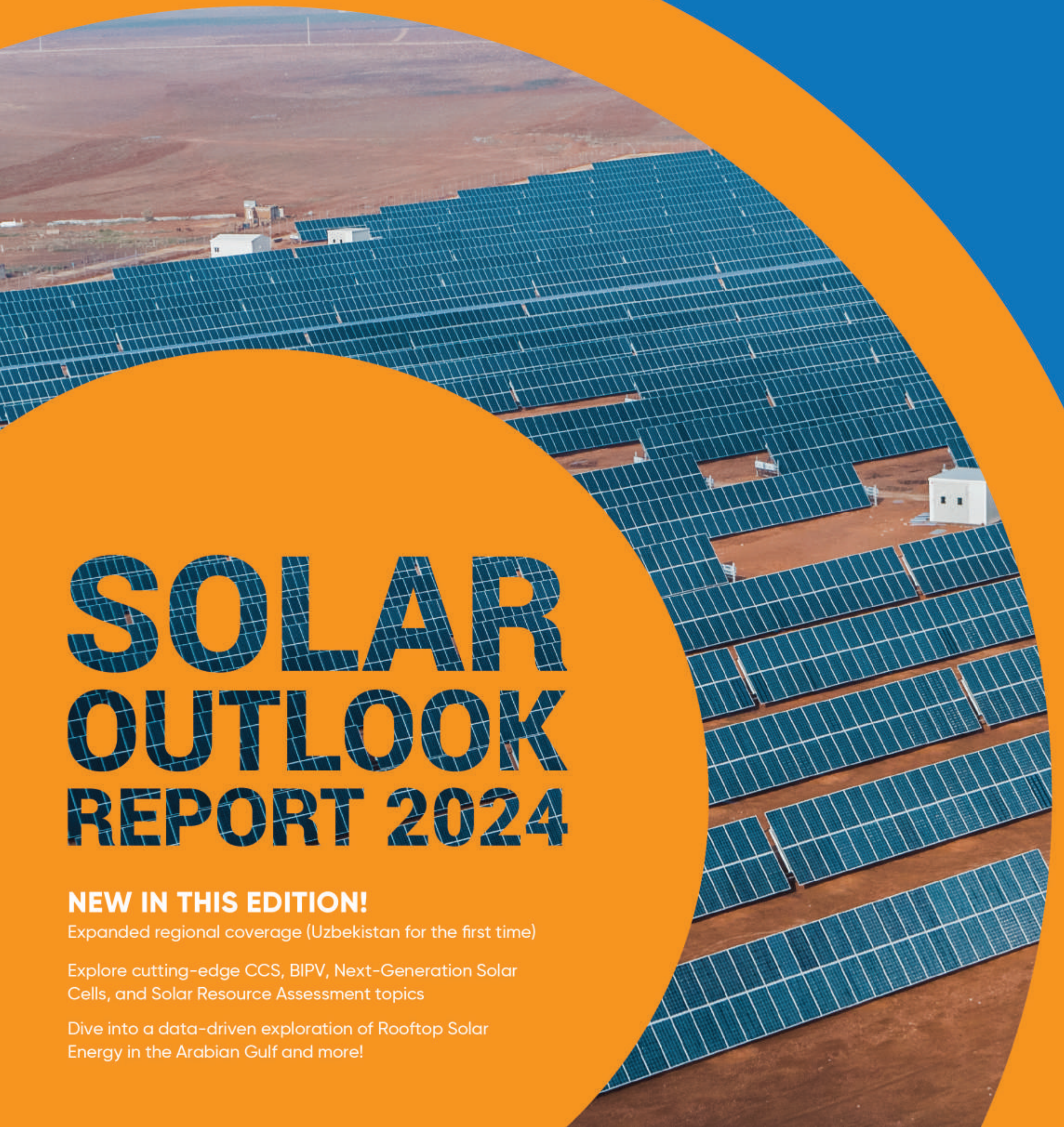
MESIA
جمعية الشرق الأوسط لصناعات الطاقة الشمسية
Middle East Solar Industry Association



SOLAR OUTLOOK REPORT 2024

NEW IN THIS EDITION!

Expanded regional coverage (Uzbekistan for the first time)

Explore cutting-edge CCS, BIPV, Next-Generation Solar Cells, and Solar Resource Assessment topics

Dive into a data-driven exploration of Rooftop Solar Energy in the Arabian Gulf and more!

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FOREWORD

The eagerly awaited COP28 (Conference of the Parties) convened in Dubai, UAE at the close of 2023, instilling a sense of optimism among global stakeholders committed to sustainability and renewable energy initiatives. Against this backdrop, it becomes imperative to assess the geopolitical dynamics of the Middle East and their impact on the adoption of renewable energy, shaping the broader energy landscape.

Endorsed by 37 countries, the UAE declaration on Hydrogen underscored the imperative for enhanced multilateral cooperation in addressing climate change and accelerating the global energy transition. Recognizing the pivotal role of renewable energy and low-carbon hydrogen technologies, the declaration highlighted their significance in meeting global energy needs and driving decarbonization efforts, all while fostering sustainable economic growth and green industrialization.

Similarly, the Global Renewables and Energy Efficiency pledge, supported by 124 countries, outlined ambitious targets for increasing renewable energy deployment and energy efficiency measures by 2030. However, amidst these aspirations lies the challenge of achieving such targets, particularly in the distributed energy sector within the Gulf region.

Looking ahead, a transformed energy mix holds the promise of creating new job opportunities, improving livelihoods, and empowering communities. Post-2030, a diversified portfolio of technologies is expected to be market-ready, offering scalable solutions to decarbonize the energy sector, with renewables, energy efficiency, and zero-emissions technologies playing pivotal roles.

The pressure to meet ambitious targets by 2030 places a strong emphasis on utility-scale projects, potentially overshadowing the needs of the commercial and industrial sectors. This underscores the importance of considering a balanced approach to energy deployment to ensure inclusive and sustainable development.

In this year's report, readers will delve into topics such as Solar Panel Performance Testing Methods, which ensure efficiency and reliability in challenging environments. Additionally, insights from our government partner, DEWA, shed light on commercially viable Perovskite Silicon Tandem Solar Cells and the integration of solar power into the grid, supported by regional-scale solar mapping and forecasting initiatives.

During COP28, Dubai unveiled ambitious clean energy initiatives aimed at enhancing domestic manufacturing competitiveness and fostering an industry-friendly policy environment. These initiatives, aligned with Dubai's Dubai Economic Agenda D33 plans for green economic development, reinforce the emirate's position as a global hub for exporters and manufacturers, enabling entities from manufacturers, data centers and agri-tech players to adopt captive solar generation to meet their energy demands.

As the MESIA Solar Outlook Report reaches its 11th edition, our commitment remains steadfast in providing valuable insights to our members, collaborators, and industry professionals. We extend our gratitude to this year's contributors, whose expertise drives innovation and progress in the solar energy sector. To our members and supporters, we express our heartfelt appreciation for your continued engagement and trust in MESIA, as we collectively shape the future of the Middle East's solar industry. We welcome new members to join us on this journey towards a sustainable and prosperous future.

HOW SOLAR PV IS SHAPING MENA'S ENERGY LANDSCAPE

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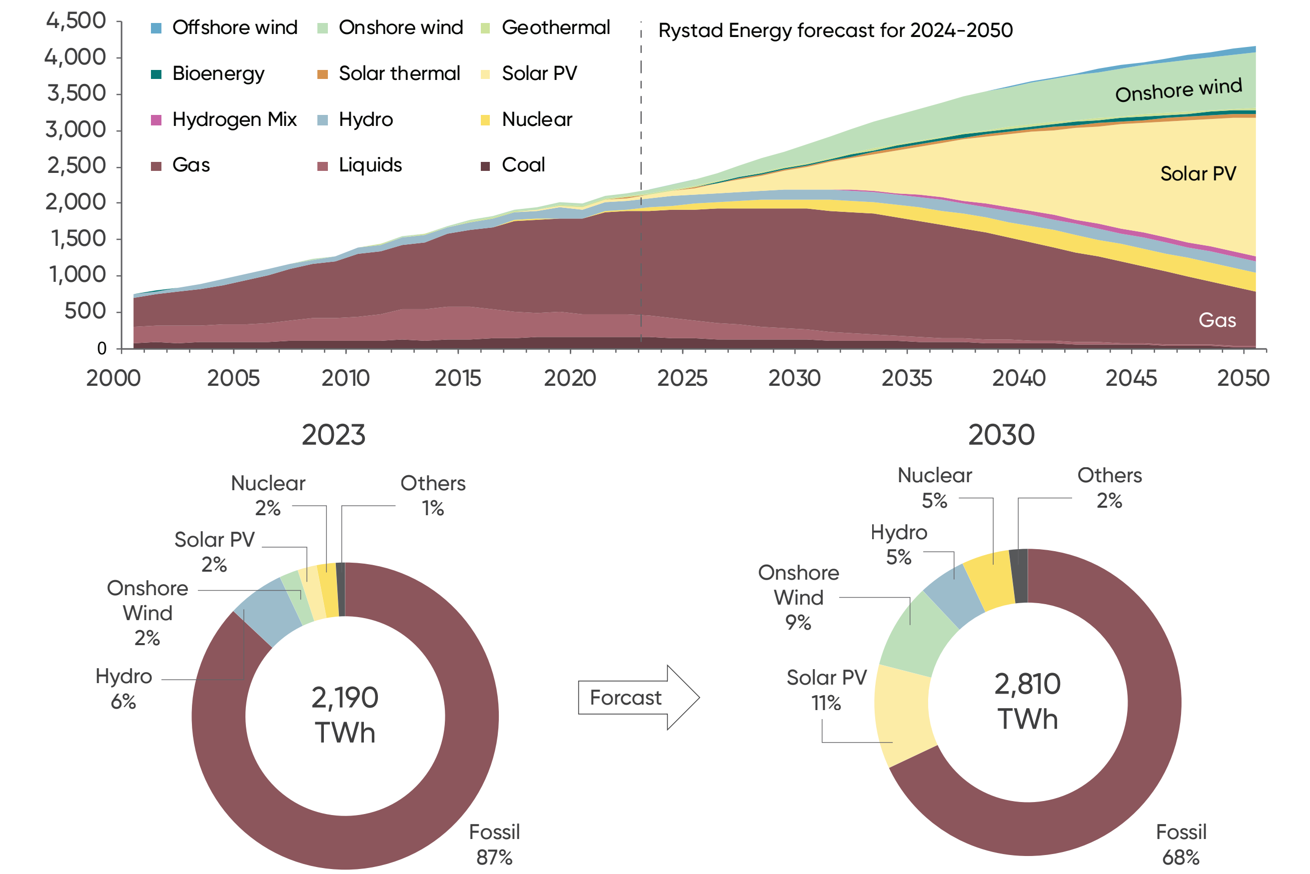
The Middle East and North Africa (MENA), a major oil and gas region, is now experiencing a growing focus on renewable energy, particularly solar PV. Amidst a surge in industrialization, persistent population growth, and economic development, coupled with concerns over climate change and environmental sustainability, solar power has emerged as a key component of the energy strategies of MENA nations. The region boasts one of the highest levels of solar energy potential globally, with an average annual solar irradiance exceeding 2,000 kWh per square metre per year, with standout countries including Saudi Arabia, UAE, Morocco, and Egypt.

MENA increased its solar capacity in 2023 by 23% on an annual basis, with countries such as Turkey, UAE, Israel, Egypt, and Saudi Arabia accounting for the bulk of the region's installed capacity. While this growth trajectory is expected to continue, it falls short of the necessary level required to even come close to replacing fossil fuels in MENA's current power generation mix. As seen in Figure 1, the region's power mix is currently dominated by fossil fuels, accounting for 87% of the total, with solar PV providing just over 2%.



*Middle East and North Africa includes Algeria, Bahrain, Egypt, Eritrea, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, Turkey, UAE, Western Sahara and Yemen

Source: Rystad Energy Global Powermix Dashboard, Rystad Energy PowerCube

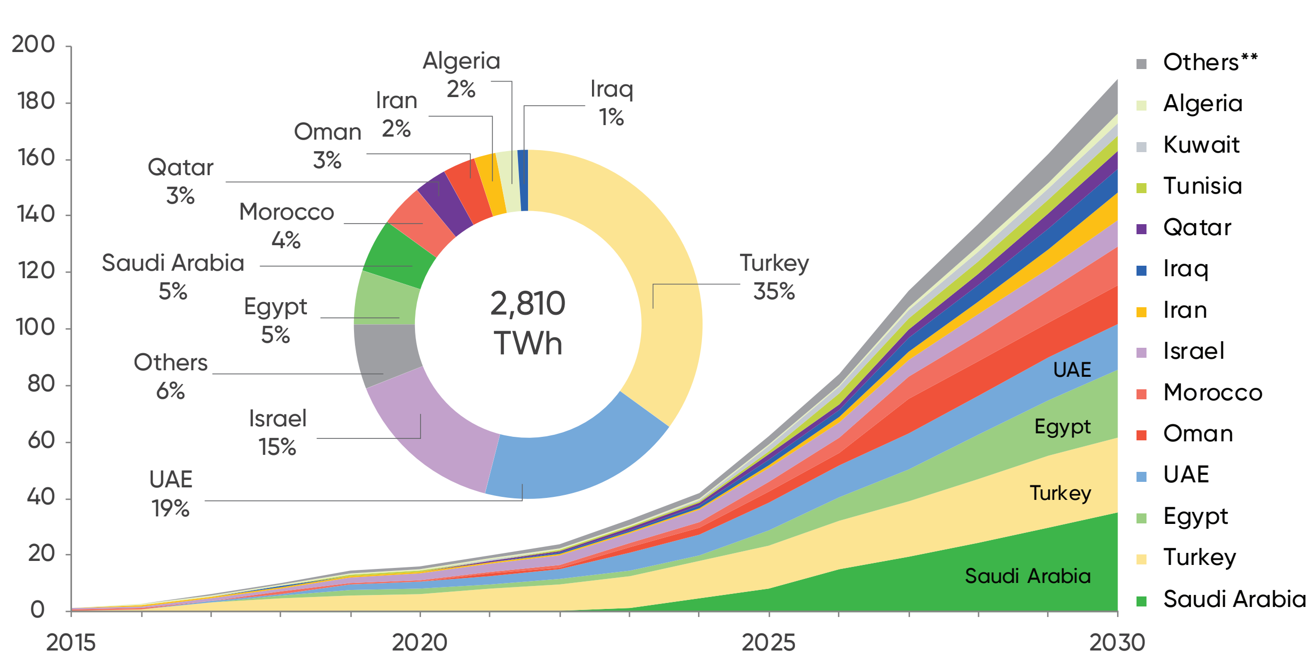
Figure (1): Power Generation Mix by Energy Source, MENA*

The region's installed capacity as of 2023 is 32 GW and is expected to reach nearly 40 GW by the end of this year, and subsequently about 180 GW by 2030, representing a compounded annual growth rate of 30%. Saudi Arabia, Turkey, Egypt, UAE, Oman, and Morocco are poised to account for over two-thirds of the installed solar capacity at the end of the decade.

Saudi Arabia's 1.5 GW Sudair solar project became fully operational early this year, lifting the country's operational solar capacity to over 2.2 GW to date. The country is targeting 40 GW of solar capacity by 2030, with companies like ACWA Power and Masdar pioneering developments. Nevertheless, considering that the current announced solar capacity in the pipeline is only 19 GW, a considerable gap of over 18 GW emerges. To achieve its ambitious plan, Saudi Arabia must install an average of 5.5 GW of new solar capacity per year between now and the end of the decade.

After hosting the 28 Conference of Parties (COP 28), the UAE embarked on a clean energy transition. Up from 6 GW of current installed capacity, the country aims to install 14 GW of clean energy capacity by 2030 – most of which is solar. Meanwhile, Oman targets a 30% share of renewable generation by 2030, up from 3% today, and Jordan aims for a 50% share of renewable generation by decade-end from 30% today. Nonetheless, solar will remain essential in transforming these countries into major renewable energy and green hydrogen hubs.

Turkey's solar PV installed capacity at the end of 2023 was 11 GW, mostly rooftop PV and commercial and industrial (C&I) projects, together representing about 78% of the total. The position of rooftop and C&I solar is due to the net metering scheme which allows households to sell the surplus electricity generated to the grid in exchange for benefits. Turkey is aiming to install around 53 GW of solar power by 2035. Meanwhile, Israel plans a power mix that is 30% renewable energy, up from 11% today, following the same strategy focused on rooftop and C&I solar installations via the net metering scheme. Additionally, Israel mandates the installation of rooftop PV panels on all newly constructed commercial buildings to maximise the use of available space for solar energy generation.



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Source: Rystad Energy Global Powermix Dashboard, Rystad Energy PowerCube

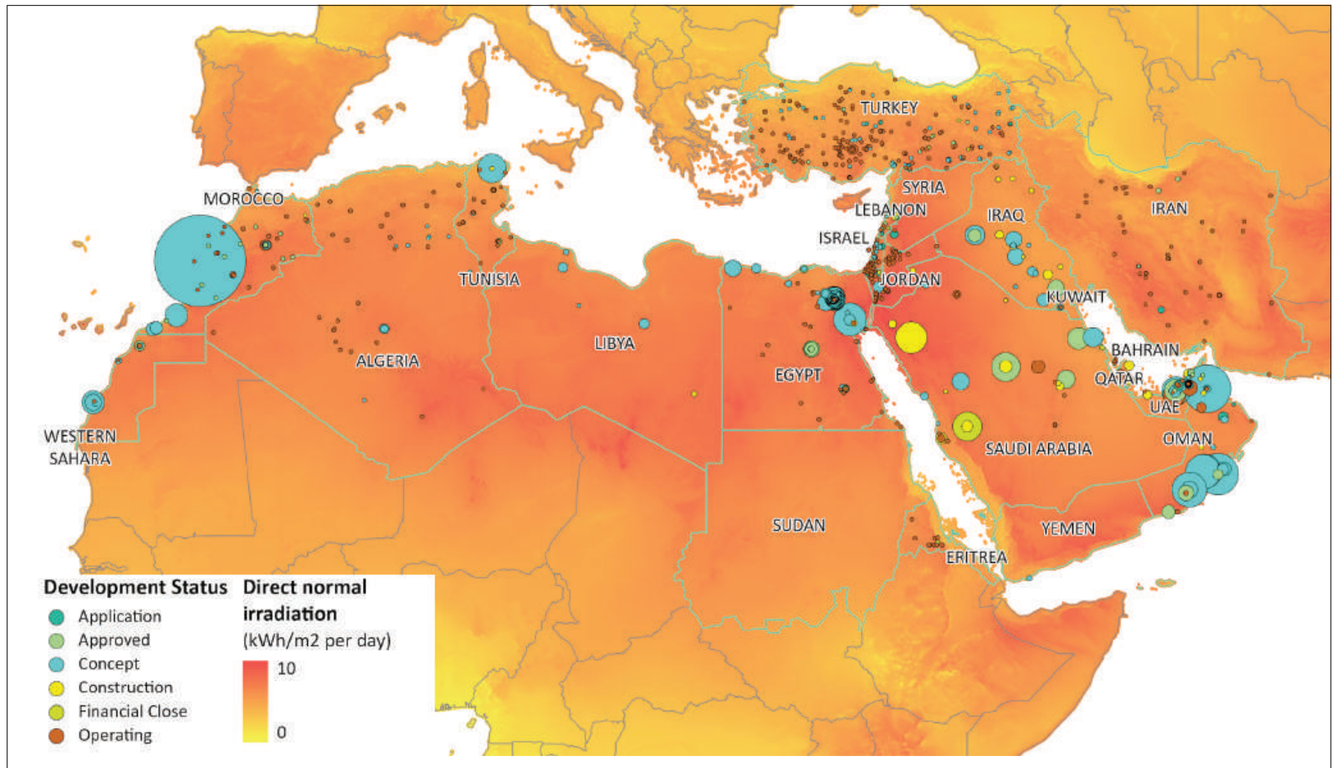
Figure (2): Solar Installed Capacity by Country in GW, MENA*

In North Africa, solar farms have been proliferating over the last decade – Morocco's Noor and Egypt's Benban projects are some of the largest globally. Both countries are expected to add nearly 35 GW of solar by 2030 – with companies like AMEA Power, ACWA Power, Scatec Egypt's New and Renewable Energy Authority (NREA), and the Moroccan Agency for Sustainable Energy (MASEN) pioneering developments. After hosting COP 27, Egypt has been upscaling its transition through renewables and green hydrogen while fostering electricity exchanges with various Arab, African, and European nations.

The country targets a 42% share of renewable generation by 2030, with solar alone targeted for nearly 27% – a significant jump from 2.5% today. Also, Morocco aims for a 52% share of renewable capacity by 2030, with solar targeted at 20% compared to just 8% today. Solar will be essential in transforming Egypt and Morocco into major renewable energy and green hydrogen hubs.

Egypt and Morocco are linked with large-scale green hydrogen projects and interconnector projects such as the 3.6 GW Xlinks UK-Morocco and the 3 GW GREGY interconnector. The UK-based Xlinks aims to develop the Morocco-UK power project by deploying 7.5 GW of solar PV, and 4 GW of onshore wind combined with a 22.5 GWh/5 GW battery storage facility in the Guelmim Oued Noun region of Morocco. GREGY will be developed by Greece's Copelouzos Group and Masdar's affiliate Infinity Power by deploying 9.5 GW of renewable capacity including solar PV and wind. Egypt's NREA and Morocco's MASEN have also launched tenders to move closer to their targets.

In a bid to diversify its energy mix and achieve its 2035 target of 15 GW solar capacity, Algeria launched a 2 GW solar tender in February 2023, involving the construction of 15 solar PV projects across 12 regions. Chinese firms dominated the results and will be developing 1.55 GW capacity. Tunisia, meanwhile, has established a 35% share of renewable capacity target by 2035, and its Ministry of Energy, Mines, and Renewable Energies initiated two tenders for 1 GW of solar PV. More tenders are lined up to offer an additional 2.2 GW of solar.



Source: Rystad Energy PowerCube

Figure (3): Solar Assets by Development Status, MENA

Competitive solar auctions and gigawatt-scale solar projects are driving the MENA region's energy transition away from fossil fuels. Saudi Arabia has already awarded around 4.5 GWAC of solar projects through four different auction rounds to date under the National Renewable Energy Program (NREP), and 3.7 GWAC solar projects are planned to be awarded this year through NREP round 5. The biggest projects offered in the NREP round 5 will be the 2 GWAC Al Sadawi solar project and 1 GWAC Al Masa solar project. Meanwhile, Kuwait and Oman announced the 1.1 GWAC Shagaya solar PV auction and the 0.5 GWAC Ibri III solar PV auction, respectively.

Also, the UAE awarded its 1.8 GWAC sixth phase auction for the Mohammed Bin Rashid Al Maktoum (MBR) solar park, adding around 7.3 GWAC of solar capacity to date in the country. The MBR solar park is one of the world's largest solar energy projects with a planned capacity of 5 GWAC by 2030 at an investment of up to AED 50 billion.

The 1.58 GWAC Al Dhafra solar project in the UAE that was awarded through an auction in 2020 at a record price of 13.5 USD/MWh was commissioned in 2023, highlighting the success of competitive auction in the MENA region.

Project	Energy source	Country	Development status	Startup year	Capacity (GWac)
Mohammed bin Rashid Al Maktoum Solar Park	Solar PV (4.4) Solar Thermal (0.7)	UAE	Operating (2.8 GW) Pre-construction (1.8 GW) Planned (0.34 GW)	2013-2028	5
Al Shuaibah PV	Solar PV	Saudi Arabia	Construction	2025-2027	2.6
Power China Solar PV	Solar PV	Iraq	Pre-construction	2026-2028	2
Ar Rass 2	Solar PV	Saudi Arabia	Pre-construction	2028	2
TuNur Solar PV	Solar Thermal	Tunisia	Planned	2026-2027	2
Al Dhafra Solar PV	Solar PV	UAE	Operating	2023	1.58
Sudair Solar PV	Solar PV	Saudi Arabia	Operating (0.75 GW) Construction (0.75 GW)	2023-2024	1.5

Auction	Lease policy	Country	Authority	Capacity (GWac)
NREP Round 5	PPA	Saudi Arabia	Saudi Power Procurement Company (SPPC)	3.7
Abu Dhabi PV3	PPA	UAE	Emirates Water and Electricity Company (EWEC)	1.5
Shagaya Renewable Energy Project Tender	PPA	Kuwait	Kuwait Authority for Partnership Projects (KAPP)	1.1
Ibri III Solar PV	PPA	Oman	Oman Power and Water Procurement Company (OPWP)	0.5

*Projects excluding solar assets that will act as feedstock for hydrogen electrolyzer

Source: RystadEnergy PowerCube

Figure (4): Top Solar Projects* by Status and Ongoing Solar Auctions in MENA

MENA's strategic location offers the possibility of exporting solar energy to neighbouring markets through green hydrogen or electricity via interconnectors, contributing to regional collaboration, energy security and economic development. The potential for solar energy in MENA thus extends beyond power generation to other applications such as water desalination, cooling systems, and industrial processes, further enhancing its significance in the region's sustainable development efforts – establishing itself as a global leader in renewable energy and the transition towards a more sustainable future.

References:

[1] *Rystad Energy Global Powermix Dashboard*
[2] *Rystad Energy PowerCube*

PROSPECTS FOR SOLAR ENERGY IN THE MENA REGION

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The MENA region stands out globally for its exceptional solar irradiance levels, rendering it an optimal hub for solar energy generation. With vast desert expanses receiving abundant sunlight, countries like Saudi Arabia, the United Arab Emirates, and Morocco are leveraging this natural advantage.

Across the MENA region, numerous countries have set ambitious renewable energy targets, placing a significant emphasis on solar power. Governments are strategically investing in large-scale solar projects to diversify their energy portfolios and diminish reliance on fossil fuels.

The future of solar energy in the MENA region is undoubtedly promising. But before digging into prospects, let's dig into the history of solar energy in the region, to gain insights into what lies ahead.

The MENA region has witnessed significant growth in renewable energy projects, particularly solar. Countries like Morocco, Egypt, the United Arab Emirates and the Kingdom of Saudi Arabia have been commissioning large-scale solar programs, and other nations in the region are following this path.

The declining unit rate for solar energy investment indicates a price decline in renewable energy technologies, even as gigawatts of capacity continue to be installed. As an example, the cost of solar panels has been steadily decreasing, contributing to reduced capital expenditure (CAPEX) for utility-scale solar projects and Al-Faisaliah (Shuaibah) PV IPP (600MW) in KSA has set a new record with the world's lowest cost for Solar PV electricity production at USD 1.04 cents/kWh, underscoring the region's competitiveness in solar energy.

Looking at the future, MENA has superior access to renewable energy sources, receiving about a quarter of the world's solar energy. By 2050, the region could supply up to 40% of the world's energy through aggressive pursuit of renewable technologies, including solar and wind. However, there are also some challenges, especially the extreme desert climates, including temperature extremes and sandstorms. Innovative solutions are being developed to overcome these obstacles. Another important challenge is ensuring the seamless integration of solar power into existing grids and developing cost-effective energy storage solutions. In parallel with the technical aspects, optimizing project bankability and attracting investors will drive sustainable solar development.

Innovative solutions are being developed to overcome these obstacles for example, utilizing cutting-edge technologies like n-type TOPCON and monocrystalline bifacial modules, along with innovative cleaning methodologies such as the Automatic Robotic Cleaning System (ARCS). These solutions have significantly improved efficiency and reduced land occupation in the last few years.

Some of the key innovative expectations in the medium term include:

- New PV module technologies such as Perovskite, high-efficiency bifacial HJT technology at commercial scale
- Improvement in existing and availability of alternative battery storage systems at commercial scale
- Enhanced on-site testing and diagnostic facilities
- Remote control, monitoring and O&M
- Data analytics (plant performance, weather conditions, forecasting) based on AI and machine learning models
- Grid stability and control (Grid Forming Inverters)

Other aspects to be considered are related to environmental benefits or energy independence. Solar power is clean and emits no greenhouse gasses during operation. It helps combat climate change and reduces air pollution. As global awareness of environmental issues grows, the demand for clean energy sources like solar will continue to rise. Solar energy provides countries with

greater energy independence. Relying less on imported fossil fuels enhances national security and stability.

MENA nations, despite being oil-rich, recognize the importance of diversifying their energy mix to ensure long-term sustainability, so MENA countries are investing in solar projects, creating employment opportunities, and stimulating economic growth.

In comparison with other renewable sources, solar energy is a strong contender due to its scalability, decreasing costs, and lower environmental impact during operation. Solar energy is highly reliable in areas with abundant sunlight and is versatile enough to be installed in various settings. Other renewable sources may be more location-dependent or require more infrastructure.

In summary, the future of solar energy in the MENA region will be characterized by the deployment of large-scale projects contributing to decarbonisation and ensuring affordable, reliable, and sustainable energy for future generations through a virtuous circle as each step reinforces the others. Investment leads to innovation, which boosts productivity, income, and spending while technological advancements and economies of scale lead to a decrease in the cost of solar panels and associated equipment. Additionally, the expanding market for solar energy attracts more investment and innovation, fostering competition and driving additional cost reductions. Ongoing research and development efforts improve the efficiency of solar panels, increasing the amount of electricity generated per unit area. Advances in grid integration technologies make it easier to incorporate solar power into existing energy systems, increasing the reliability and stability of renewable energy sources. The cycle repeats, creating a self-sustaining loop of economic growth.

Courtesy: Kingsx-UAE - SirajPower

INTEGRATION OF SOLAR POWER INTO THE GRID SUPPORTED BY SOLAR MAPPING AND FORECASTING AT THE REGIONAL SCALE

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Advanced research is conducted on solar resource assessment and forecasting tailored to the regional conditions of the MENA region. The primary objective is to support the operational efficiency of photovoltaic (PV) and concentrated solar power (CSP) plants, as well as grid operations. Several models have been developed based on sky cameras, satellite images, and numerical modeling, leveraging innovations in Machine and Deep learning. Research efforts also encompass crucial aspects of environmental modeling such as photovoltaic soiling and solar attenuation in CSP plants.

ENHANCED PHOTOVOLTAIC SYSTEM MONITORING WITH DEWASOL REGIONAL SATELLITE MODEL

Monitoring of photovoltaic systems and their integration into the grid is supported by the DEWASOL. A regional satellite model was developed at DEWA R&D, and focused on the main attenuations present in UAE like dust aerosols, anthropogenic emissions, and clouds over bright desert surfaces which sometimes could be confused by the satellite; due to its high reflectivity. DEWASOL model uses satellite images from Meteosat Second Generation over the Indian Ocean (IODC) centered at longitude 45.5° and data from numerical models to calculate solar irradiance based on cloud mapping, cloud top height, cloud opacity, clear sky modeling and solar irradiance decomposition models. The model runs operational in near real-time providing new estimates at 3km spatial resolution for the satellite window shown in Figure (1).

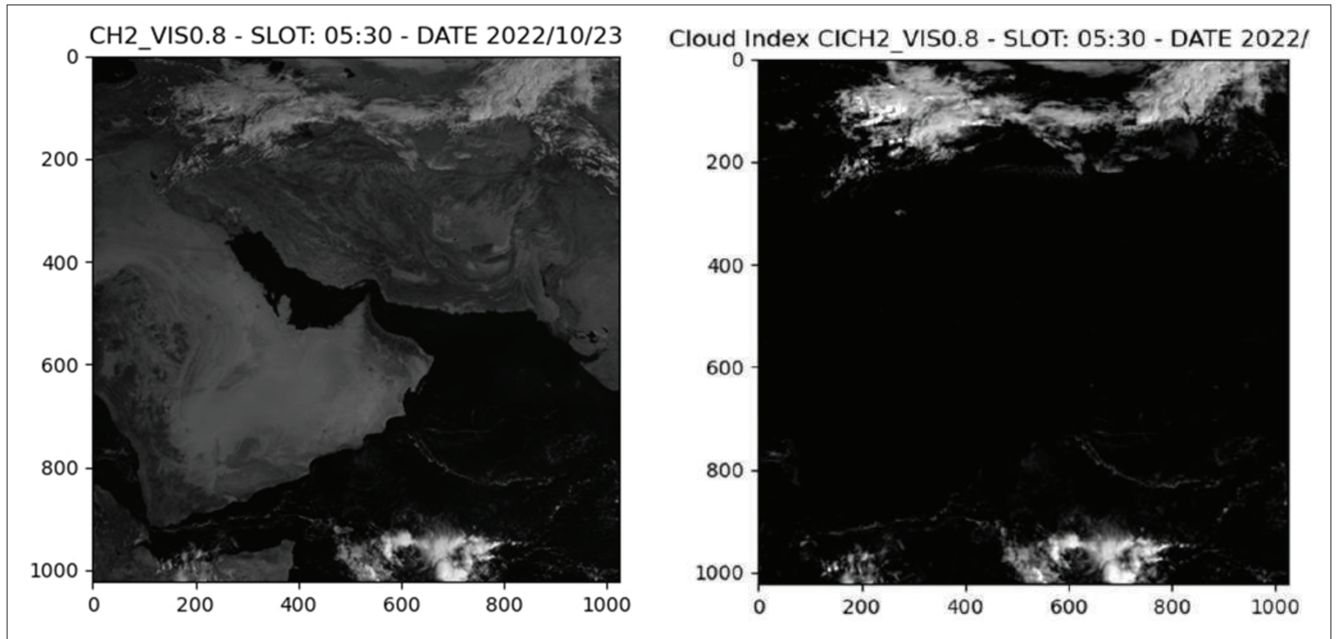

Figure (1): Meteosat Second Generation Over the Indian Ocean Satellite Image Centered at Longitude and Cloud Index Mapping of DEWASOL Model on Meteosat Satellite Images

DEWASOL model has been validated extensively using data recorded at DEWA R&D Outdoor facility which mounts Class A 9060 thermopile pyranometers and pyrheliometers mounted on a solar tracker to measure global, diffuse horizontal, and direct normal irradiances every minute and sampled every second. To ensure the highest quality of the radiometric measurements a daily inspection and maintenance are performed that are supported by an in-house developed real-time alert and monitoring system.

