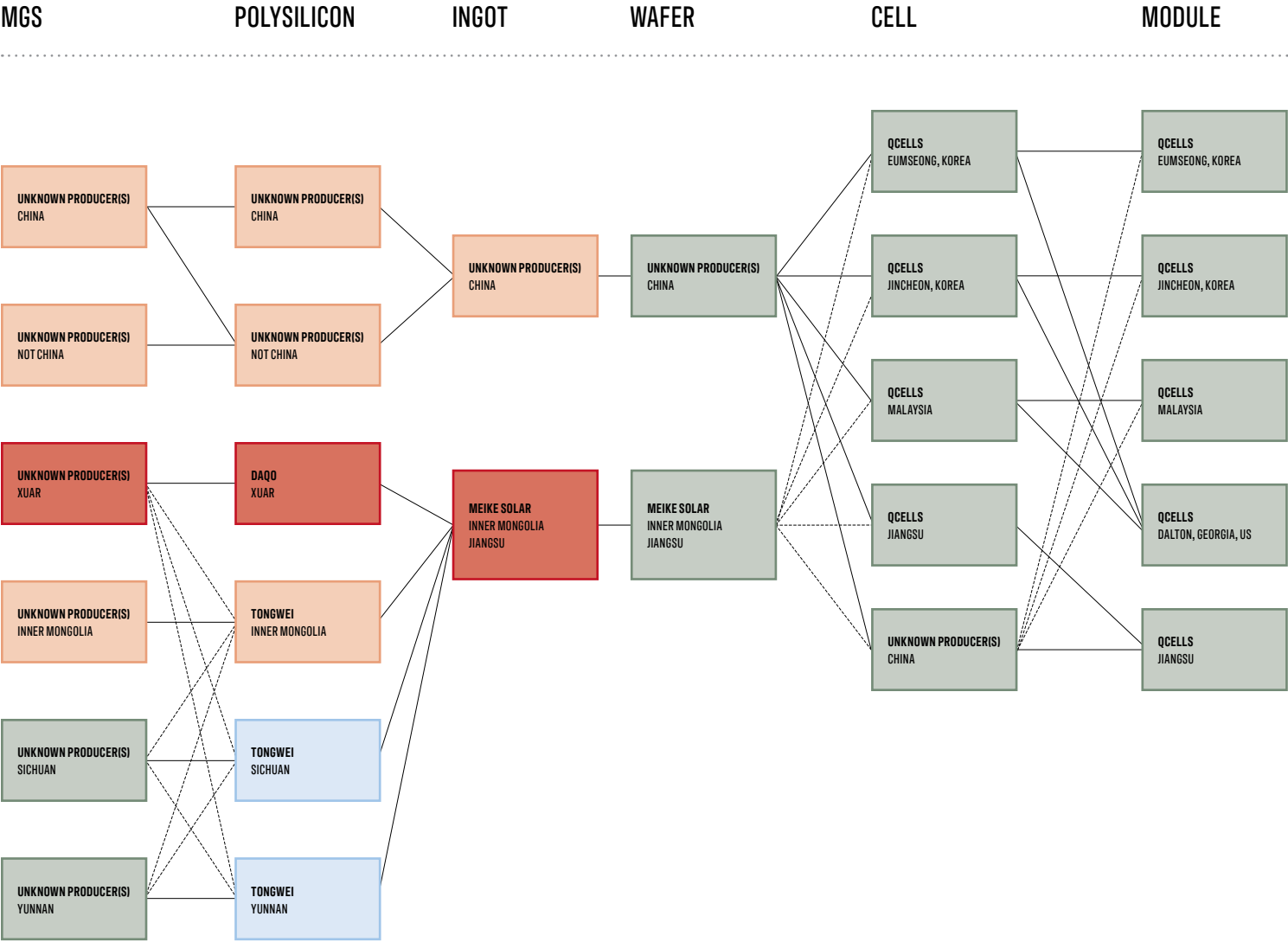
Qcells

Supply Chain

EXPOSURE KEY



Solid line = disclosed / known information (verified or unverified)
Dashed line = not disclosed but likely / possible



REC Solar

N-Peak, Alpha, and TwinPeak 4 Modules

The exposure assessment for REC Solar varies by the module produced due to the company’s bifurcated supply chain. The overall XUAR exposure for the N-Peak and Alpha solar modules produced and sold by REC Solar is assessed as NONE (Unverified). The overall XUAR exposure for TwinPeak 4 solar modules produced and sold by REC Solar is ranked as VERY HIGH.

EVIDENCE BASE

In 2021, REC Solar published a limited circulation report on its suppliers, which included the company’s commitment to a supplier code of conduct that excluded use of XUAR inputs.¹ The report listed LONGi and Yuze Semiconductor as wafer suppliers for REC Solar’s *N-Peak and Alpha* modules. Both LONGi and Yuze Semiconductor list OCI and Wacker (Germany) as polysilicon suppliers in the same report.

That same report listed Aiko Solar and United Renewable Energy (URE) as cell suppliers for *TwinPeak 4* modules. REC Solar did not provide any information about inputs used by Aiko or URE. Public domain research, however, reveals considerable information about the silicon supply used by Aiko to produce cells. There is no public domain information about URE’s silicon supply.

No further public disclosures have been made. Upon inquiry, REC provided no updated disclosure nor verification that the company’s current suppliers remained the same as in 2021. This analysis assumes REC Solar’s 2021 suppliers remained consistent in 2023. REC had an opportunity to review the supply chain maps of its product lines presented in this report and, in its response, did not dispute any information contained therein.

REC Solar indicated in a letter to Sheffield Hallam University researchers, however, that the TwinPeak 4 module is no longer in production as of the end of 2022 ([See Annex A – Corporate Responses](#)). This could not be verified through any publicly available information. In fact, [REC continued to advertise the model](#) on its website at the time of publication. Requests for more information regarding whether this model was still available for purchase/procurement were unanswered; therefore, this report provides an assessment of TwinPeak 4.

ANALYSIS

REC Solar produces all of its modules, as well as its N-Peak and Alpha cells, in Singapore. REC Solar does not appear to produce the p-type PERC cells used in its lower efficiency TwinPeak 4 modules.

REC Solar has no backward integration from wafers, ingots, polysilicon, MGS, or quartz.

Ingot/Wafer Exposure

REC Solar *N-Peak and Alpha* modules use n-type monocrystalline cells (TOPCon and HJT, respectively). REC Solar produces both its TOPCon and HJT cells in Singapore using wafers purchased from the China-based wafer producers LONGi and Yuze Semiconductor, according to its own reports. If REC Solar disclosures are correct, LONGi produces ingots in Ningxia and slices the ingots to produce wafers in Shaanxi for REC. Yuze produces ingots in Yunnan and wafers in Jiangxi for REC. Implied in these disclosures is that LONGi and Yuze are producing these ingots/wafers for REC Solar using dedicated production lines and use only polysilicon purchased from OCI and Wacker (Germany). Use of dedicated ingot and wafer production lines is plausible given how these components are produced. However, it is not clear how REC Solar verifies the sourcing for the wafers they receive from LONGi and Yuze.

N-Peak and Alpha Overall Exposure

NONE
(UNVERIFIED)

QUARTZ	NONE (UNVERIFIED)
MGS	NONE (UNVERIFIED)
POLYSILICON	NONE (UNVERIFIED)
INGOT	NONE (VERIFIED)
WAFER	NONE (VERIFIED)
CELL	NONE (VERIFIED)
MODULE	NONE (VERIFIED)

TwinPeak 4 Overall Exposure

VERY HIGH

QUARTZ	VERY HIGH
MGS	VERY HIGH
POLYSILICON	VERY HIGH
INGOT	VERY HIGH
WAFER	NONE (VERIFIED)
CELL	NONE (VERIFIED)
MODULE	NONE (VERIFIED)

ASSESSMENT

The NONE ranking is based on:

- OCI and Wacker Chemie have disclosed that no metallurgical grade silicon (MGS) produced in the XUAR is used to produce the polysilicon in REC Solar modules;
- There is no way to independently verify these disclosures.

The VERY HIGH ranking is based on:

- P-type PERC cells produced by Aiko contain XUAR polysilicon;
- P-type PERC cells produced by United Renewable Energy (URE) contain polysilicon from an unknown source.

