SIDF

صندوق التنمية الصناعية السعودي

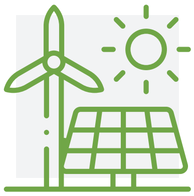
Market in Focus:
Solar Photovoltaics (PV)

December 2022

Contents

Key Highlights

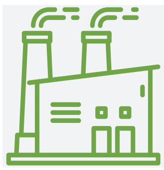
Global climate change concerns and the Russian - Ukrainian War highlighted the need for energy security that is environmentally friendly.



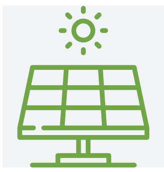
The share of renewable energy (RE) in the global energy mix is increasing yearly, with most capacity additions coming from solar photovoltaics (PV).

Saudi Arabia has set the most ambitious targets for RE in the MENA region through its National Renewable Energy Plan (NREP), aiming for 58.7 gigawatts (GW) by 2030, of which 40 GW will be solar PV.

Saudi Arabia has also set a national strategy to develop a local RE manufacturing ecosystem capable of exports.



Implementation of both NREP and local manufacturing has already begun.



There are investment opportunities at various points in the solar PV value chain which depend on global needs rather than local market demand.

The Global Picture

Decarbonization and the Green Energy Transition

At the 25th United Nations Climate Change Conference of the Parties (COP25) in December 2015, 196 countries adopted the Paris Agreement: a legally binding international treaty on climate change whose goal was to limit global warming to well below 2°C compared to pre-industrial levels and preferably to 1.5°C.
The 26th Conference (COP26) held in 2021 in Glasgow, UK, secured near-global net zero pledges, nationally determined contributions (NDCs) from 153 countries covering 80% of global greenhouse gas (GHG) emissions, urgent strengthening of targets, and accelerated action on coal, deforestation, electric vehicles, and methane.
Global emissions peaked in 2019, followed by an unprecedented 6% drop in 2020 due to COVID-19. Emissions are now rising sharply again and will grow for the next three years before starting to decline.

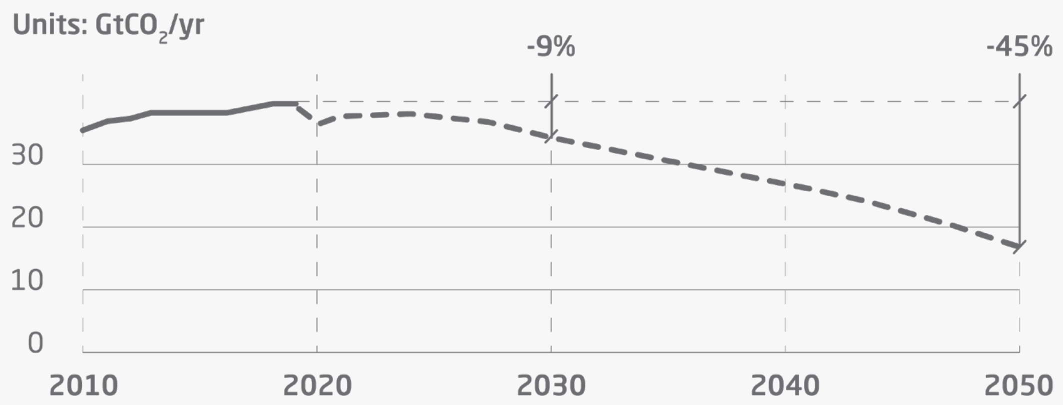


Figure 1: World Energy-Related CO2 Emissions [1]

the Russian Ukrainian war in 2022 has caused global energy prices to spike from the resulting supply disruptions. This has emphasized the need for energy security and the extent to which certain countries have become overly dependent on unreliable energy providers.

Global Demand - Renewable Energy Comes to the Fore

All the above factors have contributed to accelerating RE adoption. Since 2011, RE shares of installed electricity capacity and electricity generation have grown 53% and 40%, respectively, with solar PVs leading the way.

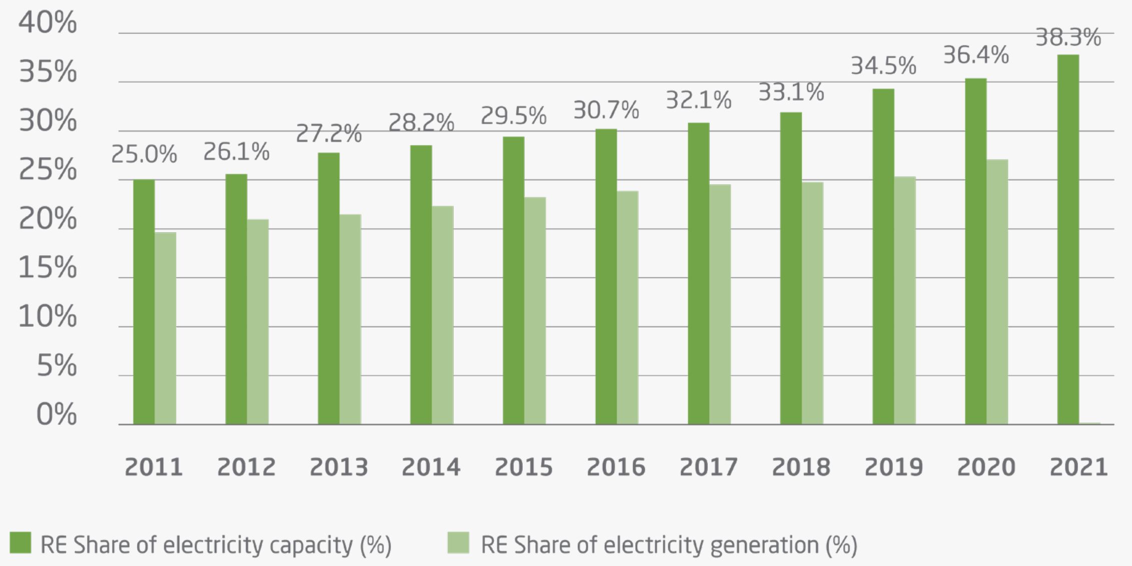


Figure 2: Global RE Share of Electrical Capacity and Generation [GW] [2]

