INTERNATIONAL SOLAR ALLIANCE

CEO CAUCUS
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Unlocking Solar Potential

A Case for Private Sector Leadership

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Foreword

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To address the urgent need to triple global renewable energy capacity by 2030, it is imperative that policies facilitate the expansion of both grid-connected and decentralized solar energy. However, achieving this requires a more diversified and resilient global solar manufacturing supply chain, with a particular focus on fostering local manufacturing. Such efforts are crucial for unlocking financing, driving technological innovation, and enhancing solar-powered applications. The active participation of the private sector is vital to scaling up domestic capacity. At the same time, governments play a pivotal role in establishing robust local solar PV supply chains by identifying domestic vulnerabilities, encouraging investments through financial and tax incentives, implementing demand support policies for long-term sustainability, and promoting public-private partnerships.

While in high-income and emerging economies, there is growing private sector engagement and participation in achieving clean energy goals—thanks to supportive policies, available financing mechanisms, and reduced risks—lower-income countries face significant challenges in attracting private investment to the solar sector. These challenges includethe absence of conducive policies for solar deployment, a lack of procurement mechanisms, and limited involvement of financiers and funders.

In response to these challenges, the International Solar Alliance (ISA) explored the solar manufacturing landscape in 2023, through the report, "Building Resilient Global Solar PV Supply Chains," and through engagements with the Transforming Solar Supply Chains workstream of the Clean Energy Ministerial, which underscored the importance of diversifying solar PV manufacturing capacity to mitigate supply chain disruptions. To further explore these issues and gather insights from solar manufacturers, developers, think tanks, and policymakers across various regions, the ISA initiated a series of high-level consultations in June 2024. Under the "CEO Caucus" banner, leading CEOs and key stakeholders engaged in discussions aimed at overcoming challenges and maximizing the potential of the global solar industry. The ISA organized five roundtables, each focused on different economic group-high-income, low-income, and emerging markets—across Asia, the USA, Europe, Africa, and Australia. These sessions were designed to capture diverse perspectives from different regions, and I am grateful to the vast range of discussants and advisors who took the time to provide us with their invaluable insights.

The insights generated from these roundtables have been analyzed and synthesized into this report, which presents a series of recommendations to promote solar manufacturing growth. The report aims to spark dialogue among our member nations and international stakeholders on collaborative strategies to enhance investment and capacity in solar production. I hope that this report will also serve as a foundational resource for us as we deepen our engagement with the private sector, and for discussions among policymakers, producers, and project developers as they work to build robust solar production networks both domestically and globally.

Dr. Ajay Mathur
Director General
International Solar Alliance

Acknowledgements

The International Solar Alliance (ISA) expresses its sincere appreciation to all the stakeholders who participated in the five roundtable discussions under the CEO Caucus. The insights shared by these industry leaders were invaluable in shaping this initiative, and their expertise played a key role in its success. We would particularly like to acknowledge the members of ISA's Corporate Advisory Group, many of whom contributed to various discussions.
A complete list of discussants involved in this initiative can be found in Annex I.

The discussions benefited greatly from the thoughtful feedback, comments, and guidance provided by members of the ISA CEO Caucus Sounding Board: Ms. Sonia Dunlop, CEO of the Global Solar Council; Mr. Rajani Ranjan Rashmi, Distinguished Fellow at TERI and Former Special Secretary, Ministry of Environment, Forest and Climate Change, Government of India; Dr. Ashvini Kumar, Former Managing Director of the Solar Energy Corporation of India Limited (SECI); and Mr. Subrahmanyam Pulipaka, CEO of the National Solar Energy Federation of India (NSEFI).

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ISA is also grateful to the Department of Climate Change, Energy, the Environment and Water (DCCEEW) of the Government of Australia for their support in developing this publication as part of the Clean Energy Ministerial (CEM) Transforming Solar Supply Chains Initiative. We would also like to recognize the contributions of Bloomberg Philanthropies, the Children's Investment Fund Foundation (CIFF), and the Global Energy Alliance for People and Planet (GEAPP).

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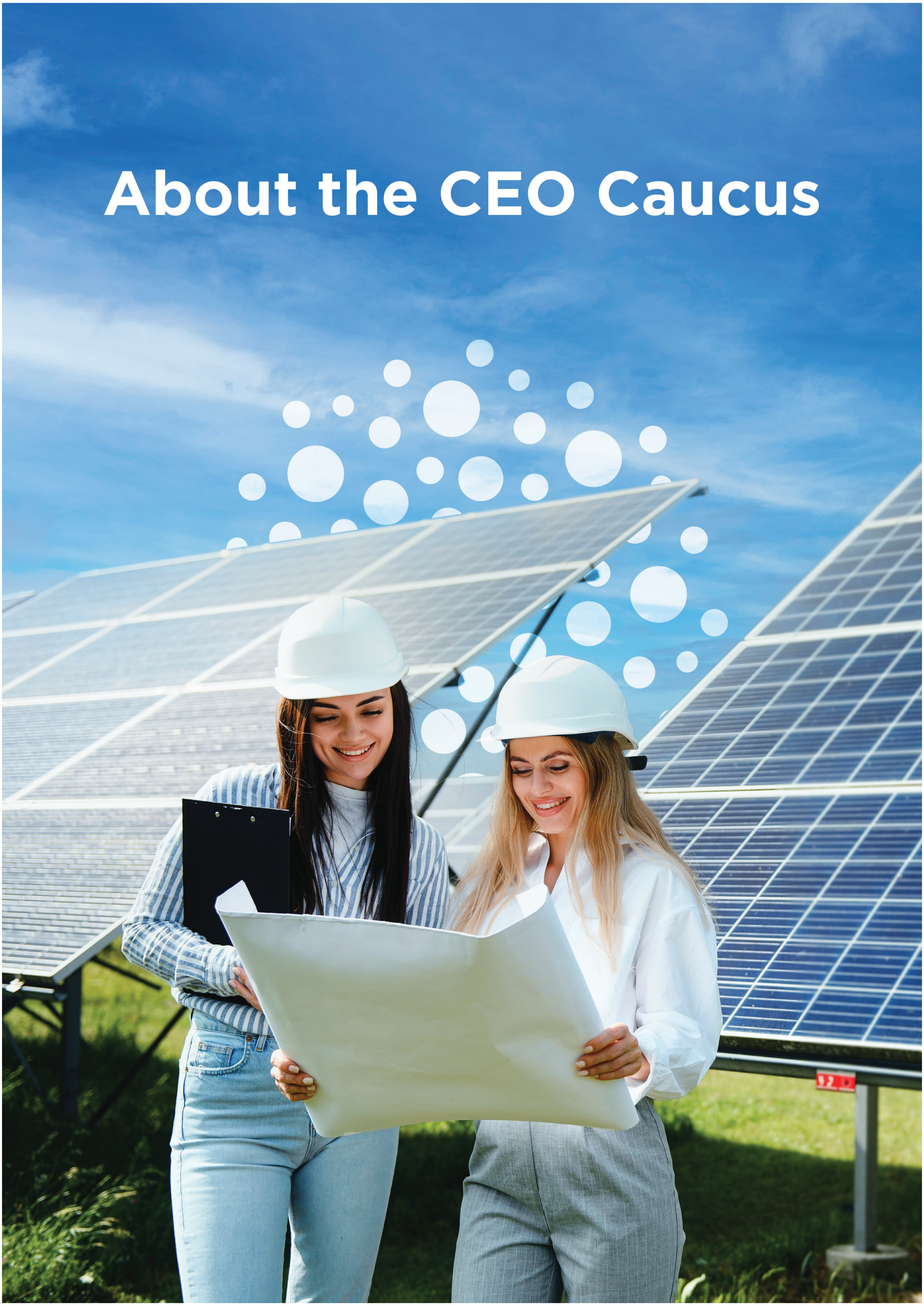
We would also like to acknowledge the contributions from Mr. Ramesh Kumar Kuruppath, Chief of Programmes at ISA, senior management and colleagues at ISA who contributed to the initiative.

About the CEO Caucus



1. About CEO Caucus

What will it take for the private sector to spur the next quantum leap in boosting solar development across the globe?

The private sector plays a pivotal role in driving global solar development and enabling clean energy adoption and transition. Achieving the full potential of global solar deployment requires the private sector to innovate in financing, scale up investments, leverage public-private partnerships, and advance technologies. Their involvement is key to scaling projects, reducing costs, and overcoming market barriers, ultimately sparking the required transformative leap in the solar industry worldwide. To enable the private sector, the public sector plays a key role in developing a facilitative regulatory framework, mobilizing capital, and forging strategic public-private partnerships.

To develop an understanding of these requirements from the private sector's perspective, the International Solar Alliance (ISA) sparked a series of high-level consultations across the world under the rubric of the "CEO Caucus", to deliberate on these crucial matters. The ISA launched the CEO Caucus on June 6, 2024, as a consultative platform for industry leaders to collaborate with other key stakeholders. Caucus meetings were aimed at identifying and addressing challenges to accelerating solar deployment at scale to achieve Net Zero goals by mid-century.

In a series of five roundtables held through 2023-2024, spanning Asia, USA, Europe, Africa, and Australia, CEOs from top companies and other key stakeholders deliberated on the obstacles to unlocking the full potential of this global solar industry.