The latest version of the regional DEWASOL satellite model provides estimates of equal or higher accuracy compared to other global solar irradiance satellite data providers based on the comparison of root mean squared errors (RMSE).

Figure (2): DEWA R&D Radiometric and Aerosols Aeronet Station, Part of NASA Network

Number Values 1227	r^2	Relative Bias	Relative Root Mean Square Error (RMSE)
GHI	0.99	-0.29 %	5.43 %
DNI	0.96	0.18 %	9.53 %

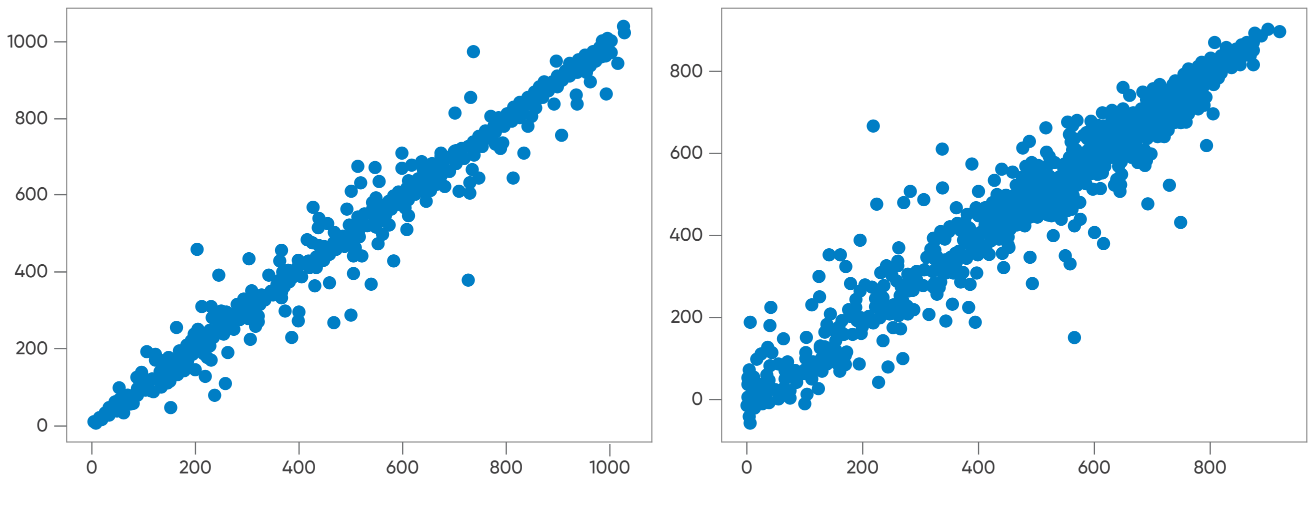

Figure (3): Validation of 15-minute Average Global Horizontal Irradiance (GHI) (right) and Direct Normal Irradiance (DNI) (Wm^-2) at DEWA R&D Outdoor Test Facility

The DEWASOL model is integrated into DEWA Shams Dubai Smart Distribution Center supporting the following applications:

1. **Fault Detection and Maintenance:** DEWASOL solar irradiance satellite estimates can be used to monitor the condition of solar installations and detect potential faults or issues such as soiling, shading, or panel degradation. By comparing against baseline performance, maintenance teams can identify problems early and schedule preventive maintenance to ensure optimal performance of solar energy systems.

2. **Grid Integration and Demand Response:** Solar data derived from satellite images can be integrated into grid management systems to support demand response strategies and grid balancing. By accurately predicting solar energy generation, grid operators can better manage electricity supply and demand, optimize grid stability, and reduce reliance on fossil fuel-based backup power generation during periods of low solar irradiance.

3. **Data Analytics and Optimization:** Utilizing machine learning algorithms and data analytics techniques, it is possible to analyze historical solar irradiance data along with solar energy production data to identify patterns, optimize system performance, and develop predictive maintenance strategies for solar power installations.

Courtesy: Nestle Waters - 1.4 MWp - YDE

NOWCASTING USING A NETWORK OF SKY CAMERAS AT MBR SOLAR PARK (DEWACAST MODEL)

Integrating a network of sky cameras into the management of solar energy can enhance the efficiency and reliability of solar power generation by providing real-time data on cloud cover, solar irradiance, and weather patterns. DEWA is developing a model based on a network of sky cameras called DEWACAST. Following is how it's possible to utilize sky cameras in the integration of solar energy:

1. **Cloud Cover Prediction:** Sky cameras can continuously monitor the sky to detect cloud cover. By analyzing the images captured by these cameras, it is possible to predict cloud movements and anticipate periods of reduced solar irradiance. This information helps in adjusting the operation of solar power systems and managing energy storage to mitigate the impact of intermittent cloud cover and ground shadings (See Figures (4) and (5)).

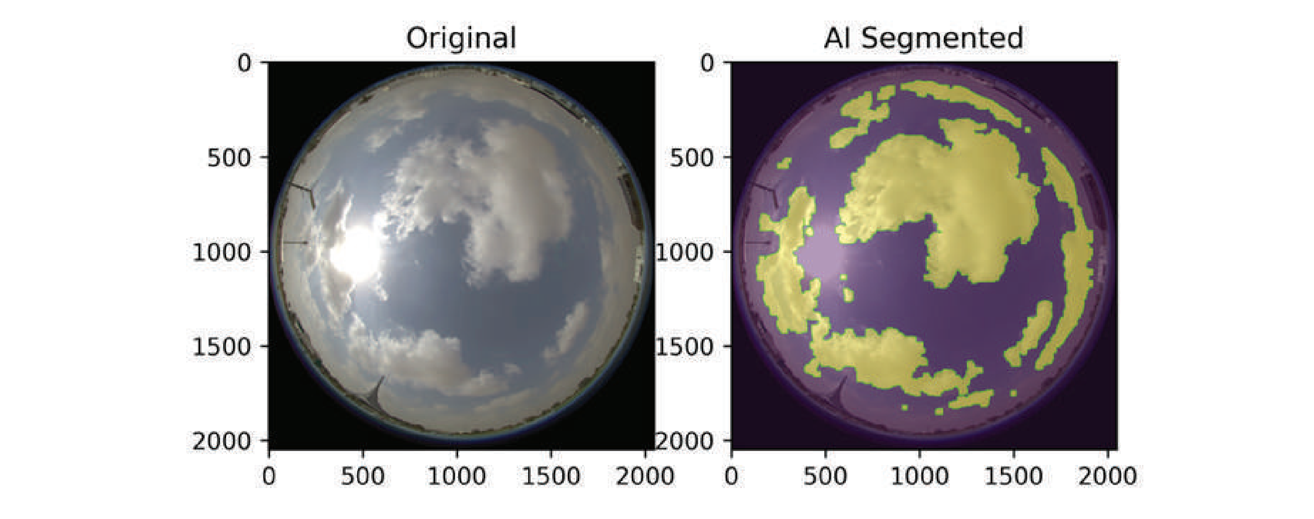

Figure (4): Deep Learning Applied on All Sky Camera Images to Detect Clouds from a Camera Installed at MBR Solar Park (Left) and Projection of Shadows (Right)

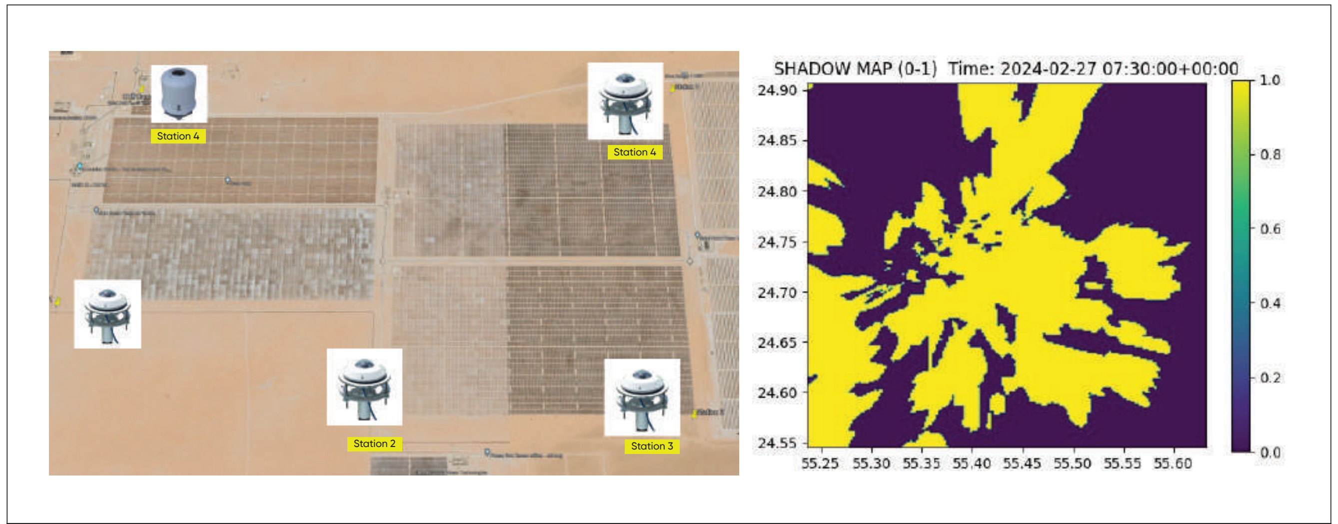

Figure (5): Network of Sky Cameras Installed in MBR Solar Park (Left) and Projection of Shadows (Right)

2. **Solar Irradiance Forecasting:** Sky cameras combined with advanced image processing techniques can provide accurate forecasts of solar irradiance. This data is essential for predicting solar energy generation and optimizing the operation of solar power plants. Integrating sky camera data with weather forecasting models can further improve the accuracy of solar irradiance predictions (see Figure (6)).

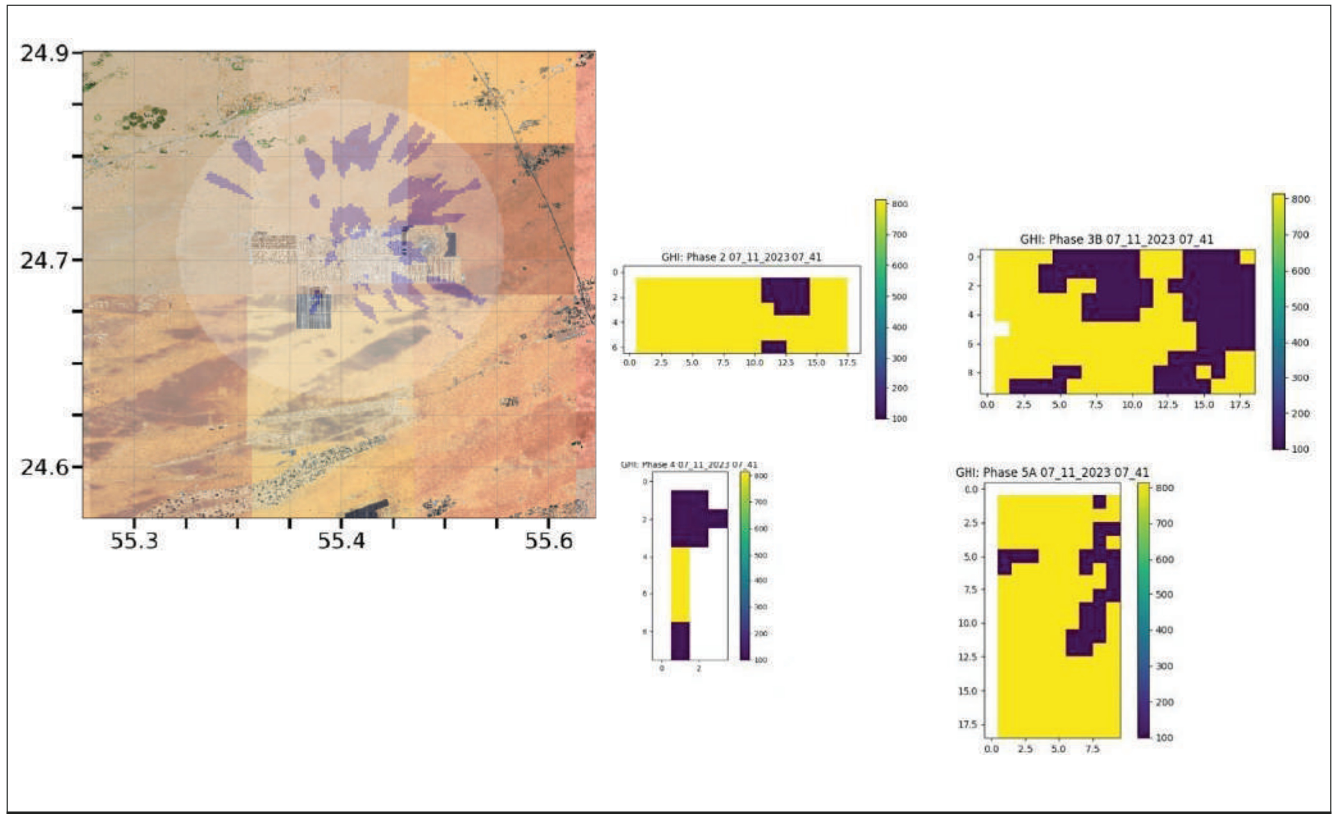

Figure (6): Cloud Projection and Calculation of Global Horizontal Irradiance from the Network of Sky Cameras at 200 Meters Spatial Resolution over PV Phases at MBR Solar Park

3. **Optimized Energy Management:** Real-time data from sky cameras can be integrated into energy management systems to optimize the operation of solar power plants and grid-connected solar installations. By dynamically adjusting the tilt angle of solar panels or repositioning solar trackers based on cloud movements, it may be possible to further optimize solar energy production and improve overall plant performance.

4. **Research and Development:** Sky camera networks can also facilitate research and development efforts aimed at improving the efficiency, reliability, and integration of solar energy into the power grid. DEWA R&D is using the network of sky camera data to study cloud dynamics, atmospheric phenomena, and the impact of weather conditions on solar energy generation supported by the latest AI models to classify sky patterns, detect clouds, and generate future images making use of generative AI.

DEWA network of sky cameras is also supported by satellite images to extend the intra-day horizon of the forecast of solar irradiance. The approach that is currently under development by DEWA is using the DEWASOL model coupled with a deep learning AI model to predict the future evolution and displacement of cloud cover over the UAE (see Figure (7)).

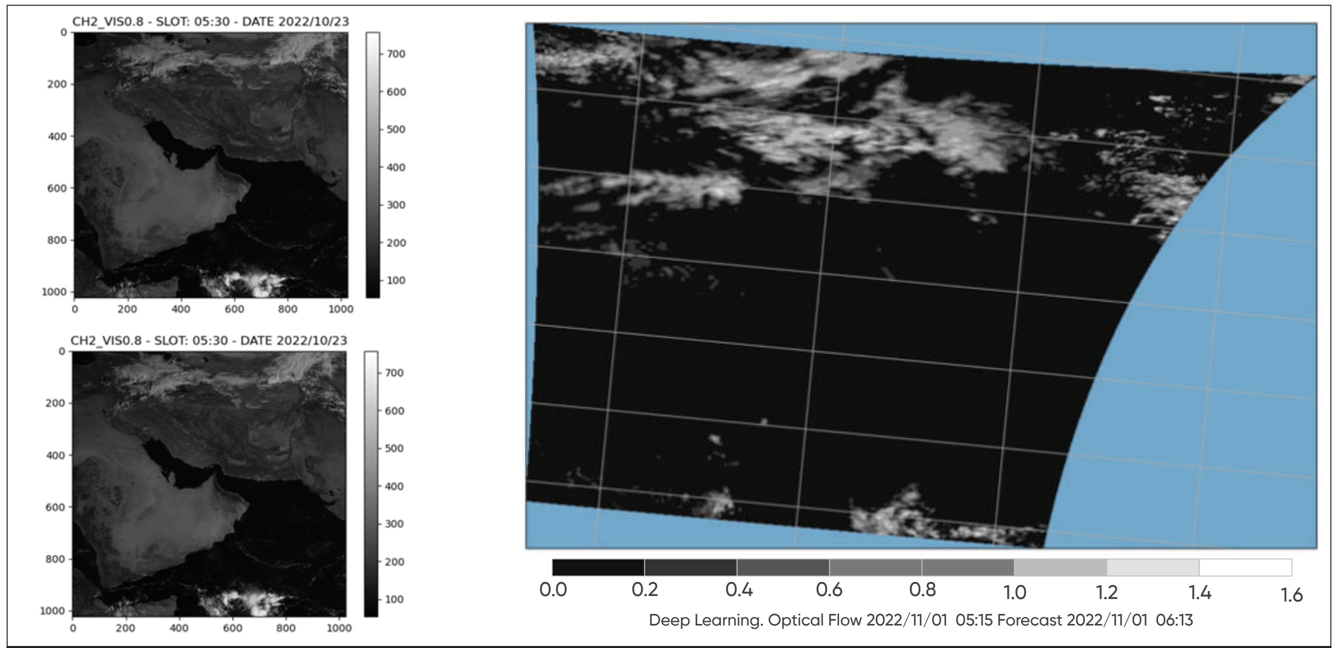

Figure (7): Deep Learning Optical Flow Applied to Two Consecutive Images to Forecast Future Evolution of Clouds

Aerosol modeling is crucial for day-ahead forecasts in MENA's solar energy projects as it accurately predicts solar irradiance affected by dust events. The implemented approach is based on WRF Chemistry models which couples weather and chemistry in the atmosphere. As shown in Figure (8), there are high spatial variabilities of solar irradiance under clear sky conditions in the Gulf region which models that don't explicitly simulate the dynamics of aerosols can't capture. Intraday forecast enables optimal planning of operations by mitigating efficiency losses due to dust, ensuring reliable energy production, and supporting grid stability.

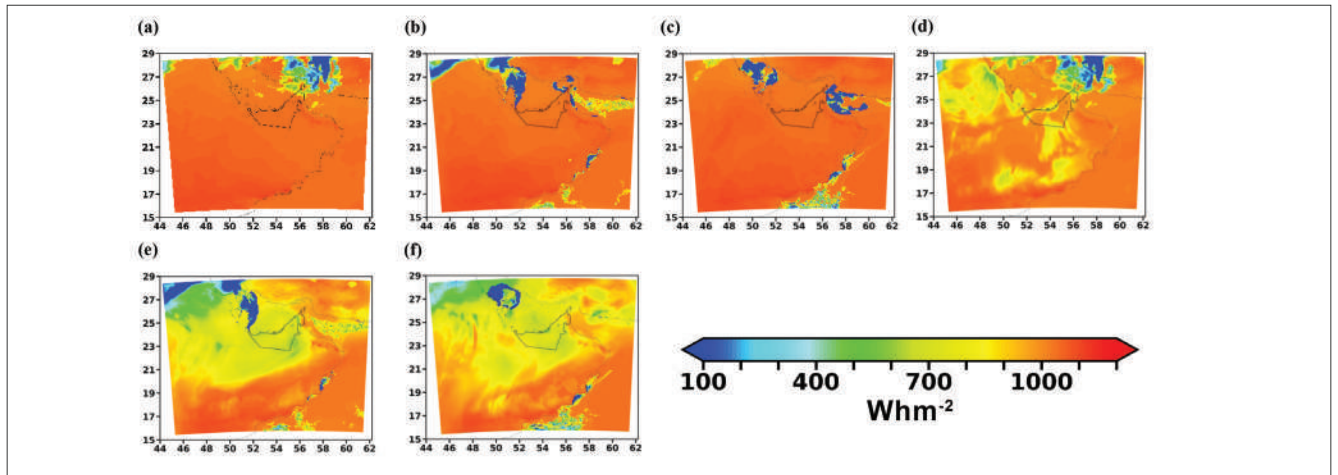

Figure (8): DDNI Forecast by WRF (Without Aerosols) and WRF Chem (With Aerosols) for 12/03/2023 08 UTC (a, d), 13/03/2023 08 UTC (b, e), 14/03/2023 08 UTC (c, f) over the Study Region. WRF and WRF Chem Forecasts are Initialized at 12/03/2023 00 UTC.

In conclusion, advancements in solar resource assessment and forecasting towards the integration of solar energy can enhance the performance, reliability, and economic viability of solar power generation and facilitate the transition towards a more sustainable and resilient energy infrastructure. As solar power becomes an increasingly significant contributor to the global energy mix, widespread adoption of the technologies discussed in this article like forecasting techniques and grid integration strategies will be essential to realize its full potential.

TOWARDS COMMERCIALLY VIABLE PEROVSKITE SILICON TANDEM SOLAR CELLS

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DEWA R&D is at the forefront of research on innovative vacuum deposition techniques tailored for the fabrication of high-efficiency perovskite-silicon tandem solar cells. This research aims to take the lead in advancing solar energy technologies to the next era of efficiency. The focus is on optimizing film deposition, enhancing interface engineering, and minimizing defects. Through strategic collaborations, the path to commercialization is being accelerated. This commitment extends beyond nameplate efficiency advancements by prioritizing commercial viability and manufacturability.

It's important to note that the commercialization of perovskite-silicon tandem solar cells depends not only on their technical performance but also on scalability, cost-effectiveness, and long-term reliability. In line with this, a two-phase plan was devised: the first phase focused on wet chemical deposition for small cells, followed by the second phase of scaling up to large-area wafer deposition for industrial applications using a dedicated vacuum-based cluster tool. Along the way, there was a need to address optimal cell and module design, exceeding the efficiency, reliability, and longevity of conventional PV modules.

TECHNOLOGICAL ADVANCEMENTS AND EFFICIENCY BREAKTHROUGHS

Single junction solar cell efficiency has almost reached the Shockley-Queisser (S-Q) limit, a crucial milestone during the past 10 years. Consequently, the photovoltaic (PV) industry is currently exploring innovative technologies such as multijunction tandem solar cells (TSCs), with silicon as the bottom cell. Since silicon solar cells benefit from a well-established mass production technology and expertise, silicon-based TSCs can enhance cost-to-performance ratios and leverage balance-of-system (BoS) costs. TSCs offer a crucial advantage in minimising thermalization losses caused by absorbing high-energy photons in single-junction silicon solar cells. These losses limit the theoretical maximum efficiency of solar cells. Hence, the top cell incorporates a high bandgap semiconductor to capture high-energy photons, yielding high open circuit voltage (Voc), and reducing thermalization losses.

Conversely, the bottom cell absorbs low-energy photons transmitted through the top cell, generating electrical carriers. Consequently, TSCs have the potential to surpass the S-Q limit by boosting efficiency. Si-based single-junction solar cells, despite their progress, are converging toward a practical efficiency limit of approximately 27%, closely approaching the theoretical upper limit of around 30%. However, the advent of tandem solar cells offers a way for further efficiency improvements. Tandem cells, composed of multiple stacked layers with varying bandgaps, enable better utilization of the solar spectrum. Mass-produced Si-based tandem cells are projected to start at around 28% efficiency, slightly exceeding the best-performing single-junction silicon cells. Market introduction is anticipated after 2025, marking a significant step toward more efficient and sustainable solar energy utilization.

Interestingly, perovskite has emerged as a promising material and has become very popular for its successful application in photovoltaics, achieving over 26% efficiency in just over a decade (Figure 1). The rapid rise in efficiency and the band gap tuning of the perovskites in the range of 1.17 to 2.3 eV through compositional engineering makes them superior to other materials for Si-based tandem solar cells. The perovskite/Si tandem solar cells have been classified into three types according to their device architectures, such as 2-terminal (2-T), 3-terminal (3-T),and 4-terminal (4-T) configurations (Figure (2)). In 2-T and 3-T device architecture, the top perovskite solar cell is monolithically integrated with the bottom Si solar cell. In contrast, the perovskite and the Si solar cells are mechanically stacked in a 4-T tandem solar cell. Recent research has demonstrated remarkable progress in enhancing the efficiency of perovskite/Si tandem solar cells. Achieving efficiencies above 30%, researchers have exceeded the Shockley-Queisser limit, a significant milestone in photovoltaic technology. Innovations in materials engineering, device architecture, and manufacturing techniques have facilitated these advancements. Notably, modifications in the carrier transport layers and interface engineering have substantially improved current density and overall performance.

The belief is that vacuum deposition holds the key to scaling the production of perovskite-silicon tandem solar cells. Vacuum deposition offers the precision and scalability necessary to transition technology from the laboratory to commercial production and provides several advantages over traditional solution processing. Specifically, it allows precise control over thin film compositional uniformity, thickness and material quality, which is crucial for consistent device performance across large-scale production. The controlled environment minimizes variability and moisture exposure, leading to more reproducible and stable devices. Additionally, this technique aligns well with existing semiconductor manufacturing infrastructure, simplifying integration and upscaling. It is intended to actively explore advancements in deposition techniques like co-evaporation and vapor-assisted solution processing to enhance film quality and large-area device performance. In addition to this, the researchers are collaborating on material engineering efforts to develop more stable perovskite compositions with improved tolerance to moisture and heat. Ultimately, the aim is to seamlessly integrate perovskite deposition with silicon solar cell production lines, enabling cost-effective and widespread adoption of this highly efficient technology.

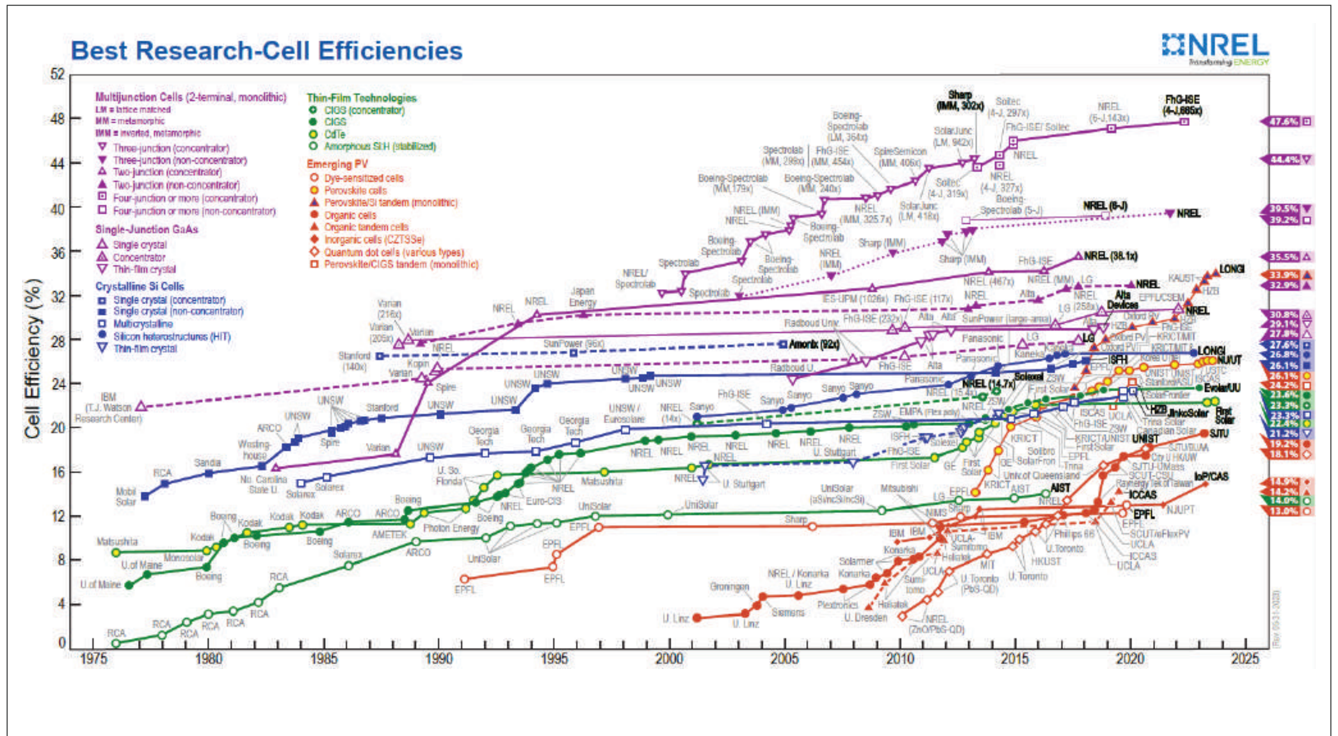


Figure (1): NREL Efficiency Chart Illustrating the Highest Efficiency for Perovskite Solar Cells is 26.1%, and for Perovskite/Silicon Tandem Solar Cells is 33.9%

Recently, the solar team at the DEWA R&D Center announced a breakthrough, achieving an efficiency surpassing 30% (Illustrated in Figure (4)) for perovskite/Silicon tandem solar cells utilizing a 4-terminal configuration. This accomplishment was made possible by modifying the carrier transport layer of the top perovskite solar cell, leading to a notable increase in current density and a significant enhancement in overall efficiency to 21.41%. As shown in Figure (3), the team fabricated perovskite solar cells by modifying the electron transport layer and mechanically stacked the same perovskite solar cell device (w/o metal electrode) as a filter on the Si solar cell for the 4-T tandem configuration, which delivered an efficiency of 8.86%. Combining these two efficiencies, the team achieved an efficiency of 30.27% for the 4-T perovskite/Si tandem solar cells measured in-house. The recent achievements indicate that the perovskite/silicon tandem solar cells have significant potential to enhance energy yield compared to traditional Silicon technology.

Unfortunately, 4-T tandem cells cannot be readily adopted for commercial PV deployment as they would effectively require doubling the amount of wiring and inverter connections. Therefore, the team is directing their efforts toward developing 2-terminal and 3-terminal perovskite solar cells that can be used in exactly the same way as existing conventional modules. This requires careful bandgap tuning and novel module wiring approaches.

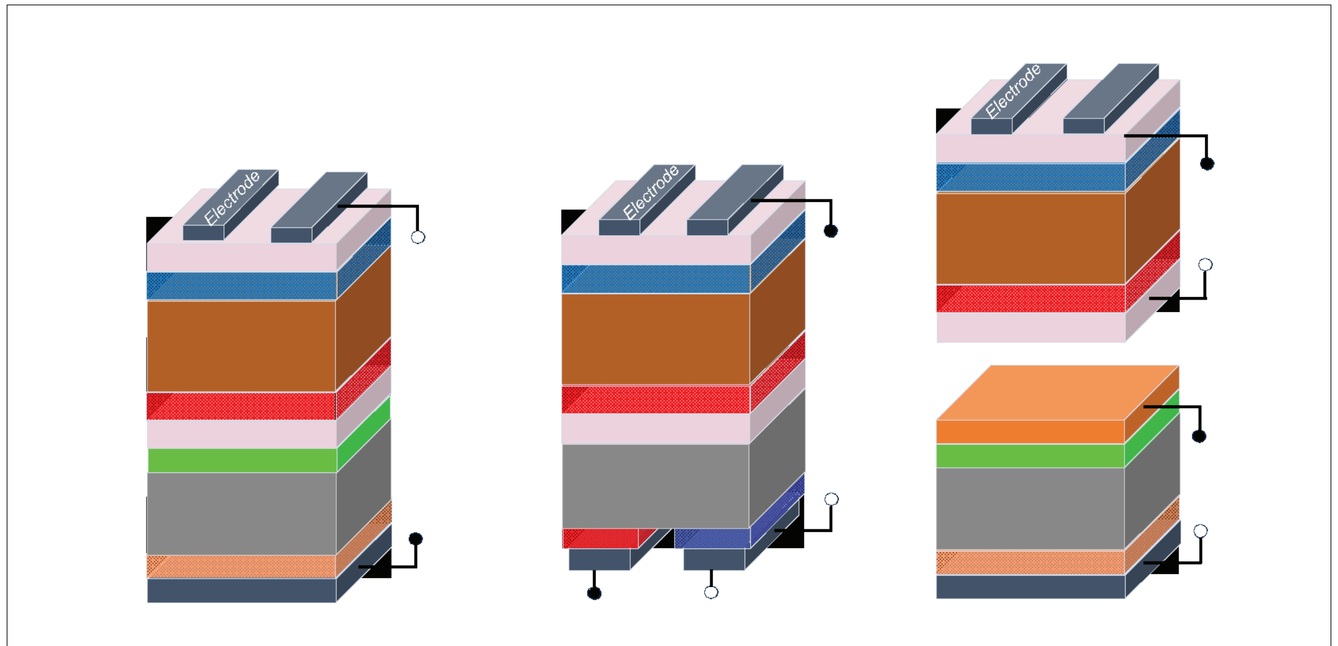


Figure (2): Schematics of 2-T, 3-T and 4-T Perovskite/Silicon Tandem Solar Cell

The stability of perovskite materials in the presence of moisture and light is a significant concern. Additionally, scalability and manufacturing consistency remain key hurdles in commercializing tandem solar cells. The researchers are actively exploring encapsulation strategies, interface engineering, and material compositions to improve stability and prolong device lifespan for hot desert climatic conditions. Similarly, for scaling up perovskite/Si tandem solar cells, the solar team is procuring a cluster tool consisting of automated high-quality thin film deposition techniques such as two low-temperature and one high-temperature thermal evaporators, an atomic layer deposition, radio frequency type magnetron sputtering, load-lock and main processing chambers and glove box. Additionally, the team has procured coating and printing technologies like spin-coater, blade-coater, slot-die coater, and screen-printer to scale up the tandem solar cells.

