

Solar logistics

# 7 trends shaping global solar supply chains



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It is no secret—the solar energy sector is undergoing transformative growth. According to the International Energy Agency (IEA), by 2050, nearly 90% of electricity generation is expected to come from renewable sources, with solar photovoltaic (PV) and wind energy contributing almost 70% of the total<sup>1</sup>.

Given the industry's rapid expansion, resilient and dynamic supply chains are essential to sustained growth. Acknowledging the array of geopolitical, economic, and environmental developments, this article breaks down seven main trends shaping today's solar supply chains, examines the logistical challenges, and presents the solutions driving the industry forward.

<sup>1</sup> <https://www.iea.org/reports/net-zero-by-2050>



## 1

# Uncertain policy restraining profitability



The solar industry faces significant profitability challenges driven by escalating costs, price cannibalisation, and shifting market dynamics. Notably, China's reduction of export tax rebates for photovoltaic (PV) products and batteries from 13% to 9%<sup>2</sup>, effective as of December 1, 2024, has increased sensitivity to logistics expenses and potential supply chain disruptions.

Additionally, China's Ministry of Industry and Information Technology has finalised stricter investment guidelines for PV manufacturing projects, mandating a minimum capital ratio of 30%<sup>3</sup>, which could slow down new manufacturing investments.

In the United States, recent legislative developments under President Donald Trump's administration have created further uncertainties. Increased tariffs on imports from Canada, Mexico, and China—25% on Canadian and Mexican goods and 20% on Chinese imports at the time of publishing—are expected to drive up costs for imported solar

components, potentially delaying or scaling back solar projects. The administration has also suspended federal approvals for wind projects and frozen funding for solar initiatives, signalling a reversion towards fossil fuels.

These policy shifts are prompting solar companies to rethink their supply chain strategies. Many firms are adopting localised manufacturing and nearshoring to reduce dependency on long-haul transportation. Additionally, advanced digital tools and analytics are becoming essential for optimising resource allocation and predicting costs with greater accuracy.

**The cascading nature of these challenges highlights the need for solar companies to adapt quickly and innovate. By addressing profitability pressures, the industry is simultaneously setting the stage for more efficient and resilient supply chain practices that can sustain growth in a competitive and dynamic renewable energy market.**

<sup>2</sup> <https://www.china-briefing.com/news/navigating-chinas-latest-export-tax-rebate-adjustments-implications>

<sup>3</sup> <https://en.ccpit.org/infoById/03d78a29ab9d11ef93940242ac1a0702/4>

## 2

## Localisation of manufacturing

Historically, the solar industry has relied heavily on imports for its components, including PV modules, inverters, and mounting systems, most of which are primarily sourced from Asia. This dependency has exposed the sector to vulnerabilities such as supply chain disruptions, leading to delays and increased costs.

To address these challenges, many regions are increasingly exploring local manufacturing opportunities. Notable examples include:

- **The United States:** the Inflation Reduction Act (IRA) incentivises domestic production of solar components to reduce reliance on imports<sup>4</sup>.
- **Europe:** the European Solar PV Industry Alliance aims to establish regional manufacturing capacity and strengthen supply chain resilience.
- **South Africa:** as part of its renewable energy programmes, South Africa is investing in local solar manufacturing to meet growing demand and create employment opportunities.

This shift towards local manufacturing is anticipated to yield several benefits:



**Shortened lead times:** producing solar components closer to project sites reduces dependency on long-distance shipping, thus streamlining supply chains and cutting delivery times.



**Cost savings:** localisation of renewable energy components is anticipated to decrease logistics costs by minimising the need for long-distance transportation and mitigating exposure to fluctuating rates and global trade risks.



**New distribution networks:** as production shifts closer to project sites, such as utility-scale solar farms, supply chains will focus on regional road and rail networks instead of long-haul sea freight. This also opens the door to more sustainable, battery- and hydrogen-powered delivery vehicles.



**Job creation:** local manufacturing development offers a chance to create local jobs, foster local participation, and develop new talent. For instance, the International Labour Organization (ILO) estimates that decarbonisation and green industrial growth could create millions of new jobs globally by 2050<sup>5</sup>, including significant opportunities in emerging markets such as the Middle East and Africa.



**This transition represents a critical opportunity to refocus on strong regional logistics networks, which can support global renewable energy ambitions while fostering local economic growth.**

<sup>4</sup> <https://www.energy.gov/lpo/inflation-reduction-act-2022>

<sup>5</sup> <https://www.ilo.org/resource/news/mena-region-could-create-10-million-new-jobs-2050-through-decarbonization>

## 3

## The rise of Battery Energy Storage Systems

The integration of renewable energy and energy storage is gaining momentum globally, with Battery Energy Storage Systems (BESS) playing a pivotal role in addressing intermittency challenges and improving grid stability. As large-scale solar projects increasingly incorporate energy storage solutions, BESS is reshaping the solar industry by enhancing reliability and expanding the range of applications for solar energy.