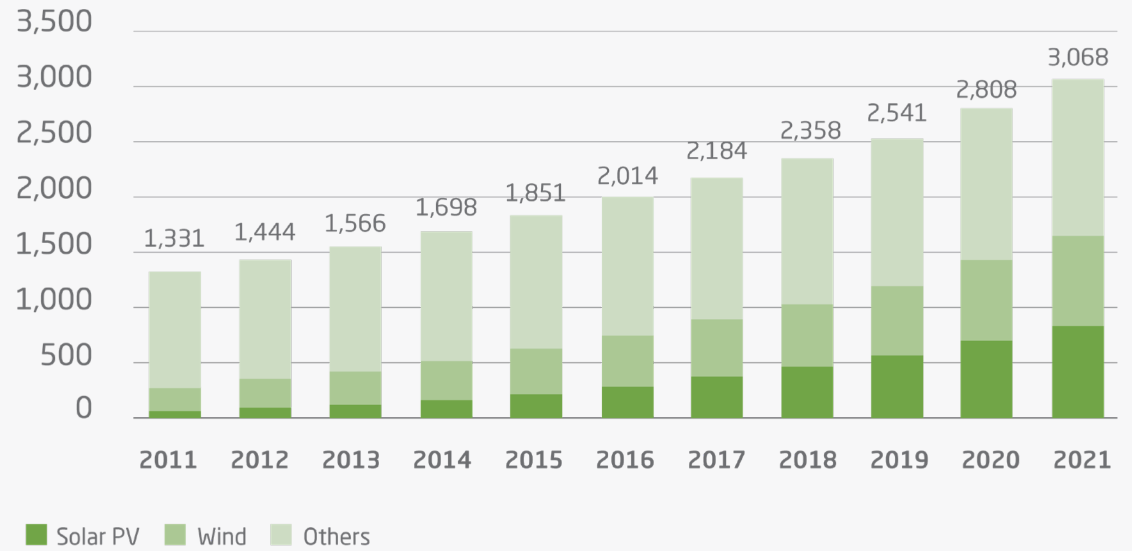


Figure 3: Cumulative Global RE Installed Capacity [GW] [3]

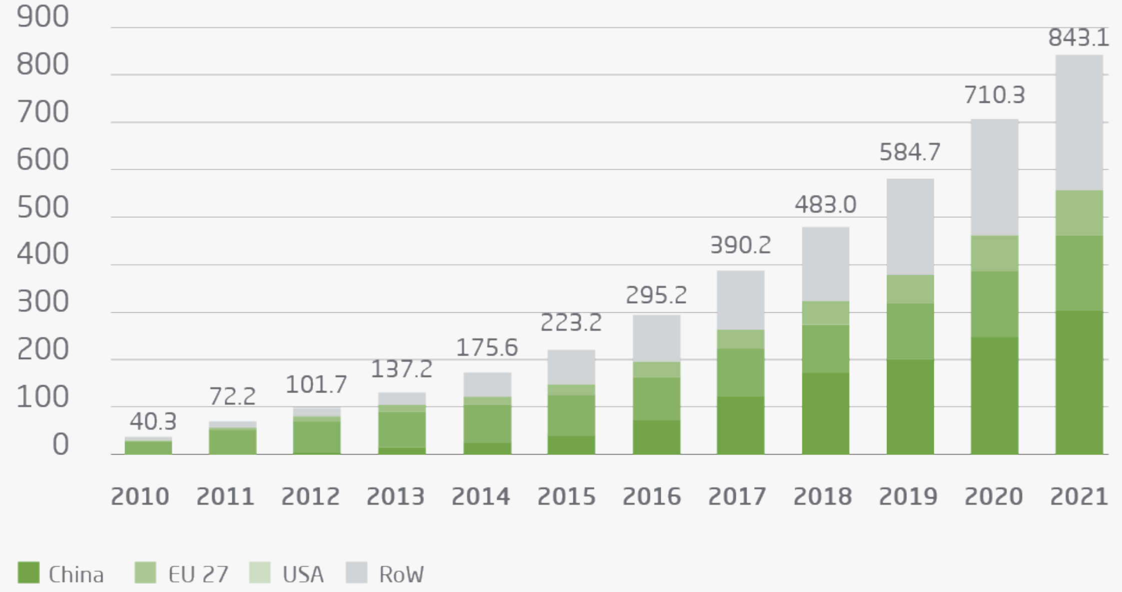


Figure 4: Cumulative Global PV Installations [GW] [4]

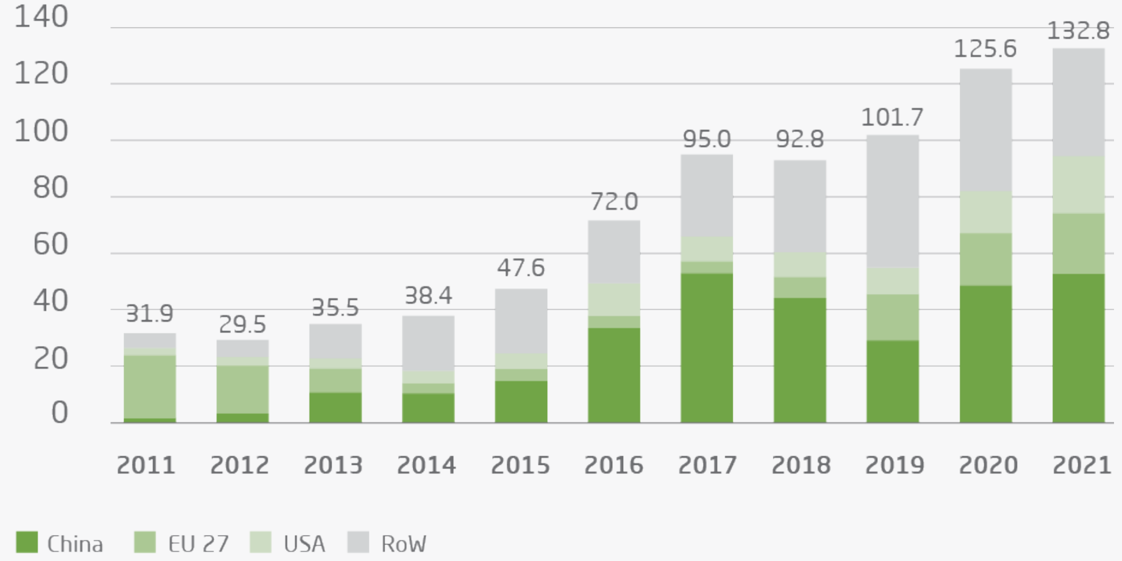


Figure 5: Annual Global PV Installations [GW] [5]

New PV installations have been growing at a CAGR of 15.3% since 2015. China accounts for 42% of global new installations since 2015. The 2018-2019 drop (Figure 5) was due to the transition to unsubsidized projects. From the rest of the world (RoW), India accounted for 6.9% of installations since 2015, and 7.8% (10.3 GW) of new installations in 2021 (Figures 4 and 5). New installations are projected to be 204-252 GW in 2022[6]. The top 10 markets are expected to install a further 1,085 GW between 2022 and 2026[7].