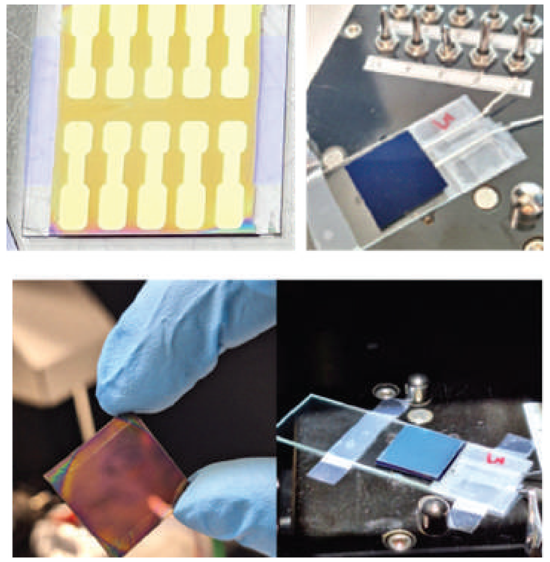
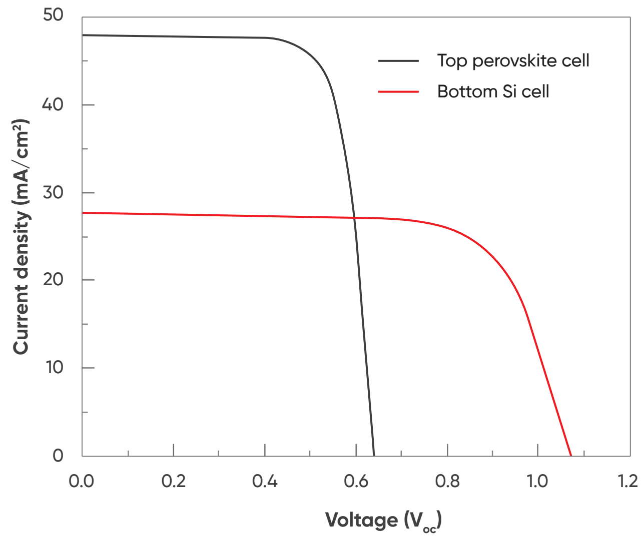


Figure (3): Four terminal tandem solar cells fabricated at DEWA R&D.

In the initial stage, the focus was on fabricating M6 Si wafer-based perovskite/Si tandem solar cells, and the team plans to fabricate M10 wafer-based tandem solar cells and their module sizes as a second step. The researchers are collaborating with academic and industrial research centres, including CSEM Switzerland, ISC Konstanz, UAE University, and the Chinese Academy of Science. This is to develop the right technology and the right assessment tools that can provide reliable insights into the performance of various solar cell technologies in Dubai's conditions.



Sample	PCE (%)	Jsc (mA/cm²)	Voc (V)	FF (%)
Perovskite	21.41	27.62	1.06	73.15
IBC-Si SC	23.14	47.82	0.642	75.36
IBC-Si SC with filter (0.075 cm2)	8.86	26.83	0.485	68.05
4 terminal perovskite/ Si Tandem	30.27	54.45	1.545	-

Figure (4): In-House Measured Photovoltaic Performance of 4-T Perovskite/Silicon Tandem Solar Cells

OVERCOMING CHALLENGES AND FUTURE OUTLOOK

Projections suggest that tandem PV technologies are poised to capture a market share exceeding $10 billion by 2032. However, determining a realistic timeline for the successful market introduction of perovskite/silicon tandems remains a challenge. Currently, both emerging start-ups and established players in the PV sector are actively exploring this technology, pursuing diverse fabrication methods and module configurations as documented in published studies or announced by companies.

Over time, the photovoltaic sector has gathered considerable knowledge and proficiency in both thin-film and silicon-based deposition, needing extensive and expensive developmental endeavours over an extended period. A great deal of this gathered know-how can now be utilized to optimize perovskite/silicon tandem techniques. However, consistent, and significant investment is crucial for the effective market introduction of this innovation. Furthermore, it is crucial to underscore the significance of process robustness during the scaling-up of technologies. This entails ensuring consistent reproducibility of different batches in depositing the perovskite absorber layer, implementing effective passivating layers and contacting materials. Eventually, the optimal deposition method should strike a balance between achieving high solar cell performance, high throughput, and ensuring reproducibility on large-area substrates.

Courtesy: Al Tajir x - SirajPower

SOLAR PANEL PERFORMANCE TESTING METHODS ENSURING EFFICIENCY AND RELIABILITY IN CHALLENGING ENVIRONMENTS

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INTRODUCTION

Solar panel technology has emerged as a cornerstone of renewable energy solutions, offering a sustainable alternative to fossil fuels. However, the reliability and efficiency of photovoltaic (PV) modules are contingent upon their ability to endure diverse environmental conditions throughout their operational lifespan. The advent of harsh winters, characterized by significant temperature drops and heavy snowfall, as well as the desert climates of the Middle East and Africa region, with their unique challenges of sand and dust exposure, has underscored the importance of rigorous performance testing. Such conditions pose substantial challenges to solar power generation equipment, necessitating comprehensive evaluations to ensure their resilience and functionality. This article delves into the crucial testing methods designed to assess solar panels' performance, including wet freezing tests, wet leakage current tests, static and dynamic mechanical load tests and specifically, sand and dust module tests suitable for desert climates. These evaluations are essential in verifying if solar panels can withstand the rigors of their environment, ensuring efficient and safe operation under all conditions.

SAND AND DUST TEST

Among several conducted tests, dust testing plays a critical role, particularly for installations in arid or desert regions where dust accumulation can significantly impact solar panel efficiency. The Method La1 dust test is a specialized procedure designed to evaluate the resilience of solar panels against dust accumulation. The essence of the Method La1 dust test lies in its simulation of a dust-laden environment, which is achieved by exposing the solar panel to an airflow containing non-abrasive powder with a particle size of less than 75 µm. The use of non-abrasive powder ensures that the test focuses on the impact of dust accumulation rather than abrasion damage to the panel's surface. A critical aspect of this test is the preparation and maintenance of the test dust. To preserve its fine granularity, which is crucial for the accuracy of the test, the powder must be kept dry. This is achieved by drying the dust by heating it for 2 hours at a temperature of +80°C before use. Furthermore, the dust used in the test is limited to a lifespan of 20 tests to maintain its consistency and reliability.

During the test, the quantity of test dust is meticulously calibrated to achieve a uniform deposition on the reference surface within the chamber, specified to be (600 ± 200) $g/m^2/h$. The test specifies a vertical airflow direction downwards, creating a scenario where dust would naturally settle on the panel's surface, as it would in a real-world environment. For enclosures falling under specific categories, the pressure within the dust chamber is varied cyclically. Additionally, the air velocity during the test is adjusted to ensure a homogeneous distribution of dust within the chamber, further enhancing the test's realism and applicability. The relative humidity within the test chamber is maintained at less than 25%, a condition that minimizes the likelihood of moisture-related variables affecting the test outcome. The Method La1 dust test is a comprehensive evaluation tool for assessing the resilience of solar panels to dust accumulation.

WET FREEZING TEST

The wet freezing test is a critical assessment method that simulates the ingress of moisture into PV modules, followed by freezing conditions. This scenario is particularly relevant in regions experiencing cold climates, where water can seep into the panels and freeze, potentially causing physical expansion and damage. The test procedure involves soaking the solar panel in water and subsequently exposing it to -40°C-85°C temperatures. This cycle is repeated 10 times to mimic the natural wear and tear that occurs over time. The aim is to identify potential weaknesses in the panel's design and construction, ensuring that modules can withstand such conditions without compromising their structural integrity or performance.

Figure (1): Wet Freezing Test Equipment
Source: DAS Solar Laboratory

WET LEAKAGE CURRENT TEST

Ensuring electrical safety and performance under wet conditions is crucial for solar panels, particularly due to the risk posed by rainwater exposure. This consideration becomes even more significant in the Mediterranean climate of Central and Eastern Africa, where seasonal rainfall patterns can subject solar installations to varying degrees of moisture and wetness, potentially impacting their operational efficiency and safety.

The wet leakage current test evaluates the panel's electrical insulation properties when wet. In the wet leakage current test, the module is submerged in water and a system voltage of 1500V is applied for two minutes to the module. It is necessary for the water temperature to be 22°C, and the electrical conductivity of the water to be over 286µS/cm. Modules pass the test if their area multiplied by the test resistance is greater than 40MΩ*m2. This test ensures that the panels do not pose an electrical hazard during rainy conditions and that their performance remains consistent, regardless of moisture exposure.

Figure (2): Wet Leakage Current Test
Source: DAS Solar Laboratory

STATIC AND DYNAMIC MECHANICAL LOAD TESTS

Solar panels are subjected to various mechanical stresses throughout their lifespan, from heavy snow loads to strong winds. Static and dynamic mechanical load tests are designed to assess the panel's ability to withstand these forces. The static load test simulates constant weight or pressure on the panels, such as snow accumulation, ensuring they can bear significant loads without structural failure. A positive and negative pressure of 5400 Pa and 2400 Pa was applied to the frontsheet and backsheet of the panels in the static mechanical load test. A three-cycle study was conducted to observe the deformation, damage, and changes in power output and performance. Conversely, the dynamic load test addresses the impact of fluctuating forces, like wind gusts and seismic activity, to ascertain the panel's resilience to such stress over time. Using more than 1000 cycles, 1500 Pa ± 100 Pa were applied sequentially to the frontsheet and backsheet of the panel to observe its performance. These tests are crucial for certifying the durability of solar panels in maintaining their shape and functionality under mechanical stress.

Figure (3): Applying 5400 Pa & 2400 Pa Positive and Negative Pressure to Frontsheet and Backsheet of Panels while Conducting Static Mechanical Load Test
Source: DAS Solar Laboratory

CONCLUSION

In conclusion, comprehensive performance testing of solar panels is indispensable for guaranteeing their long-term reliability, efficiency, and safety. By subjecting PV modules to wet freezing tests, wet leakage current tests, static and dynamic mechanical load tests, and hail tests, manufacturers can identify and mitigate potential vulnerabilities. This rigorous evaluation process ensures that solar panels can endure the harsh environmental challenges and extreme weather conditions they will face over their service life. Consequently, these tests not only enhance the resilience of solar energy systems but also bolster consumer confidence in solar technology as a durable and reliable energy source for the future.

Courtesy: Bubble Luxotel Hotel - Wadi Rum, Jordan - SMA Solar Technology

VIABLE LIFE CYCLE SUSTAINABILITY METHODS OF SOLAR PANELS

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JA SOLAR

INTRODUCTION

Solar energy has become a central focus in the MENA region's quest for sustainability due to its promising potential to provide clean and affordable energy. With much support, solar panel manufacturers are helping to improve the environment by developing clean and renewable energy technologies while also controlling emissions from their production and operations. As the solar industry explores ways to improve the life cycle sustainability of solar panels, this article will present the latest consensus and examples of best practices.

To enhance sustainability, various methods are being pursued, including technological innovation, sustainable development management, life cycle assessments, and collaboration. Leading PV manufacturers like JA Solar have successfully employed these methods, resulting in a significant reduction of in-operation Greenhouse Gas Emissions Intensity (Scope 1 + Scope 2) by 20% in 2021 and 33% in 2022, based on data from actual production and operating facilities[1]. This article focuses on three key aspects that PV manufacturers can leverage to enhance the life cycle sustainability of solar panels.

METHODS FOR ACHIEVING ENHANCED PV SUSTAINABILITY

Technological advances are the heart of manufacturing industries' progress. The PV industry has seen rapid development of PV technologies and product updates over the years. PV manufacturers strive for higher conversion efficiencies and longer product life cycles. Technical advances are expected to extend the lifespan of a typical solar panel from 25 years to 30 years, and 30-year power degradation is expected to drop from 18% to just 10%.

These improvements enable solar panels to generate more electricity and perform better, even in extreme weather conditions. Together with constant cost reduction, these advances are driving interest in solar PV, making it a renewable energy mainstay for global carbon neutrality efforts. According to IEA, the cumulative installed capacity of solar PV will surpass hydropower, natural gas, and coal, becoming the largest source of installed capacity globally by 2027.

As the main driver of low-carbon development, solar panel manufacturers are integrating low-carbon and sustainable development into their production and operating practices, a connection that is more directly connected with the life cycle sustainability of solar panels.

Sustainable development management involves establishing a robust management structure within the company to effectively achieve the goal of life-cycle sustainability for solar panels. This entails assigning clear responsibilities, roles, and authority to individuals or teams overseeing sustainability initiatives. The management structure should include dedicated personnel responsible for implementing and monitoring sustainability practices throughout the organization's operations. Additionally, it involves integrating sustainability into the company's strategic planning, budgeting, and decision-making processes.

Establishing a robust management structure focused on sustainability ensures prioritization of sustainability goals, effective resource allocation, and transparent progress tracking. This proactive approach fosters a culture of sustainability within the organization and enables continuous improvement towards achieving life cycle sustainability for solar panels and other products. Some of the best operators have gone from participating in environmental work to setting up a dedicated administrative structure to promote the development of plans, objectives and policies related to environmental, social and governance issues. Taking JA Solar as an example, the company has established a sustainable development governance structure having the board, executives and employees involved in the management and practice of sustainability, ensuring sustainable solar panel life cycles are taken at every step: raw material acquisition, manufacturing, shipping, deployment, disposal or recycling.

Life cycle assessments (LCAs) and collaboration play crucial roles in ensuring the sustainability of solar panels throughout their life cycles. LCAs are vital tools for evaluating the environmental impacts of products throughout their entire life cycle, from raw material extraction to manufacturing, use, and disposal. For solar panels, LCAs consider various factors such as energy consumption, greenhouse gas emissions, water usage, land disturbance, and recycling associated with each stage of the panel's life cycle. By conducting LCAs, manufacturers can gain a comprehensive understanding of the environmental footprint of their solar panels and identify opportunities for improvement. LCAs help in making informed decisions to design and produce solar panels with lower environmental impacts. This includes optimizing manufacturing processes, sourcing sustainable materials, reducing transportation emissions, and implementing efficient end-of-life strategies such as recycling. Additionally, LCAs provide a basis for comparing the environmental performance of different solar panel technologies and guiding policy decisions to promote sustainability in the solar energy sector.

Collaboration among stakeholders along the solar panel supply chain is essential for achieving life cycle sustainability. This includes collaboration between manufacturers, suppliers, distributors, installers, policymakers, and consumers. They can collaborate to share knowledge, resources, and best practices to address sustainability challenges more effectively, which would foster innovation in product design, production processes, and business models that prioritize sustainability. For example, manufacturers can collaborate with suppliers to source sustainable materials, optimize production processes, and reduce waste. Installers can work with manufacturers to improve installation practices and maximize energy efficiency. Consumers can also play a role by making informed choices and supporting companies that prioritize sustainability. Overall, collaboration fosters transparency, accountability, and collective action, ensuring that all parties are committed to sustainable practices throughout the life cycle of solar panels.

SUMMARY

The journey towards achieving life cycle sustainability for solar panels requires a collaborative effort among all participants of the industry. As solar energy assumes an increasingly vital role in the global quest for sustainability, ensuring the environmental integrity of solar panel production and operation becomes paramount. Through technological innovation, rigorous life cycle assessments, and sustainable development management, stakeholders can mitigate environmental impacts and promote long-term sustainability. By adhering to transparent, evidence-based practices and fostering collaboration across the solar panel supply chain, progress can be made towards a future where solar energy plays a pivotal role in addressing energy needs while minimizing its environmental footprint.

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MEASUREMENT APPROACH FOR EVALUATING THE CLEANING EFFECTIVENESS OF AUTOMATED ROBOT CLEANING SYSTEMS OF PV PLANTS

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INTRODUCTION

In the Middle East region, the PV industry is experiencing robust growth. However, the power generation of PV power plants is significantly affected by soiling loss, presenting a notable industry challenge. To address this issue and enhance power generation while conserving water resources and reducing manual O&M costs, PV cleaning robots have gained traction within the industry.

Nevertheless, due to variations in geographical locations, environmental conditions, and dust impacts, the effectiveness of PV cleaning varies. How can the efficacy of cleaning robots be assessed? This paper introduces three evaluation methodologies to address this question.

COMPARISON APPROACH FOR POWER GENERATION

In this measurement approach, the PV plant is divided into three areas with identical conditions prepared, designated as the cleaning area, comparison area, and standard area. The cleaning area is regularly cleaned using the intelligent PV cleaning robot, while the comparison area remains completely uncleaned. The standard area remains uncontaminated by dust, maintaining cleanliness throughout.

There are 6 PV modules installed in the robot cleaning row. They are connected to individual power optimizers, power analyzers, and electronic loads in order to monitor their performance for comparison. By comparing the data from the power optimizers, power analyzers, and electronic loads over a period of time, power generation data for the three areas can be obtained, and the increase in power generation brought by the cleaning robot can be calculated.

In a 50 MW PV cleaning project in a coal mining subsidence area in China, surrounded by several coal mining areas, the plant is significantly affected by coal ash. By equipping it with cleaning robots, the cumulative power generation in the cleaning area is 130,802.5 kWh, while in the comparison area, it is 115,455.4 kWh. After eliminating the original deviation rate, the increase in power generation is calculated to be 14.03% in a year.

Time	Cleaned Array	Comparison Array	Increased Generation Tate
May 2020	8,855.78	8,063.3	10.57%
June 2020	11,337.34	10,482	8.90%
July 2020	12,040.52	11,427.05	6.11%
Aug 2020	11,986.24	11,423.06	5.67%
Sep 2020	12,629.1	10,979.6	15.76%
Oct 2020	8,898.63	7,492.06	19.51%
Nov 2020	7,758.39	5,051.76	54.32%
Dec 2020	8,429.9	6,739.39	25.82%
Jan 2021	9,889.4	8,166.4	21.84%
Feb 2021	8,644.46	7,515.43	15.76%
Mar 2021	11,699.9	11,007.4	6.29%
Apr 2021	10,995.9	9,916.79	11.62%
May 2021	6,568.79	6,178.27	7.06%

Table (1): Electricity Generation from May 2020 to May 2021 (unit: kWh)

SHORT-CIRCUIT CURRENT REDUCTION COMPARISON APPROACH

This measurement approach, which has many variations, compares a pair of PV reference devices, one of which is routinely cleaned by a robot and the other of which soils naturally at the same rate as the PV array. The short-circuit current reduction due to soiling or maximum power is directly measured to calculate the difference in power generation. This is a simple analysis method that can assist in rapid evaluation.

As Figure (1) illustrates, the rooftop PV plant in the south of China is heavily impacted by metal dust. By measuring the current of cleaned and adjacent naturally soiled areas, it was found that the power generation increase rate in moderately polluted areas is 25.45%, while in heavily polluted areas, it is 36.38%.

Figure (1): The Modules on the Rooftop PV Plant were Covered with Metallic Dust, Leading to Rusting. Regular Cleaning by Robots Significantly Improved the Situation of the Modules – Source: Sunpure

OPTICAL PRINCIPLES APPROACH

This approach is the most recommended one since it's easy to operate and observe the results in a short time with a high level of accuracy. Based on optical principles, this method detects soiling particles on a collection surface according to their effect on either the reflection or transmission of light. This method utilizes an optical dust monitoring system (e.g., DUST IQ) to measure light transmission losses. By installing optical dust monitoring systems within the PV array and cleaning them in the same manner and at the same time as the PV modules, comparative pollution rate data before and after cleaning can be collected. The dust monitoring system detects light losses caused by dust deposition on panels, providing insights into the dust losses of surrounding PV modules with high measurement accuracy. By comparing the light loss difference before and after robot cleaning, the cleaning efficiency is evaluated.

In a large PV plant in the Middle East region, located in a harsh desert environment near the sea with high temperatures, humidity, and salinity, over 1000 Sunpure cleaning robots are installed. The project utilizes Dust IQ for dust monitoring to assess real-time dust pollution levels and cleaning efficiency. By comparing the cleaning effects over a continuous period of 16 days, the average cleaning efficiency is calculated to be 99.92%.

Figure (2): Robots Working on the Modules While the DustIQ Examines their Efficiency – Source: Sunpure

CONCLUSION

In conclusion, the utilization of PV intelligent cleaning robots has proven to be one of the most efficient methods for the daily maintenance of PV power stations. These robots guarantee consistent high-efficiency power generation, playing a crucial role in enabling unmanned operation and maintenance of the plants. Their significant practical value extends to the advancement of future PV installations.

Courtesy: Swiss School 780 kWp -YDE

A CALL TO ARMS: ESTABLISHMENT OF REGULATIONS FOR ROBOTIC CLEANING SYSTEMS

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INTRODUCTION

In a recent study by IEA (International Energy Agency), an independent agency working with governments and industries to shape a secure and sustainable energy future for all, it has been calculated that the energy production loss in solar installations due to soiling stands at 5 Billion EUR annually[1]. To be more specific, soiling is meant by the deposition of dust and sand on solar panels.

Figure (1): Waterless PV Panel-Cleaning Robot that is Being Tested by a Government Entity in Dubai Desert

This phenomenon can reduce the output of a solar park in an arid area by as much as 5% daily and up to 30% in a matter of hours in case of a sandstorm. These staggering figures should raise significant concerns among all of us, because most of these losses occur in solar parks situated in arid areas, mainly the MENA Region, followed by India, South America, Australia, and others. Several companies are working on developing a robotic cleaning system with the aim of solving this problem.

CHALLENGES IN ARID REGIONS: SOILING AND WATER SCARCITY IN SOLAR PARKS

We live in a changing world and we observe the consequences of climate change every day around us. One of the main answers to this energy crisis is building utility-scale solar projects. It is now beyond any doubt that most of these projects are expected to be located in arid areas where there is high irradiance, low cost of land and low wages. However, the following problems could also be present in these areas:

- Lack of water resources for cleaning
- Reduction of output due to soiling.

Apart from this, there is also the Phenomenon of Cementation, which occurs when sand accumulates on a PV panel and is subject to high humidity, a very common natural phenomenon in desert climates. The sand hardens and sticks on the panel and is very difficult to remove, even by using water. Therefore, in order for a project in these areas to have a continuous peak production, everyday waterless PV panel cleaning is necessary.

STANDARDIZING SOLUTIONS: ESTABLISHING REGULATIONS FOR PV PANEL CLEANING ROBOTS

The problem with soiling is that after the first solar park installations in arid areas, a reduced power output was observed compared to the expected. Therefore, a bottom-to-top process started, with various companies, trying to solve the everyday waterless PV panel-cleaning problem in arid areas. This has resulted in lots of solutions being proposed, but they have yet to manage to set an industry standard.

The magnitude of the problem could already be emphasized. In addition, it's expected that this problem to increase annually, as more solar installations would be done in arid areas, and due to climate change, more areas would become arid. Refer to an article published in PV Magazine titled: " Saharan Dust Drops Irradiance Across Europe" as an example[2].

Taking all of the above into consideration, the biggest challenge that the robotic cleaning system industry could be facing is the absence of Technical Standards, at the moment each company sell their solution, but there are no common denominators in which it's possible to judge each system's efficiency, and durability.

It's known that the technical Standards are documents that set out the specifications, procedures, and guidelines to ensure the safety, consistency, and reliability of the products, services and systems that are sold to customers. It's important to set technical standards for any type of product, as they provide sufficient and detailed information on how the performance of the said product could be measured and evaluated. It could as well assist customers in measuring the interoperability of components made by different companies, which will eventually assist the customer in overseeing the differences between the products.

There are several random attempts to establish specification standards, addressing at least part of the problem. One example is the PI Institut Berlin. They have developed a cleaning simulation protocol by which in a couple of months of testing they could predict the impact of thousands of cleaning cycles on the panel surface, which is equivalent to 20 years of operation. Impact on the panels is meant by whether the panels' surface is scratched by the cleaning robot or not, and by how much.

However, since the problem of soiling is mainly seen in the MENA Region, it is from there that a serious discussion is needed regarding the establishment of Technical Standards for waterless PV panel cleaning robots.

CONCLUSION

In conclusion, Middle Eastern organizations and institutions, together with manufacturers of PV panel cleaning robots have to work hand in hand, to establish universal specifications and regulations. This could be done by operating the robots in specifically built Test Fields under various conditions (e.g. temperature, wind speed, tilt angle, and humidity) and collecting all necessary data. Localization should not be only about producing locally but also about providing local scientific content. Once some Technical Standards are set, a great push would be given to the market by making product offerings better and comparable between various manufacturers, leading to the peace of mind of installers, O&M's and investors in regards to the quality of the product they have bought.

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VIABLE LIFE CYCLE SUSTAINABILITY METHODS OF SOLAR PANELS

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"We do not inherit the earth from our ancestors; we are borrowing it from our children". A native American proverb that echoes the urgent need for sustainable practices and responsible stewardship of our planet.
The current focus on Sustainability ensures the responsible use of natural resources and helps preserve natural ecosystems, biodiversity, and the overall health and well-being of the planet and all its inhabitants. Sustainability also ensures a reduction in greenhouse gasses mitigating climate change. It promotes a socially equitable approach to development, where both the rewards and burdens are distributed fairly amongst all members of society including present and future generations.

Encouraging investments in green technologies, and sustainable infrastructure is essential for our transition to a net-zero future. Energy efficient buildings form a very important contributor to a low carbon future since buildings and construction related activities generate close to forty percent of the overall carbon emissions globally.

The Middle East region with its abundant sunlight and growing environmental awareness has recently seen a significant surge in the Building Integrated Photovoltaic (BIPV) and Net-zero buildings. Net-zero buildings are designed to produce as much energy as it operationally consumes over a period of a year. They incorporate energy efficient design as well as the use of innovative materials and passive solar techniques to reduce their energy consumption. Onsite renewable energy systems -mainly solar energy in the Middle East – are then used to generate the optimized energy requirement of the building. Since solar irradiation is high throughout the year in the Middle East, the potential for Net-zero buildings is very promising indeed.

FEATURES OF NET-ZERO BUILDINGS

Net-zero buildings employ a range of design strategies to minimize energy consumption, including bioclimatic architecture, natural ventilation, optimal use of natural lighting, thermal insulation, efficient HVAC systems etc. Integration of Solar PV systems on the building envelope including roofs, facades, canopies etc are a central feature of Net-Zero Buildings.

Recent developments in architectural BIPV technologies ensure a very high aesthetic finish and efficient energy generation by utilizing Solar PV in various parts of the outer skin of buildings.

Different techniques are used for either on-grid integration of the BIPV systems or off-grid integration with energy storage and renewable energy-based backup energy systems to achieve Net-Zero energy generation.

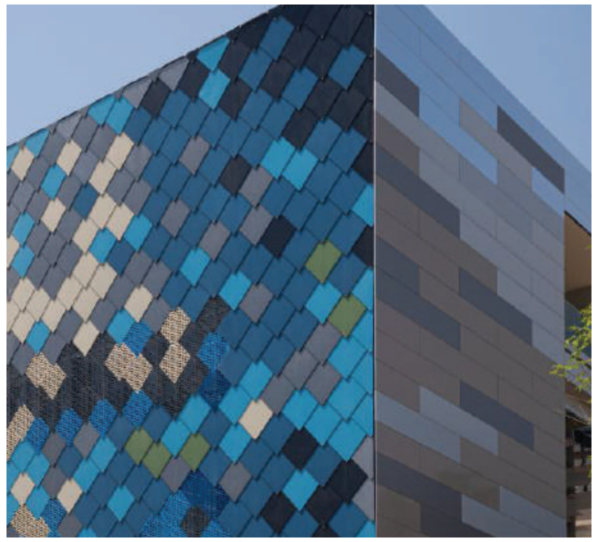

Figure (1): French Pavilion BIPV facade at Dubai Expo 2020 – Source: Empereal

CHALLENGES IN THE INTEGRATION OF BIPV FOR NET-ZERO BUILDINGS

Cost is a key factor in the adoption of BIPV solutions for some Net-Zero buildings. However, the advancement in technology allows the BIPV solar panels to be used as a building material and this reduces the incremental costs and provides an excellent return on capital investment. An example is the Mitrex solar cladding which allows all types of building facades like rain-screen systems as well as curtain walls to be fabricated using BIPV systems. When the cost of the replacement material like glass or conventional cladding is also considered, the Return on Investment of BIPV or Net Zero Buildings can be very impressive.

The aesthetics of integrating solar PV systems into building design is another challenge which is being alleviated by the various advancements in BIPV technology. Current BIPV modules lend more flexibility in terms of colours, shapes, sizes, and textures to suit various aesthetic design approaches. Durability and maintenance are also essential to prioritize when integrating solar PV into Net-Zero buildings. Ensuring the use of long-life durable solutions and taking care of them with disciplined maintenance is essential for ensuring that all objectives of solar PV integration into Net-zero buildings are achieved.

Figure (2): UAE Pavilion at Dubai Expo 2020 – Source: MOPA

KEY BENEFITS OF NET-ZERO BUILDINGS

Net-zero buildings generate their own energy requirements onsite using various renewable energy solutions, reducing, or eliminating their energy bills. This can lead to significant cost savings over the lifetime of the building. They also achieve independence from fluctuating energy prices. The environmental impact of net-zero buildings is significantly better than conventional buildings due to their efficient energy consumption and onsite generation of renewable energy. They are increasingly being sought after in the market for their sustainability credentials, lower energy costs, better energy efficiency etc, especially amongst environmentally conscious individuals and corporations.

As countries move towards meeting their net-zero commitments, current movement towards net-zero buildings future proof the investments against energy regulatory controls that may become imposed in the future. This reduces the risks of investment in new building construction while providing further risk mitigation and market attractiveness.

TRENDS IN THE MIDDLE EAST

With a concentration on architectural solar integration, numerous BIPV projects have been undertaken in the Middle East. There is an observed increase in the demand for Net-Zero buildings, necessitating the aesthetic integration of solar systems. This is driven by a growing environmental awareness and leadership thinking on sustainability inculcated by events such as the recently concluded COP28. Several technological enhancements are taking place in BIPV solar technology ranging from lightweight solar modules to coloured and patterned modules to solar cladding solutions and solar modules which meet or exceed all the building material codes and regulatory requirements.

Governments across the Middle East are promoting energy efficient buildings, and this provides a very favorable regulatory environment promoting BIPV and net-net-zero buildings. The increasing collaboration between architects, developers and the solar industry ensures that solar integration and the use of solar modules as building components are incorporated at the building design stage itself, leading to optimal design and economic outcomes.

Figure (3): Restaurant Complex BIPV Integration in Canopies, Facades and Balustrades – Source: Empereal

Calculating the energy requirements of buildings to enhance the quality of life of their occupants and reducing its impact on the environment and surroundings requires the processing of numerous data points to be processed and carefully validated. The availability of various computational tools and software to plan out the energy requirements and manage the complex design process is another factor promoting architects and planners to make net-zero buildings a reality.

The UAE pavilion at the Dubai Expo 2020 is an excellent example of BIPV solar modules integrated in an aesthetic manner into the building facades and taking the building to a LEED platinum sustainability rating. The various restaurant complexes at the Dubai Expo 2020 are also shining examples of BIPV integration and the use of solar as a building material for roofs, canopies, facades etc.

The Masdar MC2 and various other projects by Masdar City are achieving net-zero status through aesthetic design and integration of Solar PV solutions into the buildings. Sustainability City in Dubai has incorporated BIPV and solar integration into buildings at a large community scale. The new DEWA headquarters building coming up in Dubai is another example of maybe the largest-scale Net-zero building in the world.

King Abdullah University of Science and Technology (KAUST), and Qatar National Convention Centre are other projects in the region that have integrated BIPV to improve their sustainability requirements. There are various new designs and initiatives of Net-zero buildings which are emerging in all cities in the Middle East and GCC region.

These projects highlight the region's commitment to sustainable development while showcasing innovative architectural designs that seamlessly integrate solar into building structures. The current trend positions the Middle East as one of the clear leaders in the emerging BIPV and net-zero buildings market. The coming years will strengthen the current trend and bring out the sustainability and beauty of using solar BIPV to enhance architectural designs and intent in buildings around the Middle East.