- 'Bottlenecks for Building the Global Solar Energy Sector' – an inaugral virtual meeting with a diverse range of stakeholders aimed at collating the issues, held on June 6, 2024
- "Empowering Europe's Solar Future: A Roadmap to Diversify, Innovate, and Sustain – a meeting with European solar industry representatives held in Brussels, on June 13, 2024
- 'Driving Solar Energy Revolution: Growth Insights for Global Impact' - meeting in New York on July 15, 2024
- "Energizing Africa: Accelerating Development with Solar"- a virtual meeting with solar industry relevant stakeholders from the Africa region, on August 5, 2024
- "Solar Innovation & Manufacturing Resilience: Paving the Way for Australia's Sustainable Future" – a meeting with Australian industry stakeholders in Sydney, on August 14, 2024

See Annexure I for a full list of discussants.

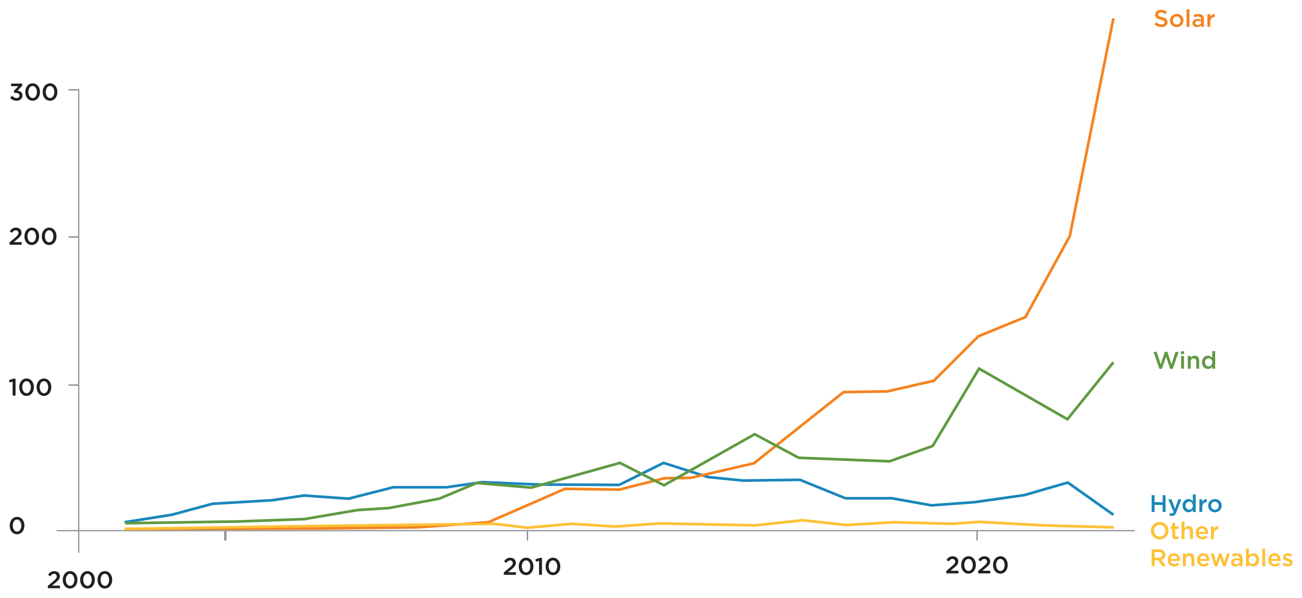
In addition to the inputs from these consultations, ISA has synthesized information available from other sources. This document serves as a distillation of those consultations and information, to propose a way forward. This document examines the key areas of Manufacturing, Technology, and Finance, which are supported by three strategic policy enablers: investment in essential infrastructure like grids, fostering institutional arrangements and collaboration, and providing targeted incentives. Together, these elements signal a strong commitment to policy support. The document captures valuable insights on critical challenges as well as emerging opportunities to meet global energy demand, driven by energy access goals and Net Zero targets, with solar energy.

2. Background

Key opportunities for solar are manifold, with fast-growing potential. The trends indicate that net expenditures on renewables, grids, and storage are estimated to surpass investments in oil, gas and coal. The ambitious target of tripling renewable capacity by 2030 provides a huge opportunity for the sector, with solar being at the forefront of the energy mix of the future. According to the International Energy Agency (IEA), renewable energy (RE) and electrification are poised to reduce approximately 75% of the energy-related CO2 emissions by mid-century, solar is expected to be a leading resource in the RE mix - with almost three-quarters of all renewable capacity built in 2023 being solar.

However, to achieve the ambitious goal of tripling renewable energy capacity by 2030, it is necessary to add at least 600 GW of solar capacity annually. While the annual addition of solar capacity is on a fast-growing trajectory, as evidenced by the addition of ~350 GW of solar capacity in 2023, which was a significant jump from the 220 GW added in 2022, we are currently falling short of this short-term target.

Fig.1 : Global Annual Solar Capacity Additions (in GW)



Source: Ember calculations based on IRENA renewable capacity statistics

3. Progress, experiences and challenges

COP28 established an ambitious target to triple renewable energy capacity by 2030, catalyzing increased supply, demand, and activities worldwide. The private sector is instrumental in expanding solar deployment through advancements in manufacturing, technology, and financing. Concurrently, governments are crucial in creating a supportive environment by implementing stable policies, fostering institutional arrangements, and offering incentives to facilitate growth. This section details these foundational pillars and enablers, drawing on insights from roundtable discussions to summarize the progress, experiences, and challenges faced in striving to meet these ambitious renewable energy goals.

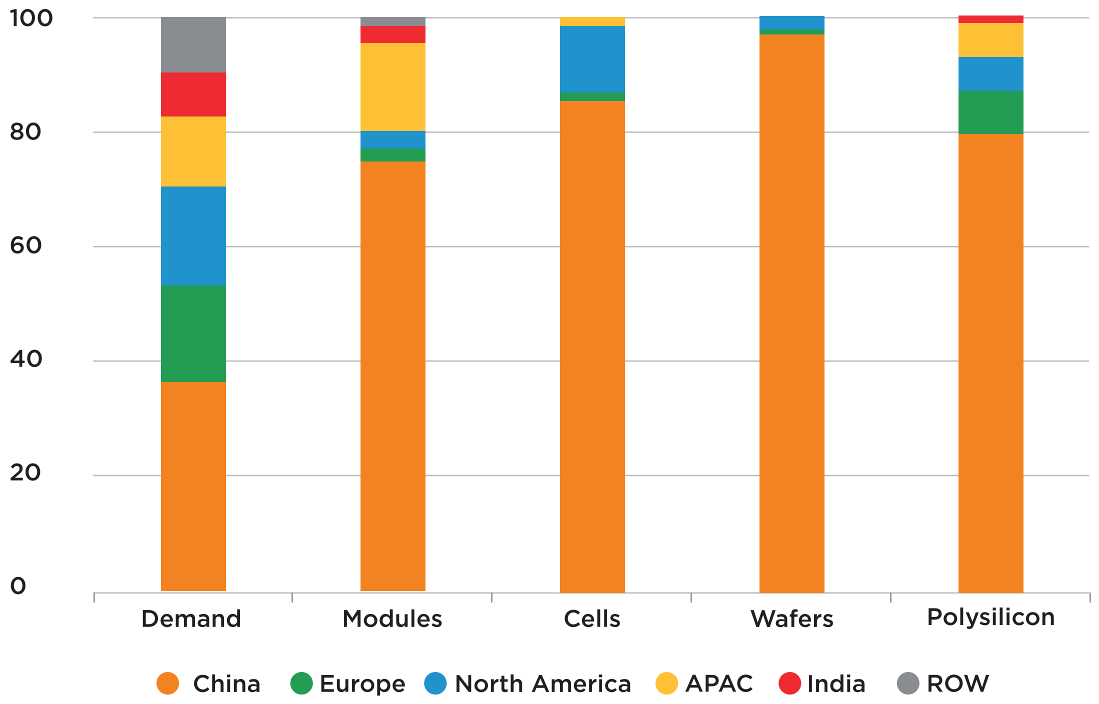
3.1. Manufacturing

While solar energy is gaining increasing traction globally, manufacturing remains predominantly concentrated in China, where its lead in production capacity continues to grow. While the USA, EU, Australia and India are endeavoring to ramp up their capacities backed with strong policy measures, Least Developed Countries (LDCs) like those in Africa are unable to do so due to financial implications. Additionally, there is a pressing need to boost domestic demand for solar and for workforce development and skill standardization to support this expanding industry.

Roundtable discussions emphasized the adverse effects of concentrated solar manufacturing on supply chain bottlenecks, particularly in regions like Africa. They highlighted the need for diversification in the solar supply chain and recognized that nations vary in financial capability. Thus, identifying opportunities within existing supply chains rather than reconstructing entire manufacturing ecosystems was deemed a more practical approach.

The ISA projects that between 700 and 1,900 MW of additional manufacturing capacity will be needed annually by 2030, to meet the high solar deployment ambition. Despite this, the solar PV industry remains highly concentrated. To meet installation targets and enhance resilience through diversification within the global solar supply chains, other countries and regions need to ramp up their manufacturing capabilities.

Fig.2: Solar PV manufacturing capacity by country and region, 2021 (in %)



Source: IEA (2022), Solar PV manufacturing capacity by country and region, 2021.

Some of the key solar manufacturing- related challenges highlighted through the discussions are listed below. Addressing these challenges presents significant opportunities for developing a diversified and resilient global supply chain, which is able to catalyze a more regionally balanced mobilization of investments for solar, regionally relevant innovations, and accelerated sustainable energy development worldwide.

3.1.1. Need to diversify global solar manufacturing capacity

In 2024, global solar module manufacturing capacity is set to cross 1000 GW, which is well over the current global demand. However, the production predominantly concentrated in China, which accounts for nearly 80% of this capacity, with China also accounting for nearly 98% of the manufacturing capacity of wafers. Spurred by their new policies for expanding domestic manufacturing capacity, the USA and India each contributed 5%, while Europe accounted for merely 1%, with most of the remaining capacity being situated in the Asia Pacific region.

