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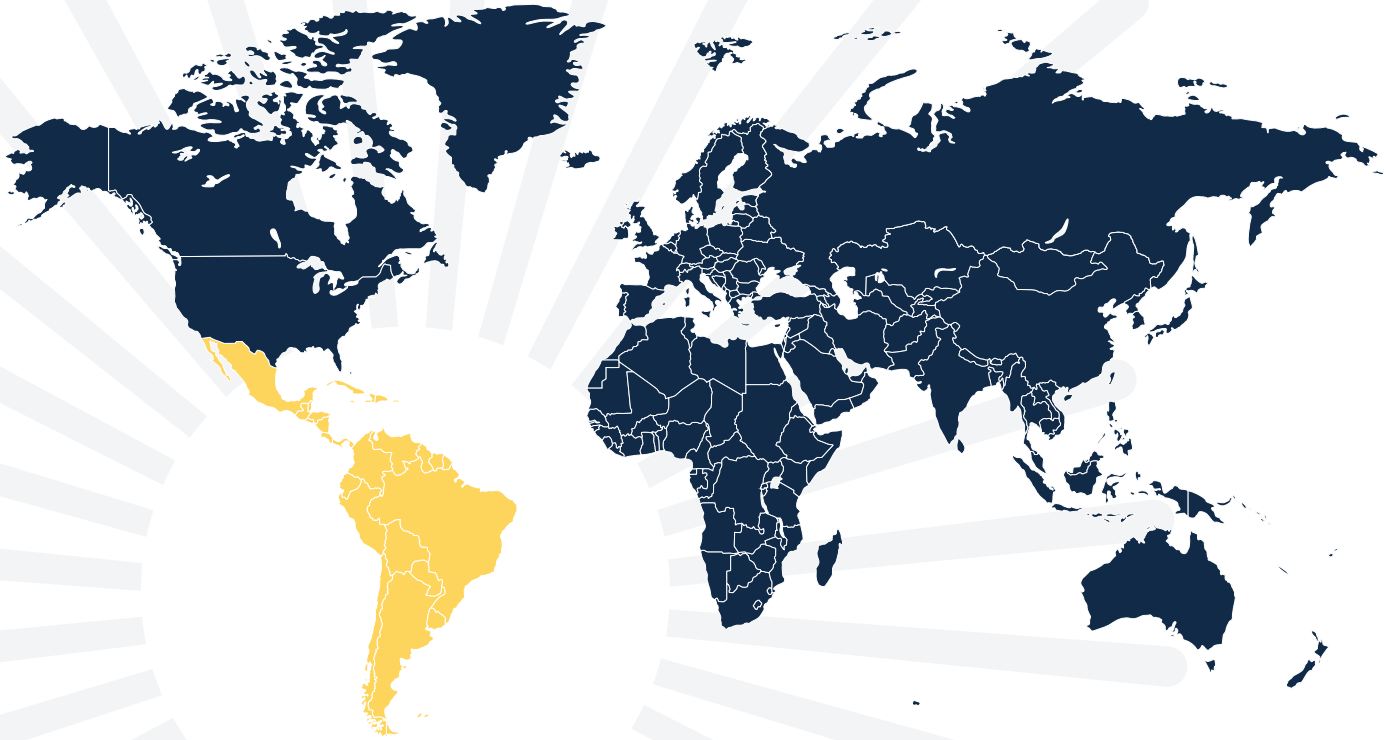

Global Market Outlook

For Solar Power

2022 - 2026

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Foreword

Welcome to the Global Market Outlook for Solar Power 2022-2026.

Solar has just reached a new dimension. At the launch of this edition during the Intersolar Europe 2022 trade show in early May, total global installed solar capacity has just passed the 1 TW threshold. That's amazing, considering that only 20 years ago, in early 2002, the cumulative grid-connected volume had reached 2 GW; today, it's 500 times that much. And while it took 16 years, until 2018, to reach the 500 GW level, here we are, a little more than 3 years later, looking at an amount that has doubled to 1,000 GW or 1 TW. After achieving 1 TW of global solar early in the year, the forecast for the rest of 2022 is similarly bright, with the world on track to install more than 200 GW in one year for the first time. With 228 GW of expected solar installations, additional capacity in 2022 will be equivalent to total global solar capacity in 2015.

This lookback at the short history of commercial solar deployment — that began at the start of this millennium with the introduction of the German feed-in tariff law — clearly unfolds how quickly solar has evolved. But as we dive deeper, it also reveals how missing visions of decision makers and flawed policy frameworks have been showstoppers, severely slowing down developments. In fact, solar could have grown even faster. Europe's largest solar market Germany has still not been able to repeat its record installation volume from 2012. Finally, it needed a new government to come up with an ambitious solar vision and prepare the legal boundary conditions to enable really strong growth. This is only one example. While the global solar industry has been doing its homework and helping solar to become the lowest cost power generation technology, it needs the right framework conditions to be able to tap solar's potential. Lengthy and costly permitting is still the major obstacle to rapid solar dissemination.

This annual Global Market Outlook is a cooperation of the world's leading regional and solar industry associations that work hard to convince decision makers about the unique benefits of solar. We want to say a big Thank You to all contributors and supporters of this solar market outlook, which would not have been possible without all the different helping hands from solar associations around the world.

The focus region of this GMO edition is Latin America, a sunny and promising region for solar power, and home to one of the rising global solar stars, Brazil, where a bucket of different attractive policy tools has made the country one of the top five global solar market prospects over the next five years. We are grateful to our partner, the Global Solar Council, which has provided this chapter through its member, Brazilian solar association ABSOLAR.

Looking ahead, the next driver for solar stems from Europe. So far, the fight against Climate Change has been the key driver for on-grid solar development to the TW-level. As we are deeply shocked about the Russian invasion of Ukraine, it has also uncovered the geostrategic importance of solar power. Depending, to a large extent, on Russian gas and oil imports, most European countries are trying to detach themselves from Russia's energy strings as soon as possible. In this context, they have begun to look from a different viewpoint at versatile solar power, which in combination with heat pumps can be also used to electrify heat supply, and provide local and individual energy security. The very sad developments in Ukraine will provide a further boost to solar, despite the negative economic implications. Our Medium Scenario projects the next doubling of global installed solar capacity to 2 TW already by 2025.

Enjoy reading our Global Market Outlook.

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Methodology: SolarPower Europe's five-year forecast consists of Low, Medium and High Scenarios. The Medium scenario anticipates the most likely development given the current state of play of the market. The Low Scenario forecast is based on the assumption that policymakers halt solar support and other issues arise, including interest rate hikes and severe financial crisis situations. Conversely, the High Scenario forecasts the best optimal case in which policy support, financial conditions and other factors are enhanced.

Segmentation is based on the following system size: Residential (<10 kW); Commercial (<250 kW); Industrial (<1,000 kW); Utility-scale (>1,000 kW, ground-mounted). SolarPower Europe's methodology includes only grid-connected systems. Installed capacity is always expressed in DC, unless otherwise stated.

All figures are based on SolarPower Europe's best knowledge at the time of publication. Exchange rates were used at the time of writing.

Executive summary

In a year characterised by continuing COVID-19 waves and economic recovery programmes, as well as an energy crisis that saw record-high electricity prices around the world, many turned to solar solutions for their energy needs. In 2021, 167.8 GW of solar capacity was grid-connected globally, a 21% growth over the 139.2 GW added the year before, establishing yet another global annual installation record for the sector. This brings the total operating solar fleet to 940 GW by the end of 2021, with the Terawatt milestone already achieved ahead of the publication of this Outlook in May 2022.

This remarkable growth has no match among any other power generation technology. Out of the over 300 GW of new global renewable power generating capacity, solar alone installed more capacity than all other renewable technologies combined, claiming a share of 56%. Solar also deployed more capacity than all fossil fuel power generation technologies together in 2021. At the same time, however, solar still meets only a small share of around 4% of the global electricity demand, while over 70% is provided by non-renewable sources.

Challenges across the supply chain did not stop the progress of solar's cost competitiveness. With a further 3% decrease compared to the previous year, today the cost of utility-scale solar is consistently lower than any range of new conventional power generation sources, while the cost-competitiveness of solar + storage versus gas peakers is already undisputable in certain regions.

Solar tender results provide testimony for the growing competitiveness of solar technology around the world, with new record-low solar tariffs registered again in 2021. Solar's new lowest bid of 1.04 USD cents in Saudi Arabia was 21% lower than the previous record set in Portugal in 2020.

With a 14% annual growth rate and an all-time high 54.9 GW new solar, China kept its market leadership in 2021, adding twice as much solar power capacity than the second-largest market, the United States, which continued its remarkable growth performance with a 42% annual expansion. After a disappointing year in 2020, India reclaimed the third position with 14.2 GW installed. The record solar years in both China and India were not high enough to maintain the Asia-Pacific region's global share, which lost 6 percentage points to 56%, while the Americas and Europe grew to 22% and 19% respectively.

Despite the increase in solar component and freight prices that affected the sector in 2021 extending into 2022, this year we expect another record-breaking performance. In 2022 our Medium Scenario anticipates additional global solar installation capacities to increase by 36% to 228.5 GW. The world will see very strong demand for solar in the next four years, growing from 255.8 GW additional capacity in 2023 to 347 GW in 2026. It will most likely add 314.2 GW in 2025, 18% more than we anticipated in last year's GMO.

If it took 10 years to upscale the world's total grid-connected solar capacity from 100 GW in 2012 to 1 TW in 2022, it will take only a little more than 3.5 years to double it to 2 GW by end of 2025. At the end of our forecasting period, we expect 2.3 TW of solar to be installed worldwide.