NECESSITY OF CARBON CAPTURE AND STORAGE TECHNOLOGY AND ITS BENEFITS & CHALLENGES ON THE ENVIRONMENT

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OVERVIEW:

Carbon Capture and Storage (CCS) involves the capture of carbon dioxide (CO_2) emissions from industrial processes, such as steel and cement production, or from the burning of fossil fuels in power generation. This carbon is then transported from where it was produced, via ship or in a pipeline, and stored deep underground in geological formations[1].

CCS can be seen as a bridge technology, allowing for the continued use of fossil fuels in electricity generation and industry until low-carbon alternatives can be implemented. CCS may also be necessary to achieve the negative CO_2 emissions required for the 1.5°C and 2°C climate goals[2].

According to the Global CCS Institute's 2021 Status Report, plants in operation or under construction have the current capacity to capture 40 million metric tons of CO_2 per year. (For Ex., the United States alone emitted over 5 billion metric tons of CO_2 in 2019). In 2021, 102 CCS facilities were in the advanced and early stages of development. Combined with facilities already under construction or in operation, these facilities could capture 149.3 million metric tons of CO_2 per year.

TYPES OF CARBON CAPTURE AND STORAGE

Carbon capture and storage (CCS) covers various techniques for capturing carbon dioxide (CO2) emissions from industrial processes or power plants and storing them underground to avert its release into the atmosphere. These techniques are broadly categorized into three main types:

Post Combustion	Pre Combustion	Oxy-Fuel Combustion
Largely used in the majority of existing coal-fired plants	Suitable for IGCC plants as CO2 partial pressure is higher than in flue gas	Can be retrofitted in existing or new coal powered plants
Partial pressure of CO2 is low	Extraction of CO2 is needed before fuel combustion	Very high CO2 concentration (up to 90%) in flue gas
Cost efficient	High equipment cost	Cryogenic O2 production is costly
Retrofit technology option	Largely applicable to new plants	Applicable for New or existing coal or gas fired plants, It does not require on-site chemical operations
Produce CO2 at low pressure compared with required sequestration	Typically higher concentration of CO2 compared to post-combustion capture	Large volume of flue gas recycling is needed to prevent high combustion temperatures
High circulation volume and performance are necessary for a high capture level	Less amount of water consumption than the post-combustion technique	Low level of pollutant emissions at low cost
Enhanced solvents like amine-based chemicals have better absorption capacity at lower partial pressure	Extensive supporting system like a physical absorption process is required to absorb CO2 from mixed gasses	Potential for advanced oxygen separation membranes with lower energy consumption

ENVIRONMENTAL BENEFITS

1. Reducing Carbon Emission

The key benefit of CCS is to capture carbon dioxide (CO2) from power plants or industrial processes by different techniques and avert it from entering the atmosphere. It aids in diminishing the concentration of greenhouse gasses (GHG) in the environment, thereby mitigating climate change and its related impacts, such as extreme weather events, global warming, and rising sea levels[3].

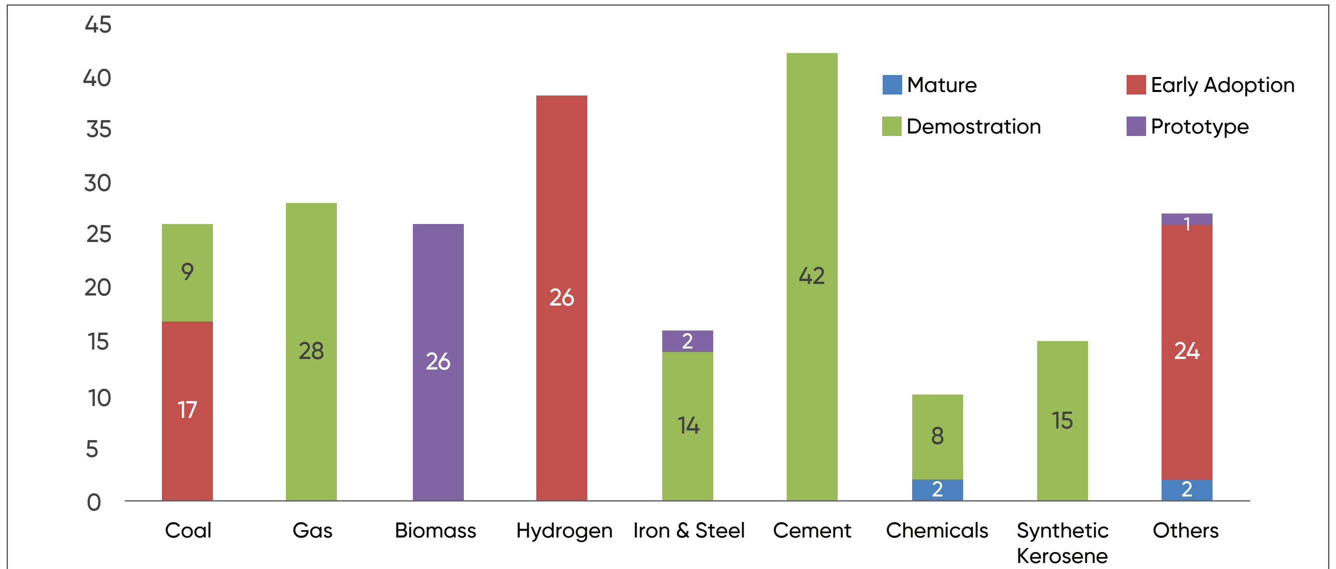

Figure (1): World Cumulative CO2 Emissions Reductions From CCUS By Application and Technology

2. Technological Innovation

Carbon capture methods such as Direct Air Capture (DAC) and Bioenergy with Carbon Capture and Storage (BECCS) act as a key enablers for carbon removal. These technologies remove CO2 from the atmosphere or capture it at the source and store it underground, helping to achieve negative emissions and further mitigate climate change[3].

CO2 Capture in Chemicals

Ammonia – Physical & Chemical Absorption
Methanol – Physical & Chemical Absorption
High-value Chemical – Physical & Chemical Absorption
Ammonia – Physical Adsorption

CO2 Capture in Iron & Steel

Direct Reduced Iron – Chemical Absorption
Smelt Reduction – Oxygen Rich Physical Adsorption
Blast Furnace – Process Gas
Hydrogen Enrichment – Chemical Absorption
Direct Reduced Iron – Physical Adsorption

CO2 Capture in Cement

Chemical Absorption
Calcium Looping
Oxy-Fuelling
Physical Adsorption
Direct Separation

CO2 Capture in Fuels Production

Natural Gas Processing
Hydrogen from Gas with Carbon Capture
Bio-methane with Carbon Capture
Ethanol with Carbon Capture
Hydrogen from Coal with Carbon Capture

CO2 Capture in Power Generation

Coal – Chemical Absorption
Coal – Oxy-Fueling
Coal – Pre-Combustion
Natural Gas – Chemical Absorption
Biomass – Chemical Absorption

CO2 Capture from Air

Direct Air capture – Solid
Direct Air Capture - Liquid

Figure (2): Carbon Capture Methods

3. Mitigating Climate Change

CCS technology can help achieve the aim of maintaining the temperature increase below the 2°C target as per the Paris Agreement. According to the International Energy Agency (IEA), the carbon capture and storage technology could add up to 13% to the necessary emissions reduction by 2060[4].

4. Support Sustainable Industry

By capturing and storing CO2 from power plants and process industries where significant CO2 emissions are generated, CCS supports the transition towards more sustainable industrial practices. It helps in reducing the environmental footprint of key industries and enhancing their long-term viability.

MAJOR CHALLENGES

Carbon Capture and Storage (CCS) is a proven and safe technology to reduce carbon emissions from the atmosphere and tackle global warming. However, there are several challenges to capturing, transporting, and storing it deep underground. A few of the major challenges to this technology are as follows:

Cost: One of the primary challenges of CCS is its high cost. The capture, transportation, and storage of CO2 require significant infrastructure and energy, making it economically challenging, especially without sufficient financial incentives or policies supporting its implementation. The cost of CO2 capture can vary greatly from a range of USD 15-25/t CO2 for industrial processes to USD 40-120/t CO2 for processes with "dilute" gas streams, such as cement production and power generation. Currently, Direct Air Capture (DAC) is the most expensive approach with an estimated cost of USD 600-1000 per ton of CO2[5].

Some CO2 capture technologies are commercially available now, while others are still in development, and this further contributes to the large range in costs.

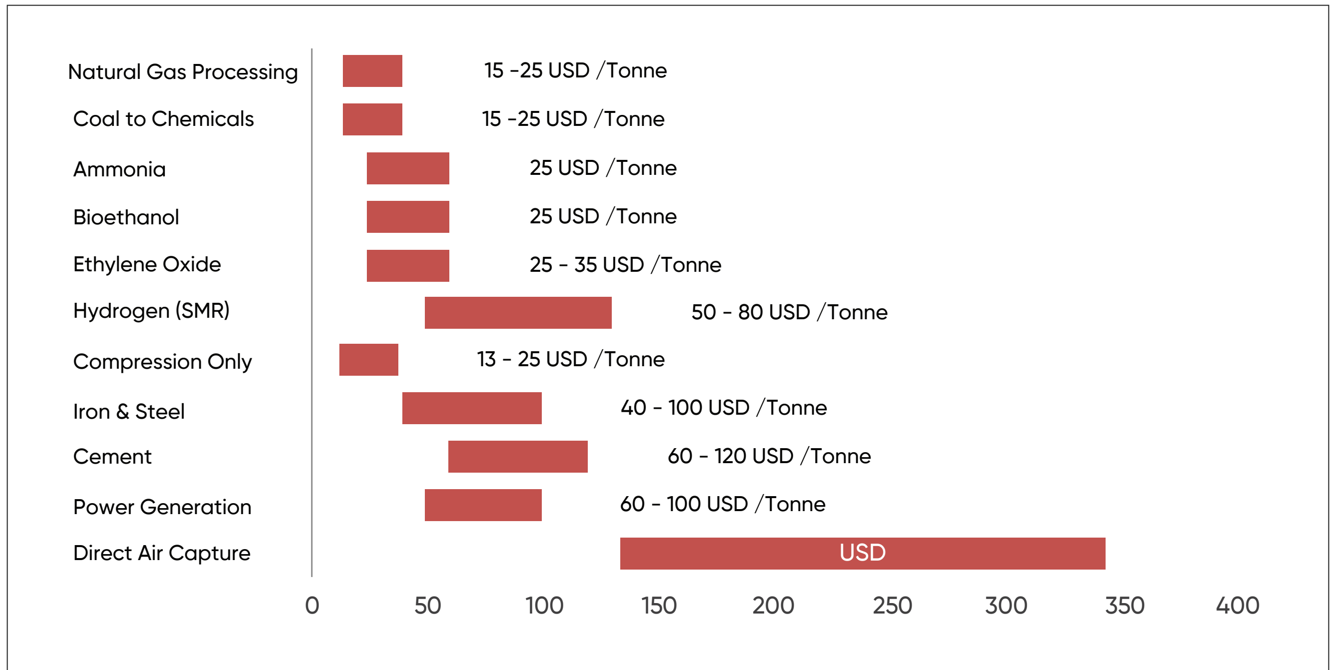

Figure (3): Levelized Cost of CO2 Capture by Sector and Initial CO2 Concentration, 2019

Storage Site Availability: Identifying an appropriate CO2 storage site is among the major challenges in the industry. There are several factors such as geological stability, proximity to emission sources, and potential risks of CO2 leakage that need to be evaluated before finalizing any storage location. Additionally, public acceptance of storage sites can be a challenge due to concerns about environmental impact and safety[6].

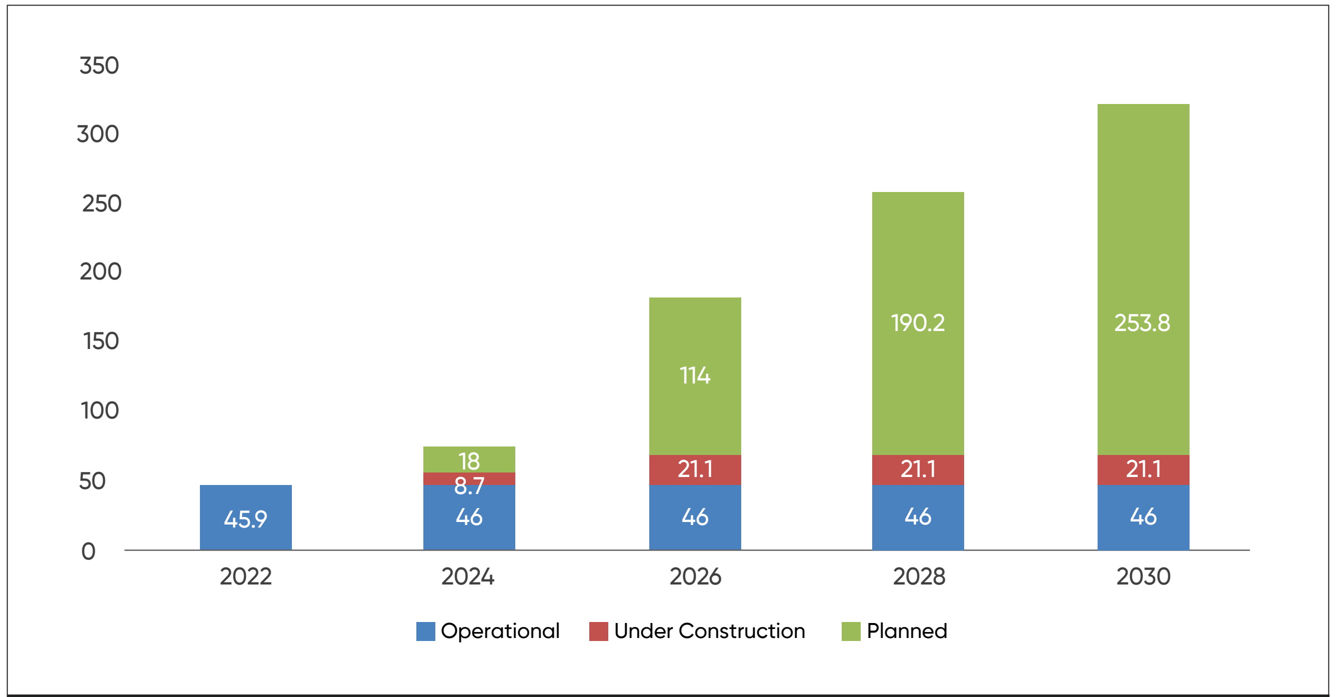

Figure (4): Operational and Planned Capture Capacity (Mt CO2 Per Year)

Monitoring and Verification: To ensure the long-term integrity of the identified CO2 storage sites, continuous monitoring and verification systems are essential. Identifying and mitigating any potential leak is essential to prevent environmental damage and ensure public trust in the technology. Several companies offer monitoring, verification and reporting services to give real-time information about such storage sites. Key players involved are Schlumberger, Baker Hughes, DNV GL, and TÜV SÜD among others.

Regulatory and Legal Frameworks: Stringent laws and policies for CCS create a pathway for developers to ensure the safety of the public and the environment. Developing suitable regulatory frameworks for CCS, including liability issues, property rights, and long-term stewardship of storage sites, presents challenges and is a must in today's situation. Uncertainties in regulations and policies can hamper investment in CCS projects and delay their deployment. Below are a few regulations followed by key countries for CCS activities[7-8].

Courtesy: Ghadir Shaar- Kingspan461 kWp-UAE - YDE

Country	Regulatory Frameworks
European Union	EU Directive 2009/31/EC (on CO2 storage) EU Directive 2008/1/EC on Integrated Pollution Prevention and Control Council Directive 85/337/EEC of June 1985 on EIA, which is to be applied to CO2 transport.
United Kingdom	UK Energy Act 2008
United States of America	IOGCC Guidelines American Clean Energy and Security Act 2009 EPA Guidance under the Underground Injection Control Programme 2007 State regulations from Wyoming, North Dakota and Montana American Clean Energy Leadership Act Carbon Capture and Sequestration Programme Amendments Act Carbon Storage Stewardship Trust Fund
Australia	Australian Regulatory Guiding Principles The Offshore Petroleum Amendment (GHG Storage) Act 2008 Australian Greenhouse Geological Sequestration Act 2008 Queensland Greenhouse Gas Storage Act 2009-08-28 The Barrow Island Act of 2003 related to Gorgon
The Netherlands	Dutch Mining Act of 2003
Norway	Norwegian Pollution Control Act
People's Republic of China	National Climate Change Program 2007 Environmental Impact Assessment Law 2002 Prevention and Control of Atmospheric Pollution Law Prevention and Control of Solid Waste Pollution Law Marine Environmental Protection Law

Storage Site Availability:
Huge infrastructure investment and technological advancement are needed to scale up CCS and make a significant impact on global carbon emissions. Still, the slow growth in deployment and the limited number of large-scale CCS projects deter the progress of worldwide adoption[9].

Public Perception and Social Acceptance:
Public perception and social acceptance of CCS technology play a considerable role in its adoption. Misconceptions regarding groundwater contamination, potential CO2 leakage, health risks, and induced seismicity can lead to disbelief and resistance among the general public.

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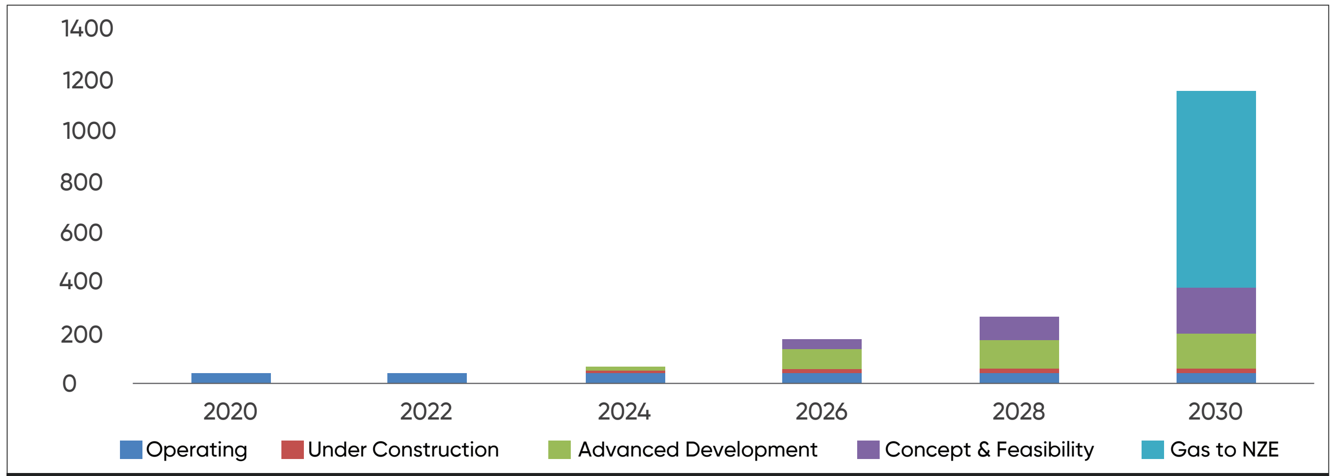

Figure (5): Capacity of Current and Planned Large-Scale CO2 Capture Projects Vs. The Net Zero Scenario, 2020-2030, (Mt CO2/Year)

CARBON MARKETS: INSIGHTS FROM THE MIDDLE EAST, SOLAR INDUSTRY & GLOBAL PERSPECTIVE

Aston Dutheuil
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INTRODUCTION

Carbon credits, while gaining momentum, have a longstanding history dating back to their introduction in 1997 under the Kyoto Protocol on Climate Change. This system serves as a crucial accounting mechanism aimed at mitigating global greenhouse gas (GHG) emissions.

The fundamental concept of carbon credits is straightforward: each credit represents ownership of one ton of greenhouse gas, typically measured as a Carbon Dioxide (CO2) equivalent, which can be transferred, traded, and utilized to balance emissions generated elsewhere.

COMPLIANCE VS VOLUNTARY MARKETS

Touching on markets and trading of carbon instruments, two distinct markets emerge: voluntary and compliance markets. Compliance markets are characterized by mandatory regulations imposed by national or international authorities. This strict regulatory oversight aims to reduce emissions from specific industries or sectors by enforcing emission limits or quotas. Compliance market mechanisms often include cap-and-trade systems or carbon taxes, compelling entities to either reduce their emissions or purchase allowances (i.e. credits) to cover their excess emissions. Compliance markets typically target energy-intensive sectors such as manufacturing, power generation, and transportation. Thus far, about 30 compliance carbon markets have been implemented worldwide to help countries achieve their emission reduction objectives, known as Nationally Determined Contributions (NDCs)[18,23]. For instance, the European Union Emissions Trading System (ETS) is the first major compliance market worldwide regulating about 11'000 installations across various energy-intensive sectors[1].

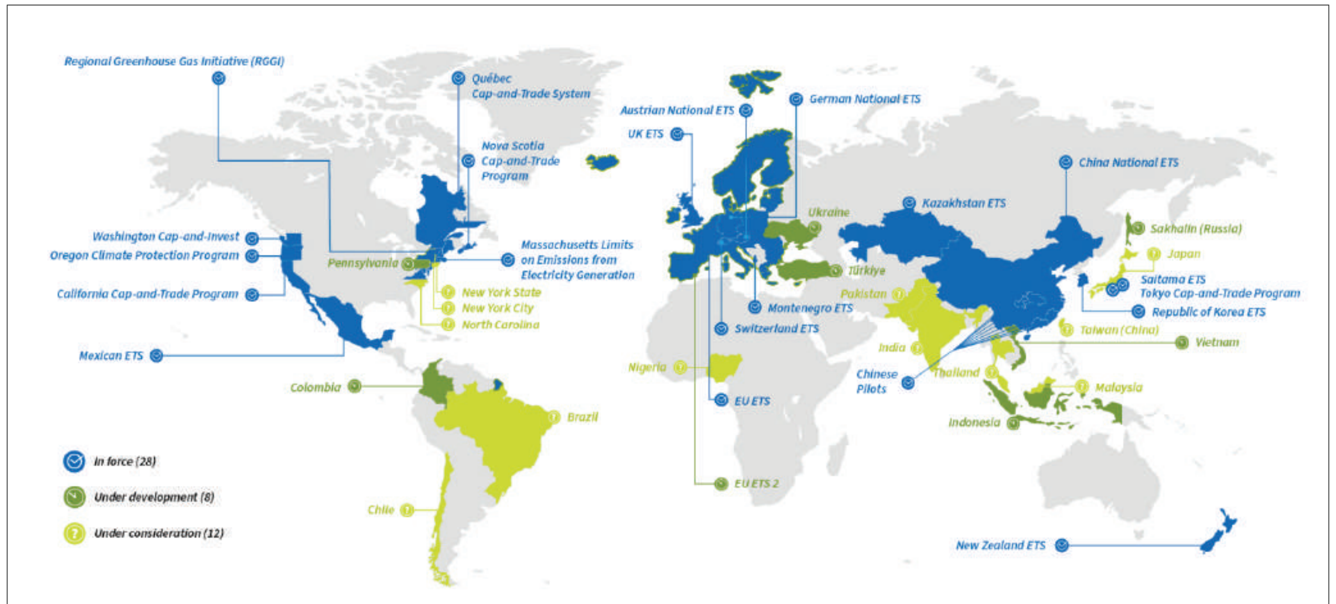


Figure (1): State of Compliance Markets and Jurisdictions – Source: ICAP

In contrast, Voluntary Carbon Markets (VCMs) operate independently of any governmental supervision. They were established in response to the unavailability of effective means for companies and individuals not constrained by compliance markets to offset their emissions. Growing climate awareness and trends in Environmental, Social, and Governance (ESG) practices, as well as the adoption of net-zero targets across sectors, have further propelled interest in voluntary carbon markets. In VCMs, two broad types of credits exist: avoidance and removal credits. Avoidance refers to emission reductions achieved by preventing or diminishing their occurrence, for instance, by halting deforestation or through renewable energy generation. Removal denotes the extraction of carbon dioxide from the atmosphere, typically via methodologies like afforestation, reforestation, or carbon capture and storage technologies[2-3].

Reduction/Avoidance Credits
Carbon Credits that reduce or avoid GHG emissions.

Technology-Based
- Renewable Energy
- Methane Collection
- Industrial Pollutants
- Household Devices/ Energy Efficiency

Nature-Based
- Avoided Deforestation/ REDD+
- Wetland Management
- No-Till Farming
- Methane from Livestock

Removal Credits
Carbon Credits that actively capture GHG emissions.

Technology-Based
- Direct Air Capture
- Mineralization
- Carbon Capture and Storage

Nature-Based
- Reforestation
- Afforestation
- Soil Sequestration/ Biochar
- Wetland Restoration

Source: S&P Global Platt

Figure (2): Two Main Categories of Voluntary Carbon Credits

Courtesy: Imerys Al Zayani 4.7 MWp-Bahrain - YDE

Voluntary carbon credits or offsets are certified by independent entities[2], and since there is no central regulator in voluntary carbon markets, VCM standards, such as Verra or the Gold Standard, exist to verify offset projects, ensuring they adhere to strict rules and maintain high standards of environmental integrity (See Figure (3)).

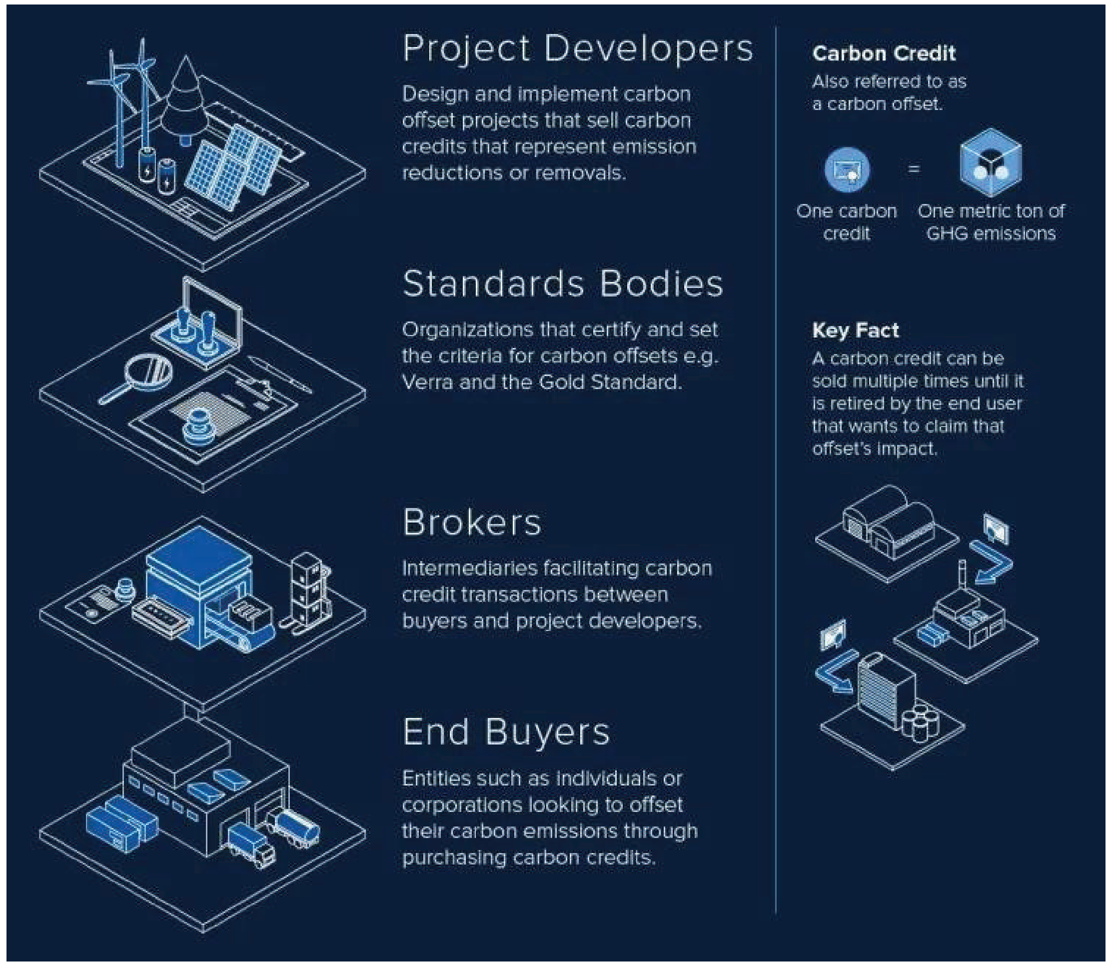


Figure (3): Components of Voluntary Carbon Markets – Source: Visual Capitalist

In terms of market size, the compliance market and the voluntary market are vastly different. At their highest points, in 2021, the voluntary carbon market value reached approximately USD 2 billion, whereas the compliance market soared to USD 850 billion during the same period[20].

WHAT IS HAPPENING IN THE GCC REGION?

In the Middle East, where compliance markets have yet to take root, a surge of initiatives underscores the region's commitment to advancing carbon market activities.

RVCMC, established in October 2022 through a collaboration between Saudi Arabia's Public Investment Fund and the Saudi Stock Exchange, has facilitated significant strides. Auctions organized by RVCMC resulted in the sale of about 3.6 million tons of carbon. These transactions, which attracted stakeholders like Aramco aiming to bolster their net-zero endeavours, reflect a growing interest from local stakeholders toward carbon markets[11].

In the United Arab Emirates, it's the launch of ACX Abu Dhabi within ADGM in late 2022 that marked a significant milestone. ACX became the world's first regulated recognized investment exchange and clearing house for environmental instruments aiming to enhance liquidity and transparency in voluntary carbon markets[12-13].

More recently, Dubai Financial Market (DFM) introduced the emirate's first Carbon Credit Trading Pilot Program during the first half of COP28 in Dubai. Over 24 leading UAE companies and project developers participated in this inaugural pilot, which unfolded from December 4th to December 8th, 2023. The program showcased a diverse array of verified carbon credits, sourced from both local and international initiatives. These credits traded on DFM, were derived from projects certified by recognized standard setters such as VERRA or the UN's Clean Development Mechanism (CDM), encompassing efforts ranging from clean energy generation to deforestation prevention and enhanced efficiency in traditional power generation[14].

CHALLENGES – GLOBAL PERSPECTIVE

Amidst growing interest and the promising potential of carbon offset schemes in the fight against climate change, fuelled by a surge in net-zero strategies and ambitious initiatives, the market is faced with structural and reputational challenges. In addition to an oversupply of about 50% in 2023[22] and the global macro-economic environment tensions induced by the pandemic, the war in Ukraine as well as the sustained interest rates and inflation hikes, scandals and criticism have reverberated throughout the industry, leading to investor withdrawals and eroding market trust.

Articles such as the investigations conducted by The Guardian alleged instances of meaningless carbon credits being emitted, casting doubt on the credibility of voluntary carbon markets (VCMs). Concerns raised included overstated threats to forests and human rights issues in offsetting projects approved by Verra. While Verra disputed the findings, asserting that they failed to accurately reflect the true impact on the ground, these revelations, coupled with existing criticisms of greenwashing, have exacerbated the fragility of the overall market, and emphasised the need for enhanced transparency and accountability[15]. Figure (4) depicts the recent nature-based carbon offset price drop.

Further criticism accumulated against VCM credits, highlighting structural issues such as additionality, double counting, and overstatement of carbon reduction impacts. The global voluntary carbon market has been impacted to the point where it lost about 75% of its value, falling from about USD2 billion at its peak in 2021 to USD 500 Million in mid-2023[20].

*Traded on CBL exchange
Source: Xpansive

Figure (4): Global Nature-Based Carbon Offsets Price

In addition to these recent shockwaves, the absence of centralized governance in the voluntary carbon market, while inherent to its voluntary nature, has posed long standing challenges. While compliance market credits are classified under regulatory frameworks, such as EUAs (EU Allowances) subject to MiFID II regulations in the European Union compliance market[3], the voluntary carbon market lacks a centralized governance body. Each standard sets its own eligibility criteria and nomenclature for carbon credits. This lack of unified standards tends to hamper market transparency and verification, as qualification criteria vary between standards, making it difficult for market participants to compare and differentiate high- and low-quality carbon credits.

CHALLENGES – SOLAR INDUSTRY

The solar industry contends with its own array of hurdles. From the perspective of solar developers and investors, carbon credits offer a mean to bolster financial viability and incentivize investment in renewable energy projects. Despite the declining cost of solar modules, the current context remains challenging for project developers. With heightened market competition and rising financing costs driven by surging inflation and increased interest rates, carbon trading may alleviate the potential contraction of returns and support investors in accelerating the integration of solar energy into power systems worldwide.

