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New Paradigms of Global Solar Supply Chain

Impact of the United States of America's Inflation Reduction Act and the European Union's Green Deal on Indian Solar Photovoltaic Manufacturers

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Key Findings

In the backdrop of huge capacities likely to be set up in the U.S. under the Inflation Reduction Act (IRA), Indian photovoltaic (PV) module exports to the U.S. may experience a period of stagnation from 2025 and decline from 2027.

Between 2022 and 2023, the global PV module manufacturing capacity has increased from 358GW to 640GW, highlighting the enhanced global demand for solar.

Future iterations of the Product Linked Incentive (PLI) scheme may have specific provisions inspired by the IRA, such as layered incentives, an extended policy period, etc.

To take advantage of the IRA while minimising the associated risks of manufacturing upstream components in the U.S., several Indian manufacturers are looking to set up module lines in the U.S. and cell or ingot/wafer lines in India.

Executive Summary

Key policies that promote local manufacturing in the United States of America (the U.S.) and the European Union (the EU) will change the paradigm of the global solar power supply chain. India, which is aggressively adding solar photovoltaic (PV) manufacturing capacity, will likely maintain the momentum in its exports to the U.S. and Europe till 2025. By then, once the local module manufacturing sector develops in the U.S. and Europe, India will need to start exploring other export markets like Africa and South America. Several Indian manufacturers are looking to set up module production lines in the U.S. to take advantage of the Inflation Reduction Act (IRA) and at the same time they plan to build cell and ingot/wafer lines in India. Finally, we expect policies like the IRA will start influencing future iterations of the production-linked incentive scheme in India, with the inclusion of layered incentives, an extended policy impact period and easier eligibility criteria to avail incentives.

At present, around 80-90% of the global photovoltaic (PV) manufacturing infrastructure is based in China. With a significant increase in solar installations underway globally (BloombergNEF estimates that installations in 2023 are set to grow 46% year-on-year to 392 gigawatts (GW)[1]), a corresponding increase is needed in PV manufacturing capacity across regions. Post-COVID-19 and the disruption of supply chains resulting from Putin's invasion of Ukraine, several countries, including India, the United States of America (U.S.) and Europe, are aggressively developing their domestic PV manufacturing ecosystem. Self-sustenance and insulation from global supply chain shocks are some of the key reasons why these countries are pursuing PV manufacturing.

In August 2022, the U.S. passed the Inflation Reduction Act (IRA), the most detailed policy document ever issued by a single country to target economic decarbonisation. One of the focus areas under IRA is the manufacture of renewable energy products like solar PV modules, inverters, trackers and batteries. Within the solar PV modules segment, the IRA provides separate layered incentives for producing upstream components, i.e., polysilicon, ingot/wafer and cell. In addition to a production incentive, the IRA aids the capital investment of manufacturers through an investment tax credit incentive.

The response to the scheme has been exemplary and many companies worldwide are vying to set up manufacturing facilities in the U.S. Many PV manufacturers recently announced setting up new PV capacities in the U.S. If these announcements come to fruition, solar module manufacturing facilities, with a total capacity of 50GW, could become operational in the U.S. by 2026. However, manufacturing upstream components will be more challenging than manufacturing modules due to

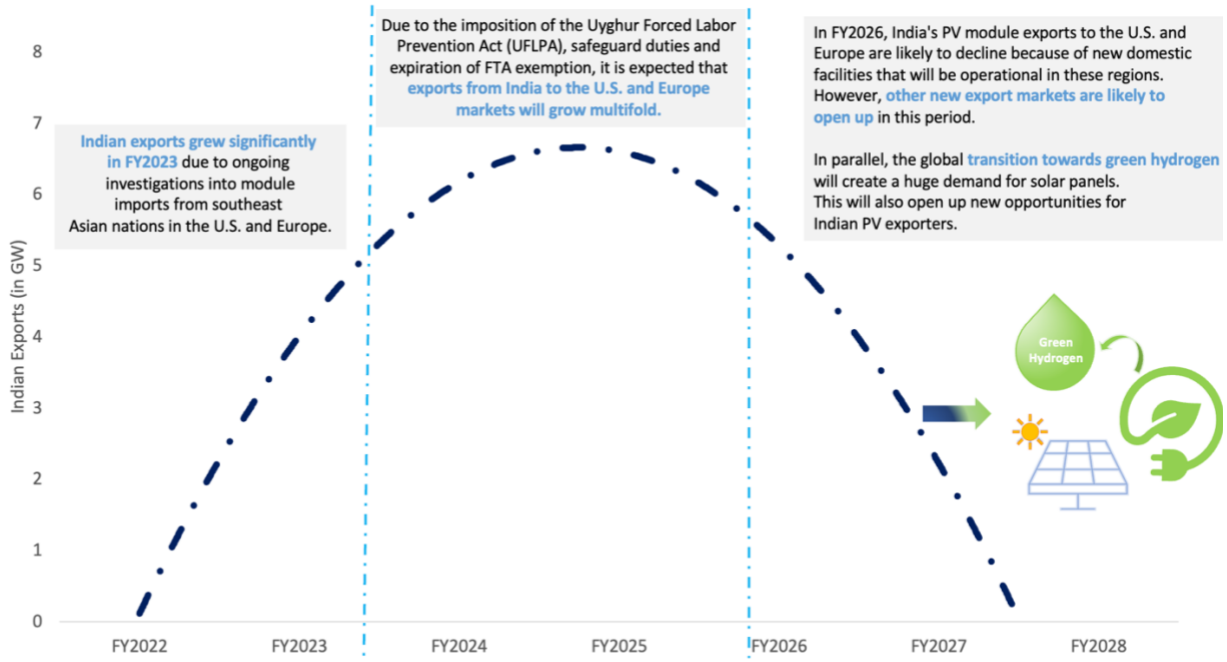
[1] BNEF. 3Q 2023 Global PV Market Outlook. September 2023.

their complex and expensive manufacturing process. Considering this, most players plan to set up only module manufacturing facilities in the U.S.

The European Union (EU), similar to the U.S., is also working on a detailed incentive bill along the lines of the IRA, under the ambit of a larger climate action plan, building on the "EU Green Deal" that was launched by the EU Commission in 2019. According to recent announcements by players looking to set up new facilities in Europe, more than 31GW of new module manufacturing capacity will likely be added in this region in the next few years. Despite the announcements, until the clear outlining of production incentives and enactment of firm trade barriers, the actual inflow of investments and on-ground construction progress in Europe is likely to be tepid.