Despite the global market growth, the number of markets in the GW range has remained 17 in 2021, although sustained growth is expected on this front, too – we forecast 21 GW markets in 2022, 29 in 2023 and 34 in 2024.

This year's regional focus is on Latin America. With the support of the Global Solar Council (GSC), we have provided an in-depth analysis of solar in a market that grew 44% in 2021 thanks to exciting developments in its GW-scale markets Brazil and Chile. The future for solar in the region looks promising, particularly in Brazil, which, for the first time, has entered the top 10 of the prospected largest solar markets over the 5-year report outlook period. Brazil is expected to install 54 GW by 2026, that's comparable to Germany's – Europe's largest solar market – level of installations, until recently.

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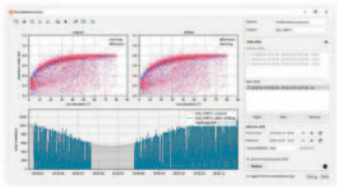

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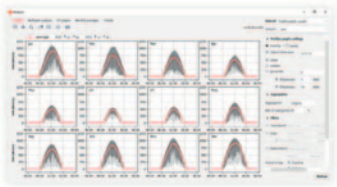

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1 Global solar market


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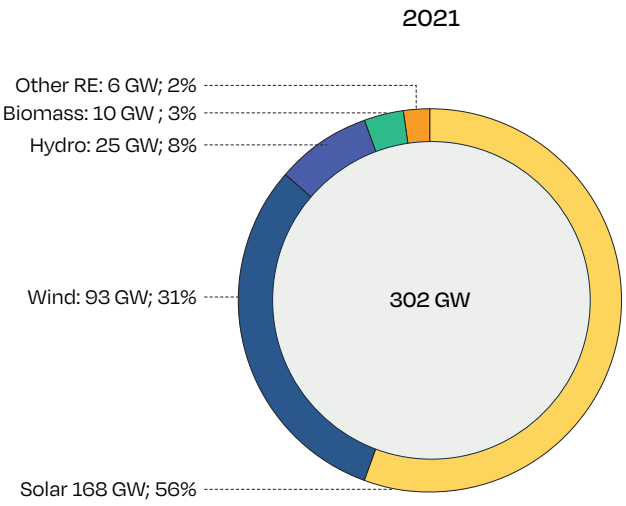
In 2021 again, solar power was ranked the top power generation source installed across the globe. From the more than 300 GW of new renewable power generating capacity added, solar PV claimed a share of 56%, grid-connecting 167.8 GW (see Fig. 1). Solar's share of newly added renewable capacity increased compared to 2020, when it had contributed 47% of total renewable capacity additions. The role of solar in the global energy transition is getting more and more prominent, considering that in 2021, solar alone installed more capacity than all other renewable technologies combined.

FIGURE 1 NET RENEWABLE POWER GENERATING CAPACITY INSTALLED IN 2021

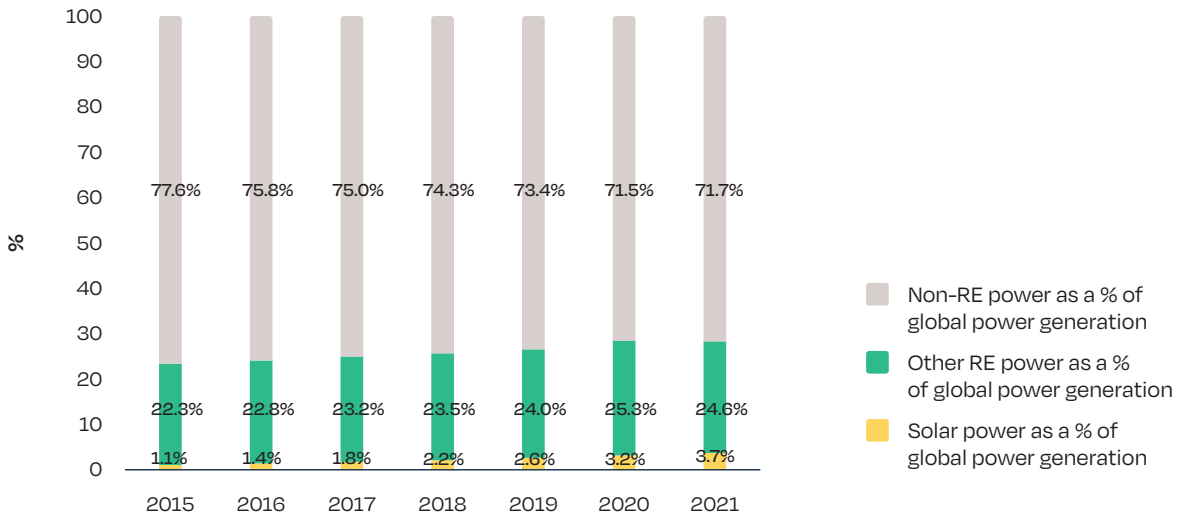


SOURCE: IRENA (2022).

When summing up all new renewable power generation capacity shares, we see a steady upward trend in recent years. Total renewable capacity grew by 11 GW, up 4% from the 291 GW in 2020. If the growth in 2021 seems low, it is because wind power in China had a year of exceptional performance in 2020. Solar's growth path, on the other hand, keeps going in the same direction: up!

However, these positive developments need to be taken into perspective. Solar still meets a minor share of the total electricity demand, generating barely 3.7% of last year's global power production, which is 0.5% absolute higher compared to 3.2% the year before (see Fig. 2). This is also valid for other renewables as a whole, which provided about a quarter — 24.6% to be exact — of the world's total power generation. But unlike solar, growth of other renewables slowed in 2021, from 25.3% in 2020. Total renewable power generation constituted 28.3% of global power output, while non-renewable sources still strongly dominated with 71.7% share. The good news is that the market potential for solar is immense, and its constantly improving cost competitiveness will enable the technology to reach an increasingly larger share and lead the global energy transition.

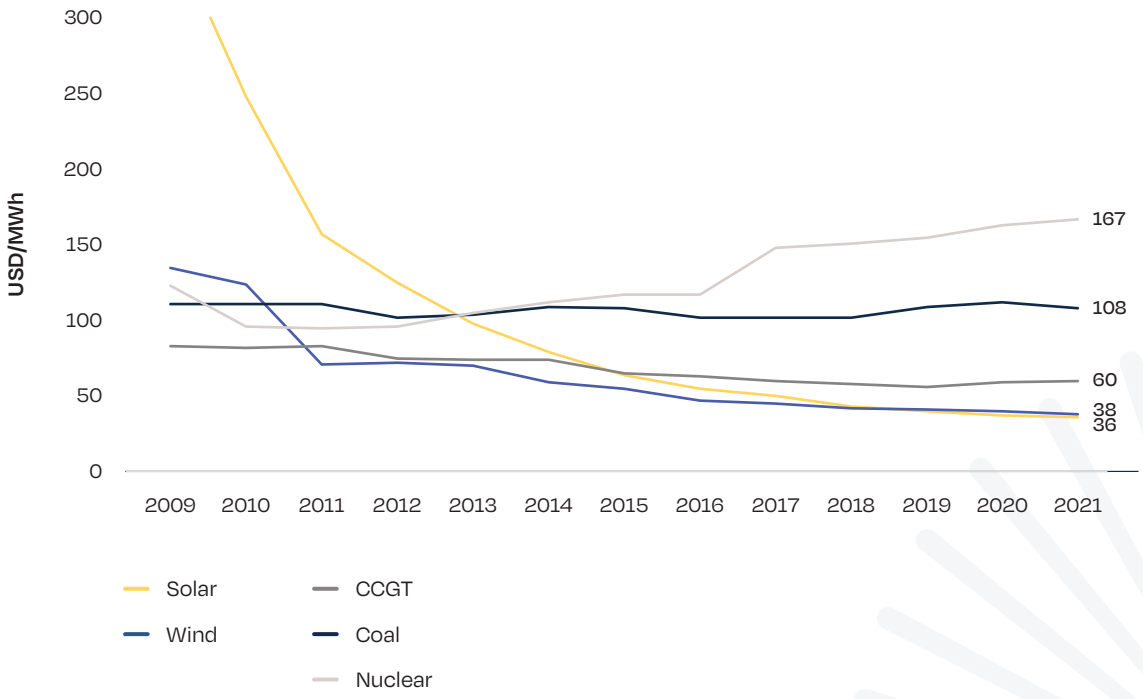
FIGURE 2 SOLAR AND RENEWABLE POWER AS A SHARE OF GLOBAL POWER 2015-2021



SOURCE: Ember (2022).

Solar's success story over other technologies has many reasons, but a key factor is its steep cost reduction curve over the last decade, which has made solar the global cost leader (see Fig. 3). While the cost of solar has been lower than fossil fuel generation and nuclear for several years, it is also now lower than wind in many regions around the world. The latest Levelised Cost of Energy (LCOE) analysis, version 15.0, published in October 2021 by US investment bank Lazard, shows how the downward trip of utility-scale solar cost has progressed by a further 3% compared to the previous year. The spread with conventional generation technologies is widening, considering that the cost of gas and nuclear went up. Solar's cost decrease has truly been extraordinary: compared to 2009, the start of our observed period, solar power generation cost has decreased by 90%.