Transporting BESS components, particularly lithium-ion batteries—the most used type in BESS due to their high energy density and efficiency—requires strict adherence to safety standards, specialised transportation equipment, and hazard-specific handling. The significant size and weight of BESS units present additional challenges. These units often exceed the capacity of standard transport configurations, demanding specialised solutions such as heavy-lift equipment for sea freight and reinforced vehicles for road transport. These requirements can add approximately 20-30% to logistics costs compared to traditional solar components.

Regional production of BESS components could emerge by the late 2030s, reducing

costs and shortening transit times for these critical systems. In the United States, federal policies such as the IRA are incentivising domestic production of energy storage systems. Similarly, Europe is advancing battery production initiatives through programmes like the European Battery Alliance (EBA), which aims to localise the supply chain for energy storage.

Meanwhile, in regions such as Africa and the Middle East, private companies in South Africa and Saudi Arabia are exploring opportunities to develop BESS manufacturing capabilities to meet the growing demand from utility-scale projects.

**Whether BESS components are imported or locally produced, their increasing adoption underscores the need for innovative logistics solutions that address safety, quality, cost, and scalability challenges. Freight forwarders and logistics providers must navigate complex supply chains, implement specialised handling capabilities, and comply with stringent safety standards to support the industry's ever-expanding global infrastructure.**



## 4

## Digitalisation and smart logistics

Whilst renewable energy represents a game changer, technological advancements are simultaneously revolutionising solar supply chains, making operations more transparent, efficient, and adaptive. By 2026, a substantial share of global logistics operations for solar projects are expected to incorporate digital tools, reflecting the broader shift towards digitalisation in supply chain management. Integrating technologies such as artificial intelligence (AI), the Internet of Things (IoT) and predictive analytics are transforming operations. But what does this look like in the context of supply chains?



**AI and IoT:** AI, combined with IoT devices, optimise routing by analysing vast amounts of data to predict the most efficient paths, thereby reducing delays. IoT devices monitor the condition of critical components like PV modules and BESS, enabling predictive maintenance and reducing downtime.



**Predictive transit time analysis:** major players in the logistics industry are increasingly adopting predictive analysis tools to enhance transit time accuracy and reliability. Advanced algorithms and AI-based systems analyse historical data and real-time inputs—including weather conditions, port congestion, and traffic patterns—to precisely forecast delivery timelines. For example, using machine learning-powered platforms like seaexplorer or Max Visibility, Kuehne+Nagel dynamically predicts delays and optimises routes, both of which are crucial for multimodal solar supply chains.

**This rapid digital transformation not only increases operational efficiency but also provides stakeholders with the data needed to make informed decisions and respond to disruptions proactively.**



## 5

## Navigating black swan events

Black swan events—unpredictable occurrences with far-reaching consequences—have become an ongoing challenge, posing a significant threat to solar supply chains globally. Disruptions such as geopolitical instability, extreme weather, or shipping route blockages require flexible and innovative logistics strategies to maintain the flow of critical solar components.