Global Supply - China maintains its lead, but Europe fights back

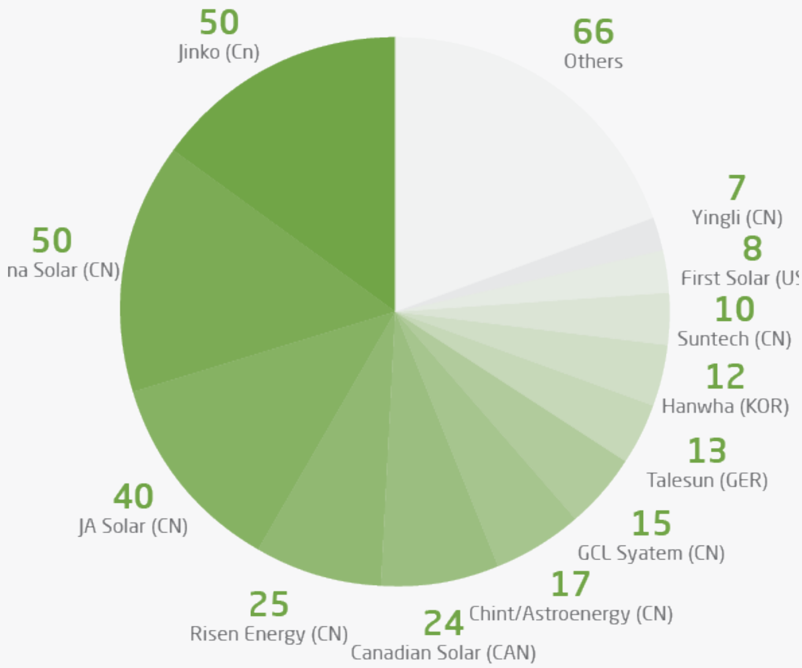


Figure 6: Tier 1 PV Module Manufacturer Capacity, Q2 2022 [GW/yr][8]

Today, China leads in module manufacturing, with its top 8 manufacturers accounting for 63% of global capacity. This lead has been in motion since the early 2000s when the Chinese government made a strategic decision to build up a local PV manufacturing industry. A strategic misstep by Germany, the previous global leader, helped cement China's advancement:

- From the mid-1990s to 2005, PV installations took off in Germany, driven by residential installations supported by the government through generous feed-in tariffs (FiTs).
- In 2004-2006, German manufacturing capacity became insufficient for the booming local demand, leading Germany to turn to China for supply, providing them with manufacturing equipment and know-how[9] . The Chinese government supported their industry through low-cost financing (debt and equity), cheap land, and control of the domestic market.
- From 2006-2011, China grew from 11% of global manufacturing to 45%, and their product quality improved drastically. This was achieved through large factories with economies of scale and extensive technology development.
- From 2011 onwards, China dominated manufacturing and became the largest installer and user of its PV modules. By investing heavily in R&D and backward integration into polysilicon production (the basic raw material of PV modules), its quality moved to "world-leading" while European manufacturing failed to keep up.

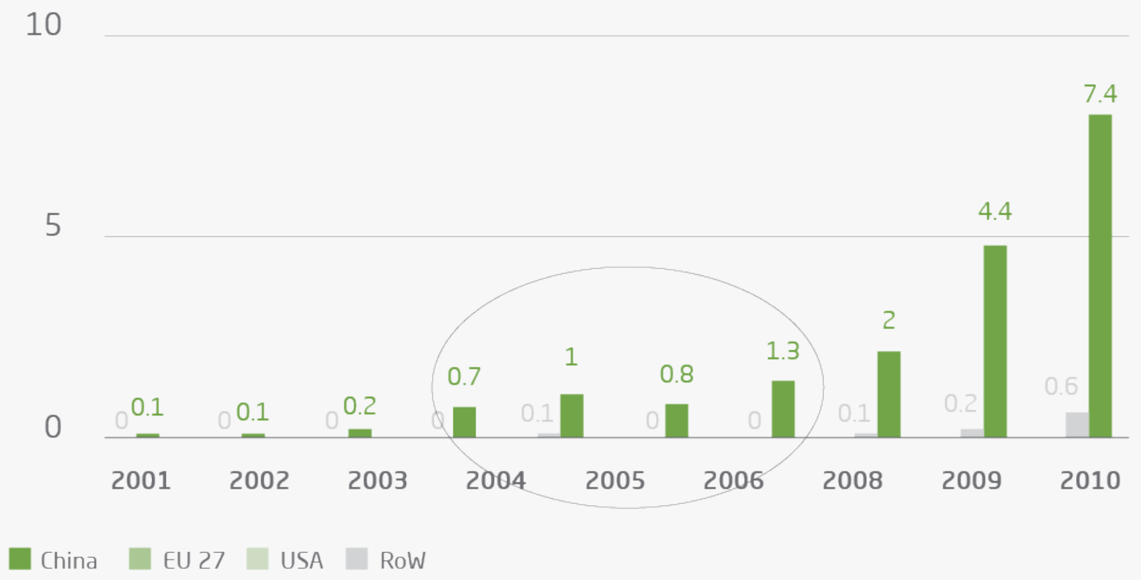


Figure 7: Annual PV Installations [GW] in Germany & China, 2001-2010[10]

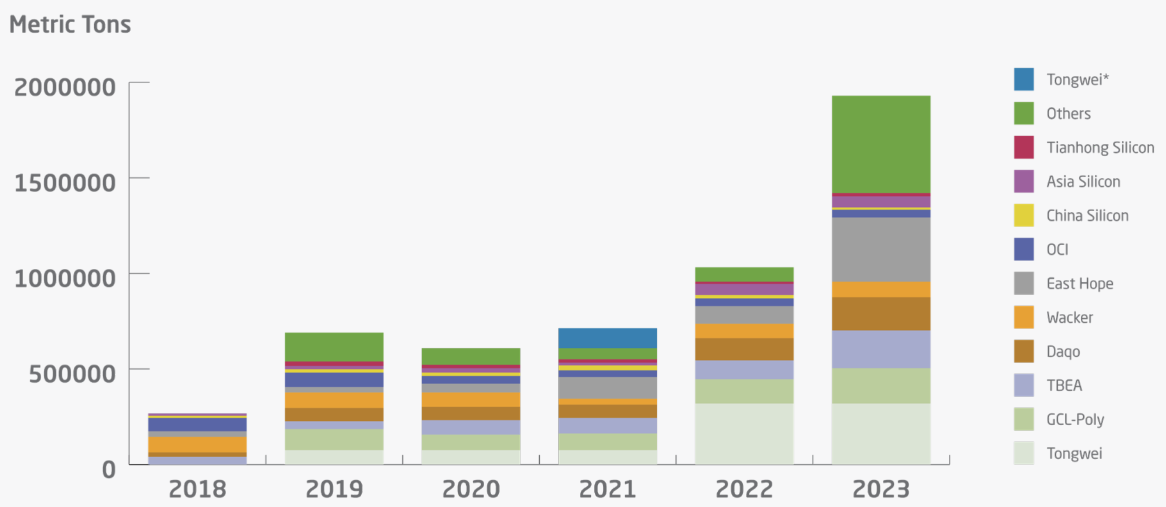


Figure 8: Global Polysilicon Capacity & Demand [m.t.][11]