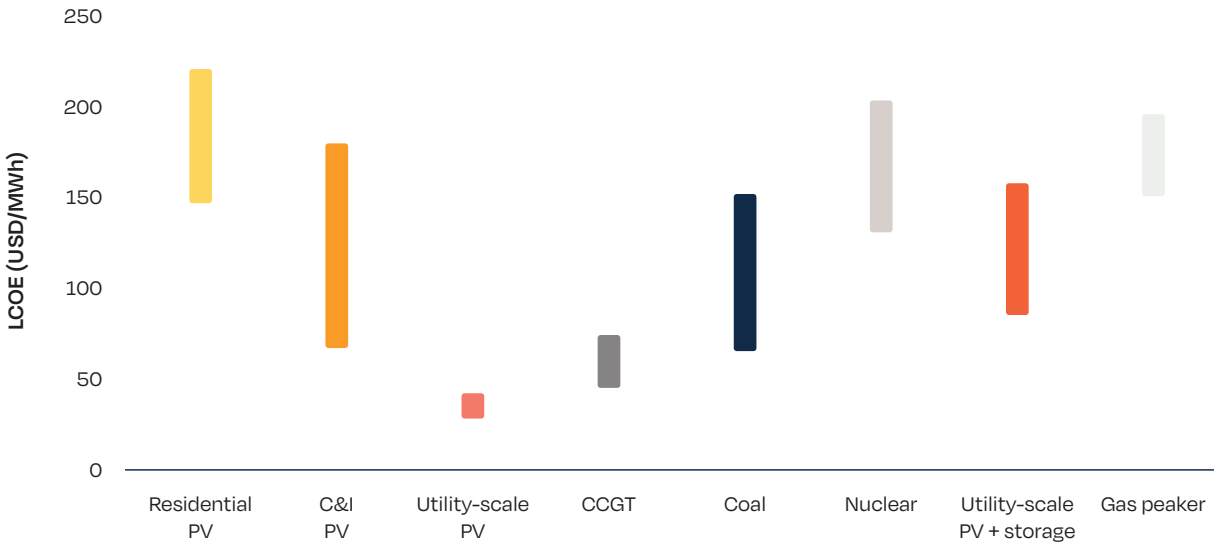
FIGURE 3 SOLAR ELECTRICITY GENERATION COST IN COMPARISON WITH OTHER POWER SOURCES 2009-2021



SOURCE: Lazard (2021). Historical mean unsubsidised LCOE values (nominal terms, post-tax).

The price of utility-scale solar today is consistently cheaper than any range of new conventional power generation sources (Fig. 4). Moreover, the cost-competitiveness of solar + storage versus gas turbines used to meet peak demand is already undisputable in certain regions. More and more countries around the world are setting up hybrid renewable auctions, whereby the co-location of various renewable sources plus battery storage provide a flexible solution to their energy needs.

FIGURE 4 SOLAR ELECTRICITY GENERATION COST IN COMPARISON WITH CONVENTIONAL POWER SOURCES 2021



SOURCE: Lazard (2021). Nominal terms, post-tax.

Tenders

Solar tender results provide a testimony for the growing competitiveness of solar technology around the world. Throughout 2021, again, record-breaking bids were announced in several countries, with awarded solar energy prices hitting new lows (see Fig. 5). If 2020 was the year when solar bids surpassed the 1.5 USD cents per kWh threshold and got close to 1.3 USD cents, in 2021 this record was also broken, twice.

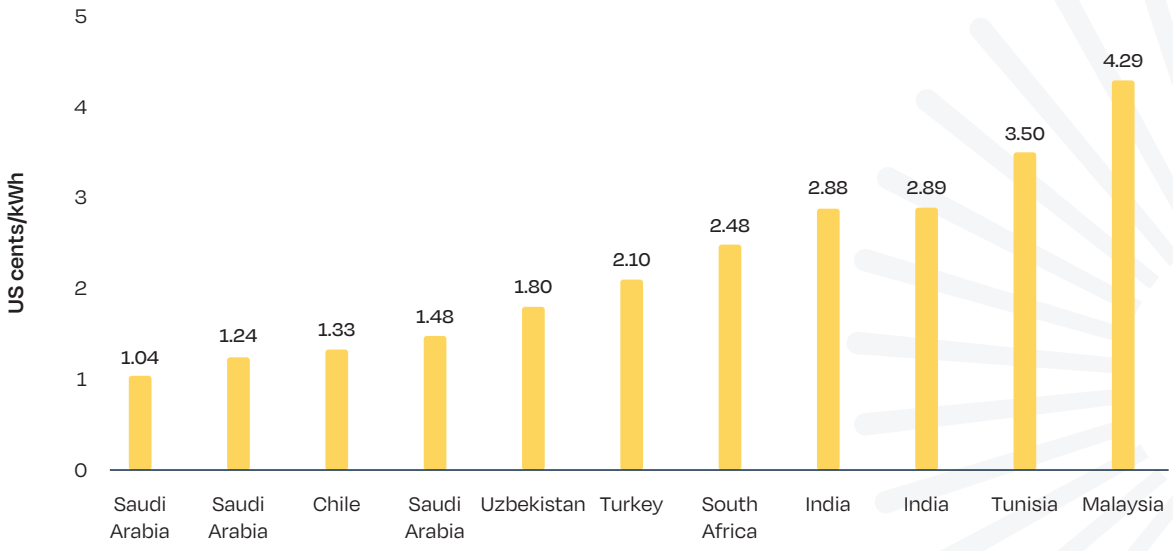
Both new world record solar tariffs were awarded in April in Saudi Arabian tenders — the first for the 600 MW Al Shuaiba PV IP project with the new world record of 1.04 USD cents per kWh, the second at 1.24 USD cents per kWh for the 1.5 GW Sudair solar complex. The new lowest bid in 2021 was 0.28 USD cents lower than the previous record holder, the 1.32 USD cents bid from Portugal's second solar auction.

Outside the Arabian Peninsula — which in addition to the two lowest bids of last year also saw a bid of 1.48 USD cent for the 300 MW Saad solar plant — another historic low tender result was registered in Chile. In an auction for 2.31 TWh of renewable energy, the Latin American country received a bid for 1.33 USD cents per kWh. Projects under this tender will supply electricity under a 15-year Power Purchase Agreement (PPA), beginning operations no later than end of 2025.

Lowest bids below the 2 USD cents level — such as the one of 1.80 USD cents/kWh for the Sherabad solar project in Uzbekistan, part of the ADB-backed 1 GW solar programme — are no longer a surprise. Not unlike last year, low prices can be seen in various geographies all over the world. At the same time, the momentarily higher PV product prices are also increasingly reflected in solar tenders.

The latest development in solar tenders is a first negative bid of minus 4.13 EUR cents per kWh that won a Portuguese Floating Solar tender in April 2022. This 70 MW solar system is part of a hybrid project that includes wind capacity and battery storage, which will overcompensate the negative solar bid.

FIGURE 5 SELECTION OF LOWEST SOLAR AUCTION BIDS AROUND THE WORLD IN 2021



1 Global solar market - Update 2000 - 2021

UPDATE 2000-2021

In 2021, 167.8 GW of solar capacity was grid-connected globally, a 21% growth over the 139.2 GW added the year before (see Fig. 6). In a year characterised by further corona waves paired with recovery programmes, as well as an energy crisis that saw record-high electricity prices in various regions across the globe, many turned to solar as a solution to their energy needs. In our previous edition, we forecasted the global sector to add 163.2 GW in our Medium Scenario, which would have meant a 17% year-on-year market increase, an optimistic view based on the expectation of a strong performance and resilience of solar across the pandemic. The actual number of 167.8 GW comes very close to our prediction, which still turned out to be too conservative but is well encompassed in our 197.9 GW High Scenario forecasted in 2020. China, the world's largest market, continued its upwards trajectory with a 14% year-on-year growth rate, a predictable decrease from the unexpected 60% growth that took place in 2020. Positive solar market dynamics could also be observed in many other countries and most global regions as well — the US, Europe and India in particular, which were hit exceptionally hard by COVID-19 in 2020.

TOP 10 Global Solar Markets

Most of the top 10 solar markets in 2021 remained the same as in 2020, but many positions changed due to different growth dynamics (see Fig. 7).

China kept its market leader position in 2021, adding twice as much solar power capacity than the second-largest market, the United States, and as much as the other top 5 markets combined. After a year of sharp increase in 2019, the Chinese market slowed down with additions of 54.9 GW in 2021 — still a 14% growth rate over the 48.2 GW installed in 2020. Nevertheless, the 2021 results are an all-time high for China, slightly above its previous record of 52.8 GW in 2017. Although affected by electricity shortages in H2/2021 and PV component price increases, total solar installations in China reached the 300 GW landmark in 2021. Distributed solar accounted for 29 GW or 53% of total installations, driven by a stellar performance from the residential segment, which added 21.6 GW. It is the first time that the distributed segment has surpassed the 50% mark.