China's strategic focus on solar PV, bolstered by industrial policies, has cultivated significant economies of scale, positioning it as a global leader in solar energy. In 2023, the world added over 420 GW of solar capacity, with China contributing around 80%. Its production capacity, more than double the global installations, led to a 50% drop in solar panel prices from December 2022. The high concentration of manufacturing in a single country can severely impact the global supply chain, leading to bottlenecks. This was seen during the COVID pandemic and again in 2022, when disruptions in China - including Shanghai lock-downs, a factory fire in Xinjiang, and a drought in Sichuan, severely impacted polysilicon production. These events drove spot prices of polysilicon to their highest levels in over a decade, in August 2022.

This current glut in the market has proved to be a substantial challenge for countries attempting to establish a domestic solar supply chain. Manufacturers emphasized the lack of profitability in PV manufacturing with current market prices significantly below sustainable margins. Thus, it is crucial to establish conducive public policies that foster the development of local manufacturing capabilities, based on the context of specific countries and regions.

The landscape for domestic solar manufacturing is changing quickly due to new policies from various countries. For example, the US has the Inflation Reduction Act (IRA), India has its Production Linked Incentives (PLI) scheme, Australia has the Future Made in Australia and Solar SunShot programs, and the EU has the Net-Zero Industry Act (NZIA). These policies are encouraging the development of new solar manufacturing facilities at home. The IRA in the US , has a goal of providing over USD 60 billion to boost domestic clean energy manufacturing by offering production tax credits to manufacturers and incentives to consumers towards the goal of expanding its capacity to 50 GW annually by 2030. India's PLI scheme with an outlay of approximately USD 2.8 billion aims to achieve manufacturing capacity of GW scale in High Efficiency Solar PV modules, thus reducing import dependence in the area. At the same time, Australia's SunShot targets an investment of 1 billion AUD to bolster PV manufacturing capabilities. Such acts also include mandatory manufacturing requirements, including region of manufacturing, in public procurement of solar modules, and are beginning to see ramping up of domestic manufacturing capabilities.

In the Africa discussion, it was noted that despite Africa holding 60% of the world's prime solar resources, it only accounts for 1% of the installed solar PV capacity. The continent's growing energy needs and resulting solar demand are completely reliant on global supply chains, posing economic risks and emphasizing the urgency of developing local manufacturing capabilities. The potential of solar manufacturing industry having beneficial impact on ancillary industries – such as glass manufacturing and manufacturing of other components required for installations, and the ensuing economic growth for developing countries was also discussed.

In the EU, the Net-Zero Industry Act(NZIA), aims to ensure that the manufacturing capacity for net-zero technologies reaches at least 40% of expected EU demand by 2030, providing predictability and long-term signals to manufacturers and investors. While the policy's impacts are yet to fully set in, at the discussion in Brussels, the issue of the low cost of manufacturing solar modules outside of the EU was highlighted, as it was making it difficult for EU- based manufacturers to compete with the imported products, leading to closures and consolidation in the sector.

A similar issue was highlighted in the discussion in Australia. Discussants made a nuanced point on the need to embed national supply chains and supporting policies with the global supply chains, to minimize redundancies and the global benefits from solar demand and supply chains can be distributed across regions.

This would mean that countries focus on areas where they have expertise, resources and capabilities – which in the Australian context could include an increased focus on processing of certain critical minerals.

Another aspect of note for shoring manufacturing capabilities is import duties and related taxes. According to an IEA assessment, global trade restrictions such as import duties on solar PV supply chain components have escalated significantly, growing from a single tax in 2011 to 16 duties and import taxes by 2022, impacting 15% of the global demand outside of China. In a recent move, South Africa imposed a 10% import tariff on solar panels to support local manufacturers, attract investment, and deepen the value chain. Such duties and taxes, while helping to ramp up domestic capacities, must be balanced well, as they also increase the cost of solar, and thus impact demand.

3.1.2. Role of demand as a catalyst for manufacturing capabilities at scale

Large-scale manufacturing is critical in the solar PV industry, especially for capital-intensive steps like polysilicon production or ingot and wafer manufacturing, where economies of scale significantly drive competitiveness. Although domestic solar demand within or near a country is not always necessary, as seen with Southeast Asian countries like Malaysia exporting to distant markets like North America and Europe, it still provides substantial benefits. Local demand lowers transport and logistics costs, reduces investment risks by securing future sales, and amplifies the benefits of local content regulations. For certain processes such as glass or plastic foil manufacturing, where competitiveness largely depends on scale without much scope for differentiation, achieving large scale remains crucial.

The inter-linked role of demand for solar in driving the manufacturing capacity additions is an aspect to be accounted for while framing policy measures to support manufacturing. It should be noted that the top three countries manufacturing solar modules are also the same top three countries in terms of annual installations of solar PV. China has maintained its leadership in the global PV market for a decade, installing approximately 55 GW in 2021, doubling that to 106 GW in 2022, and in 2023, alone accounting for over half of all global solar installations. The next two biggest markets are the US - with approximately 78 GW added from 2021 to 2023, and India, with approximately 34 GW added in the period.

Increased solar deployment has been creating a virtuous cycle, with higher installation volumes driving down manufacturing and installation costs, which in turn stimulate further installations. Increased production capacity, coupled with high demand, has led to a reduction in solar panel costs worldwide—costing 15 cents per watt in China, 22 cents in India, 30 cents in Europe, and 40 cents in the USA. With falling solar prices, making solar the cheapest source of energy in many markets, more and more countries are leveraging the technology in their energy policies. According to Ember, the number of gigawatt-scale solar markets grew to 28 countries in 2023, up from 21 in 2022, with most being in EU and other leading countries, but also including a few countries from Middle East and Latin America.

The challenge of demand being much below potential in developing economies in Africa and other regions, largely due to lack of policy certainty and the resulting issue of inadequate signals being provided to the local private sector and investors, was highlighted. Policy interventions are crucial in harnessing the potential of the solar industry, particularly in achieving net-zero targets. National and international policies and regulatory frameworks have significantly driven the industry's recentt exponential growth by establishing long-term solar capacity goals and fostering a stable investment climate that encourages expansion across the solar value chain. Ambitious policies have catalyzed success; however, the absence of specific solar deployment targets complicates the creation of a clear growth roadmap, hindering industry progression.

Additionally, it was observed that most regions are experiencing higher growth in utility-scale solar projects compared to small and medium-scale projects, and the need for an active policy intervention to raise demand for small-scale projects was advocated. This brings to the forefront the need to design sectoral policy frameworks and regulations, including building capacities of policymakers and regulators, for driving demand for clean energy through applications such as solar mini-grids, solar rooftops, solar pumps, solar cold chains, solar powered EV charging infrastructure, agri-PV, etc.

3.1.3. Standardizing and enhancing workforce skills for solar

The renewable energy sector faces a significant skills mismatch, exacerbated by insufficient funding available for training workers, poor information dissemination, and narrow national development initiatives. Small and medium-sized enterprises (SMEs), who form the bulk of the industry in developing countries, struggle to provide tailored in-house training, unlike larger organizations that can align their staff's technical skills with specific needs. With the increasing ramping of solar manufacturing capacity and installations, the lack of trained labor for solar PV manufacturing, and lack of requisite technical skills and experience in installing solar PV, were cited as a challenge across the various discussions.

According to International Renewable Energy Agency (IRENA), solar PV is the fastest-growing sector in terms of employment. It currently employs about one-third of the workforce in renewable energy and has significant potential for further growth. The NZIA recognizes that a substantial skilled workforce is essential for manufacturing net-zero technologies. The Act is introducing Net-Zero Industry Academies, which will create educational content for training providers across EU countries and develop credentials that enhance the mobility of learners and ensure the transferability of qualifications across regulated professions. It is estimated that by 2025, Europe will have more than a million solar workers, but the difficulty is determining the specific areas of the skill gaps and filling them in order to guarantee that every solar worker receives the requisite skill transfer.

In other regions too, the need for skilled workers and measures to develop this workforce is recognized. Africa is predicted to have an exponential increase in jobs in the sector, with North Africa having the potential to generate employment for 2.7 million in clean energy, including solar. The implementation of India's net-zero goals has resulted in a notable increase in job opportunities and demand for skilled workers in the solar power industry. However, it has also brought to light a clear shortage of candidates possessing the requisite technical skills and experience, which could potentially impede the expansion of solar projects. To fill this gap, India's Skill Council for Green Jobs, India, estimates to skill 1 million workers by 2030 and 10 million by 2047. Also, Australia's renewable energy sector is predicted to need an extra 85,000 workers by 2030, of these around 40% will be in high-value skill jobs that demand advanced degrees.

3.2. Technology

Solar PV stands at the forefront of renewable energy innovations, emerging as the most economically viable option due to continuous advancements that have significantly reduced cell production costs.

As the industry aims to meet ambitious global clean energy targets, collaboration across various sectors is crucial. This includes leveraging advancements in highly efficient, non-critical material-based cells like perovskite, and enhancing energy storage solutions to manage the intermittent nature of solar power. Both industry-academia partnerships and robust government policies – backed by financial support and cross-border collaborations, play critical roles in fostering these technological advancements, ensuring solar power's competitive edge against traditional energy sources globally.

3.2.1. R&D support for developing technologies for enhancing solar supply chains

The solar industry is at a pivotal juncture with ambitious deployment targets and surging demand, however, challenges stemming from upstream manufacturing and key technologies are being concentrated in the hands of a few. In the case of technology, this concentration is evident with 92% of solar-related patents being registered by just three countries, between 2019 and 2022, hampering access for developing nations. Such concentration restricts access for developing economies, creating barriers to their entry into advanced solar manufacturing.