The U.S. and the EU will play an important role in the growth of the Indian PV manufacturing sector, especially exports. The U.S. has traditionally been the largest export destination for Indian PV products. The PV module exports from India to the U.S. have increased exponentially in the fiscal year (FY) 2023 (16x from FY2022 by value). In the backdrop of huge manufacturing capacities being set up in the U.S. under IRA, Indian PV module exports to the U.S. may experience a period of stagnation from 2025 and later decline from 2027 onwards.

Figure: India PV export trends to the U.S. and Europe



Source: JMK Research

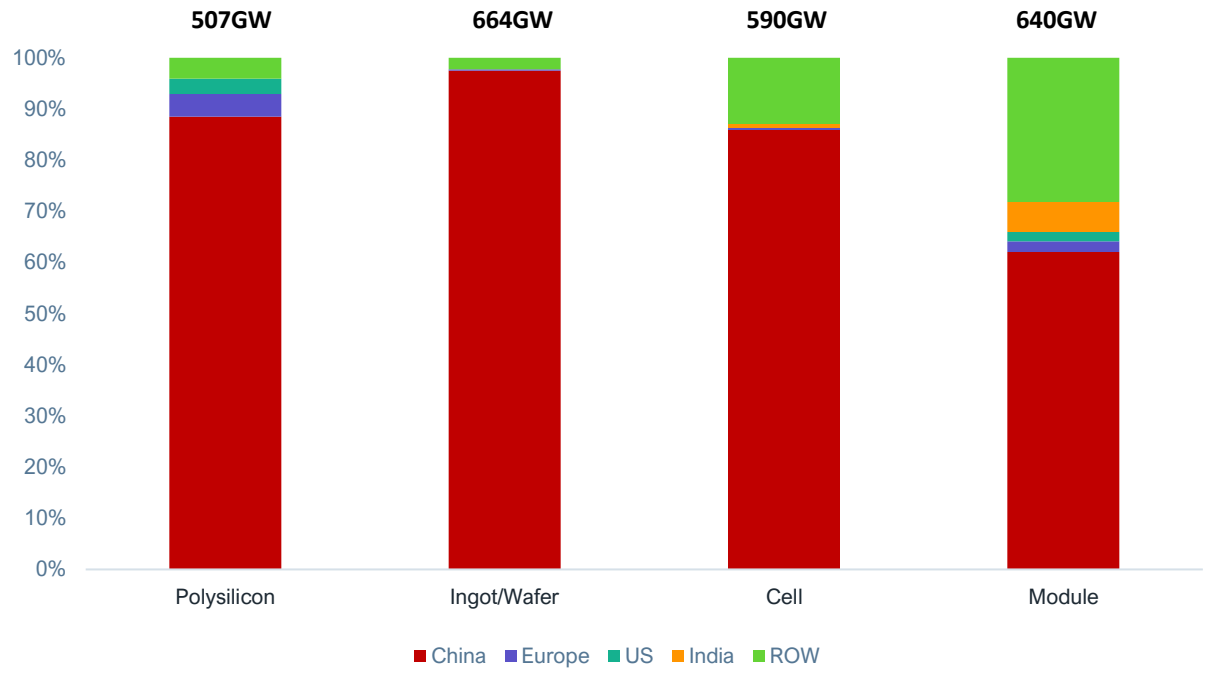
The IRA has ushered in a substantial export opportunity for Indian companies involved in the manufacturing of upstream components. With capacities under the Production Linked Incentive (PLI-I) tranche already awarded in November 2021, Indian players have a head start of at least one year compared to companies setting up facilities in the U.S. To take advantage of the IRA while minimising the associated risks of manufacturing upstream components in the U.S., several Indian manufacturers are looking to set up module lines in the U.S. and cell or ingot/wafer lines in India.

The success of the IRA will certainly influence the future PV manufacturing policy design by Indian regulators. Future iterations of PLI may include layered incentives, an extended policy impact period, easier eligibility criteria to avail incentives, etc.

Global Manufacturing Landscape

Since the early 2010s, China has been asserting its dominance in the global PV manufacturing industry. China leads the entire PV manufacturing supply chain of polysilicon, ingot/wafer, cells and modules with around 89%, 97%, 86%, and 62% share, respectively, of the global production capacity.[2]

Figure 1: Global Annual Manufacturing Capacity (Region-wise Share, December 2022)



Source: IEA, PV InfoLink

In 2022, the global solar module production capacity was 640 gigawatts (GW), of which China accounted for 62%. India was the second largest module manufacturer with a 6% share, followed by Europe and the United States of America (U.S.), with a mere 2% share each. The rest of the world, mainly southeast Asian countries like Vietnam, Malaysia and South Korea, comprised the remaining 30%.

In terms of cell production capacity, China accounted for 86% of the total (590GW in 2022), while the rest of the world, mainly other parts of Asia, held the remaining 14%[3] share.

[2] PV Magazine. US Customs solar exclusions may be a "de facto ban on Chinese polysilicon. July 2023; CPIA. China takes 97.9% of global wafer capacity in 2022. June 2023.
[3] International Solar Alliance. Building a resilient global solar PV supply chain. April 2023.

Recent Developments

The ongoing rise in the global demand for solar power will require a corresponding increase in PV manufacturing capacity. Several countries are vying to enter the PV manufacturing space while those like India, the U.S. and Europe plan to augment their capacities significantly.

There are several reasons for this PV manufacturing push. During the COVID-19 pandemic, the global PV supply chain experienced irregularities, such as a deficit of raw materials and a surge in logistics costs, leading to the unavailability of solar PV modules. Further, Putin's invasion of Ukraine sparked hyper-inflation of fossil fuel commodity prices, and this in turn, dramatically pushed up the price of electricity, the key input in the manufacture of polysilicon. International freight costs rose three to five times as well. These factors led to a substantial increase in the cost of delivered solar PV modules. Hence, self-sustenance in domestic PV requirements, supply chain diversity and insulation from global supply chain shocks are some of the primary reasons for countries to set up local PV manufacturing infrastructure. For countries like the U.S. and India, geopolitical and trade tensions with China are also reasons for focusing on the PV manufacturing segment.