During this time, the industry was characterized by price drops in polysilicon and modules due to technological advances in polysilicon production and solar cell architecture and to larger production capacities led by China. The latter affected the economies of scale and progress down the experience curve[12] for global manufacturers to enjoy. From 2011 to 2020, the annual price CAGRs of PV-grade polysilicon and solar modules were -19.5% and -15.3%, respectively.

Figure 9: PV-Grade Polysilicon Price[13]

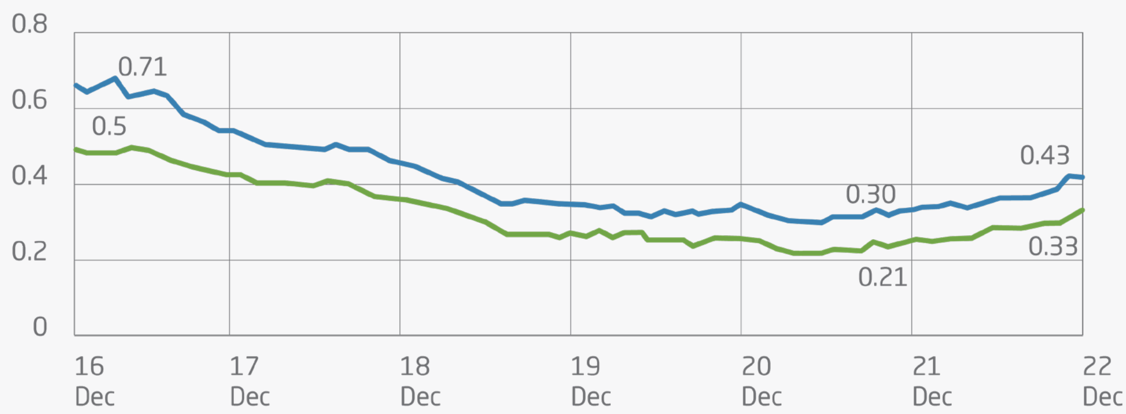


Figure 10: PV Module Spot Price (EU)[14]

However, in mid-2020, prices started to rise after several incidents at polysilicon manufacturing facilities, including a fire, a flood, and an explosion, which caused a drop in Chinese polysilicon production. The rising costs of raw materials (polysilicon & commodities) and transportation, the COVID-induced supply chain disruption, and China's increased use of their modules for their market (thus reducing export availability) have resulted in module prices rising to 2018 levels.

Rising prices and an increasing global desire to geographically diversify the solar module value chain have opened a window of opportunity for European manufacturers to reestablish a regional manufacturing ecosystem. The European Solar Initiative aims to scale up solar PV manufacturing capacity in Europe to 20 GW by 2025.

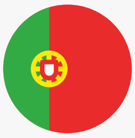
Company	Country	Status
Meyer Burger		Initiated 400MW cell / module capacity in 2021. Planning to expand to 1.4 GW cells / 1 GW modules in 2022. L-T target 5 GW.
Greenland Giga-Factory		5GW vertically integrated PERC module factory scheduled to start Q4 2023.
Enel Green Power		Heterojunction solar module factory in southern Italy will be scaled up from 200MW to 3GW by mid-2024.
MCPV		Planning a 300 MW fully integrated production line by mid-2022, and in total 15 GW for the future
REC		4 GW heterojunction module factory in France scheduled to start up in 2022.

Figure 11: Major European Manufacturing Projects[15]

Regional Trends & GCC Potential

General

In terms of ambition, Saudi Arabia is the leader in the GCC region, followed by the UAE, which already has 2.1 GW PV currently installed and a further 5.3 GW either under construction or under active development, expected to be commissioned by 2025