Further, according to the IEA, 45% of the global equipment for solar PV manufacturing is being imported from China which hosts the world's top 10 manufacturing equipment suppliers for Solar PV. Discussions highlighted that this situation puts the industry at high risk of supply chain bottlenecks and price vulnerability. Therefore, diversification of the manufacturing equipment production is a necessary step that we need to address on the way to diversify the supply chain. This effort requires international collaborations among nations for technology sharing, increased R&D initiatives, coordinated efforts among stakeholders, and supportive government policies.

R&D investment remains low in middle-income countries, with significant gaps in local parts of the supply chain that need more focus, and inadequate financial support continues to hinder academic research in photovoltaic (PV) technology. Economic fluctuations and inconsistent government policies further complicate access to funding, stymying growth despite active initiatives in countries such as Mexico, Turkey, Thailand, Chile, Argentina, India, and Brazil to boost solar technology advancements. Additionally, the market for innovative PV products remains limited, affecting the scalability of production facilities. The need for greater collaboration between research institutions and industry is evident, especially as technological advancement in low-income areas, such as Ethiopia, faces significant constraints due to resource shortages. This situation highlights the critical importance of establishing global partnerships to provide necessary support for nations struggling to advance in solar technology.

International collaboration is crucial for technology transfer and the deployment of efficient technologies. Entities like the Fraunhofer Solar Centre have made significant strides with various wafer technologies and concentrator photovoltaics achieving up to 30% efficiency. Similarly, technological advancements in the US and Japan are pushing the boundaries of solar capabilities, highlighting the importance of sustained global R&D efforts.

The private sector holds the potential to bridge this investment gap by funding innovative technology development and commercialization through partnerships and other forms of cooperation. Such efforts are essential for the global advancement of the solar sector, ensuring more equitable and widespread benefits from solar energy deployment.

3.2.2. Potential of scaling mini-grids deployment

In many developing, remote, and island regions, reliance on diesel generators or primitive sources is common. Transitioning to solar through decentralized grids, including micro and mini grids, presents a more cost-effective solution, reducing reliance on diesel and enhancing sustainability. Political leaders are prioritizing renewable energy developments to improve energy access and electrification rates, particularly in remote and underserved areas. Renewable energy sources offer decentralized, off-grid solutions to bridge the energy gap, and Africa is experiencing significant growth in renewable energy installations, with solar PV projects, wind farms, and small-scale hydropower installations becoming more common. Off-grid solar solutions, such as solar home systems and mini-grids, also play a vital role in electrifying rural communities.

The World Bank identifies these mini -grids as crucial for electrifying rural areas. Examples from Bangladesh, where community-based solar grids have transformed rural electrification, and from Puerto Rico and Mexico, where government is deploying microgrids and battery systems to enhance resilience in disaster-prone areas, In Myanmar, mini-grids have become a vital source of electricity, especially as large power installations become non-operational due to political and economic disruptions. As of 2022, mini grids are set to bring power to 35 million more people, primarily in Sub-Saharan Africa, contributing significantly to global energy access, illustrating the transformative impact of tailored solar solutions. This aligns with the UN's seventh Sustainable Development Goal (SDG7) to ensure universal access to affordable, reliable, sustainable, and modern energy.

However, the expansion of these grids often faces hurdles due to their cost and design complexities, which can impede rapid scaling. The private sector can play a key role, if they are able to form feasible business models and channel finance efficiently to these small-scale projects.

3.2.3. Technology challenges with grid integration

Traditional power grids, designed for centralized and stable energy sources, face challenges adapting to the high penetration of variable and decentralized energy sources. As power demands surge due to the electrification of heating and transport sectors, grids require substantial enhancements including expansion, modernization, and digitalization. However, grid congestion is already delaying solar project developments in several countries. Moreover, the integration of solar PV with energy storage is becoming increasingly competitive, with battery storage poised to rival conventional power sources like coal in India and China, and gas in the US. However, the storage sector faces its own challenges, including high costs, limited duration, resource scarcity, and integration issues with existing grids. To meet COP28 goals and support Net Zero emissions pathways, battery capacity needs a sixfold increase by 2030, with countries like India requiring up to 300 GW of storage to ensure grid reliability and support renewable ambitions.

To address these challenges, promoting flexibility through hybrid solar projects, which couple solar with energy storage or other renewable sources like wind, is essential. This approach ensures a consistent power supply even when solar conditions are not optimal. Additionally, enhancing grid flexibility can involve integrating grid-connected devices like heat pumps and electric vehicles, and adjusting demand through initiatives like ‘time of use’ tariffs and ‘self-consumption’ schemes, shifting consumption to off-peak hours.

3.2.4. PV waste management programmes and technologies

As solar panels reach the end of their lifecycle, they pose a significant waste management challenge if not properly recycled. These panels contain hazardous materials such as cadmium, lead, and other toxic substances that, if improperly disposed of, can leach into soil and groundwater, causing severe environmental damage. Effective PV waste management is crucial not only for environmental protection but also for material recovery, and waste management in the solar industry hinges on achieving scale to ensure economic viability. PV recycling and its role in the circular economy were key topics at several Caucus roundtables. The goal is to meticulously separate valuable materials like silicon, silver, copper, and aluminium which can be reclaimed, while structural components and glass can be separated onsite and further processed at centralized facilities and also be infinitely recycled.

This approach not only supports a circular economy but also offers substantial economic benefits by reintroducing recovered materials into the production cycle.

In high-income countries like Germany, the Waste Electrical and Electronic Equipment (WEEE) Directive, mandates the recycling and recovery of photovoltaic waste. Similarly, Switzerland's Federal Act on Electrical and Electronic Equipment ensures efficient recycling practices. However, developing recycling systems in middle-income countries faces challenges due to high costs and less efficient processes, despite initiatives like Brazil's Green Procurement National Solid Waste Policy and India's combined efforts under the National Solar Mission and E-Waste Management Rules. These initiatives represent significant strides in managing PV waste sustainably, ensuring that the solar energy industry remains environmentally responsible as it expands.

However, in low-income nations such as Nigeria and Kenya, recycling infrastructure is minimal, hindered by financial and logistical constraints. Due to the required scale to make it feasible, countries cannot establish these standards independently, but must coordinate with other nations. Developing global manufacturing standards poses a significant challenge, but the private sector sees potential in such programmes, and requires government support to actualize them.

3.3. Financing

By the end of 2024, renewable energy investments are expected to reach USD 2 trillion, with solar PV accounting for USD 500 billion of this total. This significant increase, which has outpaced investments in fossil fuels since 2020, marks a decisive turn toward more sustainable sources of energy. Yet, this growth originates from a relatively low starting point and continues to bypass many Least Developed Countries (LDCs), with only about 15% of these investments projected to benefit Emerging Markets and Developing Economies (EMDEs) outside of China.

The challenge is compounded by a 10% annual decline since 2015 in the number of climate-responsive infrastructure projects funded by private capital in emerging markets—this at a time when a 30% annual increase is necessary to meet climate finance targets by 2030. Such financial inequity, exacerbated by escalating financing costs, critically hinders the development of EMDEs, despite the cost of solar PV declining markedly; IRENA notes an 80% reduction in global solar PV capital expenditures and an 88% decrease in the levelized cost of electricity from 2010 to 2021.

The concentration of global investment in renewable energy is also skewed, with over 70% channeled into just five countries: China, the United States, Germany, India, and the United Kingdom. While the shift toward low-carbon technologies is commendable, it is essential to ensure that increases in capacity are equitably distributed to truly globalize the benefits of renewable energy investments.

3.3.1. Need for public incentives for mobilizing private finance at scale for manufacturing

Establishing and expanding solar manufacturing units requires significant private capital, especially in the form of seed capital. This investment is essential for covering high initial costs, scaling production, addressing economic and environmental expenses, funding marketing efforts, and maximizing government incentives. Continuous financial commitment from private investors is crucial for the solar manufacturing sector to meet the rising global demand for renewable energy. Such investments will play a pivotal role in driving the transition towards a sustainable, low-carbon economy worldwide.

Government support and incentives play a critical role in attracting private capital to the solar manufacturing sector. The pivotal role of tax credits, low-interest long-term loans, and backing for domestically produced solar equipment has been acknowledged across the roundtable discussions. Such incentives not only make investments more attractive but also reduce risks and contribute to the formation of a stable and predictable market environment, which is essential for long-term planning and investments.

The discussions also underscored a significant gap in the current financing capacities required to meet the ambitious expansion goals of solar manufacturing in various countries. The United States, aiming for a solar manufacturing capacity of 50 GW per year by 2030, exemplifies the extensive capital needs for scaling up existing facilities and developing new ones. This expansion, a response to the growing demand, aims to become financially feasible on the back of favorable market conditions and the integration of advanced technologies, on attaining a certain scale. Furthermore, continuous improvements in solar panel efficiency and reduction in technology costs enhance the solar sector's appeal, making it increasingly attractive to private capital investments. Investors are particularly motivated by the opportunities arising from market expansion and the escalating demand for sustainable energy solutions. The solar manufacturing sector is thus well-placed for significant future growth and sustainability.

3.3.2. Barriers to accessing finance in LDCs

The solar sector faces significant financing challenges that impede its growth, especially in developing regions and Least Developed Countries (LDCs). These include a lack of concessional and risk-adjusted finance for small-scale projects, shortages of long-term financing options, and high financing costs. This issue was especially pronounced in the discussions with the African stakeholders. Addressing these financial barriers is crucial for ensuring equitable access to clean energy technologies; enabling LDCs to meet their energy needs sustainably; and supporting global efforts to combat climate change.