OPPORTUNITIES TO REDUCE EXPOSURE

- Verified disclosure of all current n-type wafer suppliers
- Verified disclosures showing no additional XUAR polysilicon suppliers to current n-type wafer suppliers
- Verified discontinuation and end of sale of the TwinPeak 4 module

Table 1: Known wafer suppliers to Aiko and known polysilicon suppliers to the wafer suppliers

AIKO WAFER SUPPLIER	POLYSILICON SUPPLIERS TO AIKO WAFER SUPPLIERS
Qinghai Gaojing Solar	Daqo New Energy (XUAR) ; Tongwei Solar (Inner Mongolia, Sichuan, Yunnan) ; Xinte Energy (XUAR)
Meike Solar	Tongwei Solar (Inner Mongolia, Sichuan, Yunnan) , Daqo (XUAR)
Shangji Automation	Daqo (XUAR) ; GCL-Poly (Jiangsu) ; GCL-Poly (XUAR) ; Risen Energy (Inner Mongolia) ; Tongwei (Inner Mongolia, Sichuan, Yunnan) ; Xinte (XUAR)
Shuangliang Group	Asia Silicon ; Daqo New Energy (XUAR, Inner Mongolia) ; East Hope Group (XUAR) ; GCL-Poly (Jiangsu) ; Tongwei (Sichuan, Yunnan, Inner Mongolia) ; Xinte Energy (XUAR & Inner Mongolia)

By contrast, REC’s *TwinPeak 4* modules are made of lower efficiency p-type PERC cells. REC Solar does not produce p-type PERC cells, likely because the company can purchase these at a competitive price while reserving Singapore cell capacity to produce premium n-type HJT cells (for its Alpha line) and TOPCon cells (for its N-Peak line).

REC Solar purchases the p-type cells from Aiko (the second largest cell producer in the world) and URE. Aiko produces cells in the provinces of Guangdong, Tianjin, and Zhejiang, China. URE produces cells in Bac Gaing, Vietnam and in Hsinchu, Taiwan. The VERY HIGH XUAR exposure enters REC Solar’s Twin Peak 4 supply chains through the cells purchased from Aiko and URE. The VERY HIGH XUAR exposure related to those cells originates in quartz, MGS, and polysilicon.

Quartz/MGS/Polysilicon Exposure

LONGi and Yuze disclosed in 2021 that polysilicon used to produce the n-type wafers purchased by REC Solar for the *N-Peak and Alpha* modules was supplied by Wacker (to Yuze and LONGi), OCI Korea (to Yuze), and OCI Malaysia (to LONGi).² Neither LONGi nor Yuze has any production facilities in the XUAR. Neither company has provided any publicly or privately available updates on their supplier contracts that would assist in verification of these relationships.

OCI primarily uses MGS produced in China, though the company also sources some MGS from Malaysia, and perhaps Brazil and Norway. OCI reports that the company has no XUAR exposure as the company stopped purchasing MGS from the XUAR, although it continues to purchase from other Chinese provinces.³ Wacker Germany has no XUAR exposure based on its 2023 MGS supply. A Wacker executive reports that the company no longer uses any MGS produced in China.⁴ In a response to Sheffield Hallam University, a Wacker representative indicated that the company does not source any products from the Uyghur Region making this statement regarding the United States Customs and Border Protection (CBP) enforcement of the UFLPA: “Wacker’s polysilicon meets CBP’s requirements and we have established supply chains to meet CBP’s requirements.” Wacker further indicated that its German polysilicon is currently made of MGS sourced from Europe, Norway, Canada, Iceland, Brazil, South Africa, and Australia; its US-produced polysilicon is made of MGS sourced from Brazil, US, and Norway. Wacker also provided the country of origin of all of its raw silica, which indicated that none originated in the XUAR. (See Annex A – Corporate Responses)

It is not possible to verify the 2023 OCI and Wacker disclosures about current MGS supply.

REC Solar’s 2021 supplier disclosure offered no information about the silicon supply chain used by Aiko and URE cell production for the *TwinPeak 4* modules. Significant public domain information shows that Aiko purchases wafers from the China-based companies listed in Table 1; the known polysilicon suppliers to these wafer suppliers are also listed. The polysilicon supply represented by wafers purchased by Aiko show significant direct XUAR exposure. Gaojing Solar, Shangji Automation, Shuangliang Group, and Meike Solar all source at least some polysilicon from the XUAR (see Table 1). Since polysilicon from Daqo, Xinte, GCL-Poly, and East Hope is produced in the XUAR, there is a clear exposure to XUAR at the polysilicon tier, and we can assume the MGS used to produce this polysilicon is made in the XUAR. Furthermore, Tongwei polysilicon (used by all of the Aiko wafer suppliers) is assessed as a HIGH RISK for XUAR exposure due to limited available disclosures specifying polysilicon sourcing (see Tongwei chapter of this report; Tongwei’s response to Sheffield Hallam inquiries included no details regarding sourcing). GCL-Poly and Risen Energy polysilicon is made from unknown sources of MGS, and therefore presents a HIGH RISK as well.

There is no public domain data about URE’s wafer or polysilicon supply. Without any available information, the risk of XUAR inputs remains HIGH given the XUAR’s dominance in polysilicon production.

Conclusion

The REC Solar *N-Peak and Alpha* module product line was produced in Singapore from wafers produced exclusively with OCI and Wacker polysilicon in 2021. Assuming this remains unchanged in 2023, the XUAR exposure for REC Solar Alpha modules is NONE (Unverified).

The REC Solar *TwinPeak 4* module product line was produced in Singapore in 2021 from p-type monocrystalline cells that have VERY HIGH XUAR exposure due to use of XUAR produced polysilicon. Assuming this remained unchanged for the modules left in stock after the line was discontinued, the XUAR exposure for REC Solar TwinPeak 4 is VERY HIGH.

REC Solar’s apparent discontinuation of the TwinPeak 4 and the company’s concentration on products that are free of XUAR inputs reflects a significant supply chain shift for the company.

1. Personal correspondence, George McClellan, REC America’s LLC, Senior Technical Sales Manager, document *REC Supplier Declaration Pack_B_April 2021*, via email to author, 27 February 2023.

2. *Ibid.*

3. OCI Investor Relations to author, personal correspondence, 21 April 2023.

4. Jörg Hoffman, Wacker Senior Vice President for Investor Relations in Munich Germany to author, personal correspondence, 30 March 2023.