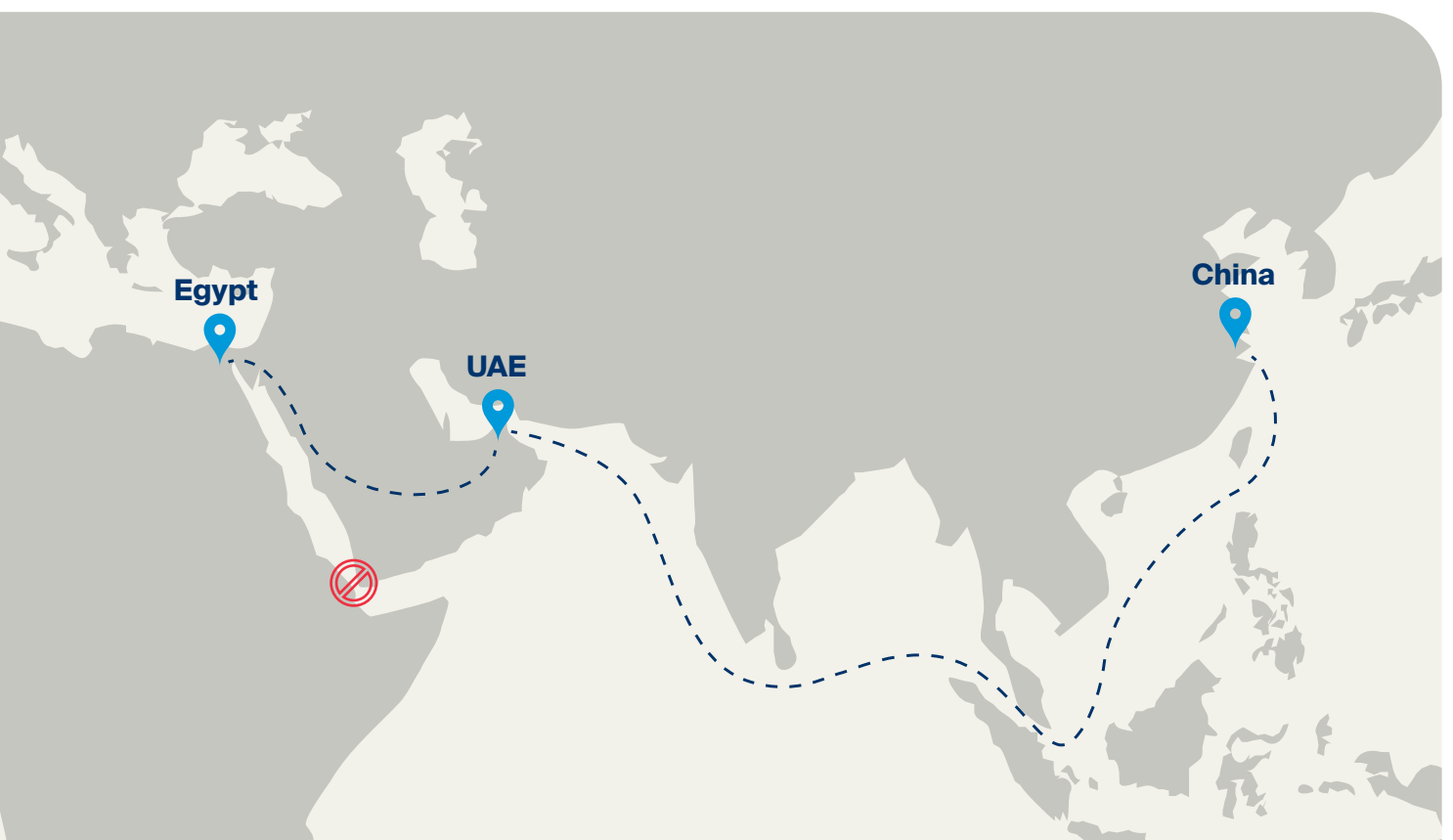
### Case study: Red Sea disruptions

The Red Sea, a vital corridor for shipping solar components, has faced periodic disruptions due to regional instability. These events often lead to diversions via the Cape of Good Hope. Depending on the specific route, this can increase shipping times by 15-20 days and costs by 15-30%. It is essential to develop effective contingencies to mitigate the impact of such

disruptions. One promising approach could be an integrated land and sea transport solution.

When maritime routes are disrupted, combining sea freight with overland routes provides an effective alternative. For example, solar components can be shipped to the Port of Salalah in Oman or Jebel Ali Port in the UAE, followed by overland transport through Saudi Arabia to reach Red Sea ports or North African destinations such as Egypt. These integrated solutions reduce reliance on blocked maritime corridors while maintaining delivery timelines.

**Solar companies must seek to become more agile and innovative in an unpredictable environment. Adaptability in supply chain management is, therefore, central to maintaining resilience in unstable times.**



## 6

## Leveraging bonded warehouses and Free Trade Zones as crucial logistics hubs

As the industry expands, bonded warehouses and free-trade zones (FTZs) are increasingly recognised as essential to optimising solar supply chains. Both, strategically located near major ports and transportation corridors, serve as vital logistics hubs, enabling the efficient movement and storage of critical components.

In the United States, the Foreign Trade Zones programme allows companies to import solar components duty-free until they enter the domestic market, providing significant financial and logistical benefits. For example, foreign-trade zones in Arizona have become a strategic choice for some solar companies to establish manufacturing hubs, taking advantage of reduced customs duties and proximity to key domestic markets. Similarly, the Port of Houston foreign-trade zone supports solar shipments for large-scale projects across the southern USA, while the one located at the Port of Long Beach is a major entry point for Asian components.

In the Middle East, the Jebel Ali Free Zone (Jafza) in Dubai stands out as one of the largest FTZs, offering significant logistical advantages. Its location near major shipping routes, coupled with advanced infrastructure and streamlined customs processes, has made it a critical hub for the distribution of solar components across the region.

In Europe, free zones are widely embraced to enhance trade and manufacturing capabilities. The European Union (EU) allows member states to designate areas within their customs territory as free zones, enabling goods to be imported without

duties or taxes until they are placed on the market. These zones, such as the Port of Rotterdam's logistics parks, play a crucial role in facilitating solar supply chains and improving access to European markets.