Small projects, in particular, struggle to attract funding due to perceived risks of non-payment or delays. Although global investment in renewables is on the rise, it remains markedly insufficient in LDCs where financial support, incentives, and tax credits are limited due to constrained budgets. These issues highlight the critical need for enhanced financial strategies to support the expansion of solar energy in less developed markets.

To mitigate financing challenges in solar projects, a combination of strategies can be effectively implemented, building on learnings from across the world. Public-Private Partnerships (PPPs) are essential as they allow public funds to attract private investment while spreading risk. Governments can bolster the sector by expanding incentives such as tax credits and subsidies, and by guaranteeing minimum prices for solar energy through purchasing agreements. However, in LDCs where governments themselves are under pressures due to constrained resources, there is a need for international organizations, investors, and private sector to work directly with the local private sector players to devise relevant channels and mechanisms for financing. For instance, the issuance of green and climate bonds provides a great avenue for raising capital by appealing to investors focused on environmental sustainability. Additionally, risk mitigation tools such as insurance, guarantees, and currency risk protection can lower the perceived investment risks. Structured finance solutions, including the securitization of solar assets, can enhance liquidity and attract a broader investor base.

Simultaneously, capacity-building within local financial institutions can increase their familiarity and comfort with financing renewable projects. Adaptable financing models, such as pay-as-you-go systems, can cater to regions with limited banking infrastructure, ensuring broader access to funding for solar projects. These diverse strategies, tailored to regional needs, are crucial for advancing global solar energy initiatives.

3.3.3. Need to tailor finance for smaller projects

Despite the exponential growth in global PV deployment and manufacturing, small-scale solar projects, especially residential and community-based systems, lag significantly behind utility-scale projects. The challenges for small-scale systems include difficulties in securing financing, lower attractiveness to investors due to complexity and lower profitability; and reluctance among EPC (Engineering, Procurement and Construction) contractors to implement or service these systems.

Debt financing through banks is often inefficient, with short financing terms and high costs arising from limited experience with renewable projects and inadequate risk analysis. Additionally, in developing countries, high initial costs and fears of non-repayment deter investment in off-grid and community projects. Even in the developed solar markets, including the USA, the residential and community solar sectors saw significant declines or lacklustre performance due to insufficient financial support for small projects, highlighting a global need for tailored financial mechanisms that support the scalability and sustainability of smaller solar initiatives.

3.4. Strategic Enablers

Future policies should not only aim at enhancing technological efficiencies but also at advancing energy storage solutions and supporting infrastructure, such as grids. This is especially pertinent in developing countries where traditional grid connections are often absent, and diesel generators prevail. Transitioning to solar energy offers making a strong-cost-effective alternative, making a strong case for the swift establishment of decentralized grids.

Policy measures are instrumental in providing a structured and favorable environment for solar energy's rapid deployment and long-term sustainability.. Targeted governmental actions can significantly influence the global energy landscape.

3.4.1. Incentives to signal policy support to solar

Incentives have played a crucial role in signalling government support and catalyzing stakeholder interest and accelerating the adoption of solar energy globally. Various mechanisms, such as direct subsidies, Feed-in Tariffs (FiT), Generation-based Incentives, and Investment Tax Credits, have significantly shaped the solar landscape. For instance, Germany's Renewable Energy Sources Act of 2000 introduced a FiT system guaranteeing fixed payments for solar electricity, helping it become a global leader in solar installations. The United States, meanwhile, leveraged the Investment Tax Credit to boost solar adoption nationwide.

China's mix of subsidies, tax incentives, and mandated renewable energy quotas has propelled it to the forefront of global solar production and installation and reduced the global cost of solar products. In India, incentives like FiTs, Renewable Energy Certificates, Renewable Purchase Obligation and Product Linked Incentives have helped in setting and meeting ambitious solar targets. These diverse incentive strategies effectively stimulate the solar sector, driving both national advancements and global market transformations.

3.4.2. Strengthening grid infrastructure development for RE integration

Developing of robust grid infrastructure and streamlining permitting processes is crucial for the timely deployment of renewable energy projects. Discussants highlighted issues such as inadequate grid expansion, inflexibility, and prolonged permitting processes, which have delayed project rollouts and contributed to inventory build-up. Simplifying grid expansion approval procedures is essential to efficiently evacuate power from renewable project sites. This necessitates urgent policy interventions. Even in the USA, project delays and cancellations are prevalent due to inadequate grid interconnections. Meanwhile, securing land parcels close to grid substations remains a significant challenge that impacts project feasibility and timelines. In regions like South Africa, the grid's original design for centralized coal power hinders the integration of solar projects, limiting the number of projects selected in renewable energy auctions.

An estimated 80 million km of grid must be refurbished or expanded by 2040 to achieve net-zero goals. Over 3 TW of renewable energy projects are queued for grid connections. The European Commission highlighted a need for €584 billion by 2030 for grid modernization to accommodate renewable installations. A comprehensive approach to enhancing grid infrastructure and expediting approvals is vital for supporting the fast-increasing volume of renewable energy projects globally.

3.4.3. Institutional frameworks for coordinating policy action and collaborations

Institutional arrangements play a critical role in supporting and expanding solar energy deployment. Effective institutional frameworks can significantly lower costs, improve efficiency, and drive adoption through strategic coordination and support.

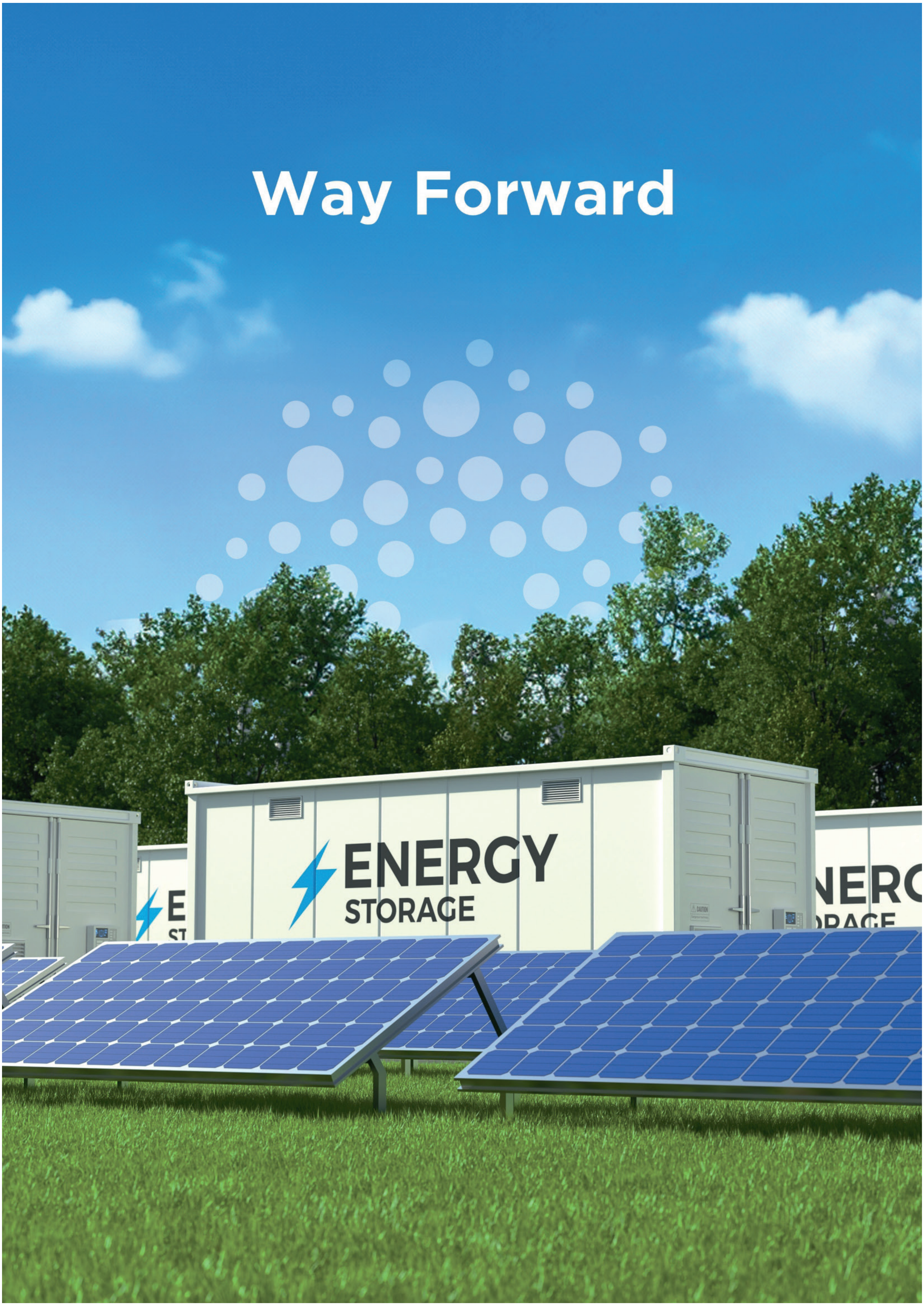
Countries leading in solar power have successfully leveraged robust institutional frameworks and established specialized agencies to champion their solar initiatives. For instance, India's Solar Energy Corporation of India (SECI), a public sector established in 2011 under the National Solar Mission to support the solar energy sector, oversees the implementation of several key government initiatives, including the Viability Gap Funding schemes for large-scale grid-connected projects, the solar park scheme, the grid-connected solar roof-top scheme, and turnkey solar project development for various PSUs. The Indian Renewable Energy Development Agency (IREDA), a specialized bank, plays a key role in financing renewable energy projects, including solar projects., The National Institute of Solar Energy (NISE) is a key player in promoting research and capacity- building. In the EU, Germany's Federal Network Agency has successfully integrated municipal utilities and local citizen energy cooperatives, enhancing decentralized solar adoption and making Germany a leader in solar energy penetration. Meanwhile, China's National Energy Administration coordinated efforts across multiple government agencies have established clear targets through Five-Year Plans and implemented supportive policies such as FiTs, subsidies and incentives to manufacturers. This has propelled China to the forefront of global solar production. In the USA, the National Renewable Energy Laboratory (NREL) serves as the central body for solar research and development, collaborating with universities and private companies to advance solar technology. This collaborative approach has positioned the US as a leader in solar innovation.