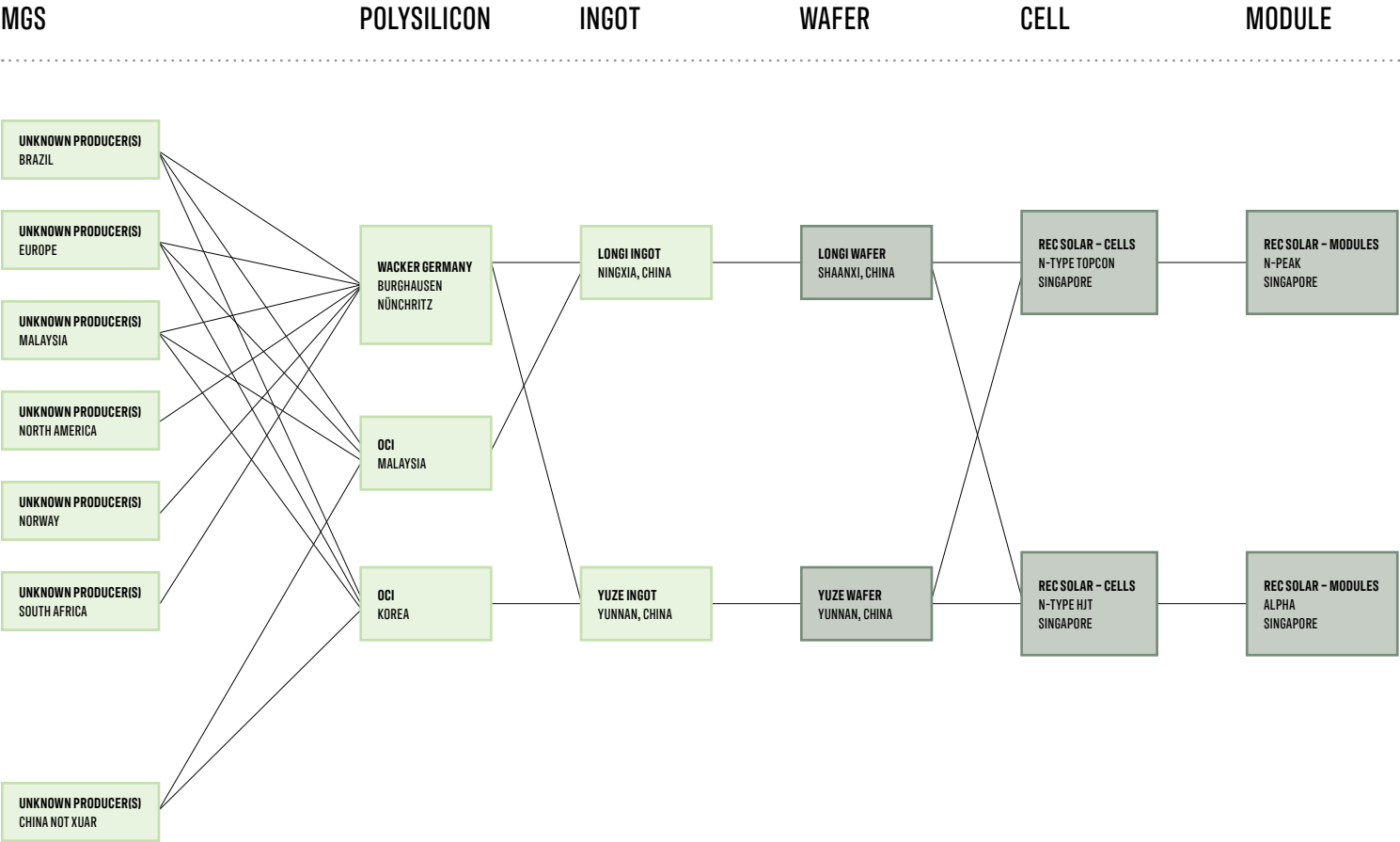
REC Solar

N-Peak and Alpha Supply Chain

EXPOSURE KEY



Solid line = disclosed / known information (verified or unverified)
Dashed line = not disclosed but likely / possible



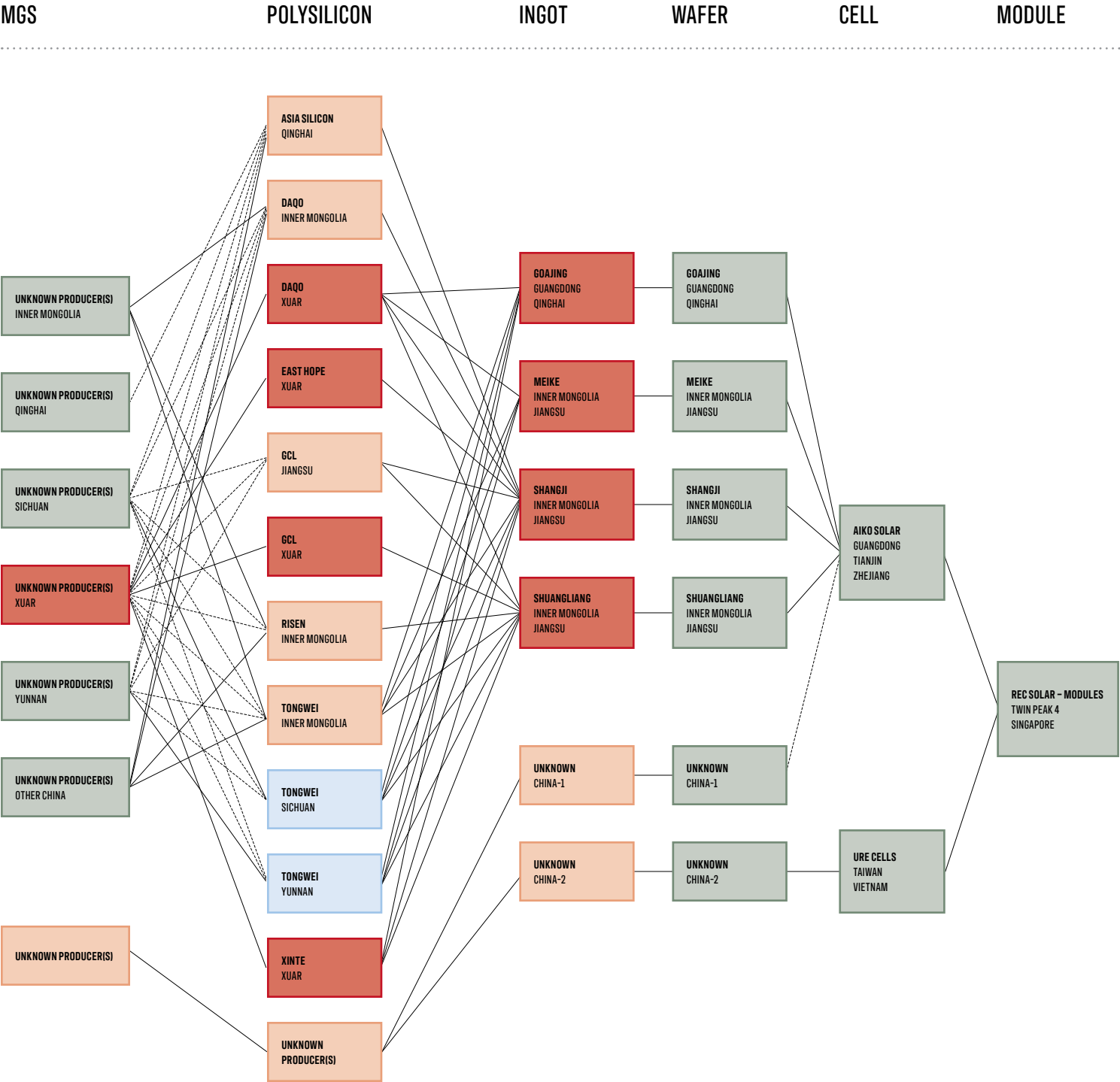
REC Solar

TwinPeak 4 Supply Chain

EXPOSURE KEY



Solid line = disclosed / known information (verified or unverified)
Dashed line = not disclosed but likely / possible



Tongwei Solar

All Modules

The overall XUAR exposure for all solar modules produced by Tongwei Solar (TWS) is assessed as HIGH.

EVIDENCE BASE

Because of a lack of transparency regarding TWS sourcing, this analysis is based on TWS capacities disclosed through public sources combined with expertise related to sourcing trends and historical data for the MGS industry in China.

ANALYSIS

TWS is the largest polysilicon and cell producer in the world. TWS operates polysilicon plants in Inner Mongolia, Sichuan, and Yunnan, China. TWS produces [limited modules](#) (1 GW) in China’s Anhui province. TWS sells the remaining polysilicon and cells to other manufacturers. TWS does not have any physical operations in the XUAR. TWS is not backwardly integrated to quartz mining or MGS production. TWS is the original equipment manufacturer (OEM) for all modules sold by Hyundai Energy Solutions.

Ingot/Wafer Exposure

TWS currently has limited internal ingot/wafer capacity. As a result, TWS currently purchases about 85% of the wafers it uses from external suppliers; those suppliers almost certainly use 100% TWS-produced polysilicon from one or more TWS polysilicon plants. Press releases have announced supply contracts for TWS purchases of wafers from large China-based wafer fabrication facilities including: [Beijing Jingyuntong Technology](#) (JYT), [Jinko Solar](#), [LONGi Solar](#), [Wuxi Shangji Automation](#), [Shuangliang Group](#), and [Tianjin Zhonghuan Semiconductor](#) (TZS; now TCL Technology). While these large wafer fabrication facilities consume polysilicon purchased from many suppliers, including polysilicon plants located in the XUAR, it is commonly known within the industry that any wafers TWS purchased are produced with TWS-supplied polysilicon. Thus, there is no exposure to the XUAR at the wafering stage, except insofar as TWS polysilicon may be made with XUAR inputs (see below).

TWS’s relationship with Jinko Solar involves a joint venture for polysilicon production. Jinko Solar has been the only ingot–wafer–cell–module producer with manufacturing facilities in the XUAR. Until recently, Jinko Solar operated Xinjiang Jinko Solar Co. Ltd., an ingot/wafer fab in Yining, XUAR. Jinko Solar announced on 24 May 2023 that its subsidiary, Jiangxi Jinko, agreed to [sell 100% equity interest](#) in Xinjiang Jinko Solar Co. Ltd. to Dong Shihong and Ziyang Major Industry Equity Investment Fund Partnership. According to Jinko representatives, that sale is now complete ([see Annex A – Corporate Responses](#)); however, as of 14 July 2023, there were no publicly available records showing that the sale has been finalized, and the company [still lists the XUAR facility on its website](#). If the Jinko sale is complete and Jinko maintains no sourcing relationships with the facility, then there is no exposure to the XUAR at the wafering stage.