FIGURE 6 ANNUAL SOLAR PV INSTALLED CAPACITY 2000-2021

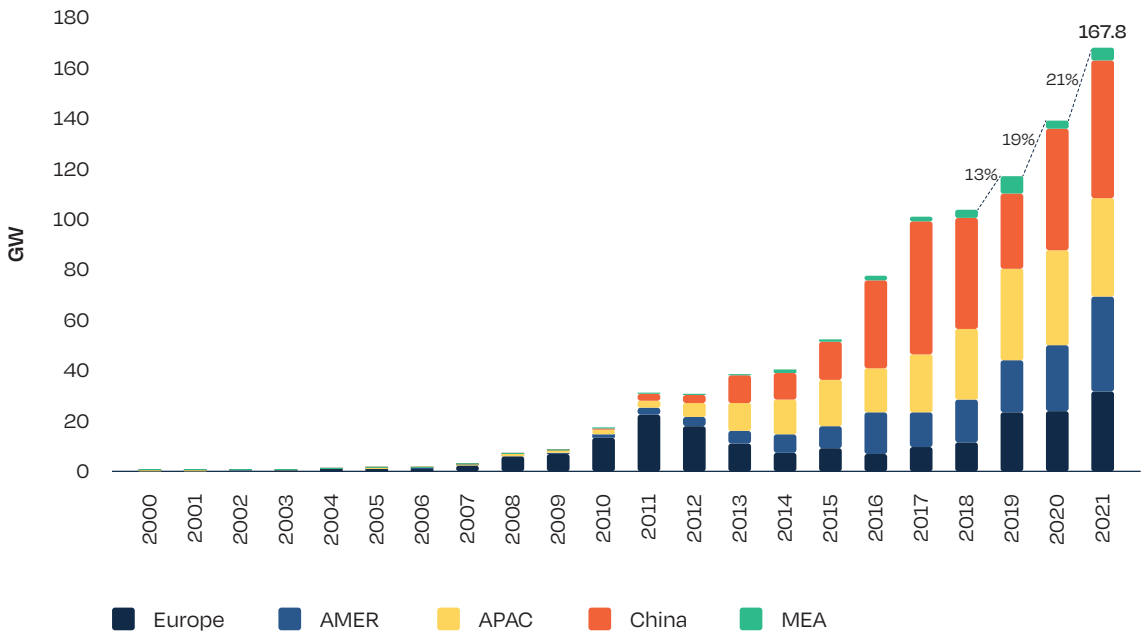
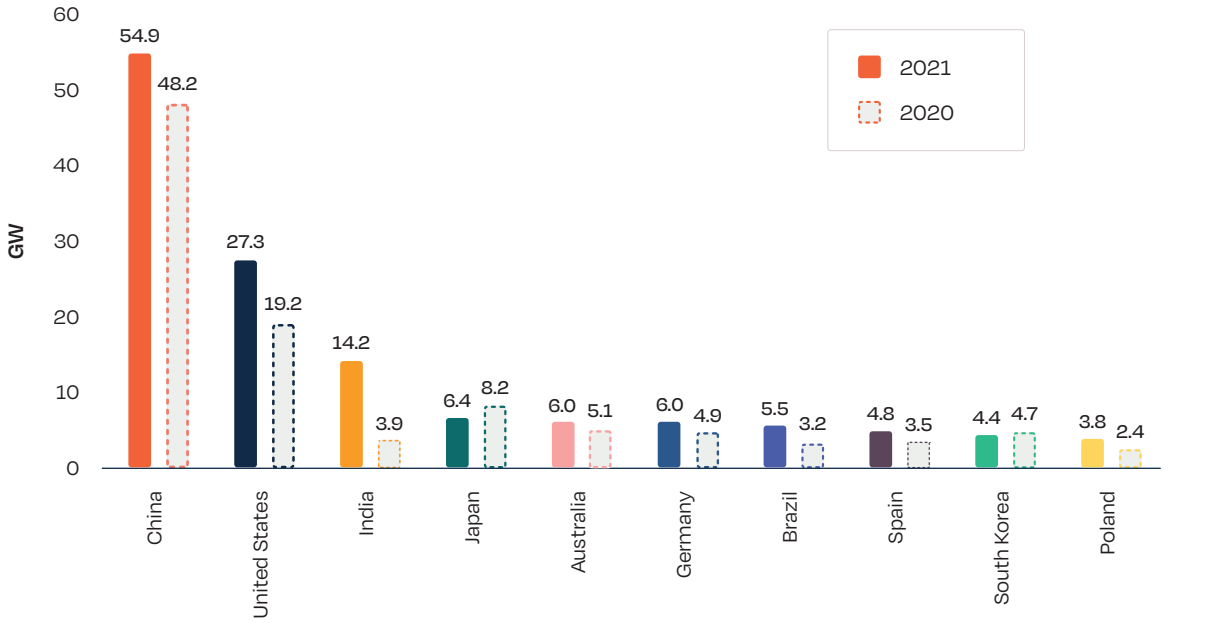


FIGURE 7 TOP 10 SOLAR PV MARKETS, 2020-2021



The **United States** stepped up its solar ambitions in 2021 with a 42% growth rate and 27.3 GW of new installed capacity. The country repeated the remarkable growth performance seen in 2020, when the market grew 43% year-on-year. As in the previous years, the bulk of installations comes from the utility-scale segment — a record 19.7 GW, or 72% of total installations. The strong development of the segment in Texas allowed the southern state to unseat California as the state with the highest annual installation for the first time. When it comes to rooftops, the residential segment installed 4.9 GW, up 51% from last year and driven by the decreasing federal solar investment tax credit (ITC), which had dropped from 30% in 2019 to 26% in 2020, and is scheduled to drop further to 22% for systems installed in 2023. The residential sector's performance constitutes a record for the country, which installed more than half a million systems in a single year.

After a very disappointing year in 2020, **India** rolled up its sleeves and installed 14.2 GW to reclaim the third position it held back in 2019. The demand for solar was constantly declining from the record-year 2017 to 2020, plummeting from 11.5 GW to a mere 3.9 GW, but the 265% year-on-year growth rate experienced in 2021 allowed the country to surpass its previous record by a large margin. This growth is expected to continue to achieve the 500 GW target of non-fossil fuel electricity capacity by 2030, and the pledge to achieve net-zero carbon emission by 2070. Nonetheless, the country is still battling with its challenges; there continues to be the nagging issue of electricity distribution companies' (DISCOMs) unwillingness to sign power sale agreements and several PPAs are being continuously renegotiated. Another big challenge remains the rooftop market, which should contribute 40 GW to India's 100 GW solar goal by end of 2022 but only accounted for 6.5 GW at the end of 2021.

Japan held on to its #4 position despite a year that saw installations decrease to 6.4 GW, down 21% from the 8.2 GW connected in 2020. The country is now back on the downward path it experienced during the three years following a record of 10.8 GW installed in 2015. Most of the installed capacity in 2021 actually comes from FiT projects that were approved a couple of years ago. However, as the feed-in tariff era has come to an end, some of the new incentive tools are slowly getting traction. It is expected that the market will

continue to shrink for a couple of years before a new uptake occurs, driven by different government actions, such as a target to equip 60% of new houses with solar and the reforms to facilitate land utilisation for PV projects. The latest auction in March 2022 was the last to be awarded with a fixed tariff, as future auctions will award feed-in premium tariffs. Amid a growing interest from corporates in renewable PPAs, self-consumption business models are also becoming more attractive, with solar power reaching competitive levels with volatile electricity prices in the C&I segment.

Australia's 2021 solar market performance continued its upward trend line that started in 2014. An 18% annual gain of 0.9 GW led to a total of 6 GW of newly deployed capacity — a new installation record for the country with the world's highest solar power installed per capita. Slowly but surely, the country is fortifying its 5th rank among global solar markets. As last year, difficult business conditions, partly caused by COVID-19, limited the growth in the industrial and utility-scale segments, but very strong interest in residential rooftop systems brought the market to a new high. Homeowners opting for solar still profited from the national Renewable Energy Target (RET) programme's Small-scale Renewable Energy Scheme, but the drivers have already started to change — with consumers increasingly striving for high self-consumption rates. While the RET Large-scale Generation Certificates Scheme (LGC) ended in 2020, utility-scale solar suffered from regulatory uncertainty and grid connection issues. In the absence of a renewable vision from the federal government, Australia's states have increasingly taken over, introducing several support policies to speed up the country's energy transition with the creation of Renewable Energy Zones (REZ) in New South Wales, Queensland and Victoria. With an initial plan to allocate 3 GW of renewable energy in the New South Wales Central West zone, the registration process collected 27 GW bids for renewable projects, a sign of the interest of the market.

Germany also kept the same spot in the solar market ranking in 2021, placed at #6. Europe's largest solar market grid-connected just below 6 GW in 2021, a 23% growth from 4.9 GW in 2020. With a proven feed-in premium scheme and regular tenders for systems larger than 750 kW, rooftop installations remained the backbone of Germany's solar industry. Rooftop systems are especially appealing in an environment of very high residential electricity retail prices. Self-consumption solar PV systems are becoming increasingly attractive to homeowners, who now mostly combine their solar investment with a battery storage system. A decrease in the feed-in premium scheme for C&I rooftop systems implemented in January 2021 had this main pillar of Germany's solar sector grow only little last year. On the other hand, an increase in the tender volume in 2019 led to more ground-mount capacity, which was also supported by a growth among PPA systems. A newly elected government that came to power in December 2021 has identified solar as a major pillar for renewables to reach 80% of the total power generation by 2030, and 100% by 2035. In the near future, the total amount of ground-mounted projects will sharply rise thanks to the 6 GW tender already planned in 2022, bringing the country closer to achieve its new 215 GW target by 2030.

With a first entry in the top 10 in 2020, **Brazil** rapidly gained positions to secure rank 7 in 2021, but remains the only Latin American country in that group. The 5.5 GW installed in 2021 translates into a 74% growth over its previous 3.2 GW record in 2020. The 2020 and 2021 numbers would have been likely even higher if the pandemic had not struck the country so bad. Around 4 GW, the bulk of last year's installations, stems from distributed solar systems up to 5 MW that can access the national net-metering scheme. The other leg of the solar sector in Brazil in 2021 were the 1.5 GW of centralised systems from energy auctions for large-scale power plants, and some PPA based systems.