Strategic international partnerships that leverage strengths of partnering countries and are being supported by institutional set-ups in partnering countries, can promote regional advancements. For instance, the skill development initiatives by India's Waree Renewable Technologies and Australia's 5B industries, and skill development centers like the Skill Council for Green Jobs, bolster the solar sector by enhancing capacity and fostering global cooperation.

Many hubs have been established as central platforms for collaboration, innovation, and capacity building. A new hub is proposed with the participation of 15 African countries to support the establishment of decentralized solar grids. This initiative will leverage existing platforms such as the African Union, International Solar Alliance, and the Renewable Energy and Efficiency Partnership Action Plan, to drive action through the United Nations University's 2003 initiatives.

These institutional frameworks and collaborations underscore the importance of a well-orchestrated approach to solar energy deployment, There is potential for even greater advancements as new regions and partnerships are cultivated.

Way Forward



4. Way Forward

With the world facing a climate crisis, there is a critical need for a nuanced energy transition and a rapid transition to renewable energy. The International Energy Agency has forecasted that renewables and electrification could reduce 75% of energy-related CO2 emissions by mid-century and make the global Net-Zero goal more feasible. This target, essential for maintaining global temperatures within 1.5°C of pre-industrial levels as per the Paris Agreement, positions renewable energy, especially solar, as a critical component in the global energy landscape. However, disparities in development, energy access, climate risks, and financial resources pose significant challenges. Despite clean energy investments of over USD 2 trillion expected in 2024, political uncertainties and inadequate infrastructure impede progress and lead to, setbacks in global climate action. Disparities in energy access and financial flows further complicate the way forward.

As we look to the future, the path forward for renewable energy, particularly solar power, requires a concerted effort from both the private sector and governments. The private sector must continue to innovate and invest in the development of manufacturing capabilities, technological advancements, and financial solutions that are critical for scaling up of solar energy. Simultaneously, governments must enhance their role by enacting supportive policies, strengthening regulatory frameworks, and providing robust incentives that encourage investment and reduce the risks associated with renewable energy projects.

To accelerate global solar deployment, it is essential to recognize and address the unique energy landscapes of each region and the capabilities and the needs of their private sector. In high-income countries, there is an urgent need to transition to clean energy sources and retrofit existing systems with cleaner alternatives. This is critical for these nations to meet their ambitious targets of reducing emissions by 50% by 2030 and becoming net-zero by 2050. This in turn, calls for substantial investments in transition finance, energy storage technologies, and a focus on strengthening their value chains in the clean energy sector. Emerging economies, experiencing rapid energy consumption growth, present opportunities for local manufacturing, job creation, and scaling renewable energy.

Despite all this and a requirement of threefold increase in renewable capacity, attracting private financing continues to be a challenge due to higher risk perceptions. Low-income countries face even greater challenges as less than 50% of their populations have access to electricity. These countries require around USD 400 billion to finance their solar energy journey but receive only a fraction of this amount. High debt costs, ranging from 20-30%, and the absence of a domestic renewable energy supply chain further stifle progress. Small Island Developing States (SIDS) face an existential crisis, as they are heavily reliant on imported fossil fuels with exorbitant electricity costs. Solar energy presents a viable solution, but development costs in these regions are three times the global average per GW. Geographical constraints and grid inaccessibility complicate their transition. This necessitates tailored solutions, such as floating solar, solar-powered transportation, advanced storage systems, etc. These divergent realities underline the fact that the energy transition and the policy push for enabling it are not uniform across the globe.

Despite the supportive role of governments and the significant strides made by the private sector in driving advancements through research, development, and investment, accelerating solar deployment remains a formidable challenge. The solar industry, while expanding, faces persistent obstacles such as technological limitations, financial barriers, and regulatory complexities, especially in developing economies. This pathway document advocates for robust collaboration between public and private sectors. It presents issues that need stakeholder action across governments, industries, and international bodies, and it suggests a way forward for developing a detailed roadmap on priority areas. It aims to streamline efforts, provide actionable strategies to enhance solar energy adoption, and ensure that it occupies a central position in the global shift towards sustainable energy. This concerted approach is vital for overcoming the uneven adoption of solar technology and achieving the ambitious environmental goals laid down globally.

4.1. Cross-sectoral policy support for unlocking the solar potential in low-income countries

To drive demand for solar energy in low-income countries, adopting and adapting successful policy interventions is crucial. These interventions can significantly enhance the landscape for private investment and technology transfer, both of which are essential for scaling up solar deployment.

In low-income economies, challenges such as limited access to finance, high capital costs, and technological barriers significantly hinder solar expansion. Tailored policies that specifically address these obstacles are needed to create an environment conducive to solar growth. Emerging economies like India and Brazil have demonstrated the effectiveness of robust policy interventions in strengthening their solar sectors. India's Production Linked Incentive (PLI) scheme, for instance, aims to build local solar PV manufacturing capacity and reduce import dependence. The PM Surya Ghar initiative, with its ambitious targets for rooftop solar, has driven demand in the residential sector. Similarly, Brazil's focus on financing solar deployment offers a model for policy-driven expansion in renewable energy. These examples illustrate the power of targeted measures in catalyzing the solar industry's growth and offer valuable lessons for other developing nations.

Generating local demand can lower transport and logistics costs, reduce investment risks by securing future sales, and maximize the benefits of local content regulations. However, developing economies face significant challenges in generating demand due to high upfront costs, limited access to financing, technical hurdles, and inadequate maintenance services.

As solar technologies expand beyond traditional applications, cross-departmental collaboration within governments becomes increasingly important. For example, the rise of agrivoltaics presents opportunities for integrating solar power with agriculture, thus offering additional income streams for farmers and promoting cleaner alternatives to fossil fuel-powered irrigation. To capitalize on these opportunities, it is essential for the Departments of Agriculture, Energy, and Environment to work together in assessing gaps and creating policies that support solar solutions tailored to various sectors. Integration with the Ministries of Urban Development, Transportation, and Housing can further extend the reach of solar initiatives by embedding solar adoption into developmental initiatives such as urban planning, residential projects, clean transport, etc.

4.2. Building institutional frameworks and regulatory transparency

To accelerate the deployment of solar projects, robust institutional frameworks are essential for coordinating efforts, engaging the private sector, and fostering partnerships within the solar industry. These institutions act as hubs for knowledge sharing, best practices, and technical capacity building, thereby enhancing the overall efficiency and effectiveness of solar energy initiatives. High-income and emerging economies have benefited from such institutional mechanisms, which have been instrumental in generating demand, mobilizing investments, and compiling data from implemented projects. This support has been vital for both the public and private sectors. As these countries seek to further strengthen their supply chains, manufacturing capabilities, and spur technological innovations, a reassessment of the types of institutions required at this stage, becomes necessary. For low-income countries, adopting best practices in establishing these institutional arrangements could significantly bolster private sector growth and solar energy deployment.

Transparent regulatory mechanisms are also critical for boosting investor confidence and streamlining project development. A clear and consistent regulatory environment reduces uncertainties and lowers barriers to entry for private sector participants. While emerging economies have made progress in developing favourable regulations, developing countries still face challenges due to less established regulatory frameworks and limited awareness among relevant stakeholders.

To address these challenges, creating centralized virtual platforms that consolidate all relevant regulations, guidelines, and incentives can be a valuable resource for stakeholders. A one-stop website would simplify navigation of the regulatory landscape, ensuring all parties have access to up-to-date information and can efficiently comply with necessary requirements. This approach would enhance transparency, support informed decision-making, and ultimately accelerate solar energy deployment.

4.3. Developing the workforce needed for solar energy growth in the future

As the world seeks to triple renewable energy capacity, the availability of skilled manpower has emerged as a critical challenge, particularly in regions like Africa. North Africa alone has the potential to create 2.7 million jobs in clean energy, yet this opportunity is threatened by a significant skills gap. Developing countries face the most pronounced challenges, with the demand for skilled workers in solar energy far outstripping the capacity of existing training programs. This skills deficit impacts the viability of solar projects, particularly in operations and maintenance, which are crucial for long-term success. The lack of required skills is a key issue in both high-income and emerging economies, which are anticipating a massive surge in green jobs.

Addressing this challenge requires a concerted effort to build capacity across the solar sector. Regular training sessions, supported by international institutions and partnerships between developed and developing countries, are essential. These sessions should cover topics such as Solar PV technology, equipment basics, system sizing, costing, installation, commissioning, and operations and maintenance.

Establishing specialized training centers, developing standardized certification programs, and training master trainers are crucial steps in formalizing and enhancing the skill sets needed in the solar industry. Additionally, creating a uniform set of skills recognized across regions is essential to ensure workforce flexibility and facilitate the seamless transfer of expertise. This approach not only strengthens the overall quality of the solar workforce but also enables workers to adapt and thrive in different markets, further supporting the global expansion of solar energy.