Quartz/MGS/Polysilicon Exposure

TWS’s polysilicon exposure to XUAR inputs varies by TWS polysilicon plant location. TWS polysilicon plants located in high MGS-producing provinces (Sichuan and Yunnan) can be safely assumed to normally use only MGS produced within the province. Both Sichuan and Yunnan MGS production use local hydropower. When limited rain results in limited local

Overall Exposure

<div>HIGH</div>	QUARTZ	HIGH
	MGS	HIGH
	POLYSILICON	HIGH
	INGOT	NONE (VERIFIED)
	WAFER	NONE (VERIFIED)
	CELL	NONE (VERIFIED)
	MODULE	NONE (VERIFIED)

ASSESSMENT

The HIGH exposure assessment is based on the following factors:

- There are no disclosures regarding which TWS polysilicon plants supply the company’s ingot/wafer suppliers;
- There is limited visibility into Tongwei Polysilicon’s metallurgical grade silicon (MGS) sourcing.

OPPORTUNITIES TO REDUCE EXPOSURE

- Verified disclosure of all MGS suppliers for each TWS polysilicon plant
- Verified disclosure of TWS polysilicon source locations used to produce cells at each plant location
- Dedicated cell production for particular TWS models with TWS polysilicon produced only in Sichuan and/or Yunnan

hydropower, MGS production in those provinces is reduced and could result in the purchase of limited quantities of MGS from the XUAR.

TWS's (or any company's) polysilicon plants located in provinces that produce low or no MGS can be safely assumed to purchase MGS from more than one high MGS producing province (the XUAR, Yunnan, and Sichuan are the top three). TWS Inner Mongolia polysilicon uses MGS produced in unknown provinces. The quartz used to produce the MGS is highly likely mined in the same province—or in close proximity—as the MGS is produced. Inner Mongolia MGS production remains limited relative to polysilicon production. Based on geographical sourcing trends for known provincial MGS production (for 2021, the last year available), the leading potential provincial suppliers of MGS for TWS Inner Mongolia (from outside of Inner Mongolia) are the XUAR, Yunnan, Sichuan, Fujian, and Gansu. Gansu and the XUAR would be the most proximate source locations.

Without verified disclosures of the source of MGS in all cases (typical and emergent) and for all plants, some XUAR risk remains across Tongwei's products. In the company's response to inquiries from Sheffield Hallam

University, the company indicated that, “due to the regulatory requirements placed on listed companies in relation to information disclosure and data security, as well as the protection of proprietary business secrets,” the company would not provide any information regarding its supply chain.

Conclusion

The possibility exists that TWS is currently completely free of any XUAR exposure. Without full disclosure, however, elevated risk remains that polysilicon made in the Inner Mongolia facility could be made with XUAR MGS. There is also some risk of Yunnan and Sichuan polysilicon being made of XUAR MGS in non-typical scenarios. These risks have a domino effect because of the lack of transparency regarding TWS's wafer suppliers and which of TWS's plants supplies the polysilicon to each plant. Disclosure of this information could move TWS's exposure assessment to at least LOW or even NONE. However, without those disclosures XUAR exposure remains HIGH.

Tongwei Solar

Supply Chain

EXPOSURE KEY

VERY HIGH

HIGH

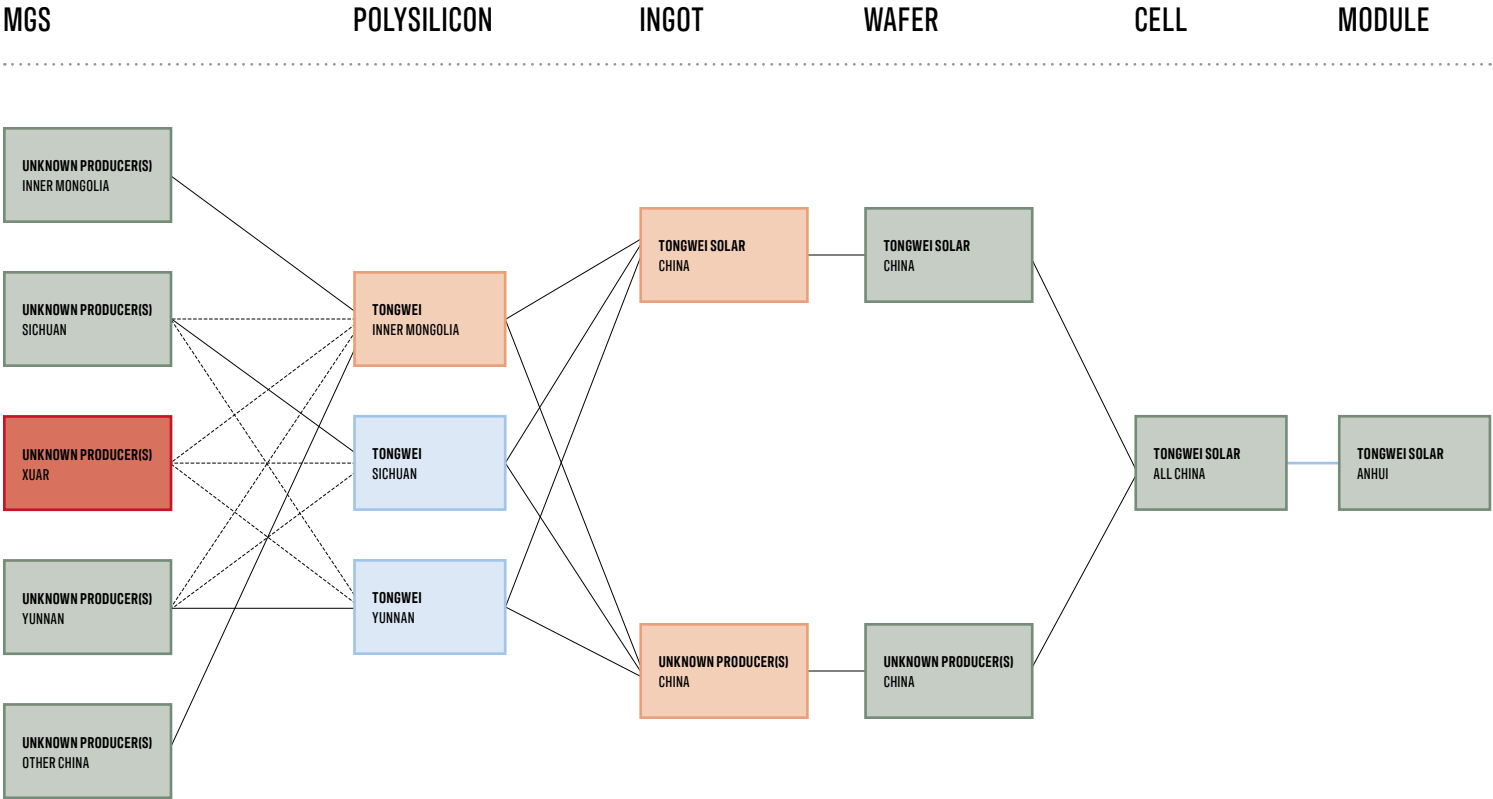
MEDIUM

LOW

NONE (UNVERIFIED)

NONE (VERIFIED)

Solid line = disclosed / known information (verified or unverified)
Dashed line = not disclosed but likely / possible



Trina Solar

All Modules

The exposure assessment for Trina Solar varies by the region of manufacture due to the company's bifurcated supply chain. The overall XUAR exposure for all Trina solar modules produced in Thailand and Vietnam is assessed as NONE (Unverified). Trina also produces modules in their China manufacturing facilities for non-US markets. The overall XUAR exposure for all Trina Solar modules produced in China is assessed as VERY HIGH.

EVIDENCE BASE

Trina stated that as of 2021 its Southeast Asian operations would [supply the US market](#). In early 2023, Trina indicated that all polysilicon for the wafers used in Thailand and Vietnam is [produced in Europe](#). If that is the case, the polysilicon producer must be Wacker Chemie (Germany), as it is the only European polysilicon producer. These claims cannot be verified through publicly accessible records.