Spain gained one place to rank 8 with a newly installed capacity of 4.8 GW, up 37% from around 3.5 GW last year. The main pillar behind Spain's development remains the strong PPA market, which installed 3.4 GW in 2021 without any kind of subsidies. This trend is expected to continue as the country has a 100 GW+ pipeline under development. This makes the country probably the world's largest subsidy-free solar market. Spain's self-consumption rooftop market only opened in early 2020 after the abolishment of the Sun Tax, which had kept that segment economically unattractive in the past. But 2021 marked a new era with a 102% year-on-year growth rate, reaching 1.4 GW of new rooftop installations. In addition to the policy improvements, the high electricity prices resulting from the energy crisis strongly incentivise homeowners and businesses to go solar.

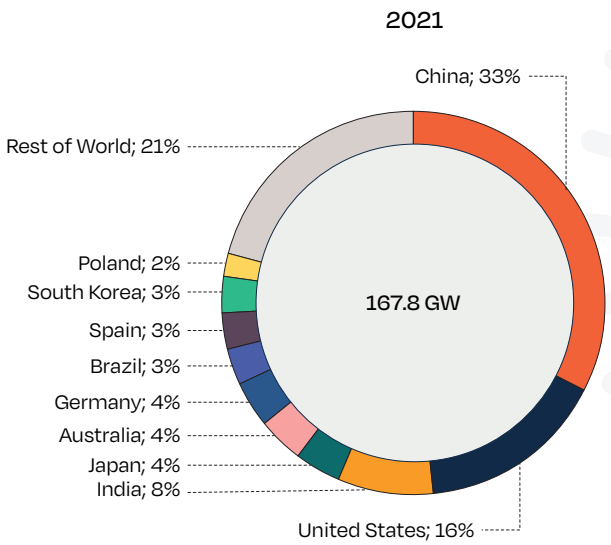
South Korea's solar market slowed down by 6% with new installations totalling 4.4 GW, which still is the country's second-best achievement. The main driver continues to be the Korean Renewable Portfolio Standards scheme, which requires utility companies with generation capacities exceeding 500 MW to supply between 6% and 10% of their electricity from new and renewable power sources by 2023. Over 90% of the PV installations in the country have been under this programme. Given the limitations to utility-scale arising from the country's mountainous terrain, South Korea focuses on the distributed solar segment, but has also been looking at alternative solutions. In 2019, it announced the construction of a 2.1 GW floating solar plant, which would be the world's largest. On top of this project, in March 2021, the Ministry of Environment announced a plan to install an additional 2.1 GW of floating PV by 2030.

A new name in this list, **Poland** rounds out the top 10 with 3.8 GW installed in 2021 and a 56% growth compared to 2020, a positive surprise that most solar analysts had not expected. The driving force for solar in Poland has been the small rooftop segment below 50 kW, which enjoyed a favourable net-metering scheme that was discontinued this year. While the future of the small rooftop market remains somewhat uncertain, the country is now shifting its attention to the large-scale segment. The first results of the auctions launched in recent years to increase renewable deployment in the country are already apparent. Unlike its peer wind, solar does not face significant regulatory barriers and has the capacity to meet the country's energy needs in a short timeframe.

In summary, 2021 was an extraordinary year for solar, even more so when considering the sustained impacts of the pandemic on many countries across the globe. Like in previous years, growth was carried to a large extent by global market leader China (see Fig. 8), but many countries contributed, looking ever more towards solar as a key tool to fight Climate Change.

Last year, 17 countries installed over 1 GW, compared to 17 in 2020 and 16 in 2019. Ukraine is the only country which was not able to maintain its GW-scale installations level in 2021, while Chile joined the club in 2021. Details on these 17 markets can be found in Chapter 3, where national and regional industry associations active in the solar sector provide their analysis on their home markets (see p. 60).

FIGURE 8 TOP 10 COUNTRIES SOLAR SHARE 2021



Regional Update

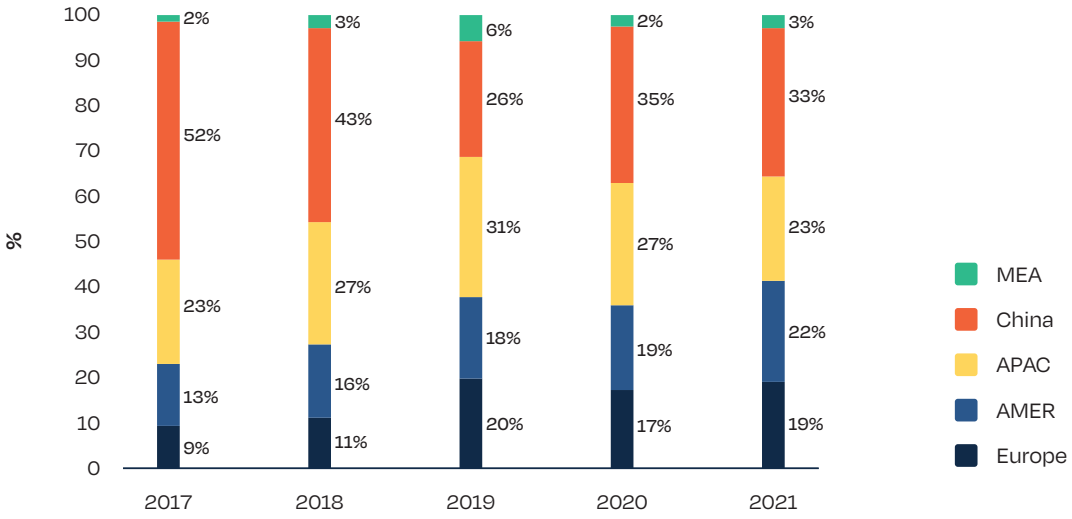
The record solar years in both China and India were not high enough to keep the Asia-Pacific region on a growth course; the region lost 6 percentage points to its global share of 56% (see Fig. 9). Nonetheless, through the addition of 94 GW, up from 85.8 GW in 2020, Asia-Pacific remains the world's largest regional solar market (note that due to its large size, China is listed separately from the Asia-Pacific region). If last year the overall limited growth was attributable to India's lacklustre performance, the loss of APAC's market share in 2021 is mainly due to the collapse of the Vietnamese market, which lost 10 GW year-on-year, and to the stronger growth of other regions across the world. Still, Asia-Pacific outperformed any other region — it was home to 5 of the top 10 solar markets and 7 countries that added GW-scale capacities.

A look at Asia-Pacific ex-China shows that the region's solar market share dropped by 4 percentage points to 23% despite adding slightly more capacity than the year before — 39.1 GW, compared to 37.5 GW in 2020. The losses were substantial enough that all non-Chinese Asia-Pacific countries put together achieved a lower global share than China alone, which also dropped to 33%, still the highest solar share in the world thanks to the all-time record of 54.9 GW installed in 2021.

Again, the US plays an even more important role in the Americas than China in Asia. The world's 2nd largest market was responsible for 73% of 2021 additions on the American Continent, 1 percentage point down from the 74% share in 2020. In 2021, both the US and Brazil once again carried most of the Continent's growth on their shoulders, while its third largest solar market, Mexico, continued its downward slide, suffering from fossil-fuel focused government policies. Newly installed solar capacity in the Americas increased by 43% to 37.3 GW over the 26.1 GW deployed the year before. As the Americas' growth rate beat the global average, the region's global market share improved again, this time by 3 percentage points to 22%.

On the other side of the Atlantic, Europe's positive solar trajectory went on in 2021; its total installed capacity grew by 7.9 GW or 33 percentage points to reach 31.8 GW last year, which translates into a global share of 19%, up from 17% in 2020. This outcome is almost to the point of our Medium Scenario of the previous GMO, when we assumed that the continent would add 31.9 GW, only 0.1 GW higher than the actual result. Almost 90% of the European markets added

FIGURE 9 ANNUAL SOLAR PV INSTALLED CAPACITY SHARES 2017-2021



more solar than the year before. Next to Europe's market leader Germany, most other GW-scale markets, Spain (4.8 GW), Poland (3.8 GW), the Netherlands (3.6 GW) and France (2.7 GW) also performed better than the year before.

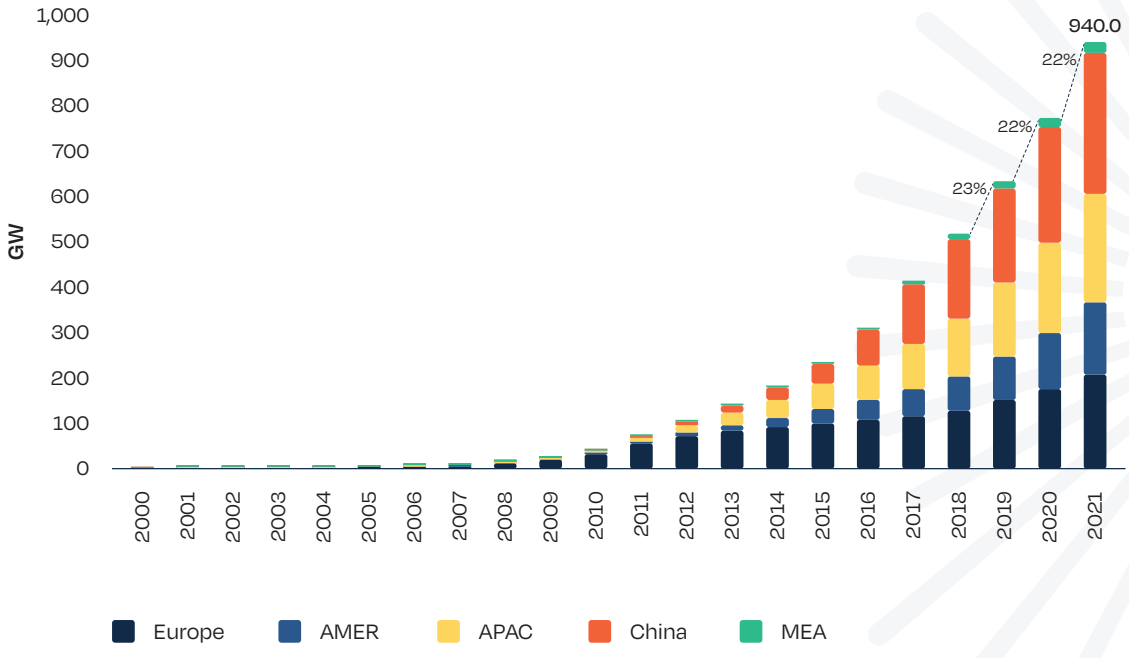
The Middle East and Africa (MEA) region added 4.7 GW of new solar power capacity in 2021, a 36% increase from last year, and is climbing back its way toward the 6.8 GW record from 2019, when multiple GW-size projects were commissioned. While several new very large projects are being developed in the UAE and other countries on the Arabian Peninsula, nothing major was grid-connected in 2021. The Middle East's largest solar market was Israel with an 85% increase in newly installed capacities to 935 MW in 2021. The sharp increase is mostly explained by the rather poor year the country had in 2020 with 505 MW of newly installed capacity. Across the African Continent, South Africa was again the largest market and installed 930 MW in 2021, slightly missing the GW-scale that it reached in 2020, but we expect it to reach this level again in 2022. However, no MEA solar market surpassed the GW threshold in 2021.