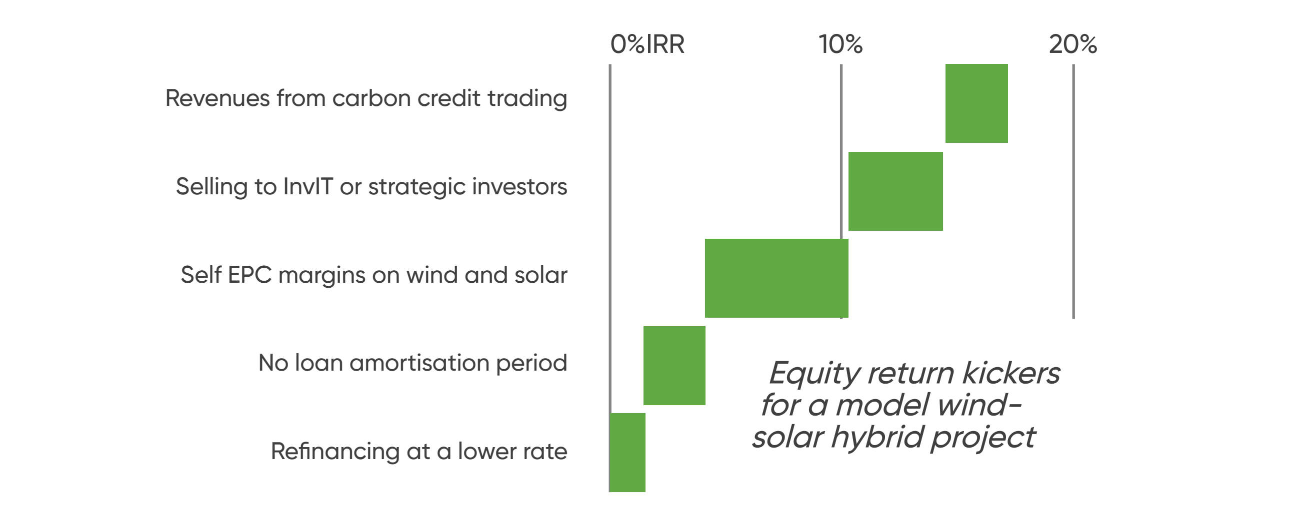


Figure (5): How Renewables Players Enhance Equity Returns Levers to improve incremental returns after projects start– Source: IEEFA analysis

As illustrated in a case study from the Institute for Energy Economics and Financial Analysis (IEEFA), the potential upside provided by carbon credit trading is often significant. (see Figure 5.) Through an analysis of the various options that large renewable energy companies possess to enhance their return on equity, it was found that revenues from carbon credit trading could add about 3% to the equity IRR of a hybrid solar-wind project in India.[25]

While the above figure seems realistic, it is virtually impossible to make it a general assumption for other similar projects. Integrating carbon revenue into financial models is not a straightforward process and presents numerous uncertainties stemming from the structure and state of the market. Limited public disclosure in transactions confines access to current pricing and trends primarily to established market participants (i.e traders, brokers, consultants). The market's high volatility and lack of standardized governance further exacerbate this issue, making the accurate forecasting of long-term carbon offsets prices a complex task.

Additionally, with renewable energy generation becoming increasingly mainstream and economically viable, especially solar technology, market participants question the necessity of channelling finance into these projects for carbon offset purposes, resulting in investors forsaking renewable energy credits for other categories. Stemming from that same rationale that renewable energy is now generally more cost-effective than fossil energy, rendering offset schemes unnecessary for incentivizing its development, Verra and the Gold Standard have ceased to tokenize new renewable energy projects as offsets, except in the least developed countries[17]. Still, other alternative financing mechanisms offer similar benefits to both project developers and companies willing to offset emissions, especially scope 2 emissions, (Greenhouse gas emissions indirectly linked to the acquisition of electricity, steam, heat, or cooling.)[19] such as Green Power Purchase Agreements (PPAs), Guarantee of Origin certificates, and Renewable Energy Certificates. However, except for least developed countries, access to VCM financing for solar projects might potentially continue to reduce as the technology becomes more accessible and is integrated into systems worldwide.

MARKET OUTLOOK AND FORWARD PERSPECTIVE

After the exponential growth of carbon markets since the early 2020s, 2023 rang like a wake-up call for global markets. Identified weaknesses underscore the urgent need for reforms, prompting stakeholders to take action. Despite facing ongoing challenges, optimism persists regarding the recovery and improvement of VCMs. Against this backdrop, the COP28 was awaited with great expectations and hope.

Carbon markets were a central topic throughout the conference. Initiatives aiming to reform VCMs while restoring the confidence of stakeholders have been unveiled. Key announcements included a collaborative effort among leading carbon crediting standards (ACR, Architecture for REDD+ Transactions, Climate Action Reserve, Global Carbon Council, Gold Standard, and Verra) to bolster program standards, aligning with the ICVCM's Core Carbon Principles (CCPs)[8]. (See Figure (6)) Multiple global organizations engaged in various levels of corporate decarbonization, including SBTi, CDP, GHG Protocol, VCMI, ICVCM, and We Mean Business Coalition unified to establish a "high integrity" framework to support companies in achieving credible climate leadership[21].

A. GOVERNANCE

Effactive governance

The carbon-crediting program shall have effective program governance to ensure transparency, accountability, continuous improvement and the overall quality of carbon credits.

Tracking

The carbon-crediting program shall operate or make use of a registry to uniquely identify, record and track mitigation activities and carbon credits Issued to ensure credits can bo identified securely and unambiguously.

Transparency

The carbon-crediting program shall provide comprehensive and transparent information on all credited mitigation activities. The information shall be publicly available in electronic format and shall be accessible to non-specialised audiences, to enable scrutiny of mitigation activities.

Robust independent third-party validation and verification

The carbon-crediting program shall have program-level requirements for robust independent third party walidation and verification of mitigation activities.

B. EMISSIONS IMPACT

Additionality

The greenhouse gas (GHG) emission reductions or removals from the mitigation activity shall be additional, i.e., they would not have occurred in the absence of the incentive created by carbon credit revenues.

Permanence

The GHG emission reductions or removals from the mitigation activity shall be permanent or, where there is a risk of reversal, there shall be measures in place to address those risks and compensate reversals.

Robust quantification of emission reductions and removals

The GHG emission reductions or removals from the mitigation activity shall be robustly quantitied, based on conservative approaches, completeness and sound scientific methods.

No double counting

The GHG emission reductions or removals from the mitigation activity shall not be double counted, i.e., they shall only be counted once towards achieving mitigation targets or goals. Double counting covers double issuance, double claiming, and double use.

C. SUSTAINABLE DEVELOPMENT

Sustainable development benefits and safeguards

The carbon-crediting program shall have clear guidance, tools and compliance procedures to ensure mitigation activities conform with or go beyond widely established industry best practices on social and environmental safeguards while delivering positive sustainable development environmental safeguards while delivering positive sustainable development Impacts.

Contribution to net zero transition

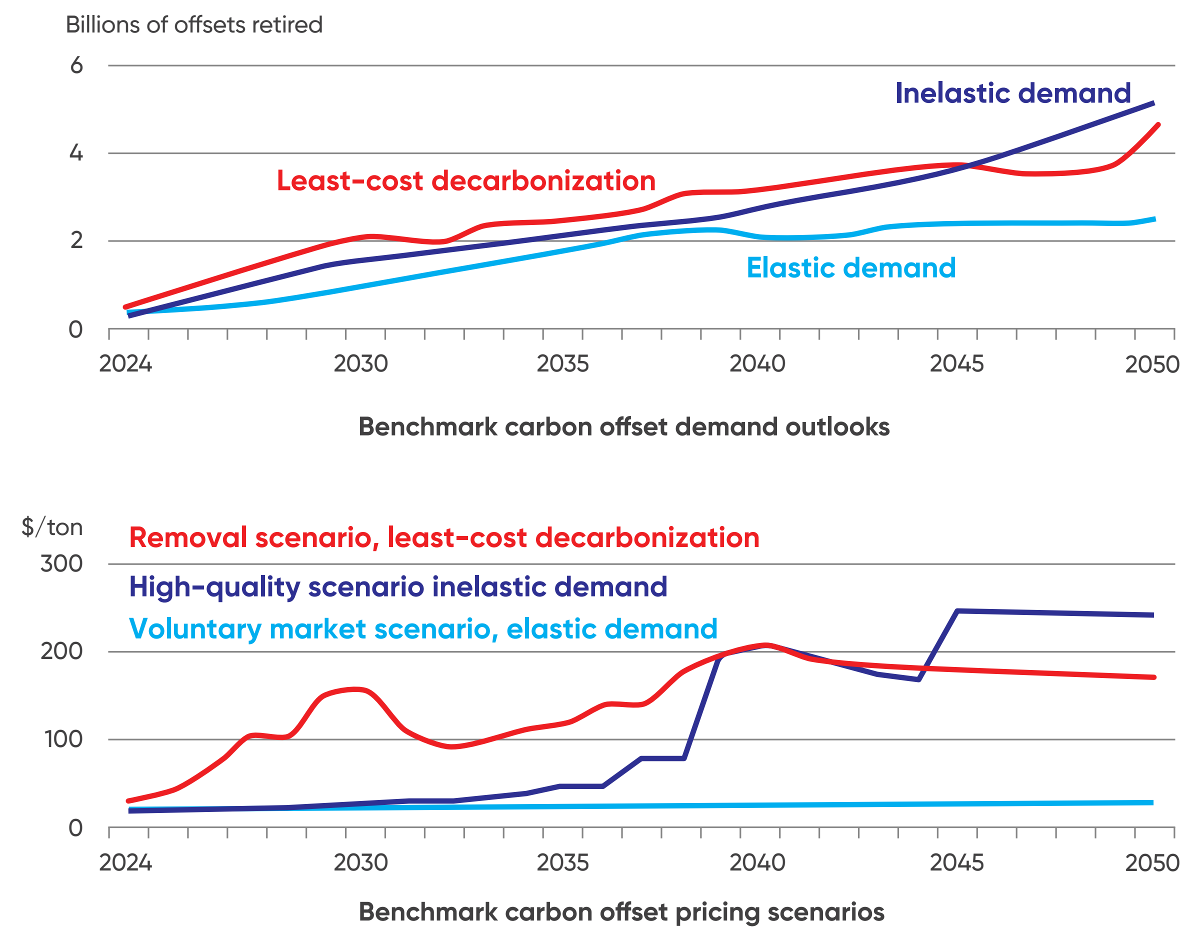
The mitigation activity shall avoid locking-in levels of GHG emissions, technologies or carbon-intensive practices that are incompatible with the objective of achieving net zero GHG emissions by mid-century.

Figure (6): The 10 Core Carbon Principles – Source: carboncredits.com

Additionally, innovative endeavours brought new promising concepts such as the Coal to Clean Credit Initiative, the first project using carbon finance to phase out a coal-fired power plant in the Philippines[10].

Although many promising initiatives and successes were presented, some aspects of the COP did not unfold as expected. Negotiations over Articles 6.2, addressing the bilateral exchange of mitigation outcomes, and 6.4, establishing a UNFCCC mechanism for the validation and issuance of carbon credits, concluded without final agreements, thus postponing finalization until COP29.

While the long-term evolution of VCMs remains uncertain at present, optimism surrounds their recovery. A report from Bloomberg depicted various evolution scenarios, all indicating an increase in demand and offset retirements. Across these scenarios, the market shows growth until 2050, albeit at differing rates. In the high scenario, the carbon offset market could achieve an annual value of $1.1 trillion by 2050, while under the low scenario, it may peak at $34 billion annually by the same year. The report underscores the significance of demand elasticity in shaping the future of Voluntary Carbon Markets (VCMs) and highlights the importance of restoring trust in markets and addressing current integrity concerns[22].



Source: BloombergNEF *Note: Prices are nominal.*

Figure (7): Bloomberg NEF's VCMs Forward Scenarios – Source: Bloomberg NEF

As the market moves closer to crucial milestones like 2030 and 2050, demand for carbon markets is expected to rise, necessitating effective initiatives to address persistent challenges. The year 2024 is anticipated to be pivotal for VCMs transformation, shaping the market's future trajectory and potential for recovery and growth.

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RISE OF BATTERY ENERGY STORAGE IN SUPPORT OF MENA'S ENERGY TRANSITION

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Nishant Kumar
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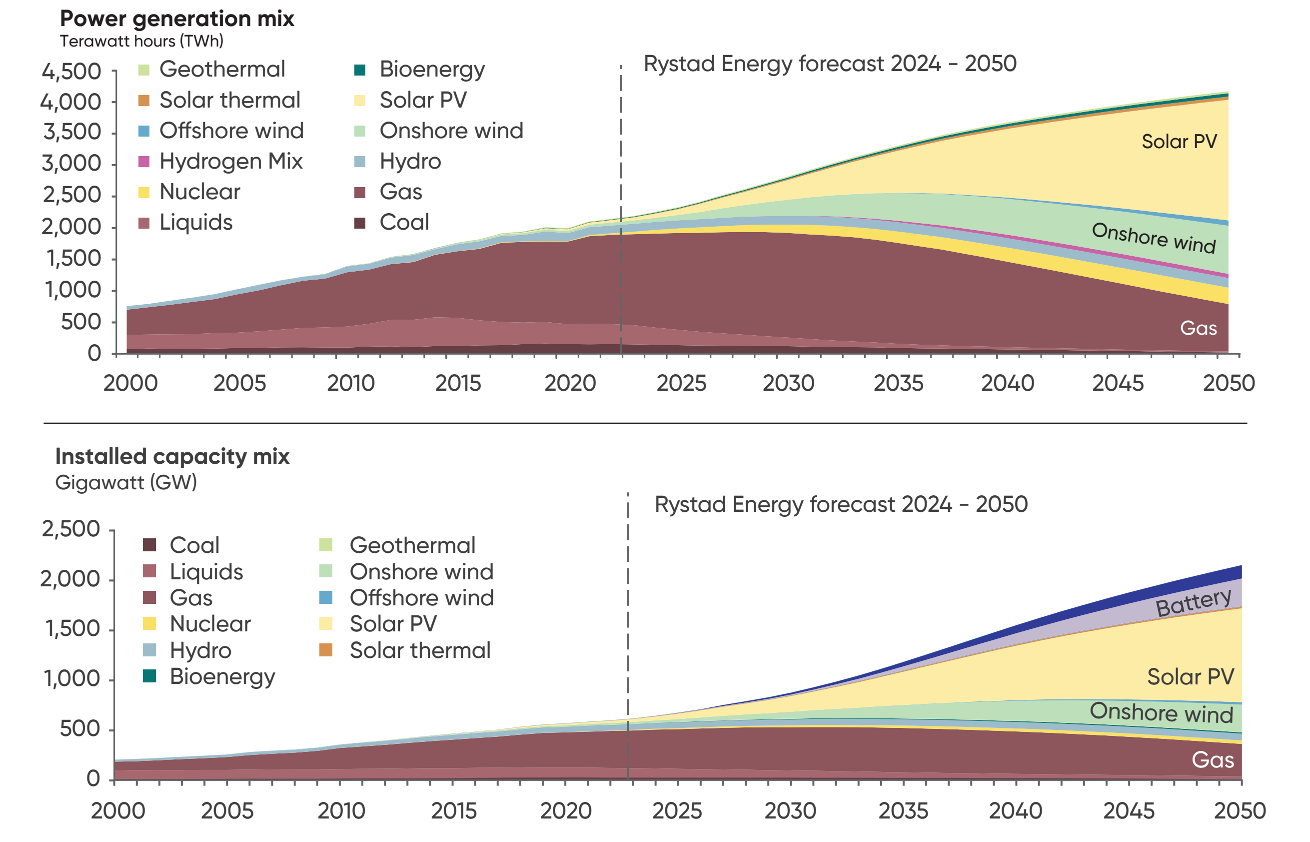
As the Middle East and North Africa (MENA) region strides ahead in its quest for clean and sustainable sources of energy, Battery Energy Storage Systems (BESS) will play a key role in enabling a smooth transition – integrating intermittent renewable energy sources such as solar and wind into the grid, and thereby bolstering grid stability and enhancing energy security. From the 2,200 TWh of power generated in MENA last year, solar and wind account for nearly 5%.

Industrialization, population growth, economic development, and the global shift away from fossil fuels will give way to the abundant potential for solar and wind that will collectively revolutionize MENA's energy landscape, especially as countries in the region have incorporated these energy sources as a core part of their energy strategies. Solar and wind are expected to account for over two-thirds of the region's power generation in 2050 – exemplifying the need for energy storage mechanisms for load balancing and reducing dependence on expensive gas peaking plants. Although countries like Morocco, Iran, Turkey, UAE, Tunisia, Egypt and Israel are at the forefront of developments in pumped storage facilities, batteries are touted to play a wider role as they can cater to demand almost instantaneously.

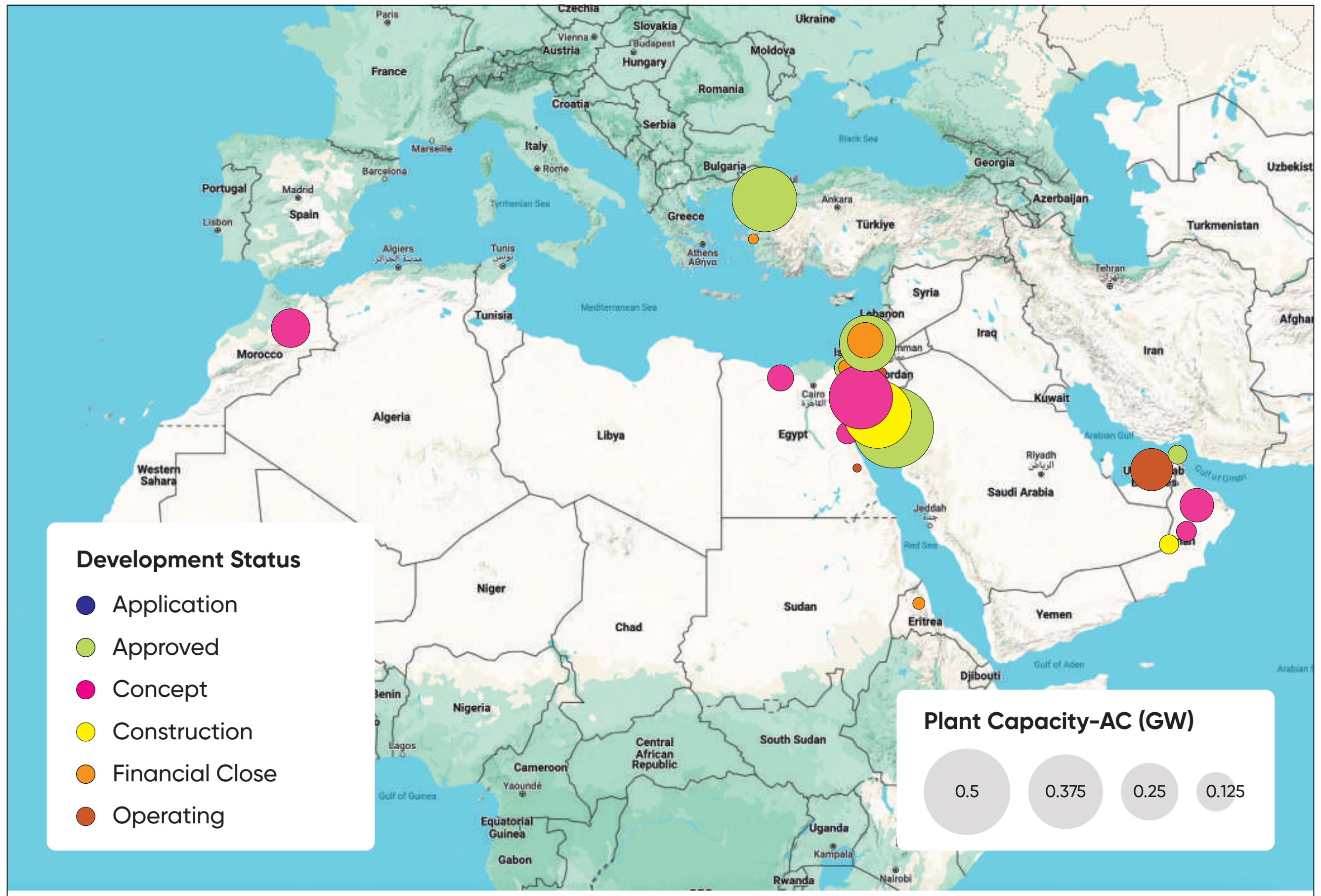


*Middle East and North Africa includes Algeria, Bahrain, Egypt, Eritrea, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, Turkey, UAE, Western Sahara and Yemen
Source: Rystad Energy Global Powermix Dashboard, Rystad Energy PowerCube

Figure (1): Power Sector Outlook by Energy Category, MENA*

Key projects under construction in the Middle East include Saudi Arabia's Neom Green Hydrogen project which includes 2.2 GW solar, 1.6 GW onshore wind, and a 400 MWh BESS. Another project in Saudi Arabia is Red Sea which includes 340 MW solar and a 1,200 MWh BESS. In addition, Abu Dhabi Future Energy Company PJSC (Masdar) and the Jordanian Ministry of Energy and Mineral Resources signed an agreement for the development of a 1 GW onshore wind project with a BESS in Jordan during the UN Climate Change Conference in Dubai (COP 28). Meanwhile, In August 2023, Israel announced an 800 MW / 3,200 MWh BESS buildout comprising four facilities of 200 MW / 800 MWh each in the northern Gilboa mountain range region.

Key projects in the pipeline for North Africa include Morocco's Noor Midelt III project (400 MW solar and 400 MWh BESS). In Egypt, noteworthy projects include the New and Renewable Energy Authority (NREA)'s Hurghada (20 MW solar and 30 MWh BESS), in addition to Scatec's 1 GW solar and 200 MWh BESS project announced during COP28. As such, MENA's BESS installed capacity is expected to surpass 6 GW by 2030.



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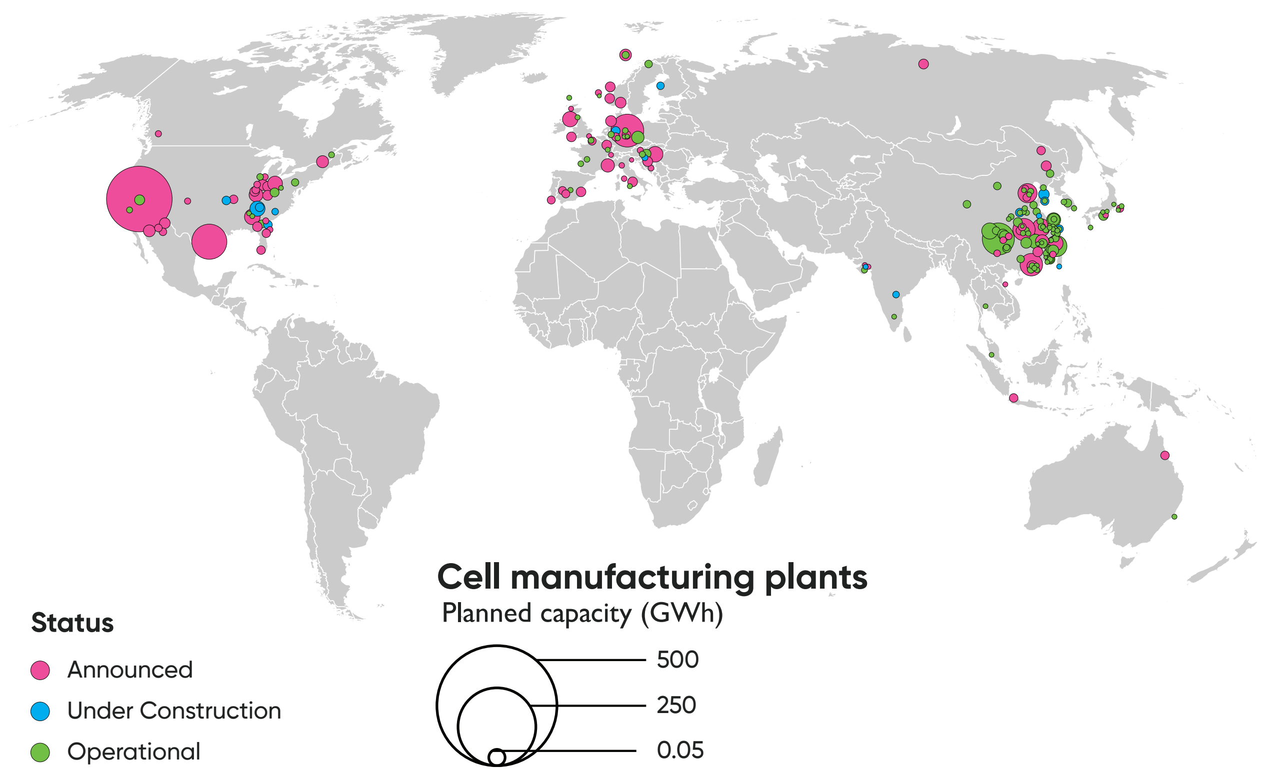
Source: Rystad Energy PowerCube

Figure (2): Power Sector Outlook by Energy Category, MENA*

On the manufacturing side, the market is currently dominated by a few large players as most of the cell manufacturing plants that are operational, under construction and announced are currently concentrated in China, Europe, and the United States. In terms of supply, MENA is entirely dependent on China at present – evident from the trade value related to lithium-ion batteries which amounted to over $1.37 billion in 2023 – with Turkey, Saudi Arabia, Israel, and UAE accounting for 83% of the region's total traded value.



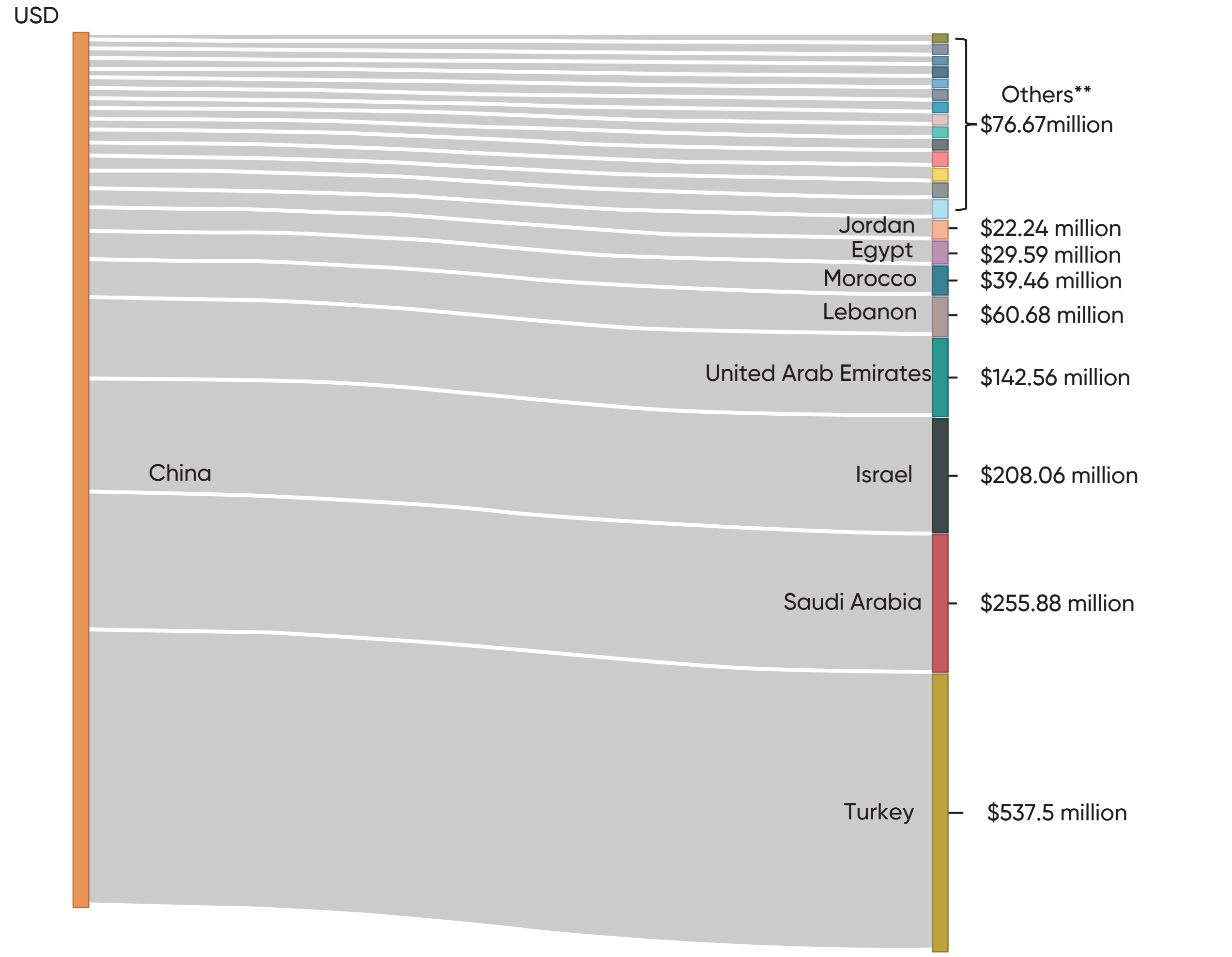
*Includes lithium iron phosphate (LFP), Lithium nickel cobalt aluminum oxide (NCA) and Lithium nickel manganese cobalt oxide (NMC) chemistry groups onlytt

Source:- Rystad Energy Battery Market Analysis Dashboard

Figure (3): Cell Manufacturing Plants* Across the Globe

KEY CHALLENGES OF LITHIUM-ION BATTERIES IN THE MENA REGION

- The MENA region is known for its extreme temperature and sandstorms, especially during the summer, where temperatures can exceed 50°C (122°F) in some areas. High temperatures can significantly impact the efficiency, performance, and lifespan of lithium-ion batteries. They can lead to increased self-discharge rates, accelerated degradation of battery components and in some cases, raise safety concerns due to the risk of thermal runaway.
- The MENA region largely depends on importing lithium-ion batteries and related components from China (Fig 4). This dependency on China's supply chains can lead to vulnerabilities, including delays, and supply disruptions. While there is a growing interest in localizing energy storage solutions, including battery manufacturing, the region currently has limited infrastructure and expertise in this area.
- Encouraging the adoption of lithium-ion batteries for renewable energy storage and grid stabilization requires supportive policies, including incentives, subsidies, and clear guidelines. The absence of such measures can slow the adoption rate and investment in battery storage projects.
- Integrating lithium-ion batteries with different renewable energy sources, like solar and wind, requires advanced management systems. This integration is crucial for maximizing the benefits of energy storage in balancing supply and demand, providing backup power, and enhancing grid stability.



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**Others include Algeria, Bahrain, Eritrea, Iran, Iraq, Kuwait, Libya, Oman, Palestine, Qatar, Sudan, Syria, Tunisia and Yemen

Source: Rystad Energy Battery Market Analysis Dashboard

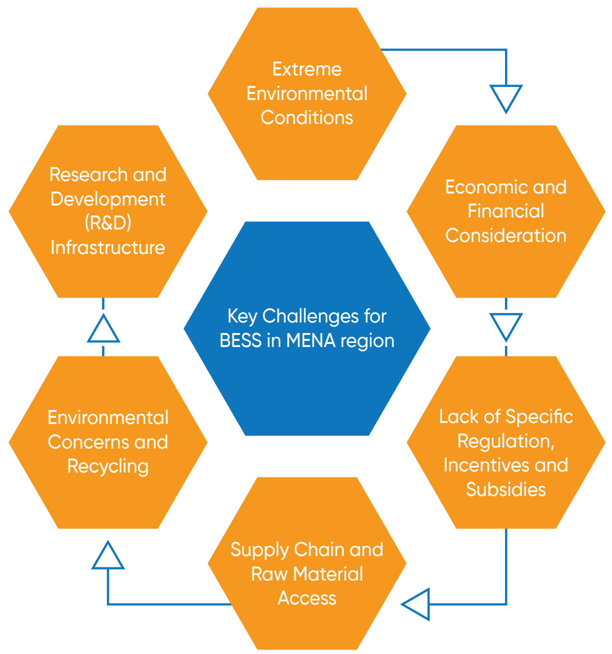
Figure (4): Lithium-ion Battery Trade Flow into MENA, 2023*

Courtesy: Hybrid PV Diesel System - Lebanon - SMA Solar Technology

KEY CHALLENGES AROUND DISTRIBUTION AND MANUFACTURING FACILITY SETTING-UP

- Lithium-ion batteries require raw materials such as lithium, cobalt, nickel, and graphite. The MENA region has limited reserves of these materials, making it heavily reliant on imports. Securing a stable and cost-effective supply chain for these materials is a significant challenge that includes geopolitical risks and transportation costs.
- Establishing a competitive lithium-ion battery industry requires a strong R&D foundation, including reliable power, water, transportation networks and waste management systems. The MENA region has limited infrastructure for research in advanced energy storage technologies, which is crucial for innovation and improving manufacturing efficiencies.
- The global lithium-ion battery market is highly competitive, with established players in Asia, Europe, and North America. Competing against these players requires significant investment in technology, quality, and brand development to capture market share.
- Manufacturing lithium-ion batteries involves processes that can have significant environmental impacts, including emissions and waste. Developing efficient recycling processes for lithium-ion batteries is crucial for sustainability and resource recovery. The region needs to establish recycling facilities and processes to manage battery end-of-life.

Although MENA's BESS market is in its nascence, it is unlikely to remain so in the future. As MENA moves away from its gas-heavy power sector to one dominated by renewables, BESS will play a pivotal role in enabling this transition, with a number of projects underway.