Assessing the XUAR exposure for cells and modules produced by Trina Solar in China from polysilicon and wafers purchased by Trina relies on very limited public disclosures. Trina's China-produced modules are made primarily with Trina's own cells, but it must purchase slightly more than a quarter of its cells from external producers. In addition, Trina's internal cell capacity (as of the end of 2022) cannot meet requirements for its announced expanded module production in China, and Trina has not disclosed how it will address the shortfall.

Due to lack of adequate disclosures regarding polysilicon, wafer, and cell suppliers, the assessment of Trina's XUAR exposure relies on available supply contract disclosures, complemented by analysis of production capacities, geographic trends, and historical contracts.

ANALYSIS

Trina does not have MGS, polysilicon, ingot, or wafer production capability as of May 2023. Trina plans to begin [self-production of ingots and wafers](#) in Vietnam using Wacker Chemie (Germany) polysilicon in mid-2023, but the production was not yet online at the time of writing, so far as public records reveal.

Analysis of the Trina Solar supply chain must begin with analysis of Trina's overall capacities. Table 1 summarizes Trina's overall capacities as of 31 December 2022. The data in Table 1 show that Trina manufactured 58.5 GW of modules across its China fabs. Since the company only produces 43.5 GW of cells in China, Trina must purchase 15.0 GW of cells from one or more external suppliers. The total 6.5 GW of cell and 6.5 GW of module capacity for Trina Southeast Asia "matches" Trina's plans to add [6.5 GW of wafer capacity](#) in Vietnam by mid-2023. Trina Thailand produces 1.5 GW-excess cells which are likely shipped to Trina Vietnam to address the imbalance in production there, but there is no disclosure to confirm the hypothesis that excess cells from Thailand are shipped to Vietnam.

The sourcing for China and Southeast Asia facilities appears to be entirely independent and is supported by corporate statements suggesting as much. For the sake of clarity, this report will first assess XUAR exposure for Trina's Southeast Asia module supply chain, and then assess the exposure for its China-produced modules.

Southeast Asia Overall Exposure

NONE
(UNVERIFIED)

QUARTZ	NONE (UNVERIFIED)
MGS	NONE (UNVERIFIED)
POLYSILICON	NONE (UNVERIFIED)
INGOT	NONE (VERIFIED)
WAFER	NONE (VERIFIED)
CELL	NONE (VERIFIED)
MODULE	NONE (VERIFIED)

China Overall Exposure

VERY HIGH

QUARTZ	VERY HIGH
MGS	VERY HIGH
POLYSILICON	VERY HIGH
INGOT	VERY HIGH
WAFER	NONE (VERIFIED)
CELL	NONE (VERIFIED)
MODULE	NONE (VERIFIED)

ASSESSMENT

The NONE (unverified) exposure assessment is based on the following factors:

- Trina Solar disclosed that all wafers used to produce modules in Thailand and Vietnam are produced with 100% European polysilicon; There is no way to independently verify these disclosures.

The VERY HIGH assessment for the China-based production is based on these factors:

- There are no disclosures regarding which TWS polysilicon plants supply the company's ingot/wafer suppliers;
- There is limited visibility into Tongwei Polysilicon's metallurgical grade silicon (MGS) sourcing.

OPPORTUNITIES TO REDUCE EXPOSURE

- Independent verification that Trina Solar only uses Wacker produced polysilicon for wafers used in Thailand and Vietnam
- Independent verification of MGS suppliers used by Wacker
- Verified disclosure of all polysilicon and incremental cell suppliers
- Verified disclosure that Tongwei Polysilicon Sichuan and Aiko Solar exclude XUAR MGS
- Supply chain shift after startup of new facility and end of Daqo contract

Table 1: Summary of Trina cell and module production with purchased cells, 31 December 2022. GW = gigawatts.

TRINA LOCATION	CELLS PRODUCED	CELLS REMAINING TO BE PURCHASED	MODULE PRODUCED	PERCENT OF TOTAL PRODUCTION
	GW	GW	GW	%
Total	50.0	15.0	65.0	-
China	43.5	15.0	58.5	90.0
Thailand	3.0	0.0	1.5	2.3
Vietnam	3.5	0.0	5.0	7.7

Note: analysis ignores yield losses for wafer conversion to cells and cells to modules and assumes production equals stated capacities.

Southeast Asia

Ingot/Wafer Exposure

Trina Solar has not disclosed its wafer producer(s) for its current **Southeast Asia cell production**. As a point of comparison, Trina currently purchases wafers for its China operations from [Shangji Automation](#) and [Shuangliang Group](#), and has recently purchased wafers from [TCL Technology](#) (TZS) and [Beijing Jingyuntong](#) (JYT) (see below), which increases the possibility that one of these four companies is the source of wafers for the Southeast Asia operations. All of these wafer producers should have the capability to produce 6.5 GW of wafers from European polysilicon on dedicated lines, though there is no verified public confirmation that this is the case. It is unclear how Trina Solar verifies that the entirety of wafers supplied to Thailand and Vietnam are produced with the European polysilicon. Trina's expansion into wafer and ingot production in Southeast Asia will improve traceability.

Quartz/MGS/Polysilicon Exposure

Trina's statement that all polysilicon for its Southeast Asia operations comes from Europe implies that [Wacker Chemie](#) (Germany) is the supplier because it is the only European polysilicon producer. Wacker operates polysilicon plants in Burghausen, Germany and Nünchritz, Germany. The [total Wacker polysilicon capacity](#) in Germany is approximately 65,000 metric tonnes per year. Trina's cell and module capacity in Thailand and Vietnam is 6.5 GW (see Table 1). Using the current (2023) 2.5 g Polysilicon/Watt (2,500 tonnes Polysilicon/GW) conversion—which accounts for all silicon losses from ingot to module production—Wacker would need to supply 16,250 metric tonnes polysilicon per year (2,500 tonnes Polysilicon/GW * 6.5 GW) to produce wafers for Trina's entire Thailand and Vietnam operations. Wacker does not publish details about polysilicon supply contracts, but it is plausible that Wacker could supply this amount of polysilicon. A Wacker executive reports that the company no longer uses any MGS produced in China, though that remains unverified through any public domain information.¹ In a response to Sheffield Hallam University, a Wacker representative indicated that the company does not source any products from the Uyghur Region making this statement regarding the United States Customs and Border Protection (CBP) enforcement of the UFLPA: "Wacker's polysilicon meets CBP's requirements and we have established supply chains to

meet CBP's requirements." Wacker further indicated that its German polysilicon is currently made of MGS sourced from Europe, Norway, Canada, Iceland, Brazil, South Africa, and Australia; its US-produced polysilicon is made of MGS sourced from Brazil, US, and Norway. Wacker also provided the country of origin of all of its raw silica, none of which originated in the XUAR. ([See Annex A – Corporate Responses](#))

China

Ingot/Wafer/Cell Exposure

Trina does not produce wafers. For its **self-produced cells**, Trina Solar currently must purchase 43.5 GW of wafers. A portion of these 43.5 GW of wafers is produced by external wafer suppliers using polysilicon purchased and provided by Trina. The remainder of the wafers are produced by external wafer suppliers with polysilicon purchased by the suppliers.

Public domain disclosures show that Trina will purchase wafers directly from [Shangji Automation](#) (4 GW) and [Shuangliang Group](#) (6 GW) in 2023, totaling 10 GW. This represents about 23% of the total 43.5 GW of wafers required for Trina's China operations. Another 20.9 GW of wafers will be produced from Trina-purchased polysilicon (see below), but the wafer producers are undisclosed. Together, the wafers purchased by Trina for China operations for which there is some information regarding sourcing account for 30.9 GW, which represents 71% of the total 43.5 GW of wafers necessary for Trina China cell production.

The sourcing for the remaining 12.6 GW of wafers required in 2023 for Trina's China cell manufacturing operations is not known. In recent years, Trina has purchased wafers from [TZS](#) and [JYT](#). One or both wafer producers could supply the remaining 12.6 GW, or Trina could have incremental supply contracts with its current suppliers Shangji and/or Shuangliang. A portion of the 12.6 GW might also be supplied by unidentified China-based wafer producers.