Total Solar Installations until 2021

The world's cumulative installed solar PV capacity grew by 22% to 940.0 GW by the end of 2021, up from 772.2 GW in 2020 (see Fig. 10). Total solar power has increased more than 500 times since the start of the millennium, when the grid-connected solar era basically began with the launch of Germany's feed-in tariff law. Comparing solar capacity in 2021 with the operating fleet at the beginning of the last decade, the global on-grid PV capacity has increased by an impressive 2,173% — from 41.3 GW in 2010.

Over
940 GW
solar capacity installed by end of 2021

FIGURE 10 TOTAL SOLAR PV INSTALLED CAPACITY 2000-2021



Sustained growth in Asia's top markets China and India maintained the standing of solar in the Asia-Pacific region. The region clearly kept its strong leadership in 2021, representing 58% of the global solar power generation capacities, but decreased its global share slightly by 1 percentage point compared to the year before (see Fig. 11). Newly installed capacities of 94 GW in 2021 led to a total of 547.7 GW, making Asia-Pacific the first solar region to have crossed the 0.5 TW level. The growth of the majority of European solar markets couldn't prevent a 0.7% market share decrease, down to 21.8%, the lowest value in the last decade. But the addition of 31.8 GW was enough to defend its second position based on a cumulative PV capacity of 205.4 GW. Like in previous years, in 2021, the Americas were ranked the third largest solar region in the world; total installed PV capacities of 161.8 GW translated in a 17.2% stake, 1.1 percentage points higher than in 2020. While demand saw a significant uptick in the Middle East and Africa region, this had no impact on its solar positioning last year. With a cumulative solar capacity of 25.1 GW, its world market share grew marginally from 2.6% to 2.7% in 2021.

A comparison of individual countries shows that China's new installation record, equal to a 14% market growth in 2021, had little positive effect on its outstanding solar dominance. At 308.3 GW, its operational solar power capacity remained exactly at 32.8% of the total market share — and again, that's close to one-third of global power generation capacity (see Fig. 12). The volume of globally deployed solar PV systems is too large to be strongly impacted by one country during the course of a single year, even if it is as dominant as China. There were no changes in the top 5 markets either. China was again trailed by the United States, Japan, Germany and India. The US increased its market share to 13.1% to 122.9 GW, making it, like the year before, the only other country with a double-digit share in global solar power generation capacities. Japan and Germany respectively lost 0.9% and 0.6%, while India gained 0.5%. Japan's 77.6 GW resulted in a share of 8.3%, while Germany holds a share of 6.45% and a fleet of 60.6 GW, just 500 MW over India, which stands at 60.1 GW and a 6.39% market share.

FIGURE 11 TOTAL SOLAR PV INSTALLED CAPACITY SHARES 2017-2021

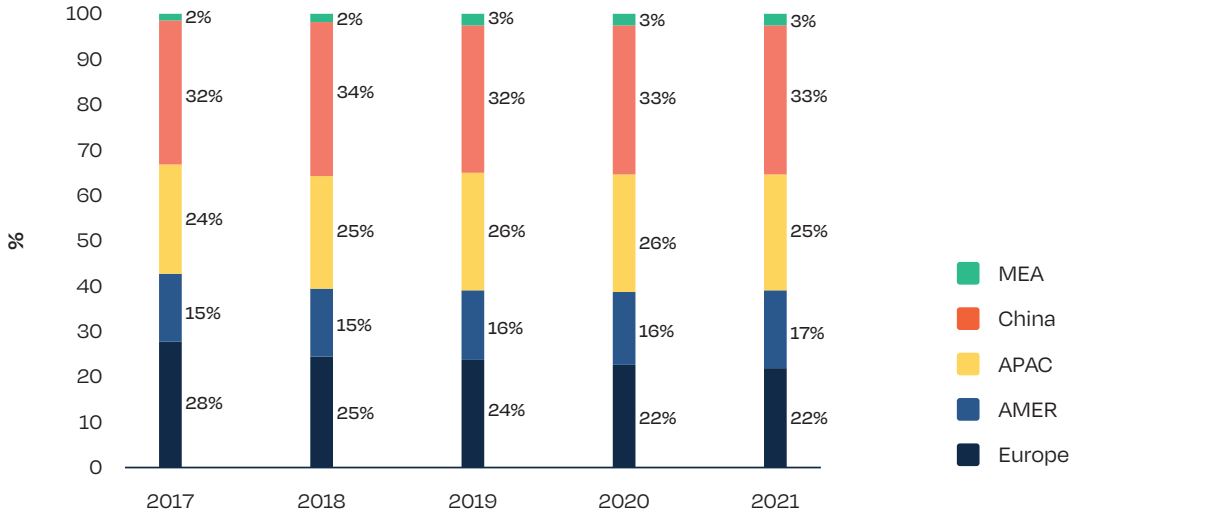
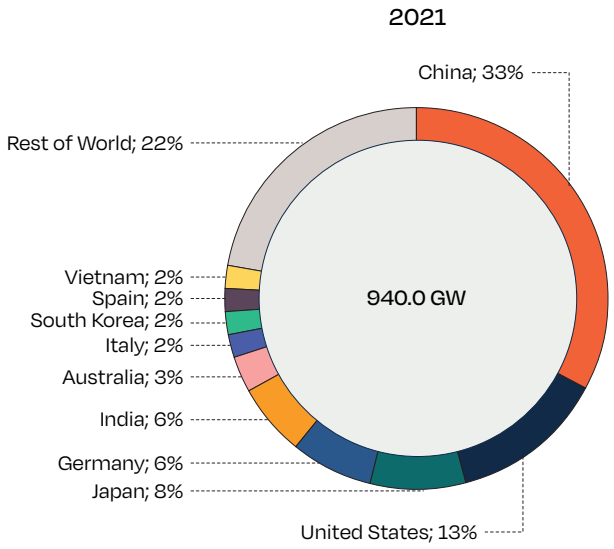


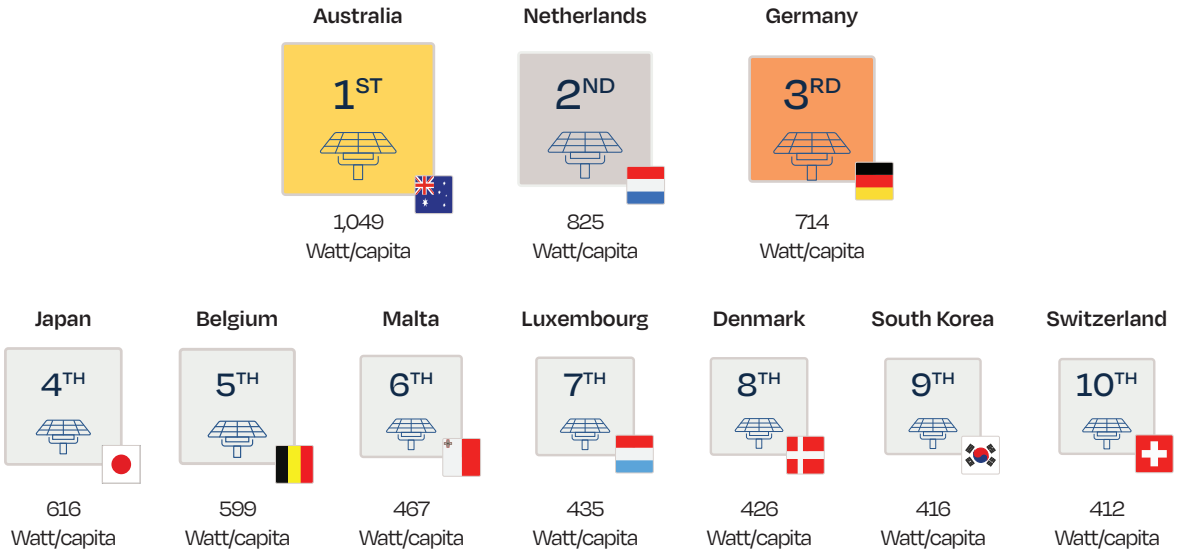
FIGURE 12 TOP 10 SOLAR PV MARKETS TOTAL INSTALLED SHARES 2021



The top 5 solar markets have been in a league of their own for quite a while, and it doesn't look like this is changing anytime soon. Australia, ranked sixth, has less than half of India's solar power capacity. The bottom half of the top 10 also saw a few notable changes: Italy, at 22.1 GW, was passed by Australia with 27 GW and is now closely followed by South Korea at 21.3 GW, which climbed its way to #8 from #9 last year; Spain at 18.9 GW took over the position from 2020's shooting star Vietnam, propelling itself to the 9th rank, while the South-East Asian country closes the top 10 with 18.6 GW.