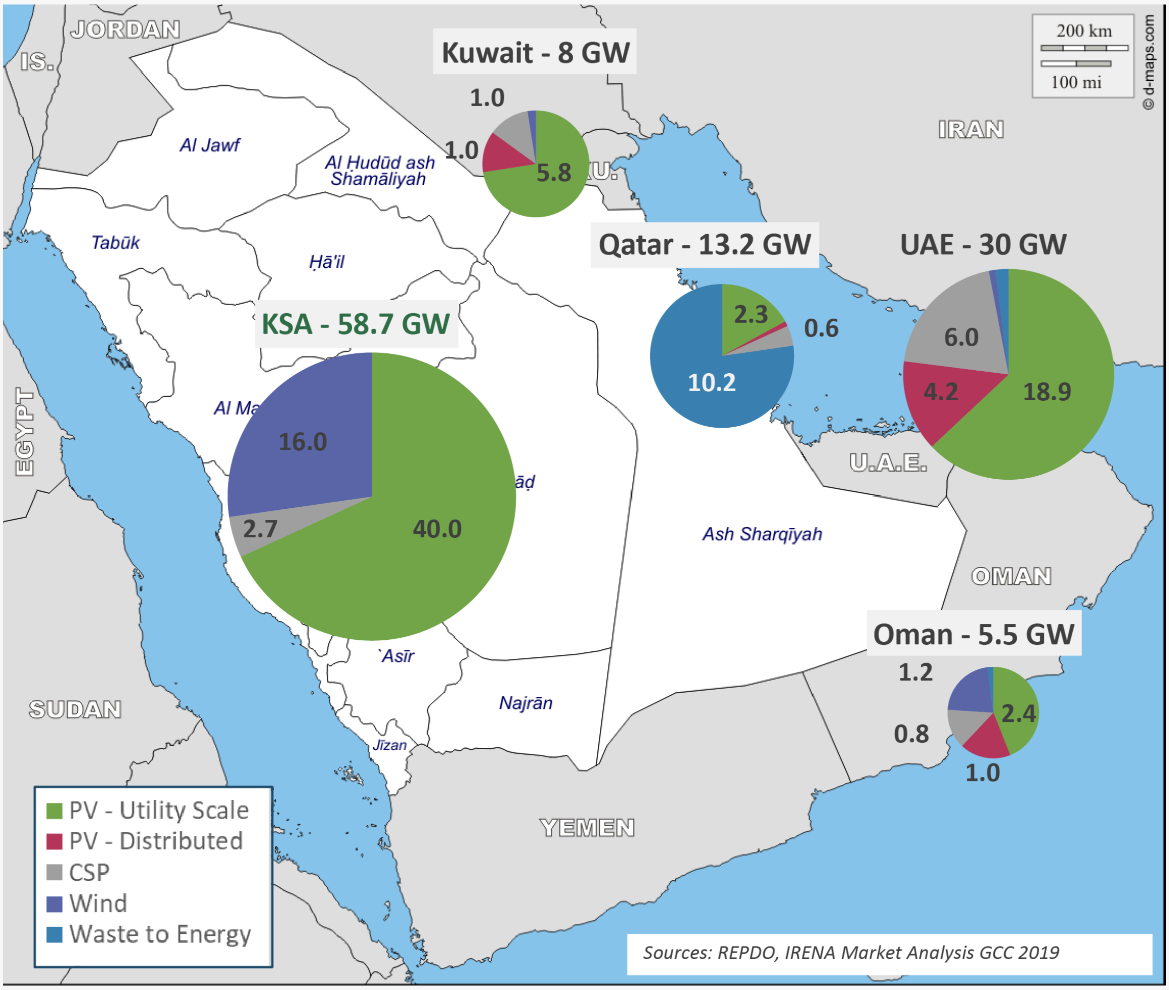


Figure 12: GCC 2030 Targets[16]

United Arab Emirates

The UAE has been at the forefront of the clean energy transition in the Gulf region in terms of PV deployment and ambitious renewable targets. The Emirates aims to generate 50% of its electricity from carbon-free sources, mainly solar PV, by 2050. Abu Dhabi, for instance, plans to install 5.6 GW of PV capacity by 2026, and Dubai aims to source 75% of its electricity generation from renewables by 2050.

Project	Location	Capacity [MW]	Winners	Tariff [¢/kWh]	Status
Noor Sweihan	Abu Dhabi	1,200	Marubeni, Jinko	2.94	Operational since 2019
Al Dhafra	Abu Dhabi	2,000	Masdar, EDF, Jinko	1.35	Completion expected by 2022
MBR-1	Dubai	13	First Solar	Undisclosed	Operational since 2013
MBR-2	Dubai	200	ACWA Power, TSK	5.84	Operational since 2017
MBR-3	Dubai	800	Masdar, EDF	2.99	Operational since 2020
MBR-4	Dubai	950 (700 MW CSP, 250 MW PV)	ACWA Power	2.4 (PV) 7.3 (CSP)	Completion expected by 2022
MBR-5	Dubai	900	ACWA Power	1.69	Completion expected by 2023 (1st 300 MW inaugurated in 2021)

Figure 13: Utility-scale PV projects in UAE

Oman

Oman aims to source 11% of electricity from renewables by 2023 and 30% by 2030. Even though it is one of the countries with the highest solar densities, in the region. Oman has only recently joined the solar PV world. Its installed capacity is expected to rapidly increase through bilateral agreements and solar tenders run by the Oman Power and Water Procurement Company (OPWP).

Oman's first utility-scale PV project will be the 500 MW Ibri II PV plant. This project is close to completion and is being developed on a build-own-operate (BOO) basis by ACWA Power (50%), Gulf Investment Corporation (40%), and Alternative Energy Projects Co. (10%) with a 15-year power purchase agreement (PPA) for an undisclosed amount.

Kuwait

Kuwait aims to have 15% of its installed electricity generation capacity from renewable sources by 2030. As with other countries in the region, PV development is dependent on the public sector.

Like Dubai's Mohammed bin Rashid Al Maktoum (MBR) Solar Park, Kuwait plans to install PV in the Shagaya Solar Park. The first phase of the park successfully deployed 70 MW of power generation capacity in 2012: 50 MW concentrated solar power (CSP), 10 MW PV, and 10 MW onshore wind.

The much larger second phase, the Al Dibdibah project, was initially set to comprise mostly CSP but was later changed to just PV. The first bids were received in 2019, but the tender was cancelled in 2020 due to the COVID-19 pandemic. The latest plan is to revive the project, but no official declaration has been made yet. Phase 3 with mixed technology, known as Al Abrag, is expected to be tendered in several packages. The anticipated capacity is 1,200 MW of PV, 200 MW of CSP and 100 MW of wind.

Kuwait is reviewing a plan to reduce government subsidies for electricity tariffs. It has independent institutional programs to encourage rooftop solar installation, which is now required on all government buildings, thus spurring a market for small-scale solar contracting.

Schemes and regulations for small-scale solar rooftops are under review, but their impact and uptake will be limited without tariff subsidy removal. The delay in the Kuwaiti solar market might end soon since the country is trying to meet its renewables targets and keep up with other GCC countries.

Vision 2030 and the National Renewable Energy Program (NREP)

According to the National Industrial Development & Logistics Program (NIDLP)—one of the enabling programs of Vision 2030—the strategy for the RE sector aims to:

- "Increase the contribution of RE to the energy mix through new projects and assessment of various sources and advanced technologies in the field of renewable energy,"
- "Create jobs and work opportunities in renewable energy by increasing local content and training and qualifying the workforce."

The revised NREP targets for installed RE capacity were announced in February 2019, and SIDF's mandate was expanded to become its financial enabler. NREP targets 58.7 GW of installed RE capacity by 2030, of which 40 GW will be solar PV, with an interim target of 20 GW by 2024.

There are no current plans for developing offshore wind or other RE technologies, even though the Saudi Geological Survey is investigating the Kingdom's geothermal potential, whether high temperature (>105°C) for power generation or low-to-medium temperature for district heating and cooling.