To achieve the scale of expansion needed in the solar industry, it is essential to establish domestic training programs such as Australia's Solar Accreditation (SAA), India's Suryamitra program, and the European Solar Academy. These programs can enable the development of a new, skilled workforce. Upskilling current energy professionals with technology-specific training can also be highly effective, leveraging their existing industry knowledge. Standardizing global training standards is crucial to ensure a workforce equipped with best practices, enhancing the quality and longevity of solar installations. Initiatives like the Solar Training Standards by the Global Solar Council and Global Wind Organization offer a model for aligning training across countries.

Thus, collaboration between countries, technical institutions, private sector actors, and industry leaders is vital. By leveraging industry associations, international organizations, and research institutions, standardized and cross-cutting curricula can be developed to align with industry needs, ensuring the private sector can meet the growing demand for skilled manpower in the solar industry across different regions.

4.4. Enhancing grid infrastructure for enabling Renewable Energy (RE) integration

The integration of renewable energy into existing grid infrastructure presents significant challenges, primarily due to the grid's need to accommodate the variability and intermittency of sources like solar and wind, which is hampering the growth potential of private sector in most markets. Traditional grids were designed for centralized, predictable power generation from fossil fuels and are often ill-equipped to handle the fluctuating supply and decentralized nature of RE. This creates issues related to grid stability and reliability. Additionally, unlike fossil fuel plants, RE sources are frequently located far from demand centres, requiring substantial investments in transmission infrastructure to efficiently transport energy.

To address these challenges, grid modernization and expansion are essential. This involves upgrading outdated equipment and constructing new transmission lines to connect remote renewable sources with demand centres. Coupled with these efforts, energy storage solutions such as large-scale battery systems and pumped hydro storage are crucial for balancing supply and demand by storing excess energy for use during periods of low generation.

The EU's Digitalization of Energy Action Plan and the USA's Grid Modernization Initiative offer models for global grid modernization. Additionally, advancing mini-grid technologies is crucial, as innovations in battery storage and grid management can make systems more efficient and cost-effective. Expanding community-based models, like Bangladesh's Solshare and India's solar mini-grids, ensures sustainability, engages local communities, and creates employment opportunities, making energy solutions more resilient and inclusive.

Advanced grid management technologies, such as smart grids and grid-scale inverters, are crucial for managing the variability of renewable energy, supported by real-time data analytics and automated controls. Additionally, decentralized energy resources like microgrids and distributed generation (e.g., rooftop solar) enhance grid resilience and reduce dependence on extensive transmission infrastructure. However, the private sector actors capable of developing these solutions often operate separately from large RE companies. Collaboration between these groups is essential to address challenges and co-develop effective solutions. Industry associations and public institutions can play a pivotal role in facilitating these interactions, fostering partnerships that drive innovation and strengthen the overall energy ecosystem.

Regulatory and market reforms are necessary to incentivize investments in grid infrastructure and to support renewable energy integration through new market mechanisms. Existing regulatory frameworks and market structures often fall short of what is needed for RE integration, necessitating updates that encourage grid modernization and support distributed generation. This will require active engagement from stakeholders such as utilities, transmission companies, sub-national governments, and infrastructure developers.

International collaboration is also critical. Cross-border grid connections and the development of global standards can enhance energy security and facilitate the sharing of renewable energy across regions. Finally, continuous research and innovation in grid technologies, along with pilot projects to test new approaches, are vital for ensuring a stable and sustainable energy future. Public-private partnership models can play a significant role in driving these innovations and implementing the necessary solutions to meet the demands of a renewable-powered world.

4.5. Multi-faceted approach to mobilize required investments

To effectively tackle the financing challenges in scaling solar energy, particularly in emerging and low-income countries, a comprehensive, multi-faceted approach is crucial. This strategy should focus on strengthening public-private partnerships (PPPs) to attract private capital while distributing investment risks. Expanding government incentives, such as tax credits, subsidies, and guaranteed pricing for solar energy, is essential to create a more favorable investment environment. However, given the limited resources and banking infrastructure in many Least Developed Countries (LDCs), international cooperation becomes indispensable. Global financial institutions, investors, and private sector players must collaborate closely with local stakeholders, especially local banks and financial institutions, to build their capacities and develop financing mechanisms tailored to regional needs.

For smaller projects, such as decentralized renewable energy (DRE), residential, and community-based systems, innovative financing models are critical. These projects often struggle to secure funding due to perceived risks and lower profitability. Approaches like pay-as-you-go systems and aggregated financing programs can attract investment by offering more flexible and scalable solutions. Capacity building within local financial institutions is also necessary to increase their comfort with financing DRE projects. Additionally, public sector institutions must be equipped to create a conducive investment environment for these initiatives.

Financing mechanisms like green bonds and climate bonds, which appeal to investors focused on environmental sustainability, are key to reducing perceived risks. Risk mitigation tools, including insurance, payment guarantees, and currency risk hedging, can further lower barriers to investment in these regions. Structured finance solutions, such as the securitization of solar assets, can enhance liquidity and attract a broader investor base, making solar investments more accessible and appealing.

Establishing dedicated technology and innovation funds in solar manufacturing can attract venture capital and private equity, supporting start-ups and projects that aim to improve manufacturing processes and reduce costs. The Breakthrough Energy Ventures fund, backed by prominent investors like Bill Gates, exemplifies the impact of funding innovative energy technologies, including advanced solar manufacturing. Additionally, governmental assistance through tax incentives and region-specific subsidies is crucial for developing any part of the complex solar value chain. To overcome financing challenges in small-scale and emerging markets, blended finance—integrating public and private capital—can mitigate financial risks and facilitate large-scale financing for clean energy transitions, ensuring that commercial entities can confidently invest in these markets.

In developed and high-income markets, access to capital, particularly at the scale required for financing large manufacturing facilities, remains a challenge. Revisiting and refining public-private partnership models for establishing these facilities could be a viable solution to explore.

4.6. Advancing ESG compliance and transparency in solar supply chains

Environmental, social, and governance (ESG) criteria are becoming increasingly important to investors in the solar supply chain, particularly in developed markets where stringent supply chain requirements are being introduced. Emerging markets are also beginning to recognize the importance of ESG compliance, as manufacturing hubs must meet these standards to access key markets in the EU and the US. This underscores the need to develop capacity and systems for ESG assessments of solar products, as well as to enhance supply chain transparency, including the required infrastructure and processes to facilitate this.

An example of a key initiative in this area is the Solar Stewardship Initiative (SSI), which has introduced a solar PV-specific Standard for ESG compliance. This Standard allows independent assessors to certify the ESG performance of solar production sites, validating the commitments of companies across the solar value chain, helping EU companies meet the regulatory requirements and transparency standards. Thus, the solar industry in high-income markets has started to pro-actively work towards improving transparency, traceability, and reducing its carbon footprint.

The next step is to extend these efforts to emerging markets by building local capacity and developing systems for ESG assessments. This includes providing training and resources to manufacturers in these regions, which will help them understand and implement the relevant ESG standards. Additionally, there should be a focus on creating robust frameworks for supply chain transparency and traceability that align with global best practices. It is also pivotal to take into account the country context and capabilities. Collaboration between industry stakeholders, governments, and international organizations will be crucial in achieving these goals and promoting sustainable practices across the global solar supply chain.

4.7. Forward-looking policies to lead and support the industry

As solar energy continues to grow at a pace that frequently surpasses projections, technological advancements and their adoption are outpacing existing policy frameworks. This underscores the urgent need to proactively identify areas where policy support and public sector-driven collaborations will soon be essential. Building forward-looking frameworks with sufficient flexibility is crucial to ensure that the solar industry is adequately supported and can sustain its rapid growth. Anticipating these needs and preparing adaptable policies will help the sector continue to thrive in an evolving landscape.

A critical area that requires forward-thinking is the minerals value chain, with critical minerals being essential for low-emission technologies like solar photovoltaics, wind turbines, and energy-storage batteries. This is an emerging bottleneck impacting manufacturers. The availability of critical minerals is limited, with extraction and processing concentrated in a few countries, leading to significant supply chain vulnerabilities, as the concentration of mineral resources in specific regions poses geopolitical risks, making reliant countries strategically vulnerable. This creates significant opportunities for mineral-rich regions like Australia and African nations. By establishing domestic refining units to convert these resources into high-value components for PV manufacturing, these regions can bolster their economies.

However, countries in Africa with critical mineral supplies, lack the capabilities, technologies and investment needed to process these. Regional partnerships and cooperation agreements could prove to be beneficial to manufacturers. Additionally, the lack of efficient recycling systems means most materials are lost at the end of a solar panel's lifecycle. Developing sustainable recycling processes and reducing dependence on virgin materials are essential for ensuring the long-term growth of solar energy.

For instance, by 2030, global decommissioned solar PV capacity is expected to reach 7 GW, surging to 200 GW by 2040, generating an estimated 400-600 kilotons of embodied materials by 2030 and 11-15 million tons by 2040. High-income countries have started establishing guidelines and mandates for recycling and recovering PV waste, while middle-income countries grapple with high costs and less efficient processes.

To address these impending issues, it's crucial to develop effective systems for recycling materials. This involves creating regulatory frameworks that define stakeholder responsibilities and encourage scalable business models. Standardization at the manufacturing level is also essential, as variations in material composition across countries complicate the creation of uniform recycling systems. Introducing a QR code system could be an immediate solution, allowing easy identification of material composition with a simple scan. International cooperation and investment in facilitating recycling technologies are vital to overcoming these challenges.