A completely different picture of global solar is displayed, when examining the installed PV capacity from a per-capita perspective. Despite its strong dominance, none of the global top 3 markets — China, USA and India — figures on the W/capita top 10 list (see Fig. 13). While three of the four countries with the highest installed system capacities per inhabitant — Australia, Germany and Japan — also belong to the 10 world's biggest solar markets, several others do not, including the new No. 2, the Netherlands, which surpassed Germany to take the second place and become the leading European country in Watt per capita, as forecasted last year. The old and new per capita solar leader will again be Australia, with an impressive installation level of over 1 kW per inhabitant. Looking at the broader picture, there are 119 W/capita installed across the whole world.

FIGURE 13 TOP 10 COUNTRIES SOLAR CAPACITY PER CAPITA 2021



PROSPECTS 2022 - 2026

Forecast 2022

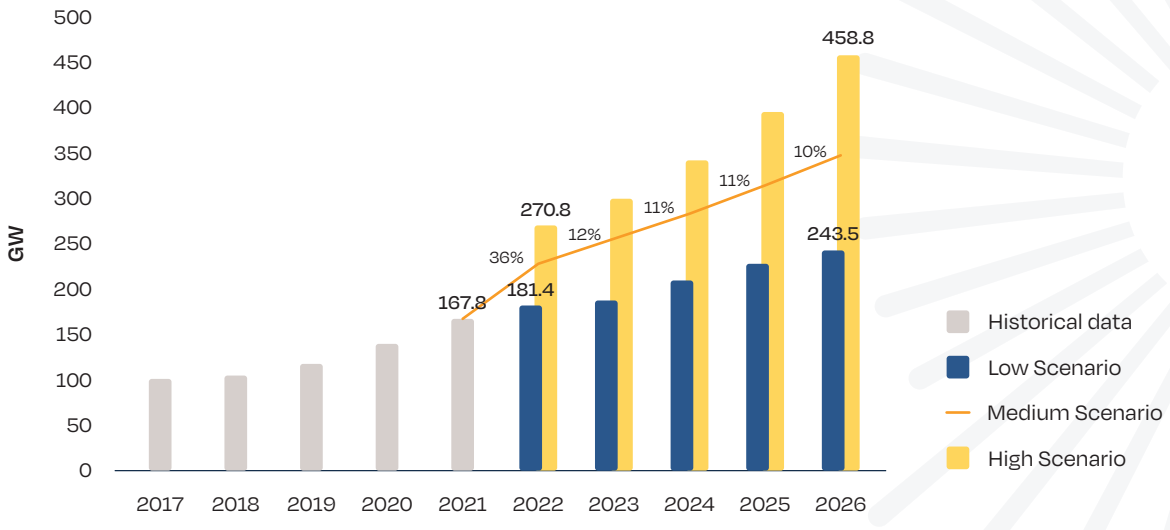
In early 2021, many had hoped that the high price environment in the solar sector would be alleviated in 2022. But as time has progressed, it has become clearer that the return to the low 2020 prices is a moving target that has been pushed back several times. Today, prices for silicon, wafer, cell and modules are considerably higher than at the beginning of 2021, and most solar analysts don't expect any price relief until the end of the year. The world is in an inflationary phase; the negative impacts of the pandemic not overcome, as the April-imposed China lockdowns show, and the Russian war against Ukraine – all factors coming together to put pressure on a global economic motor that only recently had switched on its rapid acceleration mode.

Despite all these challenges, solar is expected to see impressive growth in 2022. Our Medium Scenario anticipates newly installed capacities to reach 228.5 GW, a 36% growth rate over the 167.8 GW installed in 2020 (see Fig. 14). Like last year, our estimate is a bit more on the conservative side compared to leading solar analysts. In its March-published solar market updates for the first quarter, IHS Markit upped its forecast for 2022 to 232 GW, from 221 GW, following BloombergNEF increasing its prediction to 245 GW from 228 GW in November 2021.

Our market sensitive analysis for 2022 shows a large spread. The Low Scenario estimates a demand drop to 181.4 GW, which is extremely unlikely when looking at the strong demand for solar in recent months. However, if the local Shanghai lockdown expands to other major cities, the pandemic returns to Europe and the Americas maybe even with a very aggressive mutation later this year, or the Russian war against Ukraine spreads to other countries, this could have severe negative implications on market growth in 2022. But it's much more likely that the pendulum swings somewhat in the other direction towards our High Scenario, which forecasts up to 270.8 GW of solar additions in 2022. This assumption sounds very optimistic but when looking at BloombergNEF's mid estimate of 245 GW, our maximum is actually not so far away.

Modelled bottom-up, if our High Scenario materialised, it would mean that nearly all silicon production capacities had to be utilised. As in previous years, the biggest wildcard is China, which is the only single country with a lever to move the solar balance significantly in either direction even at a large market of today's size.

FIGURE 14 WORLD ANNUAL SOLAR PV MARKET SCENARIOS 2022 - 2026



Regional market developments 2022

With **China's** solar market dominance being as big as it has been in recent years, it's rather difficult to estimate market growth accurately. That was the case in the past, when uncapped feed-in tariffs facilitated unexpected growth records up to 53 GW in 2017, and has been getting only more complicated as the country is transitioning away from traditional incentive schemes to auctions and non-subsidised systems. After the reform was started, demand dropped to 44 GW in 2018, even further to 30 GW in 2019 and bounced back to a near record level of 48 GW in 2020, and a new record of 54.9 GW in 2021. However, 2022 is set to bring solar demand in China to a new level, which is the consensus among analysts, even though the mid scenario forecasts somewhat differ — from 80 GW (IHS) to 82.5 GW (China PV Industry Association, CPIA), 80-90 GW (AECEA) and 101 GW (BloombergNEF).

While we chose to be conservative in our previous GMO (estimating 55.9 GW, which turned out to be close to the official number), this time our Medium Scenario for China leans more to the optimistic side, at 87.2 GW. In the first 2 months of this year, China has grid connected a record PV capacity of 10.9 GW (AC), with most of the systems being rooftop installations. The solar rooftop boom in China is the main driver for PV in the world's largest market these days — not just in the residential but also in the C&I segment, where rising power prices are a major incentive to go solar. China has also announced a new programme for desert regions with plans to install 200 GW wind/solar before 2025, and a notable volume already scheduled to come online this year. One factor that might negatively influence solar installations this year is the pandemic; if China sticks to its Zero-COVID strategy and implements lockdowns in other cities of the country like it did in Shanghai, it would impact installations negatively. However, if China's solar market grows 59% YoY in 2022 as anticipated in our Medium Scenario, its global market share will increase sharply by 5.3 percentage points to 38.2%, still away from its previous record of 52.3% in 2018.

After **India's** solar sector surprised positively in 2021, augmenting deployment by 265% to 14.2 GW over the COVID-19 induced 2020 meltdown to 3.9 GW, we foresee further strong growth this year. The Indian government has been trying literally everything to meet the 100 GW target of its Solar Mission Programme scheduled to close by end of 2022, in particular pushing installations from its large-scale PV power plant tenders. Although India will miss this goal, mainly due to the solar rooftop segment's underperformance, according to our Medium Scenario the country will exceed the 20 GW level in 2022 for the first time. Following the rebound in 2021 to over 14 GW installed, we anticipate solar additions of 20.3 GW in 2022. However, with India being traditionally very sensitive to PV product prices, there is a chance of several projects getting delayed, now that the country's basic customs duty of 25% on solar cells and 40% on modules has finally been introduced on April 1, after being delayed for a year. The Low Scenario assumes new installations to total 13.6 GW for the year.