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Source: Rystad Energy research and analysis

Figure (5): Key Challenges for Battery Energy Storage Systems in MENA* Region

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Courtesy: Taj Lifestyle Center Safeway Solar Park - Jordan - YDE

INVERTER REVOLUTION: NAVIGATING THE PATH TO A DECARBONIZED FUTURE

Habibul Basar
Product Manager
SINENG

TECHNOLOGICAL ADVANCES IN SOLAR INVERTERS

Inverters play an important role in the transition towards a renewable energy supply. In the ever-evolving world of solar inverters, technological advancements are pivotal in enhancing the effectiveness of solar power systems. In a decade, we have witnessed a massive change in the solar inverter sector – bigger unit capacity, multi-MPPT technology, compact and lightweight designs, cybersecurity measures, improved durability and longevity, enhanced grid functionality and transition from 1000V system to 1500V system etc.

Inverter capacities have been on an upward trend, and the advancements in the semiconductor space have prompted this change. Central inverter capacity has increased from 100 kW to roughly 5 MW and the maximum string inverter capacity has increased from 10-15 kW to more than 300 kW for the utility sector. In the residential and C&I sectors, the capacity has reached more than 100kW. Multi-Maximum Power Point Tracking (MPPT) technology has become a standard in the rearmost solar inverters.

Solar inverter manufacturers are fastening on designing compact and featherlight inverters without compromising performance. Central inverters have a small footprint and space-saving compact design which contributes to lower transportation costs and simplified installation processes. As solar power systems become more connected, the need for robust cybersecurity measures has been boosted, as a result, leading solar inverter manufacturers are enforcing advanced cybersecurity features and secure communication protocols to cover against implicit pitfalls. In addition, enhanced cooling systems, rainfall-resistant enclosures, and rigorous testing procedures contribute to increased continuity, reducing conservation conditions and ensuring a longer lifetime for the inverters.

As inverters become smarter, they become the key information generators for solar projects with I-V curve scanning function, arc-fault circuit interrupters (AFCI) and other intelligent functions. Arc-fault circuit interrupters are able to determine whether an arc fault is at the inverter or the module level. This functionality can trigger an alarm in less than a second, thus allowing the inverter to disconnect the circuit.

EXAMINING THE LATEST DEVELOPMENTS IN SOLAR INVERTER TECHNOLOGIES USED IN SOLAR

A new generation of inverters is rising: Their functions go far beyond their original task of converting DC to AC. As digitalization progresses, it becomes easier to install, operate and maintain today's inverters. The use of digital tools for planning, system design and error diagnostics has become common practice. This goes hand in hand with the increasingly widespread use of artificial intelligence and cloud-based energy management apps that clearly visualize energy consumption and self-generated energy. Modern inverters being used in solar projects have a high scalability and are designed to adapt to changing requirements, they can be used for charging batteries or e-vehicles with excess solar power and to operate heat pumps. High communication and interconnection capabilities are the hallmarks of the latest generation of inverters. With multiple digital switching outputs, LAN ports, an integrated WIFI interface and additional digital interfaces such as Modbus TCP and SG-ready, they are able to provide numerous benefits, such as easy commissioning and system configuration, connection to a smart meter for measuring and visualizing self-consumption, quick monitoring data exchange. All in all, interesting times are ahead in the solar inverter space, given the diversified technology trends that are emerging to keep pace with the changing dynamics of the solar energy segment.

CHALLENGES AND OPPORTUNITIES IN DESIGNING AND DEVELOPING HIGH-EFFICIENCY INVERTERS

Designers of solar inverters face a multidimensional challenge in delivering slice-edge results. High efficiency, maximum power density, low weight and high reliability are some of the critical requirements designers need to consider to support modern inverter system features. High efficiency is needed to maximize the power generated from the PV panels and minimize power loss. This helps reduce heatsink requirements and system weight.

Careful selection of innovative topologies and the latest semiconductors enables significant system level benefits. Various topologies can be used for the booster and inverter stages. NPC and ANPC are widely used in 1500V inverters. Mixed voltage NPC (MNPC) is still used in residential and commercial 1000 V systems but is gradually being replaced by NPC. Three-level and four-level flying capacitor inverters are starting to be used in the latest systems. With ANPC topology, inverter efficiency has already reached up to 99%.

Typically, components with lower blocking voltages are faster, have lower switching losses and are usually lower cost. The losses in NPC and ANPC are concentrated in the semiconductors operated with high-frequency PWM.NPC, ANPC and flying capacitor topologies provide a higher system blocking voltage than the individual components. For example, an NPC using 950 V components will provide 1900 V blocking voltage. If a four-level flying capacitor topology is used in a 1500V PV inverter, components with only 650 V blocking voltage are needed which has less switching loss and cost.

The efficiency comparison of the Vinotech study shows that an ANPC operated at 16 kHz inductor current frequency has the same efficiency as a four-level flying capacitor inverter at 32 kHz. By moving from ANPC to a four-level flying capacitor the inductor current frequency can be doubled. Consequently, the inductor volume and, to a first approximation, the inductor cost can be reduced by 40%. In addition, as found in a study, the power module cost for a four-level flying capacitor is 50% of that of the ANPC, which results in a significant system cost reduction.

These new topologies provide designers of next generation PV inverter systems with solutions to address the critical design requirements of high efficiency, maximum power density, low weight and extended reliability.

INTEGRATION OF INVERTERS WITH ENERGY STORAGE SYSTEMS

Battery Energy Storage Systems (BESS) play a crucial role in the modern energy landscape, providing flexibility, stability, and resilience to the power grid. With the growing importance of storage systems in solar installations, battery-based inverters or PCS (Power Conversion System) have also started gaining traction. PCS can control the charging and discharging process of the battery, perform AC-DC conversion, and directly supply power to AC loads in the absence of a grid. PCS consists of a DC/AC bidirectional converter, control unit, etc. The PCS controller communicates with the BMS through the CAN interface to obtain the status information of the battery pack, which can realize the protective charging and discharging of the battery and ensure the safe operation of the battery. Key functions of PCS are conversion of DC to AC and vice versa, voltage regulation and control, frequency regulation, efficiency optimization, grid integration and communication etc.

HOW INVERTER CONTROL OF VOLTAGE AND FREQUENCY IMPACTS INTEGRATION WITH MODERN POWER GRIDS

Historically, electrical power has been predominantly generated by burning fuel and creating steam, which then spins a turbine generator, which creates electricity. The motion of these generators produces AC power as the device rotates, which also sets the frequency, or the number of times the sine wave repeats. Power frequency is an important indicator for monitoring the health of the electrical grid. For instance, if there is too much load– the turbines will slow down and the AC frequency will decrease.

Because the turbines are massive spinning objects, they resist changes in frequency just as all objects resist changes in their motion, a property known as inertia. As more solar systems are added to the grid, more inverters are being connected to the grid than ever before. Inverter-based generation can produce energy at any frequency and does not have the same inertial properties as steam-based generation, because there is no turbine involved. As a result, transitioning to an electrical grid with more inverters requires building smarter inverters that can respond to changes in frequency and other disruptions that occur during grid operations, and help stabilize the grid against those disruptions.

In general, inverters are to remain on during or "ride through" small disruptions in voltage or frequency, and if the disruption lasts for a long time or is larger than normal, they will disconnect themselves from the grid and shut down.

Courtesy: Armacell 1 MWp-Bahrain - YDE

SOLAR ROOFTOP LANDSCAPE IN SELECTED MENA COUNTRIES

planno
Daniel Domingues
Founder

INTRODUCTION

In the quest for sustainable energy, the MENA region is emerging as a solar powerhouse, leveraging its sun-drenched landscapes to meet its energy needs. The potential for solar energy, particularly on rooftops, is immense and largely untapped. This section offers a data-driven glimpse into the solar capabilities of these selected countries, setting the stage for what could be a transformative energy shift in the MENA landscape.

C&I ROOFTOP MARKET CAPACITY

This section presents an extensive overview of the C&I rooftop landscape. In these selected markets, with more than 115,000 rooftops identified, the potential for solar energy deployment is nearly 30GW. Saudi Arabia leads with over 50% of this potential, closely followed by the UAE, with Oman and Bahrain charting the path behind them.

Market	Rooftop Area Segment							Total
	< 2,500 m2	2,500 - 5,000 m2	5,000 - 10,000 m2	10,000 - 20,000 m2	20,000 - 30,000 m2	30,000 - 50,000 m2	> 50,000 m2	
Dubai	10,089	2,338	1,087	399	92	36	16	14,057
Northern Emirates	11,197	2,086	802	206	32	23	6	14,352
Abu Dhabi	15,817	1,194	542	199	40	32	17	17,841
Total UAE	37,103	5,618	2,431	804	164	91	39	46,250
Oman	3,018	566	240	82	19	10	7	3,942
Saudi Arabia	49,272	6,789	4,174	1,855	347	160	58	62,655
Bahrain	1,810	384	198	62	13	10	1	2,478
TOTAL	**91,203**	**13,357**	**7,043**	**2,803**	**543**	**271**	**105**	**115,325**

Table (1): Number of Rooftops Identified per Market

Market	Rooftop Area Segment							Total
	< 2,500 m2	2,500 - 5,000 m2	5,000 - 10,000 m2	10,000 - 20,000 m2	20,000 - 30,000 m2	30,000 - 50,000 m2	> 50,000 m2	
Dubai	1,201	1,024	915	680	273	176	165	4,434
Northern Emirates	1,360	874	678	336	98	107	52	3,505
Abu Dhabi	1,353	512	465	330	121	150	173	3,104
Total UAE	3,914	2,410	2,058	1,346	492	433	390	11,042
Oman	362	243	201	142	58	46	70	1,123
Saudi Arabia	4,478	2,974	3,672	3,141	1,049	752	530	16,596
Bahrain	263	168	168	101	39	45	7	792
TOTAL	**9,018**	**5,794**	**6,099**	**4,730**	**1,639**	**1,277**	**997**	**29,553**

Table (2): Total Solar Potential per Market (in MW)

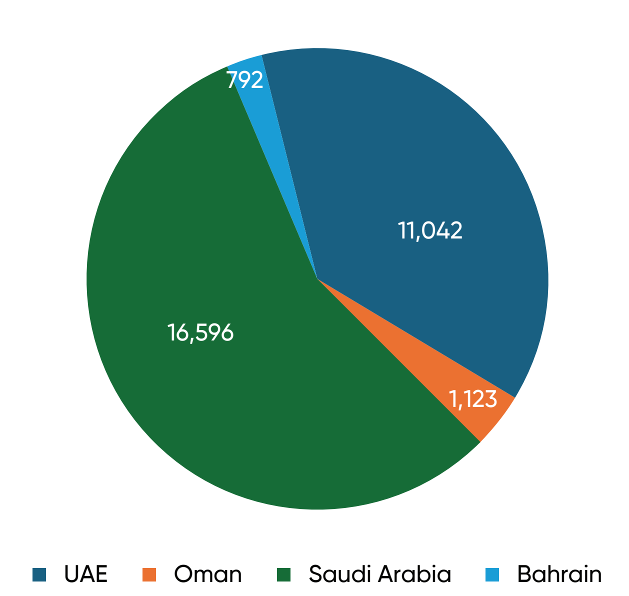


Figure (1): Potential MW

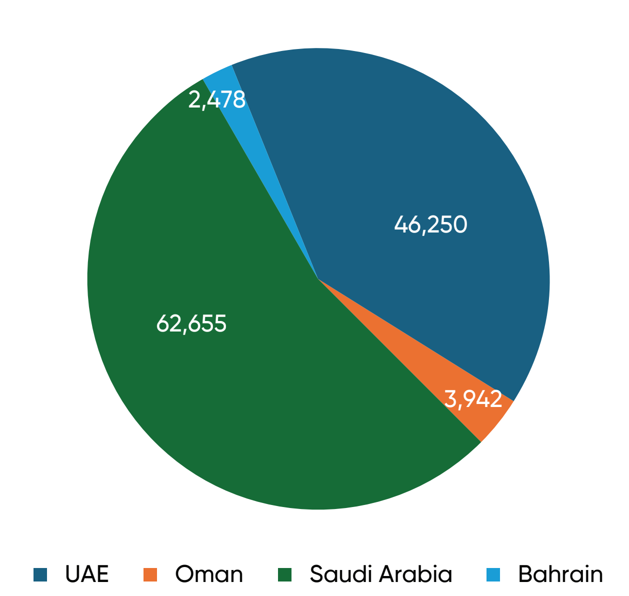


Figure (2):Number of Rooftops

A detailed examination of Tables 1 and 2 reveals a majority of rooftops under 2,500m² make up almost 80% of the count yet contribute only 30% to the solar capacity. Remarkably, rooftops larger than 5,000m², although just 10% of the total, account for 50% of the solar capacity in the region. This trend holds when dissecting the data market by market.

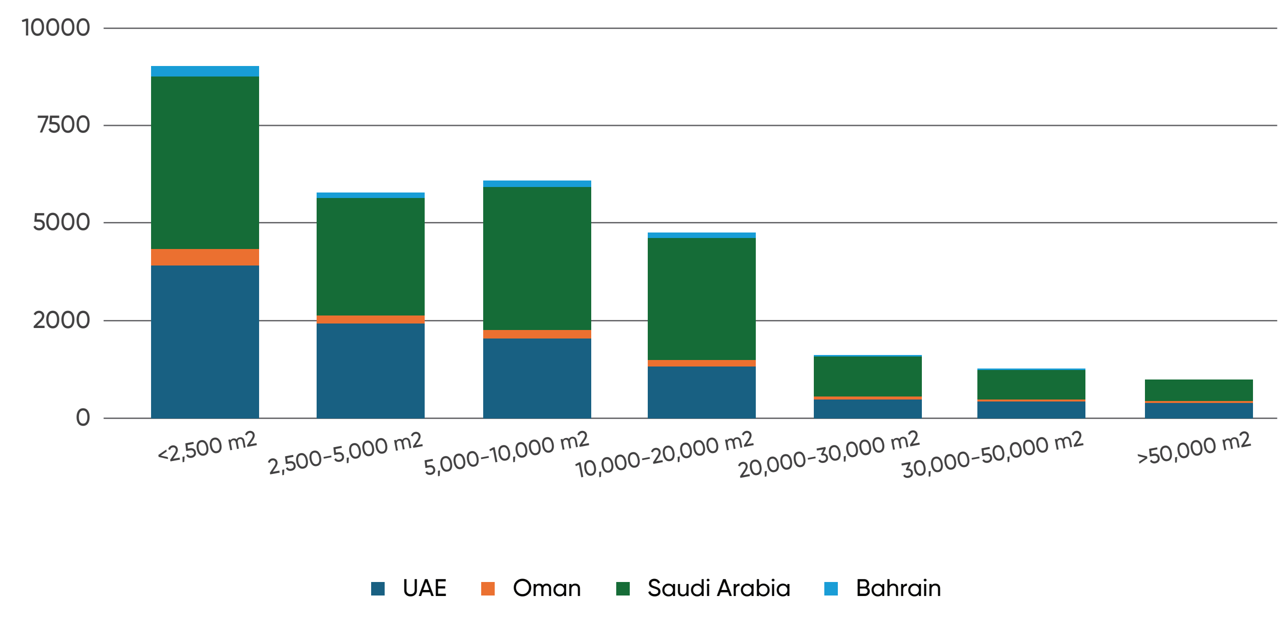


Figure (3):Solar Capacity per Rooftop Area Segment

SOLAR ADOPTION IN DUBAI

As the more mature market in the region, where regulations have been in place since 2015, Dubai serves as the benchmark for the region's adoption rates. Table 3 shows the number of rooftops identified with solar systems in the commercial and industrial areas.

Rooftop Area Segment	< 2,500 m2	2,500 - 5,000 m2	5,000 - 10,000 m2	10,000 - 20,000 m2	20,000 - 30,000 m2	30,000 - 50,000 m2	> 50,000 m2	Total
Number of Rooftops	121	152	140	74	20	13	8	528
Percentage (%)	3.8%	1%	7%	13%	19%	22%	36%	50%

Table (3): Number of Rooftops with Solar in Dubai per Rooftop Area Segment

Of the 14,057 C&I rooftops analysed in Dubai, 528 have now solar installations, reflecting a modest 3.8% adoption rate. Although this pales in comparison to more mature international markets, a closer look reveals a 30% adoption rate for rooftops exceeding 20,000m². This aligns more closely with global benchmarks and illustrates Dubai's progressive stance on larger solar projects. Interestingly, the adoption jumps to 50% for rooftops over 50,000m², indicating a trend toward solar investment on larger scales. Chart 3 reflects the adoption rate per rooftop area segment.

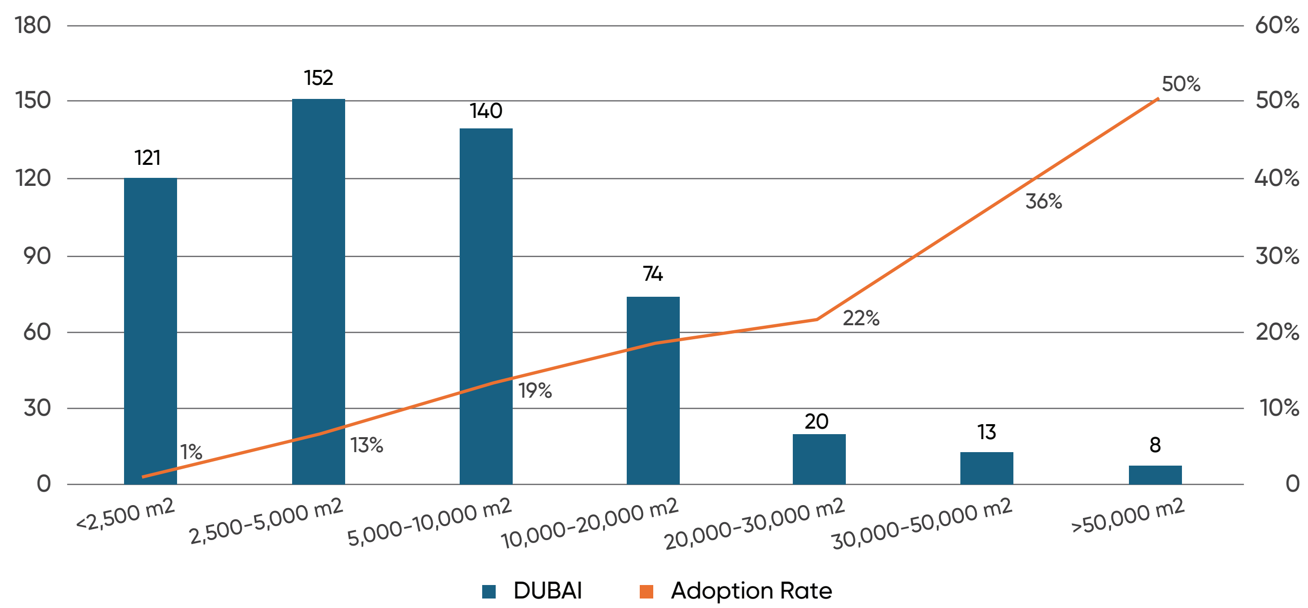


Figure (4): Solar Adoption per Rooftop Area Segment

PROJECTION OF SOLAR MARKETS

Taking cues from Dubai, projections for solar market size in other markets are crafted with caution and consideration. By calibrating Dubai's established data, we offer a glimpse into the future solar landscapes of the wider UAE, Oman, Saudi Arabia, and Bahrain.

The approach assumes similar market dynamics and a regulatory environment conducive to solar energy, while mindful of each market's unique energy policies and business landscapes. Nevertheless, it is interesting to study the market should similar policies be followed in these early solar rooftop markets.

Market	Rooftop Area Segment							Total
	< 2,500 m2	**2,500 - 5,000 m2**	**5,000 - 10,000 m2**	**10,000 - 20,000 m2**	**20,000 - 30,000 m2**	**30,000 - 50,000 m2**	**> 50,000 m2**	
UAE	46	157	272	251	121	157	128	1,132
Oman	4	16	26	27	17	15	20	125
Saudi Arabia	54	193	496	585	264	270	168	2,030
Bahrain	3	11	23	18	9	15	4	83
TOTAL	**107**	**377**	**817**	**881**	**411**	**457**	**320**	**3,370**

Table (4): Market Size Simulation per Rooftop Area Segment

The projections suggest a robust addition of 3.4GW to the region's capacity, led by an anticipated 2GW in Saudi Arabia and a significant 1.1GW in the UAE. Oman and Bahrain, though smaller, show potential for growth, particularly Bahrain, which may outperform expectations with its supportive and expansive regulations.

CONCLUSION

The data analysed reveals a significant promise for solar rooftop energy in the region, with current adoption juxtaposed against potential growth. While Dubai leads with its established market, the untapped potential in Saudi Arabia and the remaining UAE is considerable. The projections based on Dubai's mature market suggest an enthusiastic regional market expansion if supported by conducive policies and regulations.

Crucially, the data indicates a nascent market poised for rapid expansion. The relatively low adoption rates in smaller rooftop segments point to vast opportunities for growth. This is especially significant given the high adoption rates for larger rooftops, reflecting a readiness to embrace solar energy on a grander scale where it is most economically viable.

As the region moves forward, these insights offer valuable guidance for stakeholders. The findings serve as a call to action for policymakers and businesses alike to foster a supportive environment for solar energy adoption. With strategic investment and regulatory encouragement, the region could harness its solar potential to lead a green energy transition, promoting sustainable development.

In essence, the numbers tell a clear story: there is a bright future for solar rooftops in the MENA region, and the time to act on this information is now.

A. ALGERIA

RE Target by 2035	RE Target by 2035	RE Capacity 2022
15,000 MW	**35%**	**460 MW in 2022**

Source: IRENA & Solarabic Database

I. CURRENT SITUATION

By 2023, Algeria's solar energy capacity constituted a modest 2% of its total installed capacity, amounting to 460 MW. Despite this, the nation is pursuing an aggressive renewable energy agenda, targeting the auction of 4 GW of solar power in 2024 and striving to achieve 22 GW of renewable energy capacity by 2030. This goal includes 62% from solar photovoltaics (PV) and 23% from wind energy.

Algeria heavily relies on natural gas for over 90% of its electricity generation. Nonetheless, the country is endowed with vast solar energy potential. In alignment with its gas resources, Algeria is committed to developing renewable energy concurrently, maintaining that natural gas will persist as a companion to the energy transition—a stance reaffirmed at the seventh summit of the Gas Exporting Countries Forum hosted in Algeria.

II. REGULATIONS AND FRAMEWORK

Agricultural Lands and Rural Areas Supsdised Program

Algeria officially launched its Agricultural Lands and Rural Areas Subsidized Program to replace traditional power sources with solar-based energy systems for farmlands and remote homes. The focus is on places like Souk Ahras, where accessibility to the conventional electrical grid is tedious.

The program will be launched by 2024 and is primarily aimed at those areas grappling with substantial financial barriers to grid connectivity. It ensures financial aid to those wanting to adopt renewable energy solutions, particularly solar technology. Besides this, the minister announced an initiative: "the distribution of solar-powered water heaters in the houses of people who are not connected to the electricity network. Further, as part of its green project, the country transformed public institutions and facilities into renewable and clean energy systems.

III. PROJECTS

Solar Energy Projects Tenders - 3000 MW

In 2023, Algeria significantly advanced its renewable energy initiatives, concentrating on solar energy The Sonelgaz complex in Algiers was key, with two significant tenders in 2022 aiming for 3,000 MW of solar PV capacity.

Tenders Details

First Tender: 2,000 MW Solar PV Project

- **Launch Date:** February 2023
- **Objective:** To establish 15 solar PV stations with capacities ranging from 80 to 220 MW, spread across 12 states in 15 different sites.
- **Bidders:** The tender attracted 140 institutions, comprising 34 Algerian and 106 foreign companies from 20 countries.
- **Outcome:** Contracts were signed with 8 winning bidders for 14 stations. The allocation included two stations to an Algerian institution, three to mixed Algerian groups, and nine to foreign companies.

Second Tender: 1,000 MW "Solar 1000" Project

- **Launch Date:** July 2023.
- **Objective:** To establish 15 solar PV stations with capacities ranging from 80 to 220 MW, spread across 12 states in 15 different sites.
- **Bidders:** This tender drew interest from 139 institutions, including 36 Algerians and 103 foreign companies from 24 nationalities.
- **Outcome:** Six contracts were awarded to 4 bidders, resulting in two stations for an Algerian institution, two for mixed Algerian groups, and one for a foreign company. One station's share was canceled and is to be relaunched.

IV. CHALLENGES AND OUTLOOK

The Algerian solar market faced significant hurdles in the past year, particularly with the Solar 1000 project. Financial difficulties and the lack of a supervisory entity led to the project's cessation. The dissolution of the Ministry of Energy Transition and Renewable Energies, which was merged into the Ministry of Environment, increased confusion over which ministry was overseeing the project.

Despite these setbacks, the outlook remains cautiously optimistic. Algeria aimed to kickstart its solar energy production in January 2023 with the Bashar mandate. However, delays in the tender process and deal selection have postponed initiating the country's inaugural solar energy ventures.

Resolving these administrative and financial challenges will be crucial for the successful deployment of solar projects in Algeria.

Source: Solarabic Database


Courtesy: Freepik

B. BAHRAIN

Total Power Capacity (2020)	RE Target by 2025	RE Target by 2030	RE Installed Capacity (2022)
8,781 MW	**255 MW**	**700 MW**	**12 MW**

Source: IRENA, Solarabic Database

I. CURRENT SITUATION

Bahrain is actively boosting its renewable energy capacity, with solar energy at the forefront. The country has innovative plans like floating solar farms and rooftop solar installations.

Additionally, Bahrain has taken serious steps towards generating electricity through solar energy by signing project agreements that will provide 28% of the total renewable energy target by 2025. The solar energy project in Bahrain effectively contributes to achieving the goal of reducing carbon emissions and making the Kingdom reach carbon neutrality by 2060. Bahrain aims to increase the contribution of renewable energy to the electricity energy mix by 5%, equivalent to about 255 MW by 2025, and by 10% by 2035.

II. PROJECTS

Al Dur Solar Project (100 MW)

In February 2024, the Bahrain Electricity and Water Authority initiated a tender for the Al Dur Solar Project in the Southern Governorate, aiming for a 100 MW capacity. The project encompasses comprehensive turnkey solutions, including engineering, procurement, construction, and connection to the national grid, with a completion timeline of 18 months post-tender award.

Rooftop and Parking Lot Solar Systems (15.5 MW)

The Ministry of Water and Electricity Affairs released a tender in December 2023 to install solar systems totalling 15.5 MW on rooftops and parking areas. These installations will be grid-connected under a 20-year build-own-operate-maintain contract.

Sakhir Solar Station (72 MW)

GETAS Group, a Turkish firm, is investing $60 million in a 72 MW solar station in Bahrain, announced in August 2023. This project has potential expansion to 200 MW. It includes installations at the University of Bahrain and the Dana Exhibition Centre, with solar panels sourced from a Taiwanese partner of GETAS Group. The project is set to start in November and be operational within 18 months.

Blexco Solar System (2.177 MW)

Bahrain Aluminum Extrusions Company (Blexco) partnered with Kanoo Cleanmax Renewable Energy Company in July 2023 to install a 2.177 MW solar system. The installation is anticipated to fulfill 30% of Blexco's energy requirements through renewable sources, producing 3,669 MW within its inaugural year. Furthermore, it is expected to facilitate substantial reductions in CO2 emissions, equivalent to planting over 20,000 palm trees or removing 350 cars from the roadways.

III. CHALLENGES AND OUTLOOK

The solar market in Bahrain faces several challenges despite its growth. One of the main challenges is the limited space available for large-scale solar farms. Additionally, there is a need to balance the rapid economic development and the increasing energy demand with sustainable energy production. The implementation of solar projects also requires significant investment in infrastructure, storage solutions, and grid interconnectivity to ensure stability and efficiency.

The solar market in Bahrain shows promising growth, particularly in utility projects and commercial and industrial (C&I) ventures. This growth aligns with the government's dedication to renewable energy, as outlined in its National Renewable Energy Action Plan (NREAP). The NREAP establishes ambitious targets for solar power capacity by 2025 and 2035, demonstrating the government's commitment to sustainable energy development.

Although residential sector involvement presently centers on select villas, overarching trends suggest a favorable trajectory for Bahrain's solar market. Emphasis on innovative solar solutions and strategic project implementation across various sectors are pivotal factors expected to sustain momentum in Bahrain's solar market.

Source: Solarabic Database


Courtesy: Mondelez 2.3 MWp - Bahrain - YDE

C. EGYPT

RE Capacity by 2022	RE Capacity Target by 2040	RE Target by 2040
8,778 MW	**142,000 MW**	**50%**

Source: IRENA, Solarabic Database

I. CURRENT SITUATION

Egypt's renewable energy sector has witnessed a significant influx of interest from Gulf and international investors, keen on securing new licenses for projects collectively valued at over $6 billion. The investment landscape has seen the formation of diverse alliances, including a European-Gulf coalition, a Chinese consortium, and an Indian group. Per the General Authority for Investment and Free Zones, each project is estimated to be worth around $2 billion, with a dual focus on catering to the local market and exporting green energy.

To accelerate growth, Cairo has set an ambitious target to more than double the issuance of golden licenses, aiming to increase from 25 in 2023 to over 50 in the current year. The average monthly issuance rate stands at 3 to 5 licenses. Furthermore, the Investment Authority is crafting new licenses tailored for entrepreneurs, It is bolstering incentives for the tourism and environmental sectors, which are poised to benefit from the green energy push.

The private sector's investment in renewable energy projects in Egypt amounts to $4.4 billion. These endeavours aim to boost Egypt's renewable energy capacity to 10,000 MW by 2025. Solar energy investors have achieved a competitive rate of two US cents per kilowatt-hour, while wind energy projects stand at 2.45 cents per kilowatt-hour. These advancements signal significant progress toward Egypt's renewable energy goals.

II. REGULATIONS AND FRAMEWORK

Regulatory Reforms Boosting Renewable Energy Integration

In March 2024, the Electricity Utility and Consumer Protection Regulatory Authority of Egypt took a significant step by abolishing the "electricity consolidation" charge for solar energy projects connected to the grid and employing a net metering system with capacities of up to 10 MW.

This pivotal move is expected to amplify incentives and increase the share of renewable energy within the national energy mix, aligning with the state's strategic plan. Previously, this charge was levied for the integration of electricity from new and renewable energy sources into Egypt's national grid.

Incentives for Solar Panel and Heater Installations

The Egyptian government has introduced supportive measures for the installation of solar panels and home solar heaters across various sectors, including residential, agricultural, and industrial domains. These initiatives are part of a broader strategy to enhance the adoption of clean energy solutions.

The Egyptian Electricity Holding Company has highlighted the availability of numerous financing options and programs, established in collaboration with the Ministry of Electricity and Renewable Energy, to facilitate the installation of solar energy systems.

III. PROJECTS

Aswan Energy Complex, 2.5 GW

Egypt's vision for a sustainable future is taking shape with the proposal of a 2.5 GW energy complex in Aswan in January 2024. The Ministry of Electricity and Renewable Energy is in talks with international investors from Saudi Arabia, the UAE, China, Norway, France, and Germany to fund this $2.5 billion project.

The complex, aimed to be privately operated, is considering locations in West Aswan and West Sohag, leveraging vast lands owned by the Renewable Energy Authority.

Scatec's Solar Endeavor for Egypttalum, 1 GW

Norwegian powerhouse Scatec is nearing an agreement to construct a 1 GW solar plant with energy storage systems for the "Aluminium Factory" Settlement owned by Egypttalum.

The project, structured in two phases, each with a capacity of 500 MW, aims to enhance the complex's energy autonomy. The initial phase is anticipated to conclude within 18 months of signing, followed by the second phase, which is expected to be completed within an additional 24 months.

Kom Ombo's 200 MW

The Kom Ombo solar power plant, a venture by Saudi's ACWA Power, is on track to start operations in April 2024. Currently at 82% completion, the $168 million project is financed by a consortium of global financial institutions.

The plant will feature 387,465 bi-facial solar panels and 952 inverters across 4.8 square kilometres, aiming to produce 200 MW of clean energy and reduce carbon emissions by roughly 280,000 tons annually.

Gulf of Suez's Wind Energy project 1.1 GW

A pivotal agreement was forged between ACWA Power and the Egyptian government to harness the winds of the Gulf of Suez and Gabal El-Zeit in January 2023. With a robust capacity of 1.1 GW and a substantial investment of $1.5 billion, this venture stands as the most significant wind energy project in the Middle East and one of the grandest onshore wind endeavors globally.

The project promises to make a substantial environmental impact by slashing 2.4 million tons of carbon dioxide emissions yearly and conserving roughly 840 thousand tons of fuel. Moreover, it is projected to provide clean energy to one million households. The wind turbines, approximately 220 meters tall, represent state-of-the-art technology and will become prominent fixtures on the Gulf of Suez's skyline, thereby establishing a new standard for renewable energy within the region.