To aid the domestic PV manufacturing sector, in the last couple of years, India has initiated significant schemes and provisions, such as the Production Linked Incentive (PLI), Basic Customs Duty (BCD) and Approved List of Models and Manufacturers (ALMM). The schemes have borne fruit as India's module manufacturing capacity more than doubled from 18GW in 2022 to 38GW in 2023.[4]

- **PLI:** Under the PLI scheme, a group of PV manufacturers are selected through a tendering process to avail incentives for producing high-efficiency PV modules in India. Across the two tranches of PLI, the scheme has an outlay of Rs240 billion (US$2.88 billion), directly leading to at least 51.6GW domestic module production capacity, if all successful tenders translate into delivered manufacturing capacity.
- **BCD:** The government announced that from April 2022, a heavy BCD would be levied on the import of PV cells and modules. The BCD on cells is 25% while on modules it is 40%.
- **ALMM:** ALMM is a list of PV manufacturers and their products, issued by the Ministry of New and Renewable Energy (MNRE). According to the ALMM mandate, all government power purchase agreements (PPAs), open access and net metering projects must only use modules listed under ALMM. However, this mandate has been relaxed until March 2024. The latest ALMM list, issued in September 2023, includes 79 manufacturers with a cumulative listed capacity of around 18GW. No international supplier is on this list as of now.

The U.S. and Europe have traditionally been the largest importers of PV products. Aiming to change that status, the U.S. and Europe are in various stages of implementing their climate bills to provide a host of incentives to players setting up domestic PV manufacturing facilities.

[4] IEEFA and JMK Research. India's Photovoltaic Manufacturing Capacity Set to Surge. April 2023.

- In August 2022, the U.S. approved the **Inflation Reduction Act (IRA),** the most detailed policy document ever issued by a single country to target economic decarbonisation. According to the U.S. Senate, overall total investments under the IRA for "Energy Security and Climate Change" will be more than US$369 billion.[5]
- On the other hand, the EU declared its EU Green Deal in 2019 with a roadmap to achieve climate neutrality by 2050. Its detailed framework is underway and is likely to be issued in 2024.

[5] US Senate. Summary: The Inflation Reduction Act of 2022. 2022.

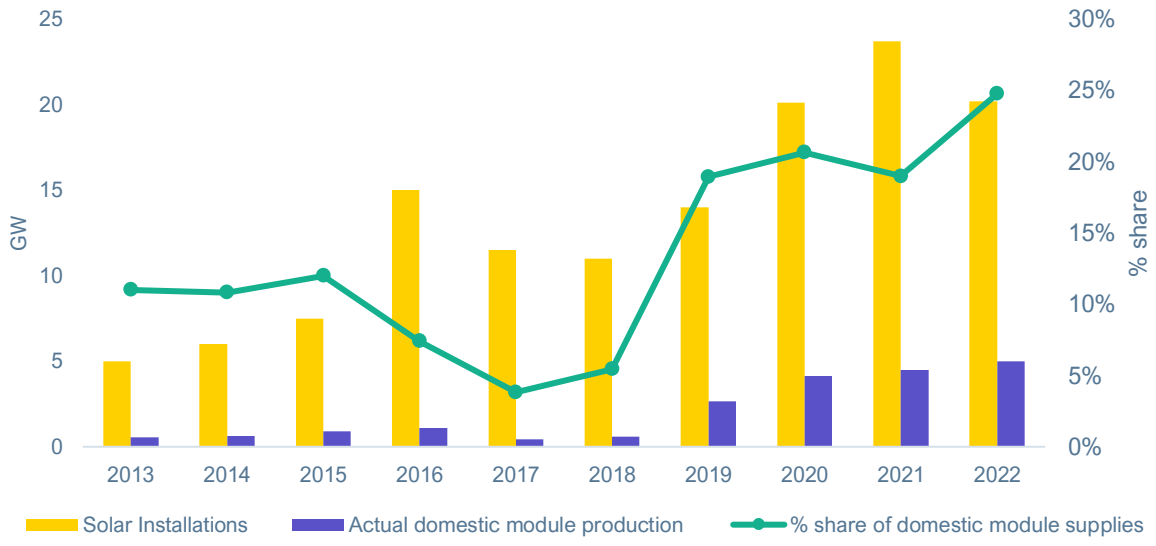
PV Manufacturing Developments in the U.S.

Current PV Manufacturing Status

Ten years ago, in 2013, the U.S. had a presence across all stages of PV manufacturing, i.e., polysilicon, ingot/wafer, cell and module. Since then, almost all ingot/wafer and cell players operating out of the U.S. have exited the market, citing their inability to compete with Chinese counterparts in terms of aggressive pricing and scale. By the end of 2022, the U.S. had a presence only in module manufacturing with 12GW capacity and polysilicon production with 15GW capacity.[6] There was a minuscule capacity of around 0.3GW in ingot/wafer as well.

Against the module manufacturing capacity of 12GW, the actual production output in 2022 was only around 5GW.[7] This domestic production represented only 24.6% share in the overall solar installations of 20.2 gigawatts-direct current (GW_{dc}) in the U.S. in 2022; the remaining installations used imported modules. Currently, the southeast Asian countries of Vietnam and Malaysia are the largest suppliers of solar cells and modules to the U.S.

Figure 2: Annual Solar Installations and Domestic Module Production Trends in the U.S.



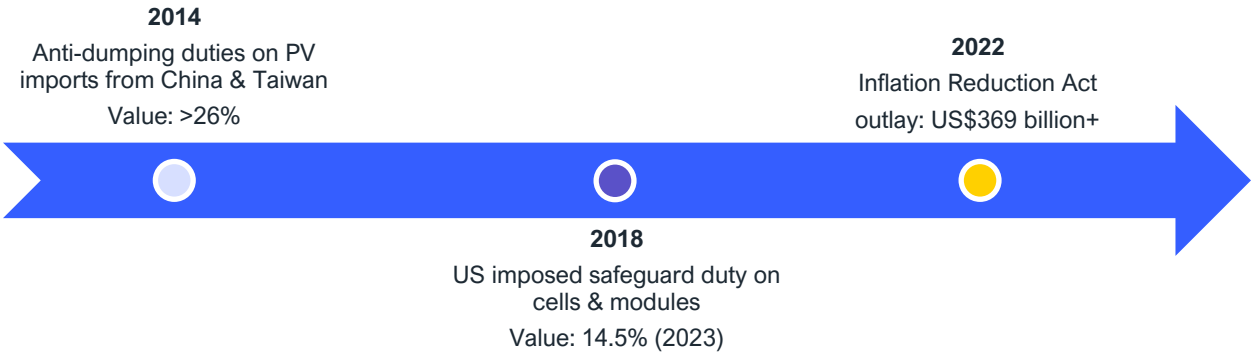
Source: Wood Mackenzie/SEIA, US Solar Market Insight: 2022 Year in Review

To address these escalating supply chain gaps, the U.S. has introduced several policies to limit imports and support the domestic PV manufacturing industry over the years. Some of these measures include imposing anti-dumping and safeguard duties on Chinese PV imports in 2014 and

[6] NREL. Spring 2023 Solar Industry Update. April 2023.
[7] NREL. Spring 2023 Solar Industry Update. April 2023.