**Leveraging bonded warehouses and FTZs provides several benefits, including financial flexibility due to the tax and duty deferral programmes and reduced customs complexities. By utilising these zones, solar companies can improve cash flow, mitigate the impact of disruptions, maintain the flow of critical components, and support the rapid expansion of the solar sector worldwide.**



## 7

## Sustainability in logistics



It goes without saying that the solar industry is central to global efforts to combat climate change. However, the sector is also committed to ensuring its supply chains are sustainable, especially given the growing pressure to adopt eco-friendly practices. Efforts to reduce emissions are driven by industry initiatives and an increased emphasis on aligning operations with international environmental standards.

Electric vehicles (EVs) are becoming a key option for last-mile deliveries in regions such as the EU and Middle East, offering a zero-emission alternative to diesel trucks. For longer distances, hydrogen-powered trucks are gaining popularity in the United States. These vehicles provide an effective solution for heavy-duty transportation, with advantages in range and refuelling speed compared to EVs, making them particularly suitable for larger solar projects requiring long-distance logistics.

Long-haul solutions are also transitioning to sustainable fuels, with technologies like sustainable aviation fuel (SAF) and

bio-LNG (liquefied natural gas) reducing emissions by up to 80%<sup>6,7</sup>. Companies such as Maersk are introducing bio-methanol-powered vessels, providing greener sea freight options<sup>8</sup>.

Better container utilisation is improving efficiency, with advanced tools maximising cargo space and reducing the number of shipments. Zero-waste warehouses, equipped with recycling programmes and renewable energy systems, are further reducing the environmental footprint of storage operations.

CO2 emission reporting tools, such as Kuehne+Nagel's myKN, allow solar companies to monitor their logistics-related emissions and make informed choices about more sustainable transportation options.

**By integrating sustainability parameters into logistics operations, the solar industry can align its supply chain practices with broader environmental goals, reinforcing its leadership in the global transition to clean energy.**

<sup>6</sup> <https://www.iata.org/en/programs/sustainability/sustainable-aviation-fuels/>

<sup>7</sup> [https://sea-lng.org/wp-content/uploads/2022/10/SEA-LNG\\_BioLNG-Study-Key-Findings-Document\\_October-2022\\_amended.pdf](https://sea-lng.org/wp-content/uploads/2022/10/SEA-LNG_BioLNG-Study-Key-Findings-Document_October-2022_amended.pdf)

<sup>8</sup> <https://www.reuters.com/sustainability/climate-energy/container-shippers-hedging-green-transition-with-dual-fuel-vessel-orders-2024-11-21/>

# Connecting the dots and building resilience

The trends shaping solar supply chains globally are fundamentally interconnected. The solar industry is navigating a period of significant change, with external factors such as political instability, regulatory changes, and increasing competition testing the resilience of its supply chains.

Mitigating vulnerabilities requires aligning logistics practices with the industry's evolving demands. Enhancing efficiency, integrating innovative solutions, developing local capabilities and resources, and improving adaptability to disruptions can support the development of a more robust supply chain. Balancing cost management with the ability to mitigate risks will remain critical for maintaining operational efficiency and reliability.

An ideal scenario for the solar market would be for OEMs to become “one-stop-shops” offering complete solutions—this could

look like integrating solar panels, trackers, installation materials, and BESS into one seamless package. By aligning strategies with this comprehensive approach, OEMs and solar solution providers can simplify procurement, reduce logistical complexities, and enhance efficiency for project developers and energy providers.

**As the renewable energy sector expands, the logistics industry is pivotal in ensuring solar supply chains remain resilient and future-ready. Companies that proactively adapt to these shifts by leveraging innovation, prioritising agility, and fostering strategic partnerships will set themselves apart in an increasingly complex market. The ability to anticipate challenges and embrace change will not only create a competitive advantage and support the rapid deployment of solar energy worldwide—it will also drive long-term success in the transition to a more sustainable energy future.**



# About us

With approximately 80,000 employees at almost 1,300 sites in close to 100 countries, the Kuehne+Nagel Group is one of the world's leading logistics providers. Headquartered in Switzerland, Kuehne+Nagel is listed in the Swiss blue-chip stock market index, the SMI. The Group is the global number one in air and sea logistics and has strong market positions in road and contract logistics. Kuehne+Nagel is the logistics partner of choice for 400,000 customers worldwide. Using its global network, logistics expertise and data-based insights, the Group provides end-to-end supply chain solutions for global companies and industries.

Learn more about our services at → [kuehne-nagel.com](https://www.kuehne-nagel.com)