The World's Largest Solar Power Plant, 10 GW

In a landmark move in December 2023, the Renewable Energy Development Authority of Egypt and China Electric Power embarked on the preliminary stages of creating the world's most extensive solar power facility. With a prodigious capacity of 10 GW and a projected investment of $10 billion, this plant is set to eclipse the current global leader located in Bahdala, India, by a factor of five.

This solar power titan is anticipated to be a game-changer for the environment, potentially curtailing around 14 million tons of carbon emissions each year while also yielding an annual saving of $1 billion in natural gas costs.

Vestas' Wind Power Station in the Gulf of Suez 250 MW

In November 2023, Vestas initiated trial operations of a pioneering wind power station in the Gulf of Suez, with a capacity of 250 MW. A thorough three-week period was dedicated to rigorous testing and operational experiments to ascertain the station's optimal performance.

Subsequently, following the successful trial phase in December, the station seamlessly transitioned into an entirely commercial operation. This noteworthy milestone was commemorated with the formal handover to the Egyptian New and Renewable Energy Authority, attended by a distinguished delegation from Vestas.

IV. CHALLENGES AND OUTLOOK

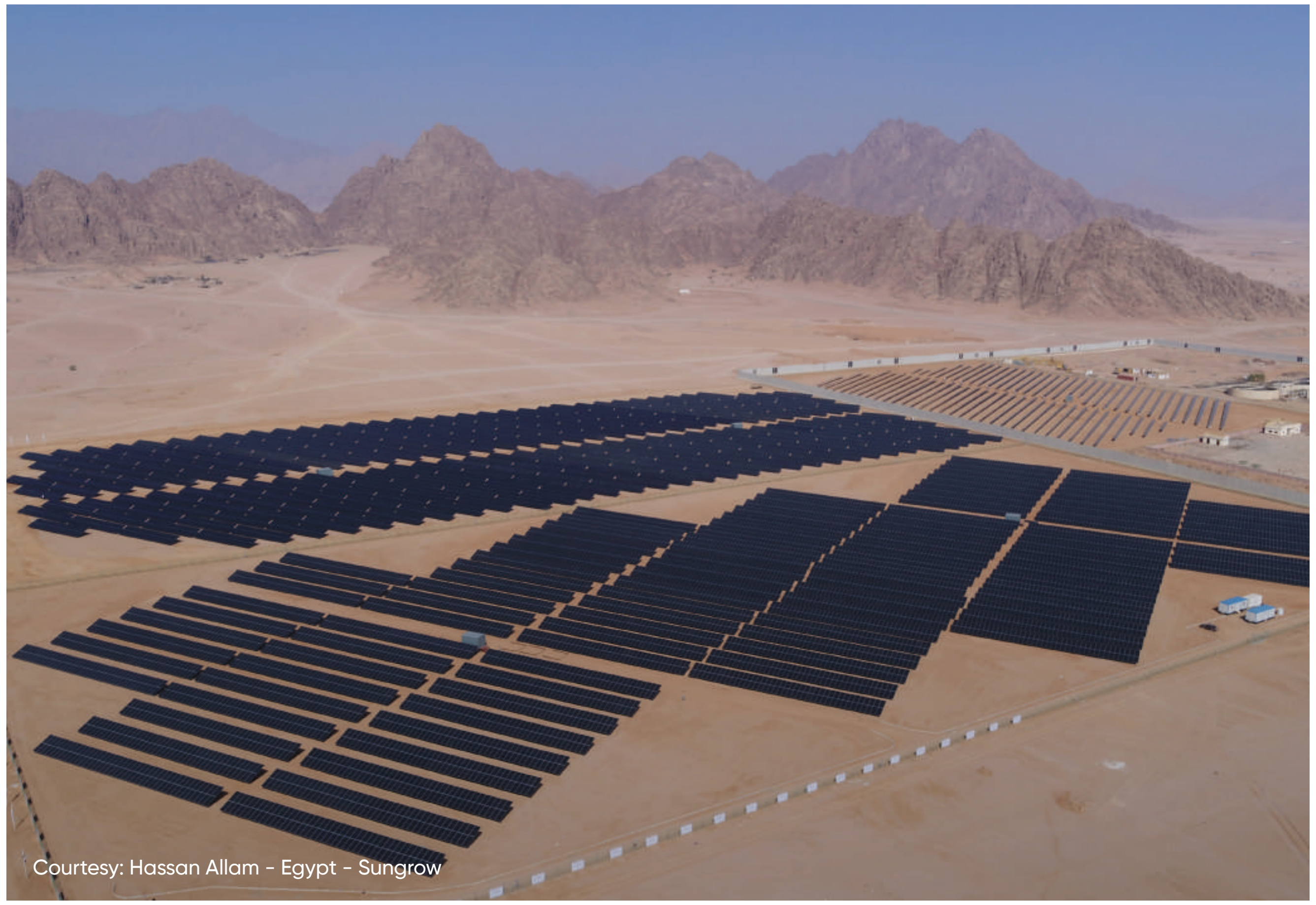
The renewable energy sector in Egypt has been navigating through a dynamic landscape of challenges and opportunities. There has been a notable escalation in the requirement for tailored financial mechanisms to bolster residential solar energy initiatives. This surge can be attributed to the mounting concerns regarding load-shedding problems and the burgeoning demographic shift towards regions abundant in solar resources.

Financial institutions have responded by crafting tailored financing solutions, including personal and auto loans for solar panel purchases. This shift reflects a growing recognition of solar energy's potential, with a marked increase in loan applications for rooftop solar stations since early last year, which is expected to continue.

The private sector's commitment is evident, with an investment of approximately $4.4 billion in a diverse portfolio of renewable energy projects, encompassing solar, wind, and hydropower. The Ministry of Planning and Economic Development has highlighted offshore wind projects as the frontrunners in the upcoming growth of renewable energy capacity.

The International Energy Agency forecasts a 65% increase in Egypt's renewable energy capacity by 2027. This projection positions Egypt in a pivotal role, and it is anticipated that it will contribute more than 25% of the total renewable energy capacity in the Middle East and North Africa region by the same year. This signifies a robust trajectory for the nation's green energy initiatives.

Source: Solarabic Database



Courtesy: Hassan Allam - Egypt - Sungrow

D. IRAQ

RE Capacity by 2022	Solar Target by 2030	RE Target by 2030
1,599 MW	**12,000 MW**	**33%**

Source: IRENA, Solarabic Database

I. CURRENT SITUATION

Iraq is currently facing an energy shortfall of approximately 13,000 MW. To address this deficit, the Ministry of Electricity has embarked on implementing multiple solar stations that are projected to contribute 4,000 MW of renewable energy, thereby reducing the reliance on fuel.

The Iraqi government has also initiated electrical interconnections with neighboring Gulf countries and Jordan, collectively supplying around 650 MW to the national grid. These efforts are part of a broader strategy to meet the Ministry of Electricity's summer 2023 goal of achieving a production rate of 24,000 MW, marking an increase of 3,500 MW from the previous summer.

II. REGULATIONS AND FRAMEWORK

Converting Government Buildings to Solar Energy

In October 2023, the Iraqi government allocated 90 billion Iraqi dinars (over $68 million) to retrofit more than 500 government buildings with solar energy systems. This initiative is part of the National Initiative for Energy Support and Emissions Reduction, which aims to reduce the country's carbon footprint and enhance energy efficiency.

The Ministry of Planning has taken a proactive approach by partnering with the Ministry of Science and Technology to conduct comprehensive studies on the selected buildings. These studies will facilitate the installation of solar energy systems. Once operational, the performance of these solar systems will be centrally monitored through an electronic system developed by the Energy Research Department in collaboration with the National Data Center Department under the Council of Ministers.

Green Schools Project

Furthering its renewable energy agenda, the Iraqi government, in collaboration with UNICEF, launched the Green Schools Project on November 14, 2023. The project's primary goal is to harness solar energy for electricity generation, starting with illuminating primary schools across Iraq. This initiative not only addresses the immediate need for reliable power but also serves as an educational tool to instil the principles of sustainability and clean energy in the younger generation. The Green Schools Initiative will light up over 250 schools and several health centers.

III. PROJECTS

Over the past few years, Iraq has forged partnerships with many companies to launch ambitious solar energy projects, aiming for a combined output of over 4,000 MW. Despite the visionary scope, these ventures have faced significant financial and legislative hurdles, which have slowed their rapid development.

In 2023, the Iraqi government actively engaged with representatives from involved companies to tackle these challenges head-on and devise practical solutions to overcome them.

ACWA Power Solar Project - 1000 MW

On April 15, 2023, discussions between the Iraqi Minister of Electricity and the Saudi Minister of Energy confirmed ACWA power's 1000 MW solar energy project in Najaf Al-Ashraf. The Ministry of Electricity has been actively working to resolve any challenges and has secured a plot of land for the project in collaboration with the local government.

POWER CHINA PROJECT - 750 MW

In May 2023, the Iraqi Council of Ministers approved a solar energy station project valued at $520 million in collaboration with Power China. This project, situated in Muthanna Governorate, possesses a cumulative capacity of 750 MW. It is organised into two phases, with the initial phase delivering 250 MW.

Following the enactment of the Federal General Budget Law for 2023, the Ministry of Electricity has been granted the authority to advance with the referral and contracting processes.

Masdar Company Projects - 1000 MW

In August 2023, the Iraqi Ministry of Electricity announced the removal of barriers for the Emirati company Masdar to establish solar energy plants. The projects are planned for the Maysan, Dhi Qar, Anbar, and Kirkuk regions. This development is a significant step towards expanding Iraq's solar energy capacity.

IV. CHALLENGES AND OUTLOOK

Despite these developments, Iraq's electricity production still falls short of meeting the total demand of its population. The summer of 2023 was marred by sabotage that disrupted the entire electrical service, highlighting the vulnerability of the country's energy infrastructure.

In response to the prevailing electricity crisis and intensified heat waves, there has been an upsurge in demand for solar systems. However, the year's first half witnessed a 50% decline in solar system purchases due to delayed heat waves and economic factors such as the elevated dollar exchange rate. Additionally, the government's assurance of a stable electricity supply during the summer further contributed to this downturn.

Nonetheless, the latter part of 2023 experienced a resurgence in interest in solar installations as the persistent electricity crisis unfolded. Notably, farmers have increasingly embraced solar energy systems over the past four years, deeming them economically advantageous compared to traditional fuel-powered alternatives. Despite their economic benefits, the substantial installation costs have spurred calls for government assistance, with official requests submitted for subsidised systems to facilitate agricultural irrigation.

Looking ahead, the Iraqi National Investment Authority has unveiled plans to produce approximately 12,000 MW of solar energy by 2030. Additionally, Iraq is poised to embark on its first venture into generating electrical energy from waste, signaling a potential new direction for the country's energy sector.

Source: Solarabic Database

Courtesy: Freepik

E. JORDAN

RE Share in Electricity Generation 2023	RE Target by 2030	RE Capacity (2022)
44%	50%	2,526 MW

Source: The Jordanian Ministry of Energy and Mineral Resources, Solarabic Database

I. CURRENT SITUATION

The landscape of renewable energy in Jordan has undergone a transformative shift since 2013, when the Renewable Energy Law was enacted. The International Finance Corporation has highlighted that the investment in renewable energy projects in Jordan soared to over $4 billion last year. This is a remarkable surge from a baseline of zero investment in 2013, marking a decade of substantial growth and commitment to sustainable energy sources.

Jordan's efforts have not gone unnoticed on the global stage. The nation now ranks 15th worldwide and leads the Middle East in the proportion of electricity derived from solar and wind energy. This is a significant climb from its previous position of 145th in the world before these renewable energy projects.

Nearly half of Jordan's electricity demand is fulfilled by wind and solar energy sources, marking a substantial increase compared to a decade ago, when the utilization of renewable energy resources was limited. Strategic investments and advancements within this sector highlight Jordan's commitment to mitigating its carbon footprint and promoting a sustainable energy trajectory.

II. REGULATIONS AND FRAMEWORK

Shift from Net Metering to Net Billing

In a significant policy shift, the Jordanian government approved a draft amendment to the "Renewable Energy" law on February 4, 2024. This amendment transitions the system from net metering to net billing, aiming to regulate the buying and selling of electrical energy produced by renewable energy systems in establishments and residences. The draft law also outlines exempting renewable energy systems, devices, and equipment from customs duties and general sales tax, fostering a more sustainable energy consumption model.

The amendments have sparked a debate among experts and investors in Jordan's renewable energy sector. While some view the changes as detrimental to investment, others believe they will help break the electricity sector's monopoly, thus encouraging a more competitive and diverse market.

Support Programs for Various Sectors

Jordan has proactively supported different sectors through the Jordanian Fund (JREEEF) under the Ministry of Energy and Mineral Resources. The past year saw the introduction of new stages of support programs, notably:

1. Agricultural Sector

In early 2023, the solar loan initiative progressed into an advanced stage, marked by a collaborative agreement between the Ministries of Energy and Agriculture. This partnership aims to support farmers by simplifying the process of installing solar energy systems.

The Jordan Renewable Energy and Energy Efficiency Fund (JREEEF) plays a pivotal role by subsidizing the interest on loans issued by the Agricultural Credit Corporation, promoting sustainable and renewable energy practices within the agricultural community.

2. Residential Sector

The third phase of the national program to support the residential sectors with solar heaters and solar systems was launched in December 2023. It offers direct support covering 30% of the cost, alongside payment facilities through banks and local associations, reducing the electricity bills for Jordanian families.

3. Industrial Sector

On February 28, 2023, the Ministry of Energy and Mineral Resources (MEMR) initiated the Energy Efficiency Program to augment productivity within the industrial sector, a key contributor to approximately 25% of the GDP. This program advocates for implementing optimal energy management practices, adopting efficient technologies, and facilitating access to green finance, aiming to enhance competitiveness and curtailing energy expenses. Furthermore, the Ministry undertook measures to reduce electricity tariffs for industrial sectors, first in early 2020 and subsequently in April 2022, providing additional stimuli for growth and efficiency enhancement.

III. PROJECTS

Baynounah Solar Power Plant, 200 MW

The Baynouna Solar Power Plant, inaugurated on February 25, 2023, represents the largest solar facility within the Hashemite Kingdom of Jordan, with a capacity of 200 MW. Prominent officials from Jordan and the United Arab Emirates attended the ceremony. Developed through a partnership between Masdar and the Finnish conglomerate Taaleri, the plant is anticipated to generate more than 560 gigawatt-hours (GWh) annually, catering to the energy needs of around 160,000 households.

Its operation is anticipated to reduce carbon dioxide emissions by 360,000 tons yearly, akin to taking 80,000 cars off the roads. The project's financial backing came from several prestigious institutions, including the International Finance Corporation and the Japan International Cooperation Agency.

Azraq Municipality Solar Station

On September 15, 2023, the Azraq Municipality unveiled a solar energy station generating half a megawatt (MW) capacity. This station is poised to fulfil 55% of the municipality's energy requirements, providing illumination for buildings, streets, and roads. The project received financial support from the Municipal Services and Social Adaptation Project. It was inaugurated by Holly Penner, the Regional Resident Representative of the World Bank Group in Jordan, alongside other notable dignitaries.

Disi Photovoltaic Station, 33 MW

The water sector also saw advancements with the commencement of the Disi photovoltaic station's commercial operation on October 8, 2023. The station, with a peak capacity of 33 MW, will significantly reduce the cost of electricity for water stations in Zei and Wadi Al-Arab. The European Union contributed a grant of 30 million euros, which also facilitated the establishment of a battery energy storage station linked to the national grid.

Wind Project Development, 1,000 MW

During COP 28, Masdar announced, in partnership with the Jordanian Ministry of Energy and Mineral Resource, an ambitious project to develop a 1 GW wind power plant, marking a substantial leap in Jordan's commitment to renewable energy and sustainability.

Al-Balqa Applied University, 7 MW Solar Project

Al-Balqa Applied University has made a commendable leap in sustainable energy use. On September 4, 2023, the university commenced operations of the largest solar energy production project among Jordanian universities. The project, with an AC of 7 MW, was inaugurated by the university's president at the Princess Tasnim bint Ghazi Research and Technology Station in Hamra Al-Sahn.

This initiative received NEPCO's official nod and began its implementation phase in February 2022. It is a testament to the university's commitment to sustainable development, aiming to slash its electricity costs by half in the forthcoming years. The financial savings are earmarked for vital projects and the enhancement of the university's infrastructure and technological capabilities.

IV. CHALLENGES AND OUTLOOK

Jordan has emerged as a prominent leader in regional renewable energy development. Nevertheless, this journey has been accompanied by notable challenges, primarily stemming from the economic and political environment. Notably, the utilities industry has encountered significant obstacles, exacerbated by the 2019 suspension of approvals for projects exceeding 1 MW. Despite reversing this decision in 2022, its impact has remained limited. Furthermore, the approval-granting authority, comprised of profit-oriented private distribution companies, has exerted influence over the pace of progress within the renewable energy sector, potentially impeding national interests.

The government's proposed shift from net metering to net billing has sparked controversy, perceived as a regression that could undermine the progress made thus far. This change has been resisted, especially by renewable energy users and investors, who see it as detrimental to their interests and contrary to the strategic goal of increasing renewable energy's share in the energy mix.

Moreover, introducing a network services allowance in April 2022, charging two dinars per kilowatt per month, has added financial strain on all entities utilizing renewable energy systems. This, coupled with the limitation on the capacity of large renewable energy projects to a maximum of 1 MW, has raised concerns about the future investment climate in the sector.

Despite the existing challenges, a ray of hope emerges. The potential enactment of legislation supporting self-consumption and energy storage could catalyze a reevaluation of the sector's feasibility. The outlook for Jordan's solar market maintains a cautiously optimistic stance, with the prospect of legislative modifications to realign the sector with its ambitious renewable energy objectives.

Source: Solarbic Database


Courtesy: Classic Fashion-Jordan - YDE

F. LEBANON

RE Target by 2030	RE Target by 2030	RE Target by 2024
30%	**3,000 MW**	**1,000 MW**

Source: IRENA & Solarabic Database

I. CURRENT SITUATION

Lebanon's solar market has faced significant challenges and transformations since 2023. The country, already grappling with a severe economic crisis since 2019, has seen a drastic fuel scarcity for energy production. This shortage has led to a steep decline in electricity production, with urban areas receiving only one to two hours of electricity per day and rural areas often left without any power.

In response to these dire circumstances, the Lebanese population turned to solar energy as a means to alleviate the impact of frequent power outages. However, the initial surge in residential solar energy system installations in 2022 failed to sustain its momentum. The residential sector experienced a decline after its peak, while the commercial and industrial sectors have shown continued growth.

The solar energy market in Lebanon witnessed an 80% decline in the import of solar panels in 2023 compared to the previous year. This downturn reflects the broader economic difficulties the country faces, including a financial collapse and a depreciation of the currency by around 95%.

II. REGULATIONS AND FRAMEWORK

Lebanon's Distributed Renewable Energy Production Legislation

In January 2023, the Lebanese Parliament's General Assembly passed a new law promoting distributed renewable energy production. This legislation permits the private sector to construct renewable energy facilities with capacities of up to 10 MW for solar and 15 MW for wind power. These facilities must be integrated into Electricité du Liban's national grid, enabling the transfer of generated energy to consumers for a transit fee.

Furthermore, the law facilitates direct commercial transactions for electricity purchases between producers and consumers, bypassing Electricité du Liban, provided the consumer's premises are on or near the producer's site. Additionally, Electricité du Liban is authorized to utilize any excess electricity from renewable sources, incorporating it into the public grid, with the state compensating the producer.

The legislation exclusively targets renewable energy investments, specifically solar and wind power, and empowers residential solar power station owners to install intelligent meters. These meters allow homeowners to sell excess electricity back to the state, with compensation calculated by offsetting the produced energy against consumption.

Lebanese Government Grants Tax Exemption for Renewable Energy Equipment

In a landmark decision, the Lebanese government announced on August 31, 2023, a tax exemption for a broad range of renewable energy technologies. This pivotal move includes a comprehensive list of equipment such as photovoltaic panels, inverters, battery chargers, charge controllers, and various types of batteries, including lead-acid and lithium-ion.

The exemption applies to future cases and importers who have already paid taxes on such equipment. Importers who follow the "duty insurance" procedure would be reimbursed for taxes paid after the budget law is enacted.

III. PROJECTS

Concentrated Solar Power (CSP) Station 70 MWh

On August 17, 2023, the Ministry of Energy and Water announced construction plans for a 70 MWh concentrated solar power (CSP) station in the Ras Baalbek area. This initiative was kickstarted with a public participation session to discuss the environmental impact, supported by the Dutch government, ensuring that all stakeholders, including ministries, municipalities, and associations, are in sync with the project's objectives.

Solar Energy for Government Buildings

In mid-May last year, the Lebanese government revealed plans to install solar energy systems in Beirut to power government buildings. This ambitious project aims to provide a continuous electricity supply and includes the additional goal of powering traffic signals and surveillance cameras with solar energy. The Interior Minister, Bassam Mawlawi, has highlighted this initiative as a step towards mitigating the ongoing electrical crisis that began in 2019 and moving towards energy independence.

Solar Power Purchase Agreements (PPAs) for 165 MW Solar Stations

Early May 2023, Dr. Walid Fayyad, the Minister of Energy and Water, endorsed Solar Power Purchase Agreements (PPAs) through the Council of Ministers Resolution. These agreements, designed to last 25 years, intend to generate 165 MW of electricity from solar energy. Each of the 11 projects is expected to contribute 15 MW.

Distributed across seven governorates, these solar power stations are expected to reach financial closure before May 5, 2024, and commence commercial operations by May 2024. Amidst the severe economic crisis, the government has set a one-year deadline for the winning coalitions to secure all necessary documents for financial closure, adhering to international standards for solar photovoltaic power plants. However, the financing plans for these stations have yet to be disclosed, reflecting Lebanon's challenges in pursuing renewable energy solutions.

IV. CHALLENGES AND OUTLOOK

Lebanon's solar market has faced a tumultuous period since 2023, marked by significant challenges that have impacted its growth and stability. The economic crisis and currency deterioration have led to an 80% decrease in the demand for solar panels. The once-promising peak adoption in the residential sector has seen a decline, casting doubts on the financial closure of the anticipated 165 MW project due to the financing crisis.
Efforts to import energy from neighbouring countries like Jordan and Egypt to solve the electricity crisis have been unsuccessful, primarily due to stringent financing conditions imposed by the World Bank. This has left the electricity sector as one of the most affected areas within the energy market.
Moreover, the increase in fires related to solar systems installed on rooftops has raised concerns about public safety and the competency of installation practices. These incidents have caused significant damage, exacerbating Lebanon's chronic electricity crisis.

Many Lebanese citizens turned to solar systems as a potential solution in response to the escalating electricity delivery issues, including longer outage times and the rising cost of oil derivatives. However, this shift has not been without its own set of problems. Reports of solar panels falling onto streets, endangering vehicles and pedestrians, and the fires highlight the urgent need for improved competencies and public safety measures.
Despite these setbacks, the Lebanese solar market holds considerable potential for recovery and growth. The environmental and financial benefits of integrating PV systems remain clear, and there is an opportunity for the market to rebound with the right support and policies in place. As the global push for renewable energy continues, Lebanon's solar market could play a pivotal role in the country's energy transition, provided that the challenges are addressed with practical strategies and a commitment to safety and quality standards.

Source: Solarbic Database

G. LIBIYA

RE Capacity by 2023	RE Capacity Target by 2025	RE Target by 2030
6 MW	450 MW	22%

Source: IRENA & Solarabic Database

I. CURRENT SITUATION

Libya's venture into solar energy offers a glimmer of hope in the face of its electricity sector's crisis. The country grapples with a daily electricity shortfall of roughly 2,500 MW, forcing many Libyans to rely on diesel generators for power, particularly in the commercial, industrial, and agricultural sectors, which face high tariffs.

Solar systems are gaining popularity in these sectors to counter the grid's unreliability. Libya's location within the Sunbelt provides abundant solar potential, with an average solar radiation of 7.1 kWh/m^2/day and over 3,500 hours of sunshine annually. This makes Libya an ideal location for generating significant amounts of clean electricity from solar energy.

However, the civil war has severely impacted Libya's energy sector, with significant disruptions to oil and gas production, the traditional sources of electricity. Blockades on vital infrastructure have reduced crude output, leading to a financial crisis and threatening national economic stability.

Despite the General Electricity Company of Libya (GECOL) having a generation capacity of 9 GW, only 2% of the power supply comes from renewable energy.

The conflict has also caused collateral damage to the electricity infrastructure. Power plants have either switched to more expensive liquid fuels or shut down due to fuel shortages, resulting in widespread power outages. The United Nations has reported a significant decline in the percentage of the Libyan population with access to electricity, dropping from 99.8% in 2000 to 70.15% in 2017. This trend is concerning, as it goes against the global movement towards broader electricity access.

II. PROJECTS

MOI between Eni and the Libyan government

In June 2023, Eni signed a memorandum of understanding with the Libyan government. This agreement marked a commitment to explore opportunities to reduce greenhouse gas emissions and foster sustainable energy development in line with Eni's strategy and Libya's decarbonization and energy transition goals. The memorandum was signed during Prime Minister Abulhamid Dabaiba's visit to Italy.

The collaboration focuses on several key areas:

Emission Reductions: Eni aims to decrease CO2 emissions by addressing routine gas flaring, fugitive emissions, and venting. Projects targeting emissions in hard-to-abate sectors are also under consideration.

Renewable Energy and Efficiency: The memorandum evaluates new renewable energy solutions and electricity efficiency initiatives in Libya.

Al-Sadadda Solar Park 500 MW

In a landmark move for Libya's renewable energy landscape, the General Electricity Company of Libya (Gecol), in collaboration with TotalEnergies, has embarked on constructing the Al-Sadadda Solar Park. This monumental project, with a capacity of 500 MW, represents the first solar energy venture in the nation and stands as the largest of its kind within Libyan borders.

Strategically situated in the Sadada region, the solar park is a cornerstone of Gecol's forward-thinking strategy to significantly enhance the penetration of renewable energy sources into Libya's national grid. The project underscores a broader commitment by TotalEnergies, as encapsulated in an agreement with Gecol, to execute projects that will contribute to 5% of Libya's solar energy output.

The signing of the Al-Sadadda Solar Park project in mid-2022 marked a significant milestone in Libya's journey toward sustainable energy solutions. The project is still in the pre-construction stage, and its anticipated integration will be into the national grid afterward.

III. CHALLENGES AND OUTLOOK

Libya faces several challenges that hinder fully exploiting its renewable energy potential. The absence of a clear regulatory framework and incentives for private investment, coupled with the lack of skilled labor due to the ongoing conflict and political turmoil, are significant obstacles. Moreover, the security situation poses risks to renewable energy infrastructure, which needs to be addressed to attract investments.

Libya should introduce an Electricity Law that establishes a regulatory framework and offers incentives for renewable energy investments. The country must redirect subsidies from oil and gas to renewables and establish a regulatory body to ensure compliance. These reforms will attract visitors and create favorable conditions for the private sector to innovate and contribute to the renewable energy market.

Libya's transition to renewable energy is essential for its long-term stability and economic prosperity. With international support and a commitment to overcoming the challenges, the outlook for Libya's renewable energy market is possibly optimistic, with the potential to significantly contribute to the global shift towards sustainable energy sources.

Source: Solarbic Database


Courtesy: Freepik

H. MOROCCO

RE Share in Electricity Generation by 2022 (Excluding Hydropower)	RE Target by 2030	RE Capacity by 2022
20%	**52%**	**4,151 MW**

Source: Solarabic Database

I. CURRENT SITUATION

In 2023, Morocco has made significant strides in its renewable energy sector. The nation announced a substantial investment increase, aiming to reach $1.4 billion annually from 2023 to 2027. This financial commitment is expected to fund the completion of approximately 1.3 GW of renewable energy capacity each year within this period, a substantial increase from the 0.16 GW completed annually from 2009 to 2022.

The past year saw the licensing of new renewable energy projects with a capacity of around 1,000 MW, marking the largest capacity licensed in a single year by the Moroccan ministry. As a result, the production of renewable energies surged by 133% in the interim outcome of 2023. The Moroccan Prime Minister, in January 2024, highlighted that more than 40% of the country's energy mix now comprises renewable energies, with a target to reach 52% by 2030.

Morocco's renewable energy production for the previous year stood at approximately 4.6 GW. The nation is on course to achieve its ambitious goal of having renewable energy sources represent 52% of the energy mix by 2030 and about 80% by 2050.

II. REGULATIONS AND FRAMEWORK

Program to Support Industrial and Agricultural Sectors

Valoris Capital announced an initiative for Morocco's energy sector In September 2023, Through its Valoris Alternative Investment Fund (VAIF), also known as "Enolis," the company introduced a novel financing approach for solar projects, targeting industrial and agricultural sectors.

"Enolis" offers a full-service package encompassing solar project financing, installation, and maintenance. This initiative is designed to supply clean, cost-effective electricity catering to industrial and agricultural enterprises.

Endorsed by the Moroccan Capital Market Authority (AMMC), VAIF is a trailblazing fund focused on fostering investments in renewable energy while alleviating financial pressures on businesses. Specialists in finance and sustainable energy steer the fund.

III. PROJECTS

Noor Midelt 3 Project – 400 MW

In December 2023, the Moroccan Agency for Sustainable Energy (MASEN) announced the pre-qualification of several international companies for the Noor Midelt 3 project. This project is part of the Noor Midelt Solar Park and is expected to have an installed photovoltaic capacity of approximately 400 MW. The pre-qualified contractors include prominent names such as Masdar, Morocco Energy, Acciona, Green Of Africa, ACWA Power, Nareva Holding, and others from around the globe.

The Noor Midelt 3 station is also set to be equipped with a battery storage system capable of 400 MW per hour, contributing to the Noor Midelt complex's goal of becoming one of the world's largest renewable solar and storage energy capacities with a total of 1,600 MW. The project will feature a solar photovoltaic power plant combined with a Battery Energy Storage System (BESS), ensuring electricity generation during daylight and maintaining an approximate net capacity of 200 MW during off-peak hours.

Noor Midelt 2 Project - 400 MW

In July 2023, MASEN qualified six consortiums to compete to construct the Noor Midelt 2 solar power plant in the Atlas Mountains. The project, with a planned capacity of 400 MW, aims to utilize photovoltaic technology and include a storage capacity lasting two hours.

Despite a four-year timeframe, the first phase of Noor Midelt 2 has faced delays, primarily due to disagreements over concentrated solar energy technology.

IV. CHALLENGES AND OUTLOOK

Despite the progress, Morocco faces challenges in its energy transition. The Climate Action Tracker (CAT) emphasizes the need for international support for Morocco's green energy policies to be successful. While the country has a significant potential for renewable energy, the current energy mix is still heavily reliant on coal. This reliance is counterproductive to the global efforts to phase out fossil fuels.

Morocco, with a low share of fossil gas, could expedite the phasing out of this energy source. However, the transition to a renewable-dominated energy mix requires substantial support to overcome the existing dominance of coal in electricity generation.

Morocco's vision for a renewable energy future is clear, intending to produce 80% of its electricity from renewable sources by 2050. The commitment to invest over one billion dollars annually in solar and wind energy reflects the country's dedication to reducing its energy bill and increasing its energy independence. With the proper support and continued investment, Morocco's renewable energy market is poised for significant growth and transformation in the coming years.

Source: Solarbic Database

Courtesy: Freepik

I. OMAN

RE Target by 2030	Installed Solar Capacity by 2022	RE Target by 2030	RE Target by 2050
30%	**2,940 MW**	**14,000 MW**	**100%**

Source: IRENA, Solarbic Database

I. CURRENT SITUATION

Oman is actively expanding its renewable energy sector, with a strategic focus on solar and wind energy investments that complement its emerging green hydrogen projects. The Sultanate's comprehensive clean energy vision aims to achieve carbon neutrality by 2050, reflecting a holistic approach to environmental sustainability and economic prudence.

By the end of 2022, Oman had achieved an installed solar capacity of 2,940 MW. The country has set robust renewable energy targets, aspiring to reach 30% renewable energy by 2030, with an anticipated capacity of 14,000 MW. The ultimate goal is a complete transition to renewable energy by 2050.

Oman's commitment to transforming its energy consumption and production patterns is evident in its aim to emerge as a leading force in green hydrogen production. Leveraging its strategic geographical position and dedicating extensive areas to green hydrogen development, Oman is well-placed to harness its potential for substantial hydrogen production.

Omani officials recognize the importance of forward-thinking in the realm of clean energy for environmental benefits and long-term economic advantages. As Oman positions itself among the regional leaders in new energy, the country is undergoing a significant transformation, guided by a clear vision from its leadership and ongoing renewable energy projects.

II. PROJECTS

Ibri 3 Solar Project, 500 MW

In January 2024, the Nama Power and Water Procurement Company (PWP) initiated the qualification process for developing the Ibri 3 solar project. With a capacity of 500 MW and an estimated cost of 155 million Omani riyals, the project is set to occupy 10 million square meters adjacent to the Ibri 2 solar energy project in Dhahra Governorate. Expected to commence commercial operations by Q4 2026, Ibri 3 aims to reduce carbon emissions by 505 thousand tons annually and boost Nama's renewable energy contribution by 1.5 terawatt-hours yearly.