2018, respectively. The IRA, the climate bill passed by the U.S. Senate in 2022, is the U.S. government's latest and most ambitious effort to develop domestic PV manufacturing capabilities.

Figure 3: Key Initiatives by the U.S. Government to Support Domestic PV Manufacturing



Source: United States Trade Representative (USTR), US Department of Energy

Inflation Reduction Act (IRA)

The IRA provides a detailed incentive plan for all renewable energy manufacturers, including those who manufacture PV modules, solar trackers, batteries etc. There are mainly two credits[8] under IRA for manufacturers:

- Up to 30% **Investment Tax Credit (ITC)** for investment costs in setting up facilities and procuring equipment.
- A Manufacturing **Production Tax Credit (PTC)** is provided for specific components based on the volume of the product manufactured locally.

Manufacturers can take only one of the two credits; a manufacturer cannot claim both investment credit and production credit for the products from the same factory.

The Production Tax Credit specifies different rates for various products as mentioned in the table below.

[8] SEIA. Inflation Reduction Act: Solar Energy and Energy Storage Provisions Summary. August 2022.

Table 1: PTC Amount for PV Manufacturers under IRA from 2022-2032

Components	Credit amount for manufacturers (2022-2029)	2030	2031	2032
Solar grade polysilicon	US$12/kg	US$9/kg	US$6/kg	US$3/kg
PV ingot/wafer	US$12/$m^2$	US$9/$m^2$	US$6/$m^2$	US$3/$m^2$
PV cell	US$0.04/watt-direct current (W_{dc})	US$0.03/$W_{dc}$	US$0.02/$W_{dc}$	US$0.01/$W_{dc}$
Polymeric back sheet	US$0.4/$m^2$	US$0.3/$m^2$	US$0.2/$m^2$	US$0.1/$m^2$
PV module	US$0.07/$W_{dc}$	US$0.053/$W_{dc}$	US$0.035/$W_{dc}$	US$0.018/$W_{dc}$

Source: US Department of Energy

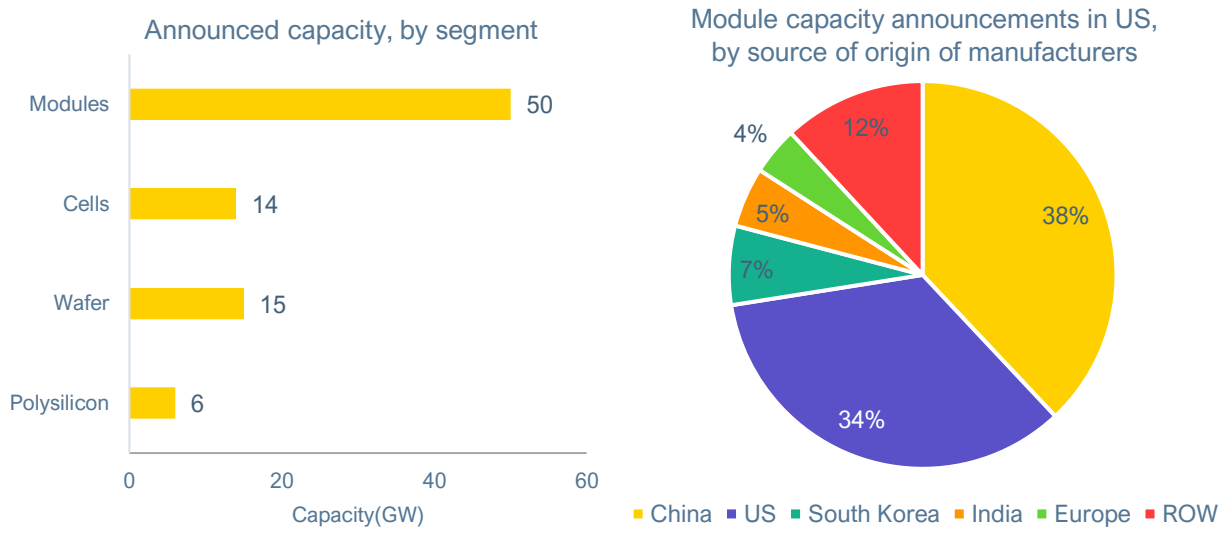
IRA Impact on Domestic PV Production in the U.S.

IRA can be a game changer for the PV manufacturing industry in the U.S. Since the IRA came into effect, PV manufacturers have announced several projects for solar cells, modules and ingot/wafers to be set up in the U.S.

Driven by generous tax credits provided under the IRA, new domestic solar manufacturing facilities with a total capacity of 85GW[9] are set to be constructed in the U.S. in the next few years. This includes approximately 50GW of module capacity, 14GW of cells, 15GW of ingot/wafers and about 6GW of new polysilicon production. Initially, these capacities will cater mostly to the domestic PV market within the U.S., with exports being a long-term target.

[9] BloombergNEF. IRA Support for Solar Modules Exactly Matches China Price. July 2023.

Figure 4: Announcements by Various Players to set up PV Manufacturing Facilities in the U.S. (by 2026)



Source: BloombergNEF, JMK Research

Firms setting up PV manufacturing capacities include U.S.-based First Solar, China-based Longi, Trina Solar and Canadian Solar, Italy's ENEL, Revkor Energy Holdings Inc. U.S., in partnership with H2 Gemini Technology Consulting GmbH of Germany, and South Korean-based Hanwha Q cells. In addition, leading Indian PV manufacturers have expressed their interest in capitalising on the IRA by setting up module facilities in the U.S. through joint ventures with their U.S. counterparts.