For its **externally sourced cells**, Trina Solar must purchase 15.0 GW of cells from one or more suppliers to account for an imbalance in its cell (43.5 GW) and module (58.5 GW) production capacity in China. Trina's main external cell source is a joint venture between Trina Solar (35%) and Tongwei Solar (65%) called [Tonghe New Energy](#), located in Sichuan Province. Tonghe New Energy started cell production in [late 2021](#). Trina plans to [purchase 10.6 GW of cells](#) from Tonghe New Energy in 2023. That leaves 4.4 GW of cells that must be purchased from one or more additional suppliers.

[Aiko Solar](#) is a previous supplier of cells to Trina and was named a Trina supplier of the year in 2019, and so is a potential supplier of at least part of the 4.4 GW. Aiko produces cells in the provinces of Guangdong, Tianjin, and Zhejiang. Trina Solar has a module fab located in Yiwu, Zhejiang, which is the location of an Aiko cell fab.

One or more unidentified cell suppliers may provide the balance of required cells for Trina's 2023 China-based module production.

Quartz/MGS/Polysilicon Exposure

Public domain disclosures show that Trina will purchase polysilicon from [Daqo](#) (XUAR), [Tongwei](#) (Inner Mongolia, Sichuan, and/or Yunnan), and [China South Glass Group](#) (CSG) for the **internally produced cells** needed for its China-based module production in 2023. Using the tonnes of poly-

Table 2: Known and possible wafer suppliers and known polysilicon suppliers to these wafer suppliers.

WAFER SUPPLIER	POLYSILICON SUPPLIERS TO WAFER SUPPLIERS
Shangji Automation	Daqo (XUAR) ; GCL-Poly (Jiangsu) ; GCL-Poly (XUAR) ; Risen Energy (Inner Mongolia) ; Tongwei (Inner Mongolia, Sichuan, Yunnan) ; Xinte (XUAR)
Shuangliang Group	Asia Silicon ; Daqo New Energy (XUAR, Inner Mongolia) ; East Hope Group (XUAR) ; GCL-Poly (Jiangsu) ; Tongwei (Sichuan, Yunnan, Inner Mongolia) ; Xinte Energy (XUAR & Inner Mongolia)
Tianjin Zhonghuan Semiconductor (TZS) - Possible Wafer Supplier	Xinjiang GCL (XUAR) , GCL-Poly (Jiangsu, Sichuan) , Daqo (XUAR) and all Daqo (Inner Mongolia, XUAR) TZS and GCL are also establishing a joint venture polysilicon plant in Inner Mongolia
Beijing Jingyuntong Technology (JYT) – Possible Wafer Supplier	Current (May 2023) polysilicon supply is not known. Xinte (XUAR) was a supplier from 2019-2021.
Qinghai Gaojing Solar	Daqo New Energy (XUAR) ; Tongwei Solar (Inner Mongolia, Sichuan, Yunnan) ; Xinte Energy (XUAR)
Meike Solar	Tongwei Solar (Inner Mongolia, Sichuan, Yunnan) , Daqo (XUAR)

silicon purchased in 2023 listed in those public disclosures and the current (2023) 2.5 g Polysilicon/Watt conversion (which accounts for all silicon losses from ingot to module production), one can calculate the wafers equivalent to the Trina-purchased polysilicon. The Trina-purchased polysilicon is equivalent to 20.9 GW of wafers, which represents 48% of the total 43.5 GW of wafers required for Trina's China operations.

The Daqo (XUAR) polysilicon purchase in 2023 is equivalent to 4.3 GW of wafers, which represents 9.9% of the total 43.5 GW of wafers required for Trina's China operations. Trina provides this polysilicon to one or more independent and undisclosed wafer fabrication facilities where wafers are produced and then supplied to the Trina cell fabs. Use of Xinjiang Daqo polysilicon alone sets Trina's XUAR risk at VERY HIGH. The [Daqo contract expires](#) in December 2023.

Another of Trina's disclosed polysilicon suppliers, Tongwei, would typically source MGS produced in Sichuan for production of polysilicon in their Sichuan facilities, and source MGS produced in Yunnan for production of polysilicon in their Yunnan plant. Sichuan and Yunnan MGS production relies on local hydropower generated during the rainy season. If there is insufficient rain, Sichuan and/or Yunnan MGS production can be limited. As a result, Tongwei may need to purchase MGS from other provinces, and the XUAR is a possible source because it is the leading producer of MGS. MGS production in Inner Mongolia remains, at the time of publication of this report, limited. As a result, Tongwei Inner Mongolia likely purchases MGS from several suppliers, possibly including suppliers in the XUAR. (See Tongwei chapter of this report for more details)

There is no reported MGS production in Hubei Province, which is the site of China Southern Glass Holding (CSG). There is no data about MGS suppliers to CSG. CSG potentially consumes some MGS from the XUAR, along with the geographically convenient Yunnan, Sichuan, Hunan, and Guizhou provinces.

For Trina's *externally sourced cells* purchased from Tonghe, XUAR exposure is low. Polysilicon used by Tonghe New Energy (located in Sichuan) can be assumed to be produced by a Sichuan polysilicon plant owned by its parent company, Tongwei. As noted above, Tongwei would typically source MGS produced in Sichuan for production of polysilicon in their Sichuan facilities (see Tongwei chapter), but there remains limited XUAR exposure related to non-typical MGS sourcing in times of drought. XUAR exposure may also enter Trina Solar's China-produced modules through externally sourced cells if purchased from Aiko. Significant public domain information shows that Aiko purchases wafers from China-based companies Gaojing Solar, Meike Solar, Wuxi Shangji Automation, and Shuangliang Group, all of which source at least some polysilicon from the XUAR. Table 2 shows the known polysilicon suppliers to these wafer suppliers.

Since Daqo, Xinte, GCL-Poly, and East Hope polysilicon is produced in the XUAR, there is a clear exposure to the XUAR at the polysilicon tier; we can assume the MGS used to produce this polysilicon is produced in the XUAR, and the quartz used to produce the MGS is mined in the XUAR. Furthermore, Tongwei polysilicon (used by all Aiko wafer suppliers) is assessed as high exposure to the XUAR due to limited available disclosures specifying polysilicon sourcing (see Tongwei chapter; Tongwei's response to Sheffield Hallam University inquiries included no details regarding sourcing). GCL-Poly and Risen Energy polysilicon is made from unknown sources of MGS as well.

Disclosures regarding wafer suppliers would be necessary to reduce exposure.

Trina Solar Future

Trina Solar [announced construction](#) of a fully integrated site in Qinghai province in July 2022. This site will produce MGS, polysilicon, ingots, wafers, cells, and modules, with zero XUAR inputs anticipated. Table 4 summarizes planned capacities. Given the fact that MGS, polysilicon, and ingot capacities exceed wafer, cell, and module capacities, one can conclude that Trina plans for this site to supply a greater percentage of its China manufacturing demand. If Trina is able to secure the requisite non-XUAR polysilicon, this can enable the company to reduce exposure.

Trina's addition of 6.5GW of wafer production in 2023 will also allow for greater vertical integration and traceability once it is online.

Table 3: Capacity projections for Trina Solar Qinghai Province integrated site. TPY = metric tonnes per year, GW = gigawatts.

PRODUCTION UNIT	TOTAL CAPACITY	PHASE-1 BEGINS END OF 2023	PHASE-2 BEGINS END OF 2025
Metallurgical grade silicon	300,000 TPY	100,000 TPY	200,000 TPY
Polysilicon	150,000 TPY	50,000 TPY	100,000 TPY
Ingot	35 GW	20 GW	15 GW
Wafer	10 GW	5 GW	5 GW
Cell	10 GW	5 GW	5 GW
Module	10 GW	5 GW	5 GW

Conclusion

The XUAR exposure for all Trina Solar modules produced in Thailand and Vietnam is NONE (Unverified). There is no way to independently verify the Trina Solar claim that all polysilicon used is produced by Wacker nor the Wacker claim that no China-produced MGS is used to produce its polysilicon.

Trina Solar produces 58.5 GW of modules in Jiangsu and Zhejiang Provinces, China for global markets excluding the US. Trina produces 43.5 GW of its China modules using cells made internally from wafers purchased externally. Trina purchases a portion of the wafers from wafer producers that use the wafer producers' own polysilicon supply chains instead of polysilicon directly purchased and supplied to them by Trina. These wafer suppliers directly source from the XUAR. Thus, the overall XUAR exposure assessment for modules produced by Trina in China from all purchased wafers is VERY HIGH.