4.8. Supporting R&D for technological advances

The private sector has been instrumental in driving solar technology forward, resulting in significant gains in efficiency and affordability. Companies like First Solar, for instance, have pioneered the development of thin-film cadmium telluride panels, showcasing how private innovation can push the boundaries of photovoltaic (PV) technology. These advancements have made solar energy more viable across diverse regions, with solutions like floating solar systems enabling installations on water bodies in land-constrained areas such as Singapore. Additionally, solar energy storage has seen significant progress, with companies like Tesla and LG leading the charge. Their innovations in battery technology have mitigated the intermittent nature of solar power, ensuring more resilient and reliable grid integration.

The public sector can support and spur technological advancement by investing in R&D through a programmatic approach. For instance, Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) is spearheading initiatives to establish the country as a global leader in solar panel recycling. By focusing on research, development, and demonstration (RD&D) investments, CSIRO aims to develop mid-stream processing technologies for critical minerals like rare earths and silicon, which are essential for solar cells. The global adoption of such projects could significantly enhance the recovery of critical minerals from discarded PV components, embedding circular economy principles and advancing true decarbonization. To sustain and accelerate these technological advancements, several key areas require attention. Digital collaboration platforms that leverage AI and big data, as demonstrated by the Horizon EU Program, can enhance research efficiency and foster global participation, driving further innovation in the solar sector.

4.9. International collaboration for addressing barriers

International collaboration is vital to the global expansion and diversification of the solar industry. By establishing issue-focused and region-specific engagement platforms, the private sector can effectively navigate regulatory landscapes, secure critical investments, and expand into new markets. These platforms facilitate dialogue and cooperation among industry stakeholders, allowing them to collectively address challenges and engage with government bodies and public institutions. This collaborative approach fosters the exchange of best practices and technological advancements, driving growth and resilience in the solar industry.

A collaborative model, similar to Europe's Airbus consortium, offers a promising solution, which could serve as a blueprint for building regional expertise and capacity in the solar sector. The Airbus consortium started in 1967 as a joint partnership between France, Britain, and Germany, becoming a pioneer in the commercial aviation industry, thanks to its technological advances. Forming this consortium helped Airbus attract public and private investments, boost its competitiveness against the American aircraft industry, and embrace new business models. Airbus also became known for creating innovative aircraft through active collaboration with technology experts and engineers. By working together on specific supply chain components, nations can ensure an equitable distribution of resources and expertise, leading to the development of a robust global solar consortium. This approach would enable the identification and development of the most viable supply chain components in different regions, contributing to a resilient and diversified global manufacturing ecosystem.

Through these concerted efforts, the solar industry can bridge regional disparities, accelerate technological innovation, and build a sustainable, diversified manufacturing base that supports the global energy transition.

Annex I: List of Discussants

I. Inaugural Roundtable: Addressing Bottlenecks for Building the Global Solar Energy Sector | Virtual, June 6, 2024

1. Ms. Sonia Dunlop, CEO, Global Solar Council
2. Mr. Rajani Ranjan Rashmi, Distinguished Fellow, Former Special Secretary MOEFCC
3. Dr. Ashvini Kumar, Former MD, Solar Energy Corporation of India Limited (SECI)
4. Mr. Subrahmanyam Pulipaka, CEO, National Solar Energy Federation of India (NSEFI)
5. Dr. Praveer Sinha, CEO, Tata Power
6. Mr. Vikram Kapur, Group President, ReNew
7. Mr. Vineet Mittal, Chairman, Avaada
8. Mr. Ashok Kumar Sharma, Deputy MD and COO, SBI
9. Mr. Pankaj Sindwani, Chief Business Officer, Tata Capital
10. Mr. Sameer Gupta, Chairman & Managing Director, Jakson Group; CII Group on Renewable Energy and Manufacturing
11. Dr. Satyendra Kumar, Director & CTO, Rsolec
12. Mr. Sujoy Ghosh, Vice President & Country Managing Director, First Solar
13. Ms. Walburga Hemetsberger, CEO, Solar Power Europe
14. Mr. Piyush Mathur, Co-Founder, CBO, Odyssey Energy Solutions
15. Mr. Vineet Mittal, Director, Navitas Solar / FICCI Taskforce Lead
16. Mr. Harsh Baweja, Director Finance, REC Ltd.
17. Mr. Gaurav Sood, CEO, Sprng Energy (Shell)
18. Mr. Amit Paithankar, CEO, Waaree Energies Ltd
19. Mr. Ranjeet Mehta, Executive Director, PhD Chamber of Commerce
20. Mr Richie Merzian, International Director, Smart Energy Council
21. Dr. Tzu-Yar Liu, Chief Policy Officer of Green Energy & Environment Research Laboratories, ITRI
22. Ms. Maanikya Kamra, Assistant Director, FICCI
23. Ms. Jyoti Mukul, Chief of Energy, CII
24. Mr Amit Jain, Senior Energy Specialist, World Bank
25. Ms Priya Shankar, India Director - Climate and Environment Program, Bloomberg Philanthropies

II. Empowering Europe's Solar Future: A Roadmap to Diversify, Innovate, and Sustain | Brussels, Belgium, June 13, 2024

1. Keynote Address: Ms. Kadri Simson, European Commissioner for Energy
2. Mr. Gaetan Masson, CEO, Becquerel Institute
3. Ms. Anett Ludwig, Head of Supply Chains, Solar Power Europe
4. Ms. Anna-Maria Spyriouni, Head of EU Affairs, Climate Bonds Initiative
5. Mr. Sébastien Mahieu, Managing Director, Belga Solar
6. Mr. Anes Jusic, Senior Banker, EBRD
7. Mr. Michel Casselman, General Manager, PMV EU
8. Ms. Elisabeth Cremona, Energy and Climate Data Analyst at Ember, and EU Young Energy Ambassador at EUSEW
9. Mr. Abdallah Alshamali, Policy Director, Global Solar Council
10. Mr. Johan Lindahl, Secretary General, European Solar Manufacturing Council (ESMC)
11. Mr. Noam Boussidan, Manager Policy Engagement and Regional Action, World Economic Forum

III. Driving Solar Energy Revolution: Growth Insights for Global Impact | New York, USA, July 15, 2024

1. Ms. Riddhima Yadav, Vice President, Brookfield Asset Management
2. Ms. Caroline Abramo, CEO, Pana Low Carbon Economy Investments
3. Mr. Raphael Carty, Callida Energy and Professor, NYU Stern
4. Ms. Petal Gahlot, Permanent Mission of India to the UN
5. Mr. Chandrasekar Govindarajalu, Practice manager, ESMAP, World Bank
6. Dr. Stephen Hammer, CEO, The New York Climate Exchange
7. Mr. Andrew Kern, Vice President, Energy Markets, Bright Power
8. Mr. Binaya Pradhan, Consul General, India
9. Mr. Bill Sisson, Executive Director, North America, World Business Council for Sustainable Development
10. Mr. Richard Edelman, CEO, Edelman
11. Mr. Gurpreet Brar, Special Projects, Office of CEO, Edelman

IV. Energizing Africa: Accelerating Development with Solar | Africa (Virtual), August 5, 2024

1. Samson Tsegaye, Country Director, Ethiopian Solar Energy Foundation, Ethiopia
2. Uvie Ogono, Founder & CEO, Solynta Energy, Nigeria
3. Wessam El-Baz, Co-Founder & CEO, Nexus Analytica, Egypt
4. Damilola Asaleye, Co-Founder & COO, Ashdam SolarCo Ltd., Nigeria
5. Tinyan Ogiehor, Off Grid Lead, Power Africa, Nigeria
6. Ana Hadjuka, Founder & CEO, Africa GreenCo, Zambia
7. Abel Didier Tella, Director General, The Association of Power Utilities of Africa, Ivory Coast
8. Yinka Omorogbe, Founder, Etin Power, Nigeria
9. Adly Kafafy, VP-Africa & New Ventures, TAQA Arabia, Egypt
10. Isaiah Nyakusendwa, Founder & CEO, The Renewable Energy Association of Zimbabwe, Zimbabwe
11. Omolara Osiyemi, Director of Operations, Africa Solar Industry Association, Rwanda
12. Emma Laswai, Deputy Executive Secretary, Tanzania Renewable Energy Association, Tanzania
13. Henry Carr, Senior Policy Manager, CrossBoundary, Kenya
14. Ramy Moussa, Assistant Professor, American University in Cairo,Egypt
15. Johnstone Chikwanda, Energy Expert, Energy Forum Zambia
16. Knollis Delle, Assistant Research Officer, Commonwealth Secretariat
17. Bonani Seteni, Senior Manager, Energy Council of South Africa

V. Solar Innovation and Manufacturing Resilience: Paving the Way for Australia's Sustainable Future | Sydney, Australia, August 14, 2024

1. Keynote Address: Dr. S. Janakiraman, Consul General, Consulate General of India, Sydney
2. Oliver Hartley, Director, Bright Dimension
3. Scott Hamilton, Senior Advisor, Smart Energy Council
4. Glenn Morelli, Director and Owner, Tindo Solar
5. Manfred Fahr, Solar Portfolio Manager, Enel Green Power Australia
6. Tom Stapleton, Partnerships Manager, Agile Energy Group
7. Roshan Dharmasena, Head of Operations and Maintenance, Gentari Australia
8. Prof. Brett Hallen, ITP Renewables
9. Julian Kasby, Senior Development Manager, Spark Renewables
10. Rong Deng, Lecturer, UNSW
11. Iain Macgill, Associate Professor, UNSW
12. Con Hristodoulidis, Acting Chief Policy and Impact Officer, Clean Energy Council
13. Richard Corkish, Honorary Senior Lecturer, UNSW

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