In the U.S., building polysilicon, ingot/wafer and cell factories will be significantly more challenging than setting up module production facilities. There are some specific challenges that firms will need to overcome to set up capacities in upstream PV components:

- **Longer gestation period:** As there are no prior cell and ingot/wafer capacities in the U.S., factories will need to be built from scratch. The time taken to set up a cell or ingot/wafer line takes three to four times the time taken to set up a module line. Setting up a new polysilicon factory takes at least two years.
- **Expensive electricity:** Setting up capacities in upstream components would mean incurring significantly higher capital and operating expenses. For polysilicon, electricity expenses account for 40% of the production cost. Low-cost electricity, leading to low operating expenses, is key to the competitive production of polysilicon and ingot/wafer. In the U.S., industrial electricity is much more expensive vis-à-vis China.
- **Stricter regulations leading to project delay:** Ingot/wafer and cell manufacturing are chemically complex processes involving the consumption and release of several gases, including inert gases such as argon. Thus, setting up these facilities will require a lengthy and strict inspection by U.S. authorities, leading to commissioning delays.

- **Lack of skilled manpower:** The availability of qualified personnel is an essential factor in ensuring the optimum efficiency of the PV production plant. With almost 80-90% of the PV manufacturing infrastructure in China, there is a dearth of skilled manpower everywhere, including the U.S.

> **To truly unleash the PV manufacturing revolution, the U.S. and Europe will need to facilitate the development of an entire ecosystem, not just incentives.**

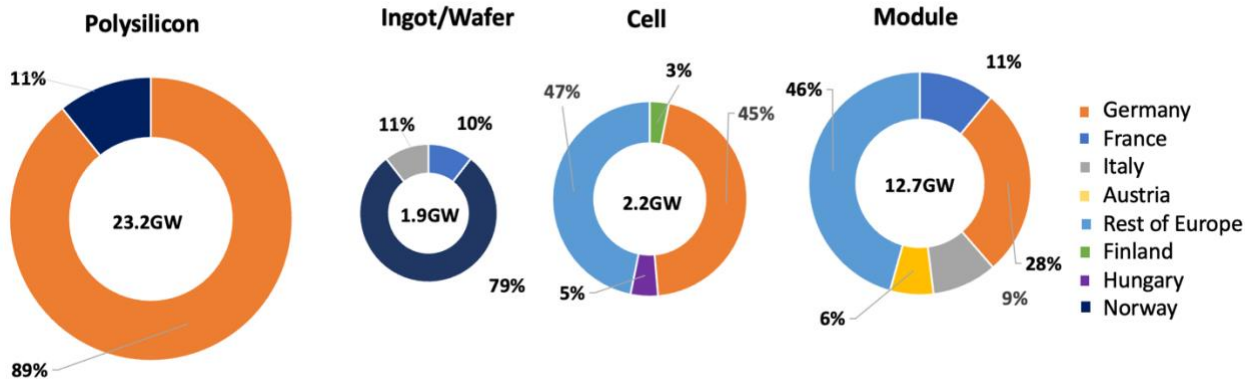
The challenges demonstrate that to truly unleash the PV manufacturing revolution, the U.S. (and Europe) will need to facilitate the development of an entire ecosystem, not just incentives. China did that successfully in the early 2010s. The Chinese government provided support at each stage of the value chain, including ancillaries and skill development of the workforce. To drive down operational costs, subsidised electricity was provided to manufacturers. In addition to setting up large-scale units, PV manufacturers were motivated to ensure they invest in research and development (R&D) concurrently to remain ahead of the curve in terms of global PV technology.

PV Manufacturing Developments in Europe

Other than the U.S. market, there is significant proposed activity in Europe in the PV manufacturing space. As of November 2022, Europe's annual manufacturing capacity for polysilicon, ingot/wafer, cells and modules was 23.2GW, 2.2GW, 1.9GW and 12.7GW, respectively.[10]

The most prominent PV manufacturing country in Europe is Germany, which has an 89% share in polysilicon production, 45% in cell manufacturing and 28% in module manufacturing capacity. Norway has the largest share of 79% in ingot/wafer manufacturing capacity. France, Italy and Austria are other countries in Europe with respectable PV module manufacturing capacities.

Figure 5: Annual PV Manufacturing Capacities in Europe (as of November 2022)



Source: *IEA, Solar Power Europe*

In 2022, the Russia-Ukraine war led to an agricultural and energy crisis, highlighting the importance of self-sufficiency in energy production and diversity of supply chains. Europe is increasingly focusing on renewable energy for its future energy needs.

> **Between 2021 and 2022, module imports from China increased by 110% from 41GW to 87GW, making Europe the largest importer of Chinese modules.**

With the increasing energy demand, Europe has seen a rise in PV installation over the years, and the current cumulative PV installation stands at 208.9GW.[11] However, PV imports from China facilitate a

[10] IEA. Solar PV manufacturing capacity outside China and total investment in 5-year periods. November 2022.
[11] SolarPower Europe. EU Market Outlook for Solar Power 2022-2026. December 2022.

large chunk of these installations in Europe. Between 2021 and 2022, module imports from China increased by 110% from 41GW to 87GW, making Europe the largest importer of Chinese modules.[12]

A vibrant domestic PV manufacturing market is vital to reducing Europe's dependency on imports and helping it achieve self-sufficiency in energy production through renewable energy.

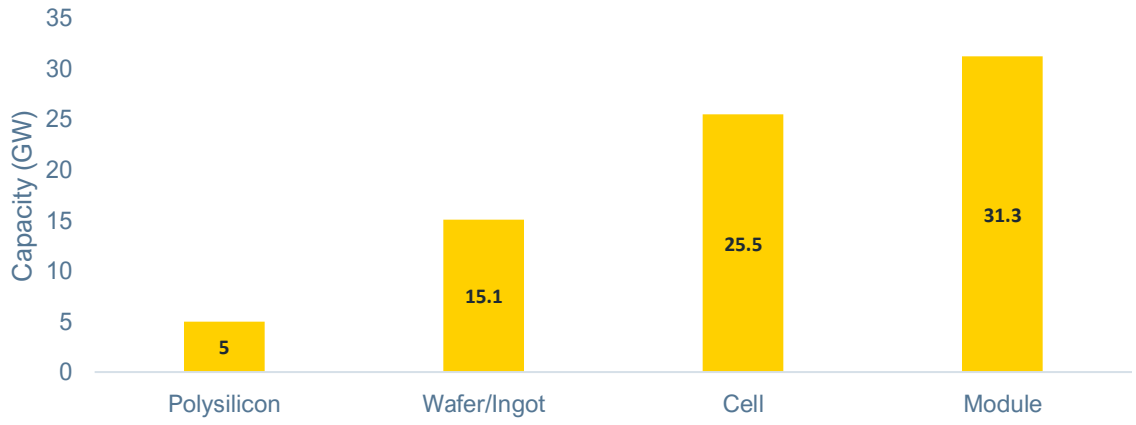
European Green Deal (EU Green Deal)

The European Commission launched a dedicated action plan in 2019, known as the European Green Deal, which covers a wide range of policy areas.[13] The European Green Deal aims to achieve three primary goals, i.e., carbon neutrality by 2050, sustainable economic growth and socially justified transition.