Trina's module capacity in China is 15 GW greater than its cell capacity, which requires Trina to purchase cells from one or more external suppliers. The overall XUAR exposure assessment for modules produced by Trina in China from purchased cells is VERY HIGH based on the lack of disclosures regarding cell providers and the possibility that Aiko Solar provides a small percentage of its cell purchases. The main incremental cell supplier, Tonghe New Energy – the joint venture between Trina and Tongwei – has a LOW XUAR assessment based on Tongwei's polysilicon production in Sichuan.

1. Personal correspondence, Jörg Hoffman, Wacker Senior Vice President for Investor Relations in Munich, Germany, to author, 30 March 2023.

Trina Solar

SOUTHEAST ASIA SUPPLY CHAIN

EXPOSURE KEY

VERY HIGH

HIGH

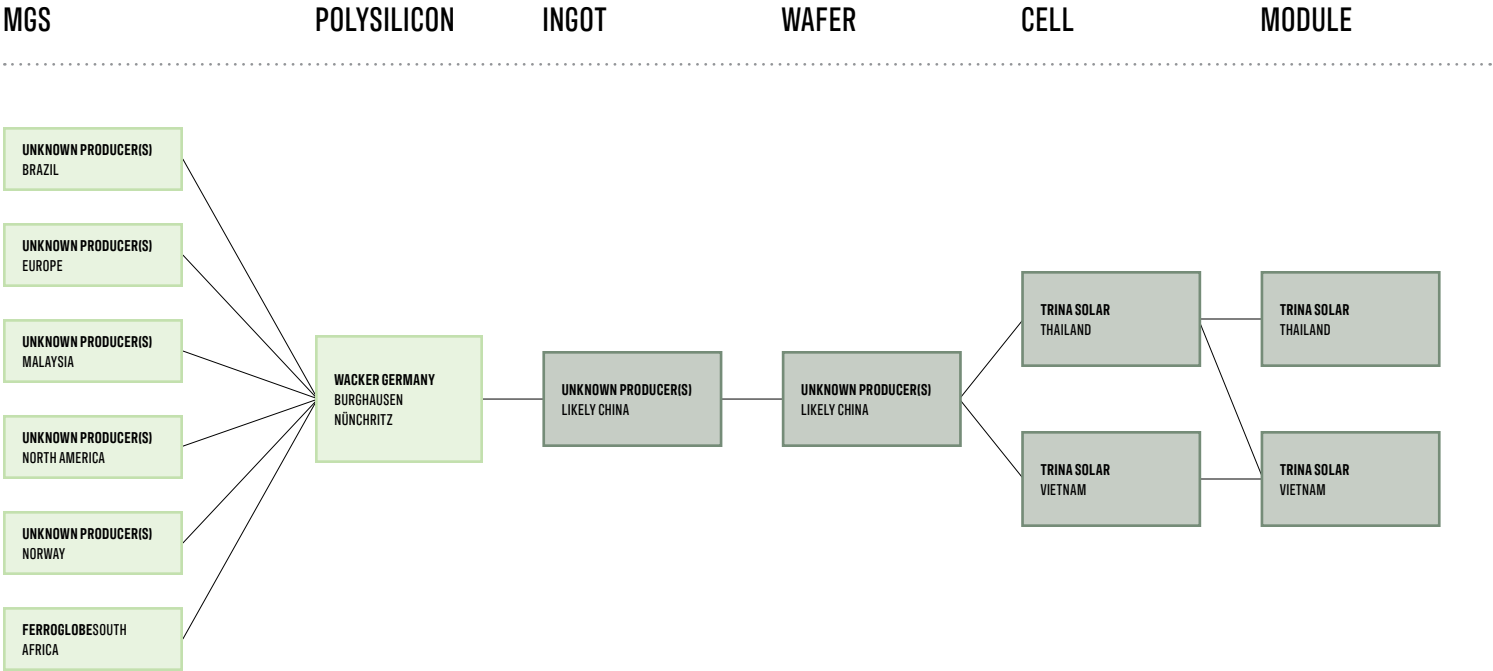
MEDIUM

LOW

NONE (UNVERIFIED)

NONE (VERIFIED)

Solid line = disclosed / known information (verified or unverified)
Dashed line = not disclosed but likely / possible



Trina Solar

China Supply Chain – Self-Produced Cells
(Made of Directly Purchased Wafers)

EXPOSURE KEY

VERY HIGH

HIGH

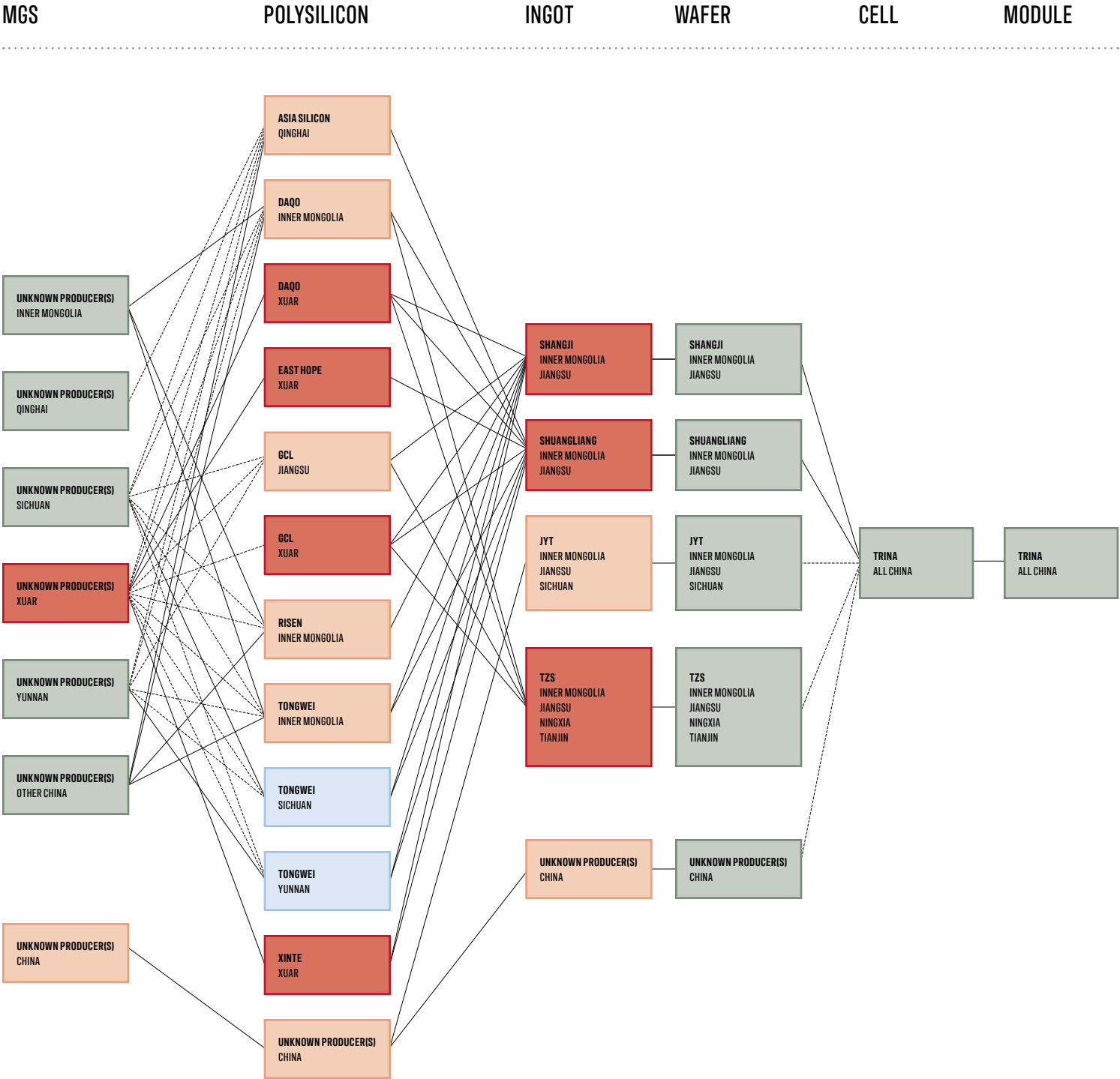
MEDIUM

LOW

NONE (UNVERIFIED)

NONE (VERIFIED)

Solid line = disclosed / known information (verified or unverified)
Dashed line = not disclosed but likely / possible