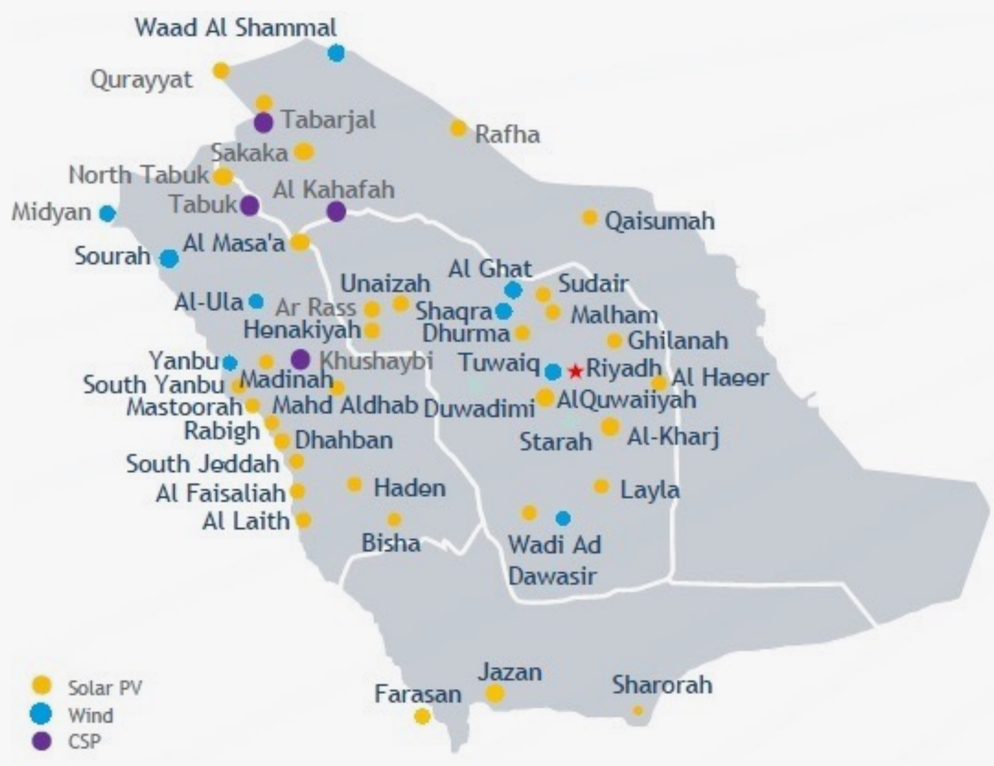


Figure 14: NREP Projects in KSA

The realization of these targets was originally split between the Renewable Energy Project Development Office (REPDO) within the Ministry of Energy (MoE) and the Public Investment Fund (PIF). REPDO was to develop 30% of this capacity, and the remaining 70% by PIF.

Projects fall into two categories: Group A (<150 MW), which targets local developers, and Group B (>150 MW), which targets international developers. The first three MoE rounds comprised a mix of Groups A and B. From Round 4 onwards, all future projects are expected to be Group B only since the smaller projects have resulted in overly high bids.

All projects are pre-developed (identifying and securing land, licensing, setting technical specifications, etc.) by the MoE. Then, they are either openly tendered by the MoE (bids based on the lowest levelized cost of electricity (LCOE) in hal/kWh and ownership of the plant lying with the developer) or passed on to PIF. The latter, along with ACWA Power as their primary developer of choice, would come to an agreed tariff approved by MoE and the Water and Energy Regulatory Agency (WERA). In both cases, the PPA is signed with the Saudi Power Procurement Company (SPPC), the "Principal Buyer," who would then monitor project implementation and operation.

Under a new process, all activity, from pre-development to tendering, will pass to SPPC, who will handle pre-bid clarifications, post-bid negotiations, bid evaluation, and sign the PPA. In September 2022, SPPC tendered two PV projects totaling 1.5 GW: 1,100 MW in Al Henakiyah and 400 MW in Tubarjal.

Non-NREP Utility-Scale Demand

In line with Vision 2030, the Saudi Green Initiative (SGI) was announced in 2021, along with the first wave of 60+ initiatives designed to meet SGI's targets, representing over SAR700 billion in investments[17] . The Kingdom plans to reduce its carbon emissions by over 278 MTPA by 2030, aiming to reach net zero by 2060.

An initiative under the SGI umbrella is the Saudi Telecom Company (STC) Solar Pilot Project, which aims to install solar power capacity across STC infrastructure by 2024.

Another initiative is the plan to run AlUla on 100% renewables from a solar PV plant and battery farm (1 GW of installed capacity) by 2035.

Finally, demand in NEOM in northwest KSA is expected to reach 6 GW of solar power by 2030.

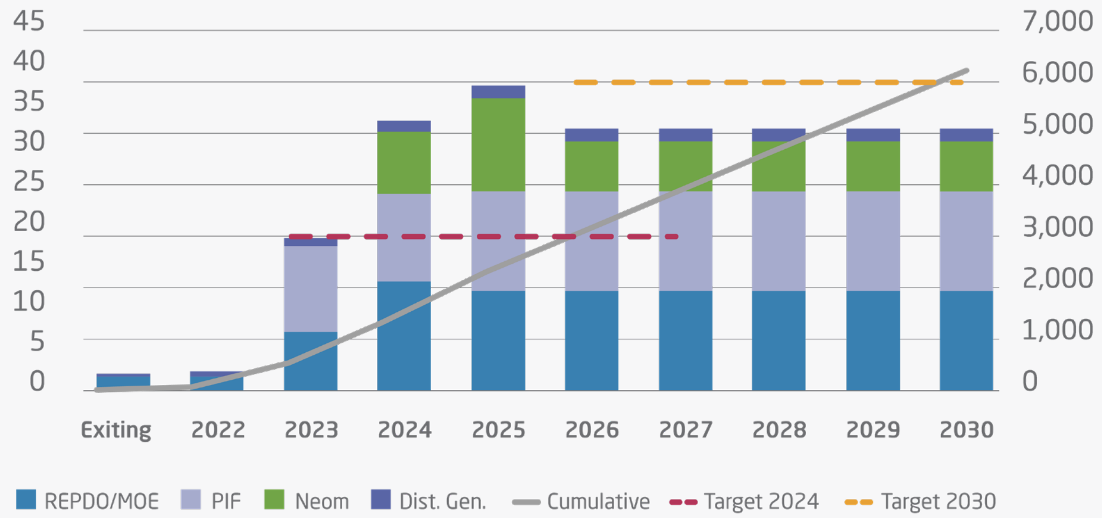


Figure 15: PV Projected Implementation[18]

Growing Demand: The Potential of Distributed Generation (DG)

Beyond NREP and the utility-scale requirements of the giga-projects, distributed generation, an alternative to centralized generation, has the potential to increase PV penetration and generate demand.

Figure 16: Potential DG Demand by Key Sector

In most other countries, DG adoption has been policy-driven since governments hoping to achieve rapid RE penetration have facilitated the sale of power to the grid, especially in the residential sector, at prices higher than the cost of buying grid electricity. Cost savings from self-consumption rather than power buying from the grid is another driver, as installation costs have fallen along with their LCOE. This was brought into focus during the last nine months as retail electricity prices have increased up to 10x in countries not enjoying energy autarky.