Although the EU Green Deal was launched in 2019, no significant activity began until its "**REPowerEU plan**" initiative was issued in May 2022. The REPowerEU plan mandated at least a 45% share of renewables in the overall energy mix by 2030.[14] The plan emphasised an equal focus on renewable energy generation and self-sufficiency in PV manufacturing to achieve this target.

In December 2022, the European Commission launched the "**European Solar Industry Alliance (ESIA)**" under the ambit of the EU Green Deal and REPowerEU plan. The establishment of ESIA marked the EU's initiation of a focused approach towards PV manufacturing. Since its launch, several PV manufacturing announcements have been made in Europe. Various PV manufacturers will add more than 31GW of new module manufacturing capacity in Europe in the next few years.

Figure 6: Announcements to set up PV Manufacturing Capacity in Europe under ESIA



Source: European Solar Photovoltaic Industry Alliance, JMK Research

[12] Rystad Energy. Global Solar PV Growth and Manufacturing Outlook. June 2023.
[13] European Commission. The European Green Deal. December 2019.
[14] IEA. RePowerEU Plan: Joint European action on renewable energy and energy efficiency. May 2023.

The European Commission is expected to issue a comprehensive framework similar to the IRA in the U.S. within a year. This framework will lay down detailed incentives along the PV manufacturing value chain. Despite the announcements, industry observers are sceptical about the actual inflow of investments and on-ground construction progress in Europe's PV manufacturing until this detailed framework is formally issued. Like the U.S. and India, manufacturers in Europe are also keenly awaiting support from the European Commission in the form of firm barriers against PV imports. Sans the barriers and production incentives, setting up manufacturing facilities in Europe will not be financially sustainable, especially considering the steep downward trajectory of imported module prices in 2023.[15]

[15] The Hindu. Chinese solar prices fall to record lows, make mockery of BCD. October 2023.

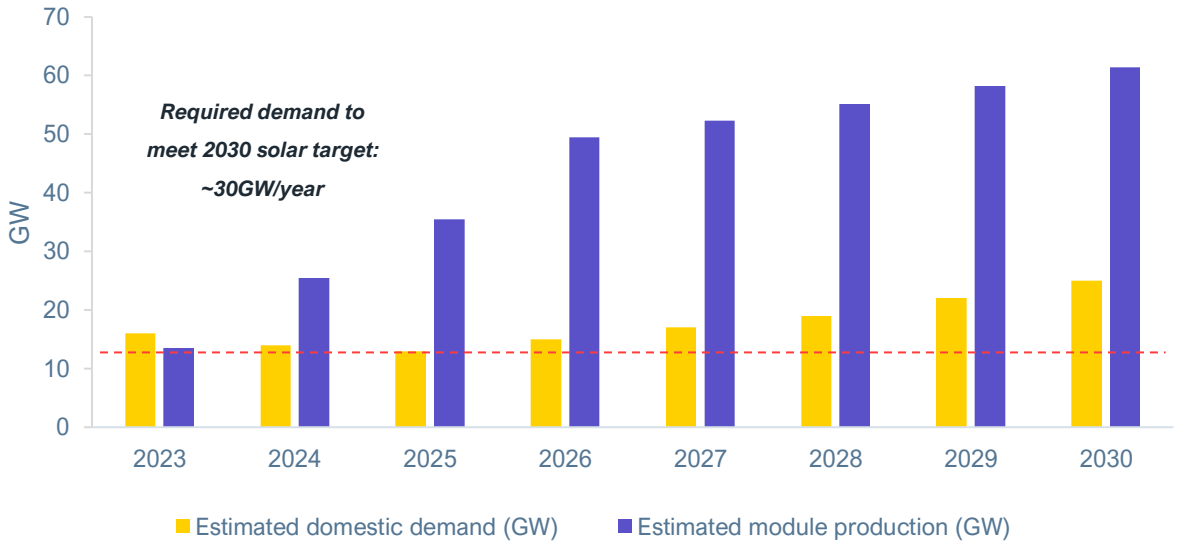
Impact of U.S. and Europe PV Manufacturing Push on India

Future PV Export Trends

The U.S. and other overseas markets, such as Europe, play an essential role in the growth of domestic PV manufacturing in India. The U.S. has traditionally been the largest export destination for Indian PV products. The PV module exports from India to the U.S. have grown exponentially recently (16x in the fiscal year (FY) 2023 vis-à-vis FY2022). In FY2023, India exported nearly US$1 billion worth of PV modules to the U.S., a share of around 97% of the entire global module exports out of India.

In the past couple of years, several Indian PV manufacturers have declared ambitious plans to expand their manufacturing capacities. Based on the estimated trajectories of demand and supply (refer to Figure 7) in the coming years, a substantial portion of the production is projected to be exported overseas, even after meeting domestic demand.