Manah 1 Solar Energy Project, 500 MW

The EDF Renewables and Korea West Power Company (KOWEPO) consortium announced financial closure for the Manah 1 Solar PV Project in January 2024. Construction began in September 2023, with commercial operations projected for Q1 2025. The project, financed by prominent institutions, including the Export-Import Bank of Korea and Societe Generale, aligns with Oman's strategy for zero neutrality by 2050, contributing approximately 3.3% to the nation's total electrical energy by 2025.

German University of Technology Project 2.2 MW

The German University of Technology in Oman signed a landmark agreement with Solar Wadi in December 2023 to operate solely on renewable energy. The 2.2 MW solar power plant will generate over 3.8 million kilowatt-hours of clean electricity annually, reducing CO_2 emissions by 1,675 tons annually and supporting the region's sustainable energy transition.

Dhofar Wind Power Project (50 MW)

In October 2023, Nama Power and Water Procurement Company registered the Dhofar wind energy project with the International Renewable Energy Certification Organization (I-REC Standard). This milestone marks the first Gulf Cooperation Council country to issue I-REC certificates, fostering the growth of certified renewable energy in the region.

Sohar Solar Plant, 86 MW

Solar Wadi has been granted a license to develop a photovoltaic solar station in Sohar Industrial City, with a capacity of 86 MW. The station will be built using a "self-consumption" system, catering to the city's energy needs without exporting to the public grid. In January 2023, Solar Wadi began seeking applications for the plant's design, construction, and operation. Recently, the regulatory agreement was finalized, and currently, the project is under detailed engineering for EPC finalization, and it's expected to start construction at the beginning of 2025.

III. CHALLENGES AND OUTLOOK

Despite the progress in the utility-scale sector, the distributed generation (DG) sector still confronts challenges, particularly the need for legislative support to foster growth. Oman's commitment to becoming a leading hydrogen exporter by 2030, with $20 billion in recent energy sector investments, underscores its potential.

However, integrating renewable energy into the national grid and establishing a robust legislative framework remain critical hurdles. Exploration of Oman's geological formations for underground hydrogen storage presents a promising avenue for energy security and sustainability, further supporting the nation's transition to a regional hydrogen hub.

Source: Solarbic Database

Courtesy: Freepik

J. QATAR

RE Target by 2030	RE Capacity by the End of 2024	RE Share of Electrical Capacity
20% from Solar	**1,675 MW**	**7.2%** by 2022

Source: Solarabic Database

I. CURRENT SITUATION

According to the International Renewable Energy Agency (IRENA), Qatar's solar energy capacity reached 805 MW in 2022. This capacity reflects the country's commitment to expanding its utility-scale solar projects, which have been experiencing a surge in growth due to substantial investments. These projects are a cornerstone of Qatar's strategy to diversify its energy sources and reduce its reliance on fossil fuels.

The distributed generation sector, including smaller-scale solar installations, is also rising. However, this sector's growth is haphazard, hindered by the absence of a comprehensive regulatory framework and supportive legislation that would facilitate orderly development. Despite this, the demand for Commercial and Industrial (C&I) solar projects continues to climb, driven by businesses' economic benefits and sustainability goals.

In contrast, the residential sector has yet to fully embrace solar energy, primarily due to the low electricity tariffs that Qatari nationals enjoy. These reduced rates diminish the financial incentive for homeowners to invest in solar technology.

In 2022, there was significant discourse regarding the potential removal of subsidies on household electricity tariffs and the introduction of net metering policies. Such policies would allow residential solar system owners to sell excess electricity back to the grid, accelerating the adoption of distributed generation and supporting the nation's transition to renewable energy. However, as of the latest updates, these legislative changes have not been enacted, leaving room for future policy development to shape the landscape of Qatar's solar energy market.

II. PROJECTS

Mesaieed and Ras Laffan Industrial Cities: A 875 MW Solar Milestone

The solar power station, a beacon of Qatar's green energy initiatives, is engineered with an impressive capacity of 875 MW. Annually, it's projected to deliver around 1,800 GWh of clean electricity, which translates to a substantial reduction of nearly 900,000 tons of carbon dioxide emissions, With a target operational date set for 2024.

In January 2023, The project's journey began with an agreement between Samsung C&T, the project's EPC, and leading solar technology providers JA Solar, Sungrow, and TrinaTracker.

PV Palels: JA Solar pledged to equip the station with over 1.6 million "DeepBlue 3.0" photovoltaic panels.
Inverters: Sungrow is committed to supplying the advanced "SG320HX" series inverters.

Trackers: TrinaTracker's role is to supply cutting-edge solar trackers for bifacial photovoltaic plants.

III. CHALLENGES AND OUTLOOK

The solar market in Qatar faces several challenges that could affect its growth trajectory. Legislative hurdles remain a significant barrier, with the distributed generation sector particularly impacted by the lack of supportive regulations and clear policies. The residential sector's growth is stifled by low electricity tariffs for Qatari citizens, which reduces the incentive for household solar adoption. Moreover, the anticipated legislative changes, such as lifting the tariff subsidy for the household sector and issuing net metering legislation, have not been realized, further impeding the sector's development.

Despite these challenges, the outlook for Qatar's solar market is promising. The country's commitment to investing in utility-scale solar projects is evident, with substantial growth expected in this area. If the government addresses the legislative issues and implements the discussed changes, it could catalyze the growth of the distributed generation sector. The market's success hinges on establishing a supportive regulatory environment that encourages investment and adoption across all sectors. With the right policies, Qatar's solar market can significantly expand and contribute to the nation's energy diversification and sustainability goals.

Source: Solarbic Database

Courtesy: 800 MW - Qatar - longi

K. SAUDI ARABIA

Target by 2060	RE Target by 2030	RE Capacity by 2023	RE Capacity by 2030
Net zero carbon emissions	**50%**	**9.5 GW**	**58.7 GW**

Source: Vision 2030 & Solarabic Database

I. CURRENT SITUATION

Saudi Arabia has been vigorously advancing its renewable energy sector, with a strategic aim to add 20 GW annually, targeting 130 GW of renewable energy capacity before 2030. This ambitious goal is part of the Kingdom's broader vision to foster a sustainable future, backed by over 80 initiatives across public and private sectors and a staggering investment exceeding 705 billion riyals (approximately 188 billion US dollars).

In pursuit of an optimal energy mix, Saudi Arabia is working towards having renewable energy account for 50% of its electricity production by 2030. The "Renewable Energy Technologies Localization Initiative" underscores this commitment, focusing on nurturing the local private sector, empowering Saudi companies to innovate in renewable technologies, and developing skilled Saudi human resources to meet international standards.

A notable development occurred with the introduction of the "Oil and Gas Sector Emissions Reduction Charter" during COP28. Saudi Arabia and the UAE observed the participation of 50 companies, collectively representing more than 40% of global oil production. These companies committed to achieving net-zero methane emissions and eliminating gas flaring by 2030, following the objectives outlined in the "Global Accelerator for Reducing Emissions" initiative. These commitments signify initial strides towards the overarching aim of achieving climate neutrality by 2050.

The solar energy sector, in particular, has seen a surge, with new projects accounting for 60% of the Kingdom's renewable energy initiatives. The remaining 40% comprises hydrogen and wind energy endeavors. Aramco, the nation's oil giant, has been instrumental in driving down solar energy costs to a record low, with the price per kilowatt-hour now standing at less than $0.02, positioning solar power as one of the most cost-effective energy sources worldwide.

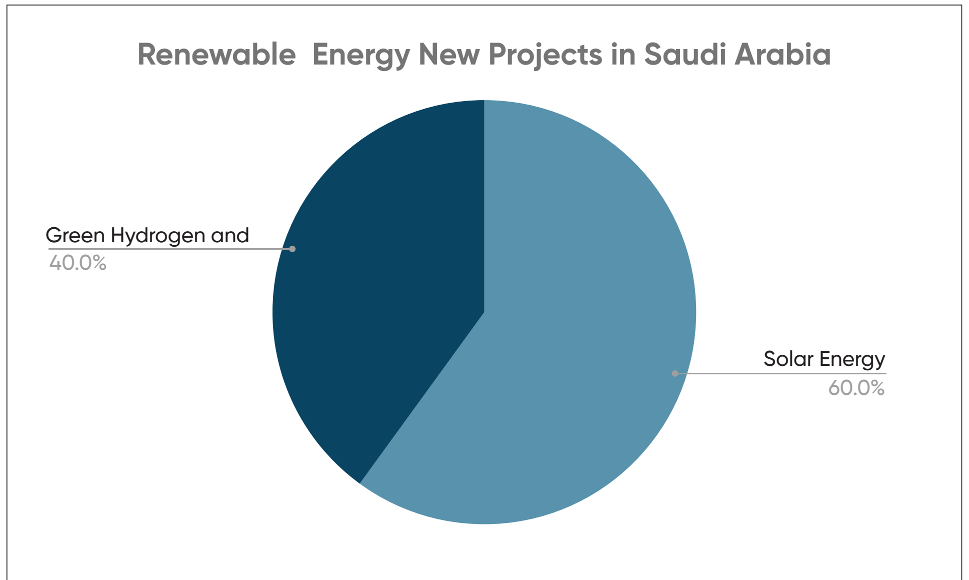


Figure (1): Renewable Energy New Projects in Saudi Arabia

II. PROJECTS

Four Solar Energy Projects (3,700 MW)

Saudi Power Procurement Company (Principal Buyer) has initiated the qualification process for four groundbreaking solar energy projects with a combined capacity of 3,700 MW. These projects, part of the fifth phase of the National Renewable Energy Program, include:

Its operation is anticipated to reduce carbon dioxide emissions by 360,000 tons yearly, akin to taking 80,000 cars off the roads. The project's financial backing came from several prestigious institutions, including the International Finance Corporation and the Japan International Cooperation Agency.

- **Al-Sadawi Project** in the Eastern Province, boasting a capacity of 2,000 MW.
- **Al-Massaa Project** in the Hail region, with 1,000 MW.
- **Al-Hanakiya Project (2)** in the Medina region, contributing 400 MW.
- **Rabigh Project (2)** in the Makkah Al-Mukarramah region, adding 300 MW.

On November 12, 2023, the qualification process for these projects was initiated, marking a pivotal moment in the Kingdom's renewable energy journey. By February 2024, a list of developers qualified to bid for these projects has been announced, marking a significant step towards Saudi Arabia's renewable energy aspirations.

Sudair Station 1,500 MW

By the end of October 2023, The Sudair solar photovoltaic power station, a landmark project within the Sudair Industrial City, has marked a significant milestone by commencing the commercial operation of its second phase. This phase has augmented the station's capacity by 25%, propelling its operational capacity to 1,125 MW. The station is on track to achieve its full potential, with the total project capacity set to reach 1,500 MW.

The project, which stands as one of the "world's largest" single-contracted solar PV plants and the largest of its kind in Saudi Arabia, is a testament to the Kingdom's commitment to renewable energy. It is the first project under the Public Investment Fund's renewable energy program. It has recorded the second-lowest cost globally for solar PV electricity production at just 1.239 US cents/kWh.

The Sudair Photovoltaic Independent Power Producer (IPP) demonstrates significant potential in furnishing power to an estimated 185,000 households and mitigating approximately 2.9 million tons of emissions annually. This endeavor incorporates state-of-the-art solar photovoltaic (PV) technology, featuring bi-facial panels equipped with tracking mechanisms and an automated robotic cleaning system, optimizing efficiency and promoting sustainability.


Courtesy: Red Sea Project - KSA- Sunpure

13 HIGHLIGHTS OF LEADING SOLAR PV MARKETS IN GME

SOLAR OUTLOOK REPORT 2024

III. CHALLENGES AND OUTLOOK

Saudi Arabia's solar market, one of the most rapidly expanding in the MENA region, has faced a series of challenges despite significant legislative efforts over the past two years aimed at revitalizing the distributed generation(DG) market, particularly within the commercial and industrial (C&I) sectors. One of the main hurdles has been the extreme slowness in obtaining necessary approvals, leading to most of which have led to the majority of projects being installed with a zero export format.

On the localization front, Saudi Arabia has been proactive, with several initiatives launched to foster the domestic renewable energy industry. Notably, on December 20, 2023, seven agreements were signed by Saudi companies to localize the renewable energy industry and integrate Saudi graduates specialized in this sector. Furthermore, the Local Content and Government Procurement Authority announced on January 22, 2024, a new initiative to localize the production of iron towers for wind energy systems, and the blades and balancing systems, by including them in the mandatory list for resettlement.

Despite these efforts, the local products still struggle to compete with Chinese offerings regarding price and technology. This presents a significant challenge for the Kingdom as it seeks to achieve its ambitious renewable energy goals and establish itself as a leader in the industry.

Looking ahead, the outlook for Saudi Arabia's solar market remains optimistic. The Kingdom's commitment to overcoming these obstacles and its strategic investments in the sector suggest a bright future.

Source: Solarbic Database

L. TUNISIA

RE Installed Capacity by 2022	Targeted RE Capacity by 2030	RE Target by 2030
472 MW	3,800 MW	30%

Source: Solarabic Database

I. CURRENT SITUATION

Tunisia's renewable energy market is at a crossroads. The country needs to diversify its energy mix away from fossil fuels, mainly imported natural gas. A dwindling domestic energy supply, rising demand, and a desire for greater energy security drive this urgency.

The government has recognized this need and launched ambitious plans. They are investing over a billion dollars in renewable energy projects, intending to reach 1,700 MW of renewable energy production capacity by 2025. This includes large-scale solar and wind farms and initiatives encouraging rooftop solar adoption.

Despite these efforts, renewable energy only contributes 3% of Tunisia's electricity generation. The national grid remains dominated by fossil fuels, with natural gas accounting for nearly half of the energy mix. Delays in project implementation due to bureaucratic hurdles and a need for more transparent long-term policy frameworks have hindered progress.

II. UPDATES ON REGULATIONS AND FRAMEWORKS

Program: Energy Transition in Education

In January 2024, the Tunisian Ministry of Education initiated a significant energy transition program, focusing on installing solar panels across all educational institutions. With an allocated budget of approximately 100 million dinars, the program builds upon a successful pilot within the National Energy Transition Program for public entities.

The ministry has already achieved the installation of solar panels in 40 institutes in Greater Tunis, 15 primary schools, and regional education delegations in Beja, Nabeul, and Tozeur.

III. PROJECTS

Solar Power Project, 1 MW

In February 2024, Representatives of the Tunisian government inaugurated of 1 MW solar station in Djerba, Medenine governorate. This project aligns with the licensing system for renewable energy production, targeting full sales to the Tunisian Electricity and Gas Company.

The project's budget was 3 million Tunisian dinars (approximately $1 million), with an expected annual output of 1,735 MWh, enough to power about 500 homes. Spanning two hectares, the site is equipped with roughly 1,900 photovoltaic panels.

100 MW Solar Power Plant

Amea Power, alongside the Tunisian Ministry of Energy and other financial contributors, finalized a deal to construct a 100 MW solar plant. The endeavour is valued at around $86 million in Kairouan Province. Initiating within a month, the plant is projected to commence operations in the final quarter of 2024.

The African Development Bank and the International Finance Corporation have invested in the project, each contributing about $26 million, with half of the IFC's share being concessional.

Bourguiba Solar Station, 200 MW

The Bourguiba station's construction kicked off in 2023. By September, 40% of phase one was complete, with electric poles installed over 80 km of the planned 132 km. The station, sprawling across 400 hectares in Tataouine Province, is set to generate 200 MW of electricity, tripling the annual energy needs of Tataouine.

IV. CHALLENGES AND OUTLOOK

The journey towards a renewable energy future in Tunisia has challenges. The country has experienced a growing dependence on imported fossil fuels due to increasing energy consumption and falling domestic hydrocarbon production. This reliance on natural gas has left Tunisia vulnerable to supply disruptions and volatile energy prices.

Key actions are recommended to overcome these challenges, such as establishing a renewable energy planning and scheduling framework, enhancing renewable resource assessment, simplifying procurement procedures for power grid development, and involving local banks in financing renewable energy projects. Policy and regulatory issues, unstable regulatory frameworks, and a monopoly in the energy market have been obstacles to attracting international investments.

Looking ahead, Tunisia's energy transition is integral to its sustainable economic and social development strategy. To reduce primary energy demand by 30% and increase the contribution of renewables in electricity production to 30% by 2030, the country is poised to make significant progress if it can effectively address these challenges.

Source: Solarbic Database

Courtesy: Freepik

M. UNITED ARAB EMIRATES

RE Target by 2030	Installed Solar Capacity by 2022	RE Target by 2030
30%	2,940 MW	14,000 MW

Source: IRENA & Solarbic Database

I. CURRENT SITUATION

The solar energy market in the UAE has shown significant growth and development in 2023. The demand for solar panels increased by 40%, indicating a solid shift towards sustainable energy, driven by the public and private sector's desire to achieve financial savings and support environmental conservation efforts.

The UAE has made considerable strides in implementing solar energy systems, which have become more accessible and quicker to deploy. reducing global panel costs by about 7% has also contributed to the increased affordability and supply of solar systems in the Region.

Moreover, the UAE's hosting of COP28 has been a pivotal event, emphasizing the country's commitment to clean energy technologies and climate action. The launch of the "Oil and Gas Sector Emissions Reduction Charter" during COP28, with the pledge by 50 companies to achieve net-zero methane emissions and stop flaring by 2030, showcases the UAE's leadership in driving sustainable practices within the energy sector.

II. PROJECTS

Abu Dhabi Solar Energy Plants

On March 8, 2024, the Ministry of Defense and Masdar, the Abu Dhabi Future Energy Company, signed a partnership to develop a series of solar energy plants in Abu Dhabi. Emerge, a joint venture between Masdar and the French EDF Group will oversee the development of these projects, handling financing, design, procurement, construction, operations, and maintenance for 25 years.

Energy Storage Battery Systems, 400 MW

The Emirates Water and Electricity Company (EWEC) has invited expressions of interest to develop a 400 MW Battery Energy Storage System (BESS). Announced on March 7, 2024, this project is a cornerstone in EWEC's strategic vision to enhance the flexibility and reliability of the power system.

13 HIGHLIGHTS OF LEADING SOLAR PV MARKETS IN GME

The BESS initiative is designed to provide critical ancillary services, including frequency response regulation and electrical voltage regulation, which are essential for maintaining grid stability as the integration of renewable energy sources increases. This project aligns with EWEC's commitment to sustainability and supports its ambitious goal to boost solar energy generation capacity to 7.5 GW by 2030.

Under the Independent Power Producer (IPP) model, the project will be a collaborative effort where the selected developer will forge a long-term power purchase agreement with EWEC. This agreement positions EWEC as the sole procurer of electricity within the emirate, ensuring a secure and consistent demand for the energy produced by the BESS.

The project's scope encompasses the development, financing, construction, operation, maintenance, and ownership of the BESS, along with the necessary infrastructure works. Once operational, the BESS will contribute significantly to EWEC's decarbonization strategy, accelerating the deployment and utilization of renewable energy within the UAE and reducing the average carbon dioxide intensity from power generation by approximately 42%, from 330 kg/MWh in 2019 to an estimated 190 kg/MWh by 2030.

Al-Ajban Solar Station, 1.5 GW

A consortium, including EDF's renewable energy arm and Korea Western Power, will develop the Al-Ajban independent solar power plant, as announced on February 14, 2024. The UAE utility company plans to invest over one trillion won ($748 million) to construct the 1.5 GW plant, located 70 kilometers east of Abu Dhabi.

The construction is set to begin in June 2024, with completion expected by July 2026. This project will supply electricity to approximately 160,000 homes and reduce carbon dioxide emissions in Abu Dhabi by over 2.4 million metric tons annually.

Aldar Solar Projects, 34 MW

Aldar Properties has partnered with Yellow Door Energy to harness solar energy across 45 of its real estate assets in the UAE. The partnership, formalized during COP28, is a testament to Aldar's commitment to clean energy and its goal to achieve net-zero emissions by 2050.

The solar energy systems, financed, designed, built, operated, and maintained by Yellow Door Energy, will have a capacity of 34 MW. These systems will be implemented across Aldar's diverse portfolio, including retail, education, and hospitality sectors, over the next 20 years.

Courtesy: Sevens Stadium - UAE - Sirajpower

The transition to solar power is set to commence in 2024. It is projected to reduce carbon dioxide emissions by 23,000 tonnes in the first year alone, contributing to a 12% reduction in Aldar's Scope 2 greenhouse gas emissions related to purchased electricity against its 2022 baseline. Over the project's lifetime, it is expected to avoid more than 560,000 tonnes of CO2 emissions.

Emirates NBD Solar Projects, 1.2 MW

Emirates NBD signed a strategic partnership with Sirajpower at COP28 on December 11, 2023. The partnership aims to provide renewable and sustainable energy at the bank's two main locations using solar energy systems with a total capacity of 1.2 MW. This initiative underscores the bank's commitment to sustainability and aligns with the UAE's vision for an environmentally friendly future.

Hassyan Energy Production Complex, 2,400 MW

By the end of November 2023, ACWA Power Saudi Arabia announced the start of commercial operation of the Hassyan project, with DEWA issuing the commercial operation certificate. The complex, with a capacity of 2,400 MW, added the last power production unit of 600 MWs to the previously operated units. ACWA Power owns 26.95% of the Hassyan Complex project.

Renewable Energy for Expo City Dubai, 100,000 MWh

Expo City Dubai and DEWA signed a cooperation agreement on November 21, 2023, to supply the entire Expo City with renewable electrical energy. This agreement supports Expo City's journey towards climate neutrality by 2050 and the goals of COP28, with plans to increase on-site power generation in the coming years.

The agreement stipulates that DEWA will supply Expo City with over 100,000 MWh of solar energy sourced from the Mohammed bin Rashid Al Maktoum Solar Park through International Renewable Energy Certificates (I-RECs). This initial allocation is based on the expected total energy consumption for 2023, with provisions to incorporate additional I-RECs as the community's energy demands grow.

III. CHALLENGES AND OUTLOOK

The United Arab Emirates (UAE) has been at the forefront of adopting sustainable practices and investing in renewable energy. Despite occasional legislative hurdles, the nation's commitment to environmental progress continues to strengthen year after year.

On National Environment Day, February 4, 2024, Sheikh Mohammed bin Zayed Al Nahyan, President of the UAE, extended the Year of Sustainability initiative to 2024, reinforcing the nation's dedication to environmental stewardship.

The UAE was the first Gulf country to pledge to achieve net-zero carbon emissions by 2050. This ambitious plan involves an investment of 600 billion dirhams ($163.37 billion) in clean and renewable energy over the next three decades.

The UAE's outlook on solar energy is optimistic. With substantial investments in clean energy projects and a clear strategy for sustainability, the nation is well-positioned to meet its environmental goals. The extension of the Year of Sustainability and the inauguration of landmark projects like the Mohammed bin Rashid Al Maktoum Solar Energy Complex testaments the UAE's unwavering commitment to a greener future. As the UAE continues to navigate the challenges ahead, its trajectory towards becoming a global leader in renewable energy looks promising.

Source: Solarbic Database

N. UZBEKISTAN

RE Target by 2030	Installed Solar Power by 2022	RE Target by 2030
25%	253 MW	12,000 MW

Source: IRENA & Solarbic Database

I. CURRENT SITUATION

Uzbekistan's renewable energy landscape is rapidly expanding. By the close of 2021, the nation had established a solar energy capacity of 104 MW and a wind energy capacity of 1 MW. In contrast, hydroelectric power comprised a significant portion of the energy infrastructure, exceeding 2 GW, over 10% of the total installed capacity.

The country has set ambitious targets to achieve 8 GW of renewable energy capacity by 2026 and extend it to 12 GW by 2030. To reach these goals, Uzbekistan intends to construct 5 GW of solar energy facilities, 3 GW of wind farms, and 1.9 GW of hydroelectric power plants, thereby increasing the share of renewables in the energy mix to 25% from the 10% recorded in 2019. Uzbekistan is progressing, with approximately 1.5 GW of renewable energy projects being built and nearly 7 GW in the planning stages.

II. PROJECTS

Three Solar Projects Totaling 897 MW

In April 2023, a landmark initiative was undertaken by the Asian Development Bank (ADB) and Abu Dhabi Future Energy Company PJSC (Masdar) to establish three solar power plants in Uzbekistan's Surkhandarya, Samarkand, and Jizzakh regions. Collectively, these facilities will contribute a significant 897 MW.

The financial framework for this project includes three separate loans from ADB's ordinary capital resources, totalling $64.5 million, distributed as follows: $36.7 million for Sherabad, $13.5 million for Samarkand, and $14.3 million for Jizzakh. Fast forward to March 18, 2024, the first operational phases of two of these plants have been successfully integrated into the power grid, boasting a combined capacity of 511 MW, Samarkand and Jizzakh solar power plants.

Upon full integration into the power grid, the Samarkand and Jizzakh solar power plants are projected to produce an impressive 1.12 billion kWh annually. This output will be sufficient to supply electricity to approximately 240,000 households and is expected to reduce carbon dioxide emissions by over 1 million tons each year.

ACWA Power's Expansive Solar and Storage Projects in Uzbekistan

In a significant stride towards renewable energy, Saudi Arabian energy conglomerate ACWA Power announced in March 2023 that it had successfully secured a series of power purchase agreements (PPAs) with Uzbekistan's Joint-Stock Company National Electric Grid of Uzbekistan (NEGU) and the Ministry of Investment, Industry, and Trade. This monumental agreement encompasses a substantial 1.4 GW of solar power capacity and an impressive 1.5 GWh of energy storage capacity.

In Tashkent, ACWA Power plans to construct a 400 MW PV plant. This plant will be complemented by a 500 MWh battery energy storage system (BESS), which will play a crucial role in stabilizing the grid and ensuring a reliable supply of solar energy.

The historic city of Samarkand will witness the development of two expansive 500 MW PV projects. Each project will be equipped with its own 500 MWh BESS, further solidifying the city's status as a hub of innovation and progress.

Additionally, the storied city of Bukhara will be home to another 500 MWh BESS. This installation is part of a broader initiative that includes constructing overhead transmission lines. These lines are designed to efficiently dispatch the generated power to the national grid, thereby enhancing the overall energy infrastructure of Uzbekistan.

III. CHALLENGES AND OUTLOOK

Uzbekistan's outlook on solar energy is optimistic, with substantial projects underway. The World Bank-supported initiative to install two-kilowatt solar panels on 150,000 private homes is a notable example of the country's commitment to expanding solar capacity. Rooftop solar installations are gaining traction, offering a viable option for energy supply, especially in remote areas lacking grid connectivity.

Despite the progress, the solar energy sector in Uzbekistan faces several challenges. The high cost of solar panel installation remains a barrier to widespread adoption, as it is relatively expensive compared to the average income. While state subsidies exist, they have not been sufficient to make solar panels a common sight in Uzbek households. Moreover, the focus on non-residential photovoltaic (PV) installations, such as in schools and government buildings, though accelerated by the 2019 Law on the Use of Renewable Energy Sources, requires continued legislative and financial support to maintain momentum.

Uzbekistan's solar energy sector is poised for significant growth and is supported by government initiatives and international assistance. However, addressing the economic barriers to solar panel adoption and ensuring sustained legislative support is crucial for achieving the country's renewable energy goals.

Source: Solarbic Database


Courtesy: Solar Power Plant - Freepik

GLOSSARY OF TERMS

- **°C** Celsius
- **ABC** All Back Contact
- **AC** Alternating Current
- **ACWA** Arabian Company for Water and Power Development
- **ACX** Abu Dhabi Climate Exchange
- **ADB** Asian Development Bank
- **ADGM** Abu Dhabi Global Market
- **AED** United Arab Emirates Dirham
- **AI** Artificial Intelligence
- **AIKO** AIKO Solar
- **ANPC** Active Neutral Point Clamped
- **AR** Anti-Reflective
- **Atlas Mountains** Atlas Mountains
- **BECCS** Bioenergy with Carbon Capture and Storage
- **BESS** Battery Energy Storage Systems
- **BIPV** Building Integrated Photovoltaic
- **BMS** Battery Management System
- **BoS** Balance-of-System
- **c-Si** Crystalline Silicon
- **C&I** Commercial and Industrial
- **CAN** Controller Area Network
- **CAPEX** Capital Expenditure
- **CCS** Carbon Capture and Storage
- **CDP** Carbon Disclosure Project
- **CO2** Carbon dioxide
- **COP** Conference of the Parties
- **COP28** 28th Conference of the Parties

GLOSSARY OF TERMS

CSEM	Centre Suisse d'Electronique et de Microtechnique
CSP	Concentrated Solar Power
DAC	Direct Air Capture
DC	Direct Current
DEWA	Dubai Electricity and Water Authority
DFM	Dubai Financial Market
DNI	Direct Normal Irradiance
DUST IQ	Optical dust monitoring system
EBIC	Electron-Beam Induced Current
EDX	Energy-Dispersive X-ray Spectroscopy
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
EPC	Engineering, Procurement, and Construction
ESG	Environmental, Social, and Governance
EU	European Union
EUA	European Union Allowance
EUR	Euro
eV	Electron Volts
EVA	Ethylene Vinyl Acetate
EWEC	Emirates Water and Electricity Company
$g/m^2/h$	Grams per square meter per hour
GCC	Gulf Cooperation Council
GECOL	General Electricity Company of Libya
GETAS	Genel Elektrik Ticaret ve Sanayi A.Ş
GHG	Greenhouse gases
GHI	Global Horizontal Irradiance
GREGY	Greece's Copelouzos Group and Masdar's affiliate Infinity Power

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GLOSSARY OF TERMS

GW	Gigawatt
GWh	Gigawatt-hour
HJT	Heterojunction
I-REC	International Renewable Energy Certification Organization
IEA	International Energy Agency
IEEFA	Institute for Energy Economics and Financial Analysis
IFC	International Finance Corporation
IODC	Indian Ocean
IOGCC	Interstate Oil and Gas Compact Commission
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
IRR	Internal Rate of Return
ISC	Fraunhofer Institute for Solar Energy Systems
KAUST	King Abdullah University of Science and Technology
KSA	Kingdom of Saudi Arabia
kW	Kilowatt
kWh	Kilowatt-hour
La1	Method La1
LCAs	Life Cycle Assessments
LEED	Leadership in Energy and Environmental Design
LFP	Lithium Iron Phosphate
M10	10th Generation Wafer Size
m2	Square meter
M6	6th Generation Wafer Size
MASEN	Moroccan Agency for Sustainable Energy
MBR	Mohammed Bin Rashid
MC2	Masdar City Phase 2

14 GLOSSARY OF TERMS

- **MENA** – Middle East and North Africa
- **MiFID II** – Markets in Financial Instruments Directive II
- **MOEE** – Ministry of Electricity and Energy
- **MW** – Megawatt
- **MWh** – Megawatt-hour
- **MΩ** – Megaohm
- **N-type** – N-type Solar Panels
- **Na** – Sodium
- **NCA** – Lithium Nickel Cobalt Aluminum Oxide
- **NEGU** – National Electric Grid of Uzbekistan
- **NMC** – Lithium Nickel Manganese Cobalt Oxide
- **NPC** – Neutral Point Clamped
- **NREA** – New and Renewable Energy Authority
- **NREAP** – National Renewable Energy Action Plan
- **O&M** – Operation and Maintenance
- **Pa** – Pascal
- **PCS** – Power Conversion System
- **PERC** – Passivated Emitter and Rear Cell
- **PID** – Potential-Induced Degradation
- **PJSC** – Public Joint Stock Company
- **PPA** – Power Purchase Agreement
- **PV** – Photovoltaic
- **PVB** – Polyvinyl Butyral
- **PWP** – Public Water and Power Company
- **R&D** – Research and Devel-opment
- **RE** – Renewable Energy
- **ROI** – Return on Investment

14 GLOSSARY OF TERMS

- **RVCMC** – Riyadh Voluntary Carbon Market Club
- **S-Q** – Shockley-Queisser
- **SBTi** – Science Based Targets initiative
- **Si** – Silicon
- **SiNx** – Silicon Nitride
- **STEM** – Scanning Transmission Electron Microscopy
- **T** – Terminal
- **t CO2** – Metric tons of carbon dioxide
- **TEM** – Transmission Electron Microscopy
- **TiO2** – Titanium Dioxide
- **ToF-SIMS** – Time-of-Flight Secondary Ion Mass Spectrometry
- **TOPCON** – Tunnel Oxide Passivated Contact
- **TPU** – Thermoplastic Polyurethane
- **TSCs** – Tandem Solar Cells
- **TWh** – Terawatt-hour
- **UAE** – United Arab Emirates
- **UK** – United Kingdom
- **USA** – United States of America
- **USD** – United States Dollar
- **VAIF** – Valoris Alternative Investment Fund
- **VCM** – Voluntary Carbon Markets
- **VERRA** – Verified Carbon Standard
- **VOC** – Volatile Organic Compounds
- **W** – Watts
- **WRF** – Weather Research and Forecasting
- **WVTR** – Water Vapor Transmission Rate
- **µm** – Micrometer

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