Trina Solar

China Supply Chain – Self-Produced Cells
(Made of Directly Purchased Polysilicon; Unknown Wafer Producer)

EXPOSURE KEY

VERY HIGH

HIGH

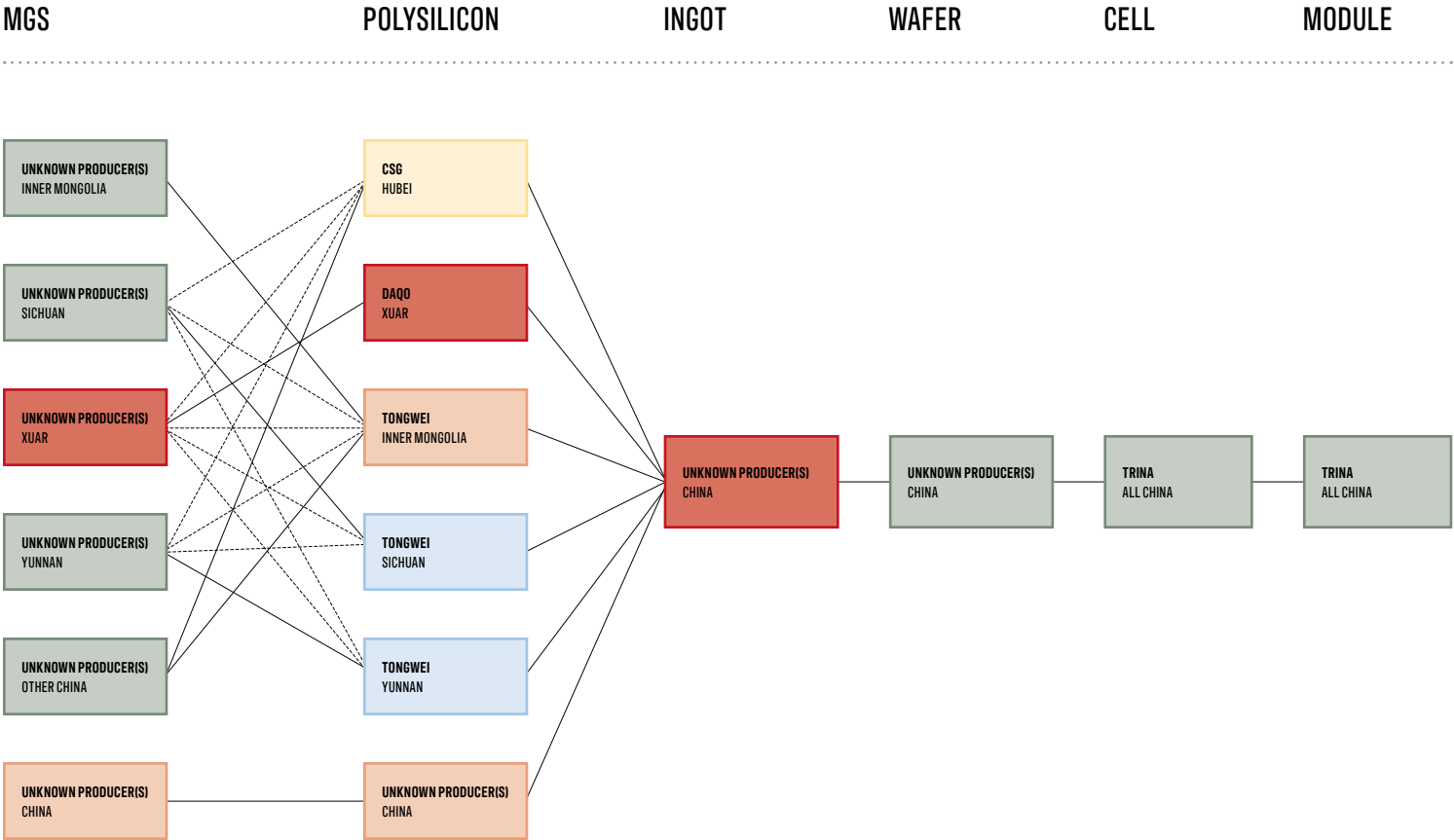
MEDIUM

LOW

NONE (UNVERIFIED)

NONE (VERIFIED)

Solid line = disclosed / known information (verified or unverified)
Dashed line = not disclosed but likely / possible



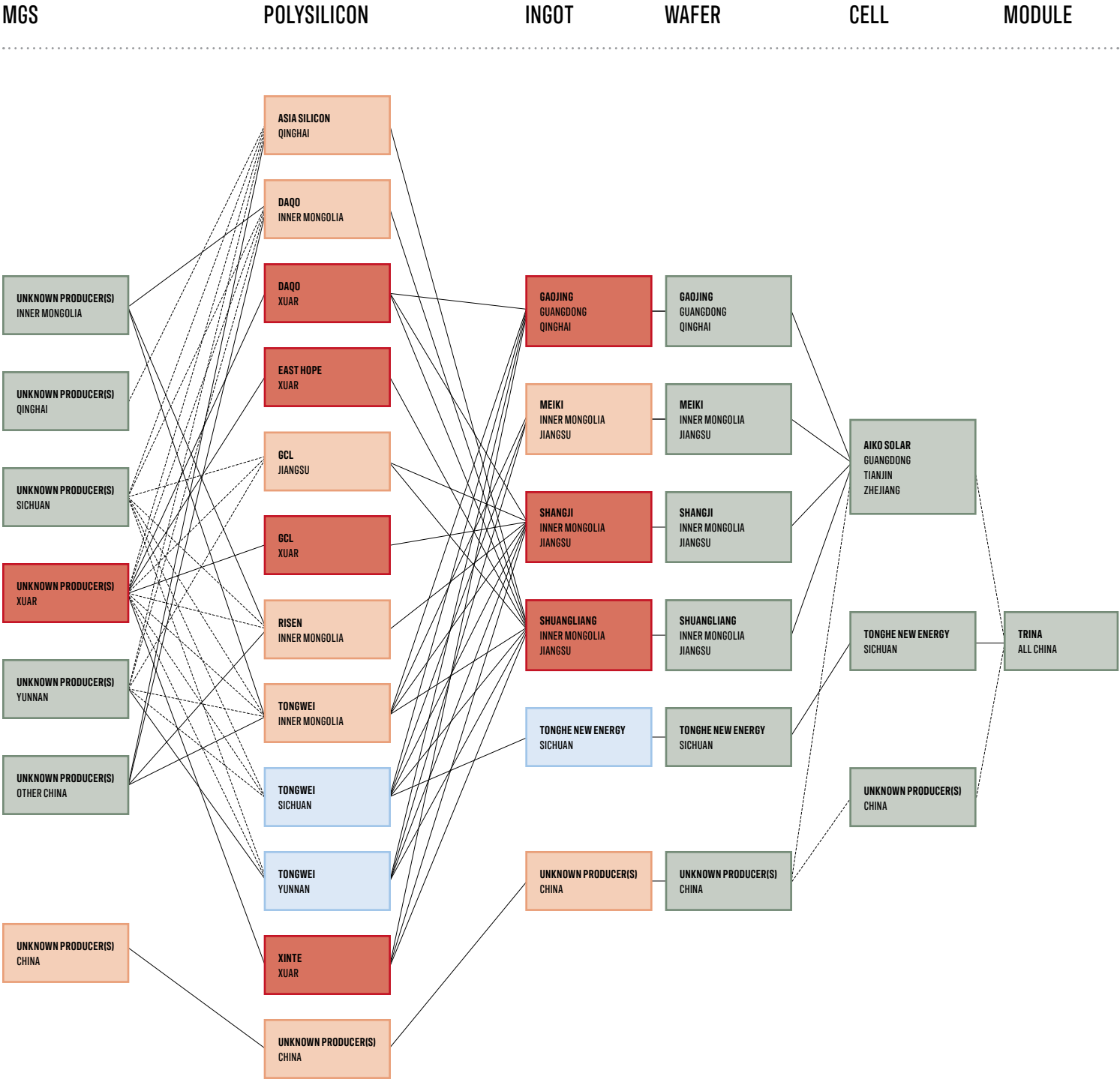
Trina Solar

Trina Solar China Supply Chain – Externally Produced Cells

EXPOSURE KEY



Solid line = disclosed / known information (verified or unverified)
Dashed line = not disclosed but likely / possible



Decision Tree