Figure 7: Forthcoming Growth in Domestic Manufacturing Calls for a Strong Export Market

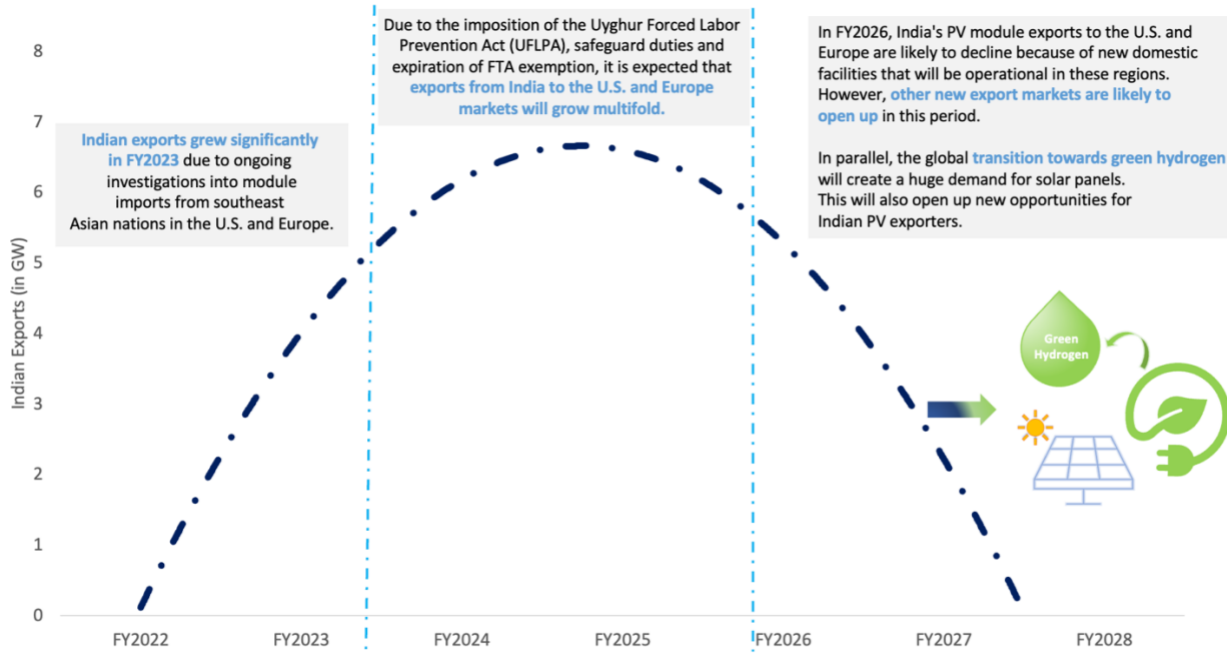


Source: News articles, JMK Research
Note: Actual production of domestic high-efficiency modules is assumed at 50% of the manufacturing capacity.

With the simultaneous rise in the capacities of Indian manufacturers and the corresponding demand for PV in the U.S., module exports are likely to see a significant upswing for the next few years. An added boost will be the expiry of tariff exemptions under the Free Trade Agreement (FTA) in July 2024, currently granted to PV imports in the U.S. from southeast nations such as Vietnam, Malaysia,

etc. Thus, Indian manufacturers will have significant opportunities until July 2024 to sell their products in the U.S. market. However, once the capacities being set up under IRA are operational by 2025 or 2026, Indian PV module exports to the U.S. may experience a period of stagnation followed by a decline from 2027 onwards.

Figure 8: Future India PV Export Trends to the U.S. and Europe



Source: JMK Research

For Indian players, exports to the U.S. market are likely to dwindle post-2027; however, target export markets other than the U.S. and Europe are likely to open up by then. For their PV requirements, several countries are trying to find an alternative to China. This prevailing "China+1" sentiment in securing their supply chains will also be a key driver for the increasing preference for India-based PV products in the global market. However, there might be a possibility of the U.S. formulating a “friend-shoring” agreement under the Quadrilateral Security Dialogue (QUAD) with India, under which the U.S. continues to import a fixed quantum of PV products from India, thereby ensuring the continuation of export opportunities for Indian PV manufacturers to the U.S. post-2027.

In parallel, the global transition towards hydrogen-based energy sources is poised to gain momentum, with major economies actively promoting hydrogen production initiatives. The U.S., for instance, has committed to shifting one-third of its total hydrogen production to renewable sources by 2030.[16] Achieving this target requires the establishment of renewable energy infrastructure,

[16] S&P Global. Hub hopefuls: US policy spurs the clean hydrogen transition. June 2023.

notably in the form of solar and wind plants. This presents a significant growth prospect for Indian PV exporters to capture this market.

Aiding the Development of the Upstream PV Components Market in India

Manufacturing upstream components in the PV manufacturing chain is more complex and capital intensive vis-à-vis assembling the final product, i.e., solar modules.

There are certain U.S.-specific challenges in manufacturing these upstream components. In addition to the stricter regulatory environment in the U.S. regarding chemical processes of cell and ingot/wafer production, relatively expensive industrial electricity rates in the U.S. will also hinder the development of polysilicon plants. Electricity expenses make up around 40% of the manufacturing cost of polysilicon. Additionally, running these plants will require a substantial skilled labour workforce in upstream manufacturing, which will take time to develop.

Considering the challenges in manufacturing upstream components in the U.S., most players are currently setting up facilities in the U.S. that only focus on modules. With integrated facilities already being set up under PLI, India is better poised to manufacture and supply these upstream components. Realisation of the opportunity created by this forthcoming demand-supply gap will further push Indian manufacturers to refocus and develop upstream manufacturing capabilities in tandem. To take advantage of IRA while minimising the associated risks of manufacturing upstream components in the U.S., several Indian manufacturers are looking to set up module lines in the U.S. and cell or ingot/wafer lines in India. Indian PV manufacturers such as Vikram Solar (2GW) and Navitas Solar (1.2GW) have already announced plans to set up module capacities in the U.S.[17]

IRA vs PLI and its Influence on Future Policy Design for Indian PV Manufacturers

Compared to India's flagship programme to incentivise PV manufacturing, i.e., the PLI scheme, the IRA is more detailed and covers a wide range of sectors in renewable energy, such as solar modules, inverters, trackers and batteries. While PLI focuses on incentivising actual production, IRA also has a separate component called Investment Tax Credit (ITC) to avail upfront incentives on capital costs. As pointed out in the previous section on IRA, the response to the scheme has been exemplary and several companies worldwide are vying to set up their manufacturing facilities in the U.S. Other details and points of comparison between the IRA and PLI are mentioned in the table below.

[17] Solar Power World. Vikram Solar picks Colorado for 2-GW solar panel factory. June 2023.