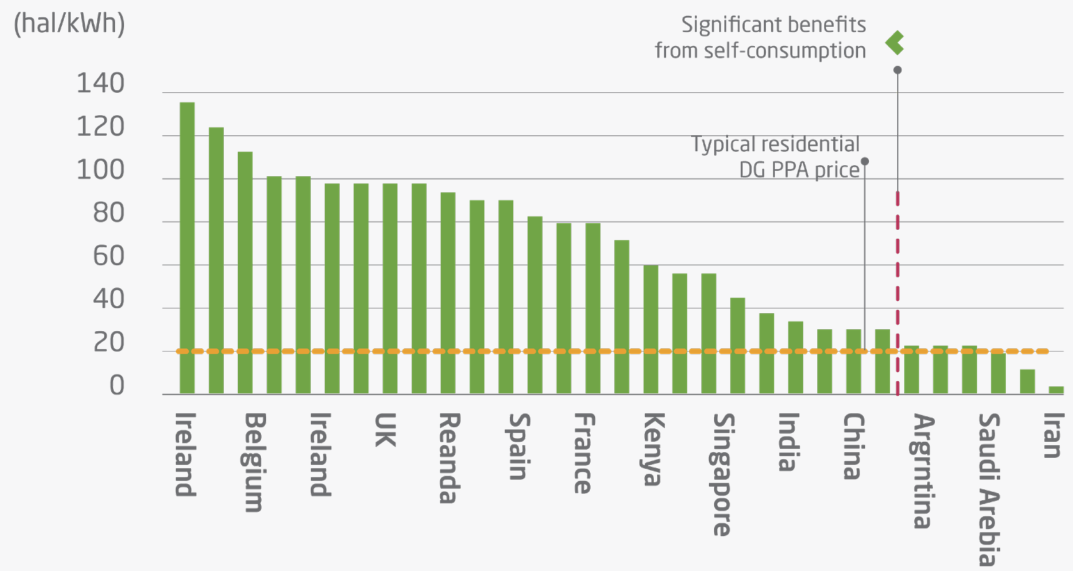


Figure 17: Average Residential Electricity Price, Sep. 2020 (pre-2021/2022 power crisis)

These residential schemes were also supported by the possibility of specialized financing from local commercial banks.

Opportunities in the Value Chain

Current Status

A few elements of the solar PV value chain are localized in the Kingdom. There are three module assemblers and one manufacturer of encapsulant:

Figure 18: Solar PV Value Chain

The growth of existing module assemblers in the Kingdom has been challenging due to the lack of clear project demand supported by local content requirements targeting high-value equipment. The lack of a track record to empirically prove quality, along with a higher cost base than that of Chinese imports - though the recent rise in freight costs has meant that there is minimal price disadvantage for the time being - adds further obstacles to the adoption of locally produced modules for utility-scale projects. The low rate of module production discourages the development of component producers. A game-changer will be the construction of PIF's long-announced giga-factory in partnership with a yet-to-be-named global leader. Assuming that the purpose of the plant is to supply PIF's projects, this will guarantee production and act as a magnet for component manufacturers.

However, in the small-scale DG segment, the willingness to use Saudi-made modules is much higher, and this is where the majority of local producers' sales come from.

As for utility-scale usage, the Sakaka PV plant[19] uses Jinko modules, while the S. Jeddah plant[20] , currently under construction, uses LONGi.

Investment Oppurtunities

European and US module manufacturers are keen to establish non Chinese value chains and reduce transportation costs. Although KSA does not yet have a significant manufacturing sector, buying the technology can move it to a leading position in some sectors, focusing on exports and leveraging its geographical proximity to Europe.

1. Solar Cells

The greatest value-add in the value chain is cell manufacturing. For assemblers, investing in in-house cell manufacturing adds value, but it's contingent on R&D expenditure and runs the risk of obsolescence. Focusing on assembly only makes the firm a price taker for the most important component. Silicon-based cell R&D focuses on incremental efficiency gains: material volume reduction and better architecture, like larger cell sizes, heterojunction, n-type, and half-cell. Disruptive change will come from new cell materials and technology, e.g., perovskites, thin-film, quantum dots, and organics. Currently, 1st generation technologies dominate the PV market with a growing shift to 2nd and 3rd generation technologies that offer higher efficiency, lower cost, or newer use cases:

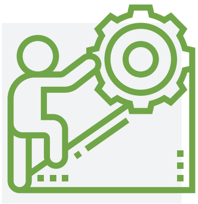
Key PV Technologies[21]			Brief Description	Efficiency[22]	TRL[23]	Key Players (selection)
0. Established Tech.	1st Gen. Wafer-based technologies	Monocrystalline silicon (m-Si)	■ Established technologies with low costs and high economies of scale (95% market share today) ■ Proven track records in a variety of utility-scale projects around the world ■ Efficiency levels are not expected to improve further	22%	9	JA Solar Q Cells Trina Solar Canadian Solar AE Solar Jinko Solar kalyon
1. Advanced Tech.		Polycrystalline silicon (p-Si)		17%	9	
		Passivated emitter & rear cell (PERC)	■ Key improvements in integrating a back-surface passivation layer at the back of the cell ■ Commercially available; considered as a new industry standard	24%	9	
	2nd Gen. Thin-film technologies (TFT)	Heterojunction (HJT)	■ HJT cells combine Si wafer between a-Si and TCO[24] layers ■ Perform well in hot climates	28%	9	Meyer Burger REC Panasonic
		Amorphous and micromorph Si cells	■ Based on non-toxic materials ■ Little silicon needed for production ■ Mostly used for indoor applications	14%	8	Kaneka Panasonic
2. Next Gen Tech		Cadmium Telluride (CdTe)	■ Most mature and largest market share of thin film tech. ■ Efficiency levels decline in use ■ Low-temp. production (cheaper than CIGS tech.)	22%	9	First Solar calyxo
		Copper Indium Gallium Diselenide (CIGS)	■ Requires complex stoichiometry and multiple production phases ■ Indium is a relatively rare element	23%	7	Solar Frontier AVANCIS manz
	3rd Gen. Emerging technologies	Organic thin-film	■ Printing promises lower manufacturing costs per Wp ■ Best performance at high temperatures ■ Shortest energy payback time of all solar tech. (3 months)	18%	6-7	Heliatek epishine OPV
		Organic glass	■ PV using conductive organic material for light absorption ■ Lower efficiency levels than organic PV film tech.	13%	5-6	H. GLASS
		Perovskite	■ Mineral absorbing light at high-efficiency levels ■ Crystals dissolve easily and need moisture protection	26%	4-5	Q Cells SwiftSolar

An investment possibility would be to establish a next-generation cell manufacturing plant with a focus on R&D and the acquisition of a 3rd generation leader to access required knowledge and capabilities and reduce time-to-market.
Disclaimer: The companies shown above are only there as examples of sector mapping purposes. Their inclusion in no way implies any recommendation, advice, or endorsement of any form by SIDF.

2. Solar Glass

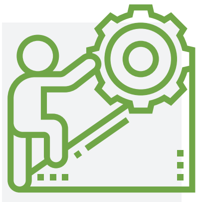
Solar (low-iron) glass is a type of high-clarity glass made from silica with very low amounts of iron. This low level of iron removes the greenish-blue tint that can be seen, especially on larger and thicker sizes of glass. Low-iron glass typically has a ferric oxide content of about 0.01%. Ordinary plate glass contains about 10x as much iron content.
This is a high-CapEx installation (possibly $500 Million for 200,000 Tons per annum capacity). However, with EU manufacturing demand projected to be 17-25 GW by 2025[25] and assuming 40 m.t./MW medium-term demand from Europe alone would be 680-1,000 KTPA. The increasing use of glass-glass bifacial modules could double this.
The competitive advantage of a local manufacturer would come from lower freight costs for the finished product and locally available raw material, low-iron silica. KSA has one mine, Muadinoon Mining Co., based in Tayma (NW KSA), with a 75 tph capacity.
Apart from Israel's Phoenix, there are no producers of low-iron float glass in the Middle East.

Challenges, Key Success Factors, and Enablers



Challenges

- No roadmap (published pipeline of specific projects) to realize NREP 2030 targets:
    - Creates the demand on which original equipment manufacturers (OEMs) can anchor a large-scale investment
- Restrictive regulatory environment for non-NREP projects, especially on-grid distributed generation. Such regulations are expected to be relaxed soon
- Low Grid tariffs for the residential and industrial segments mean that the financial incentive for DG self-consumption is low
- Bankability concerns stemming from lack of track record for local modules
- Higher cost base vs. international competition:
    - Utilities, labor, and environmental costs (China subsidizes)
    - Tariffs on solar PV components (even those where there is no local supply)
- Aggressive competition from imports:
    - Strategic Chinese government support to capture flagship projects
    - No tariffs on assembled modules
- Lack of public awareness of financial and environmental benefits of solar PV



Key Success Factors

Industry

- Establishment of stable, predictable local demand:
    - Clear project pipeline for NREP projects
    - Mandated installation of PV modules on houses, mosques, factories, etc.
- Reducing PV assembly manufacturing cost base
- Protection from cheap imports
- Imposing power-based (not just CapEx-based) local content requirements for NREP projects
- Availability of retail financing for DG installations
- Establishment of PIF Gigafactory. (Creates huge demand for components)

Company

- Selection of experienced, international technical partner to provide know-how and potentially export sales channel
- Product approvals from end users, where necessary
- Establishing partnerships with DG installers (for module producers)
- Complying with international quality standards and obtaining product certifications where appropriate:
    - For solar modules:
        - Compulsory: IEC 61215 & 61730
        - Market standard: IEC 61701
        - Recommended additional: IEC 62716 & 60068

Enablers

- Raw material availability (low-iron silica)
- Tax and labor regulation breaks depending on factory location
- Proximity to European and N. African markets
- Loans for IPPs from SIDF for manufacturers with up to 20 years repayment period, up to 75% of the project's cost, and up to 3 years grace period for repayments
- Availability and low cost of industrial land (Modon, KAEC, SPARK)
- New industrial developments targeting the RE sector: Oxagon (Neom Industrial City) and SPARK (Dammam)
- Low utility costs: electricity at $0.048 per kWh for the industrial sector and natural gas at $1.25 per MMBTU
- Saudi EXIM Bank provides financial products for export development

APPENDIX

Licensing procedure for all manufacturing projects:

1. Obtain Investment License from MISA.
2. Obtain Commercial License from Ministry of Commerce.
3. Sign land contract or building permit.
- Economic Cities & Special Zones Authority (ECZA)
- Saudi Authority for Industrial Cities and Technology Zones (MODON)
- Royal Commission for Jubail & Yanbu

4. Obtain final Industrial License (granted once plant is operational) from Ministry of Industry.
5. Obtain Environmental Operation License from General Authority of Meteorology and Environmental Protection

The Ministry of Industry and Mineral Resources, represented by the Industrial Agency, is responsible for issuing industrial licenses for all industrial activities. The investor uses the same valid license to start operation and production, provided that the conditions and standards are met, and the relevant procedures are followed. The Ministry issues a license for the factory, which remains valid for a renewable period of three years.

For Products Targeting NREP Projects and/or SIDF Financing
A letter of Endorsement from the Ministry of Energy:
- Submission of detailed technical feasibility and business plan.
- This ensures that the end products will be acceptable in NREP projects.

Stakeholders
- Ministry of Investments (MISA)
- Ministry of Energy
- Local Content Government Procurement Authority (LCGPA)
- National Industrial Development Clusters (NIDC)
- Water & Energy Regulatory Authority (WERA)
- Ministry of Industry & Mineral Resources
- Ministry of Municipal and Rural Affairs and Housing (MoMRAH)
- Ministry of Commerce
- Saudi Authority for Industrial Cities and Technology Zones (MODON)
- Royal Commission for Jubail & Yanbu
- General Authority of Meteorology and Environmental Protection

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4. BloombergNEF.
5. Exawatt
6. The experience curve, also known as Henderson's law, is an economic term which means that the more a firm produces of a particular good or service, the more it gains in efficiency. Thus, the cost of production decreases in proportion to the volume of products produced.
7. Bloomberg
8. PV Magazine
9. IRENA GCC Market Analysis (2019)
10. Saudi Green Initiative. (2022, July 6). Retrieved August 22, 2022.
11. SIDF estimates based on discussions with stakeholders
12. REPDO Round 1, 300 MW, Developer: ACWA Power
13. REPDO Round 2, 300 MW, Developer: Masdar (Mubadala)
14. Roland Berger
15. Cell efficiencies in lab conditions. Real-world efficiency depends on module composition, irradiance, shading, temperature, panel orientation, location, dust, dirt, and time of year.
16. Technological Readiness Level: 1 = Basic tech. principles observed, 5 = Technology validated in a relevant environment, and 9 = Actual system proven in an operational environment
17. A transparent, conductive oxide layer

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