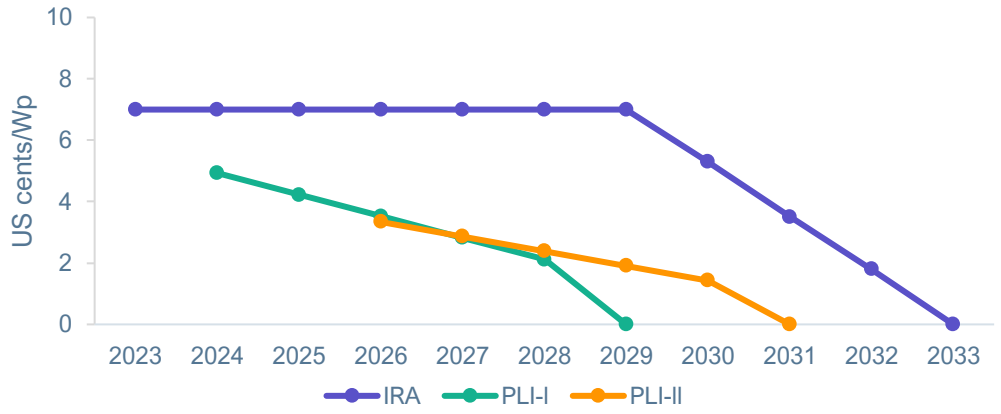
Table 2: Comparison between the IRA and PLI Schemes

Parameter	IRA	PLI
Year of issue	2022	PLI-I: 2021 PLI-II: 2022
Manufacturing sectors covered	Solar, batteries, inverters, trackers	High-efficiency solar modules
Types of incentives	1. Investment tax credit (ITC) 2. Production tax credit (PTC)	PLI
Outlay for manufacturing	1. ITC: US$10 billion (covering all manufacturing sectors) 2. There is no capping on PTC	Rs240 billion (US$2.89 billion)
Incentive disbursal mode	Tax credits	Cash disbursal
Eligibility	All manufacturers are eligible	Eligible manufacturers are selected through a tendering process
Scheme period	Until 2032	Five years after the respective PLI beneficiary facility's scheduled date of commissioning

Source: MNRE, US Government Publishing Office

The IRA provides layered incentives to separate components of the PV supply chain, ranging from polysilicon to ingots/wafers to cells and modules. The incentive period is extensive (until 2032) compared to just five years (from the scheduled date of commissioning of the beneficiary facility) under the PLI. Production incentive under the IRA (per Watt-peak (Wp) of modules produced) is significantly higher than under the PLI (see Figure 9).

Figure 9: Production Incentive Comparison between the IRA and the PLI for Solar Modules



Source: MNRE, US Government Publishing Office
Note: 1. For PLI, module efficiency is assumed in the range of 21% to 23%. The local Value Addition factor for both tranches of PLI is assumed to be 0.9.
2. The integrated manufacturing facilities under PLI-I and PLI-II are assumed to be commissioned in 2024 and 2026, respectively, three years after their tender result declaration.

Future iterations of PLI will certainly look at IRA as well as EU Green Deal provisions to incorporate some of the requirements in their policy design for the next phase. This might include an option to avail an upfront cost subsidy (especially for smaller players trying to enter the market), an extended policy impact period, slightly relaxed eligibility criteria for qualifying entities, etc.

Conclusion

In the past decade, China has been the most prominent player in the solar PV supply chain in the world. Around 80-90% of the entire PV manufacturing infrastructure is in China. China is set to double its solar manufacturing capacity in the next two to three years, so it will continue to hold by far the pole position globally. Several other countries will also develop their domestic PV manufacturing base. Major economies like the U.S., Europe and India are focusing on bolstering their domestic solar PV value chain through policy initiatives. Initially, these policies and incentives will help fulfil domestic demand, but eventually, they will help local manufacturers expand and tap global markets.

All major PV importers around the globe are actively pursuing a "China+1" strategy to insulate their PV procurements against future supply chain shocks that become unavoidable in some instances due to the concentration of manufacturing in just one country. Hence, they either identify a suitable alternative to China for meeting their PV demands or develop their domestic PV manufacturing ecosystem.

Countries such as India and the U.S. are directing their efforts towards building manufacturing capacities across the solar PV manufacturing chain. However, developing capabilities in the upstream stages of PV manufacturing of cells, ingots/wafers and polysilicon is significantly more challenging. Both polysilicon and ingot/wafer production are labour- and electricity-intensive and are going to be the focal point in achieving self-sustenance of PV production.

> **Once the domestic market develops in the U.S. and Europe, Indian players must explore other overseas export markets, including Africa and South America.**

It will take two to three years to establish PV manufacturing capacity in the U.S. and Europe. Till then, Indian players have a very attractive opportunity to be their PV supplier, especially in the U.S. market, with its duty restrictions on PV imports from China. But once the domestic market develops in the U.S. and Europe, Indian players must explore other overseas export markets, including Africa, South America, etc.

In the crucible of progress, a pivotal point that needs to be addressed is that concentrating solely on advancing the solar PV supply chain is not enough. It is equally essential to reduce reliance on imports for PV equipment/machinery and ancillary components.

By FY2027, the global transition to green hydrogen will create a huge demand for solar PV panels. This will also open up a considerable size market for PV manufacturers for their products.

With annual global solar installations forecast to reach at least 1TW by 2030, it is clear that there will be no dearth of PV demand in the future. Thus, Indian players must focus equally on domestic and

international markets. Indian PV products will also need to compete in global markets with other large PV manufacturing countries in terms of quality and scale. Thus, all Indian manufacturers setting up new lines are focusing on the latest PV module technology, such as mono passive emitter and rear cell (PERC) upgradable to tunnel oxide passivated contact (TOPCon) or heterojunction technology (HJT).

In the rapidly evolving landscape of PV technology, it will be crucial for Indian manufacturers to plan and prepare for future upgrades. Building a solar module plant only to find that it gets outdated in three to five years is a dangerous business proposition. China's leading manufacturers invest up to 5% of their annual revenue in R&D, enabling them to define and lead global PV technology trends.[18] Given their R&D focus, coupled with their control of upstream components such as ingot/wafer, it will be challenging for other countries to counter Chinese dominance in the global supply chain, at least in the near term.

The U.S. is a global leader and superpower, which other countries look up to and try to emulate. IRA, by all measures, is a landmark legislation on climate change. An initiative of this magnitude by the largest country in the world will motivate others to do the same. Similarly, in the near future, India could consider publishing a detailed unified framework for achieving its nationally determined contributions (NDC) target of net zero by 2070.

[18] IEEFA. Photovoltaic Manufacturing Outlook in India. February 2022.

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The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends, and policies. The Institute's mission is to accelerate the transition to a diverse, sustainable, and profitable energy economy. www.ieefa.org

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