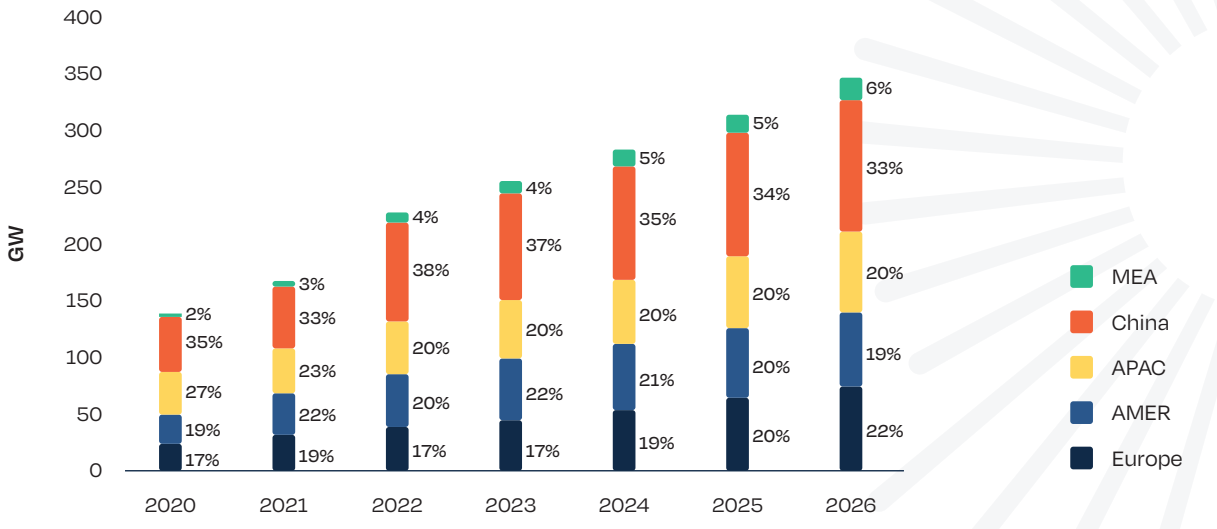
Most other Asia-Pacific GW markets are also expected to see positive developments in 2022 — 4% to 6.2 GW in Australia, 5% to 4.6 GW in South Korea, and 33% to 2.5 GW in Taiwan. The only two of the region's GW markets to see demand drop significantly are Vietnam and Japan. Tailing off the solar heydays of 2020, fuelled by the very generous FiT 2 programme that ended that year, Vietnam experienced only 2 GW of new capacity additions in 2021 or roughly only a sixth of nearly 12 GW installed in 2020. We estimate solar activities to drop further in the future. There are no more incentives; all new solar installations have to rely on self-consumption. The industry's hopes still rest on the pilot PPA programme and the long overdue implementation of the FiT3 draft. However, the National Load Dispatch Centre (NLDC) announced that it will not approve any new solar or wind capacity in 2022 because of grid constraints. As a result, our Medium Scenario forecasts a 72% contraction to a meagre 551 MW of new installations in Vietnam in 2022. The Japanese solar market's decline won't be as severe, but the country is believed to see a 9% reduction to 5.8 GW, the lowest level in 9 years as it continues its energy transition. After auctions with 20-year fixed tariffs were introduced in 2017, 2022 marks another step away from its once overly generous feed-in tariff. As of April, Japan has introduced a new market-based feed-in premium mandatory for projects above 1 MW participating in its auctions, which means that an extra-remuneration (the premium) is added to the wholesale electricity price. By doing so, the total remuneration remains linked to the current electricity price. At the same time, FIT levels for smaller systems were reduced, while administrational burdens were eased.

However, our Medium Scenario forecast clearly shows that the Asia-Pacific Rim together will continue to strongly dominate global demand with a combined share of 58.4% in 2022. But when adding up 2022 installation estimates only for the region's countries other than China, they will not only again lose 3.1% on top of the 3.7% they already lost in 2020, the Americas might own a slightly larger piece of the solar cake than Asia-Pacific ex-China for the first time, reaching 20.3%. This shows that Asia-Pacific as a group is simply growing too slowly these days compared to its peers America and Europe.

Although the Americas are expected to lose 2% global market share, they will remain the world's second largest region for solar installations in 2022 at 20.3%. The major driver for solar in the Americas is the US with an expected share of 66% in 2022, down 7 percentage points from 73% in 2021. A forecast for 2022 in the US is difficult these days. Despite the Biden Administration's positive attitude towards clean energy, a huge pipeline of utility-scale systems across the country and a rapidly growing rooftop segment, a few policy developments have been creating a high level of uncertainty in recent months. A so-called Withhold Release Order (WRO), which enables US Customs and Border Protection to detain solar module imports using silicon from Xinjiang based producers that are allegedly using forced labour, has led to detainments of several MWs of solar modules. And an investigation carried out by the US Department of Commerce (DOC) looking into imposing anti-circumvention tariffs on crystalline silicon PV modules and cells coming from Cambodia, Malaysia, Thailand and Vietnam could lead to tariffs as high as 250% on solar products coming from these Southeast Asian countries. But with solar's main incentive tool, an investment tax credit (ITC) designed to decrease every year and reach a bottom in 2023/2024, there is gigantic appetite to invest in solar in the US. That's why our Medium Scenario anticipates 13% growth to 30.8 GW this year, while acknowledging that there is a high likelihood that anti-circumvention tariffs will be implemented, which is reflected in our 24 GW Low Scenario.

For the other major American market, Brazil, there seems to be only upside potential this year. Backed by an established and fairly regular power tender scheme, an extraordinarily attractive net metering programme up to 5 MW, and a quickly growing subsidy-free corporate solar market, Brazil is expected to boost newly installed solar capacity by 62% to 8.9 GW. Like last year, the third American GW-level solar market, Mexico, continues to face a difficult political environment for renewable deployment and will see installations decrease by 35% to 965 MW in 2022.

FIGURE 15 EVOLUTION OF GLOBAL ANNUAL SOLAR PV MARKET SHARES UNTIL 2026



Despite Europe's significant growth projected for 2022, the continent, like other regions around the world, will lose 1.4% of the market share to end up at 17.1% on the back of China's strength. The 7.3 GW additions in grid-connected capacity to 39.1 GW expected for 2022 remain lower than the 7.9 GW added in 2021. Continued solar growth can be seen across Europe with the main driver being again the EU, which has been working on various sophisticated legislative toolsets of its Green Deal toward carbon neutrality by 2050 with intermediate goals for its member states in 2030. The invasion of Ukraine by Russia has pushed many European countries to realise the advantages of low cost and versatile solar power, which in combination with heat pumps can be also used to electrify heat supply and provide local and individual power and heat security. Gaining independence from Russian gas supply has been the major policy theme in the EU in recent months. In its REPowerEU programme, the European Commission presented a plan to reduce Russian gas imports by two thirds by year-end with solar targeted to contribute around 58 GW. This number is not only much above our EU-27 Medium Scenario of 33.6 GW, it is even 18.3 GW higher than our High Scenario of 39.7 GW, which we consider the upper limit for the bloc, taking into consideration issues with module supply, permits and installers.

A close look at the European Union's 27 members shows that 25 of them, including all the largest markets, are expected to install more solar than the year before. We are most upbeat on the EU's largest market in 2022, Germany, which has already deployed 1.5 GW in the first quarter and 731 MW in March alone. For the full year, we assume Germany to add 7.4 GW, close to its 7.6 GW installation record in 2012 during Europe's first solar boom phase. This is only the start; there's much more to come. The legislation for the country's ambitious energy transition programme, including a target of 215 GW of installed solar capacity by 2030, which the new government coalition presented recently, is scheduled to go into effect end of June. In addition to Germany, the European Continent will likely have 7 other GW-markets, again more than any other global region this year. That's three more than in 2021 and all of these GW-markets are expected to deploy more solar power in 2022 than the year before. Established European solar market leaders, Spain, the Netherlands and Poland, will likely each add over 3.5 GW, while France is anticipated to touch the 3 GW level, Greece returning to the GW level in a long while but with a new record, and Denmark joining the group for the very first time. Turkey, the only non-EU member, will comfort its position in the Europe group with 2 GW. After the revision of its regional support schemes, Belgium saw a strong decrease in 2021, and dropped out of the GW group. Though it is expected to get back on its feet and see its annual installations increase, it is expected to remain below the GW mark.

While the growth in installations in 2021 did not result in a market share gain for Middle East and Africa, this will be different this year. Additions of 9.4 GW mean a 99% growth rate, and surpassing the record levels deployed in 2019. Our Medium Scenario foresees the region growing by 1.3 percentage points, reaching a global market share of 4.1% on the back of UAE and South Africa turning into GW markets again. While UAE is targeting its 2 GW Al Dhafra project to come online this year, South Africa is experiencing various solar activities, from government tenders to corporate sourcing. News about solar activities can be heard from many countries in the region, increasingly understanding the cost advantages of solar power.

Global Solar Market Developments 2023 to 2026

The mid-term global economic outlook is hard to predict and will depend a lot on the development of the war in Ukraine. The IMF forecasted in its April-released World Economic Outlook 'War Sets Back the Global Recovery' that global growth will slow from 6.1% in 2021 to 3.6% in 2022 and 2023, and further decrease beyond. Still, the world will see very strong demand for solar for the four years starting from 2023 to 2026, as this clean technology not only offers a price hedge, but also energy security on the national and individual levels. We have considerably increased our forecasts for each of these years. But unlike in the 2021 GMO edition when we emphasised that 2022 market growth would stand out as a recovery year from the pandemic, the coming four years are expected to see a more homogenous growth distribution at a low 2-digit level.

The strong growth on the demand side will be facilitated by massive new production capacity expansions across the solar value chain coming online, including silicon. Every serious PV manufacturer seems to invest in additional capacities, while

newcomers are entering the space, and investors seriously look into it. Beyond the Chinese leaders getting even larger, global trade frictions, increasingly ESG related, are feeding the narrative for local production hubs as the importance of solar as a key technology for more energy independence is increasingly understood by policy makers.

In our Medium Scenario, we expect the global solar market absorbing 255.8 GW in 2023, the first time ever that annual PV deployment will exceed the quarter-TW level. This would take place only five years after the 100 GW annual installation level was reached, and about three years earlier than forecasted in our GMO 2021 (where 266 GW was predicted for 2025). This would also mean a 12% growth rate over the 228.5 GW added in 2022. Our Medium Scenario is a bit less optimistic than BloombergNEF, which currently forecasts 265.5 GW for 2023. It all depends on assumptions on material supply, primarily silicon, and price. While global solar demand is higher than supply today, it is being further fuelled by the Russian invasion of Ukraine. The key question is whether the planned new silicon manufacturing capacities will come online fast enough, as we are seeing massive expansions for wafer, cell and module capacities.

Much of the world's solar demand between 2024-2026, 55%, will come from the top three solar markets: China, the United States and India, the only countries that will each install more than 20 GW in 2023 (China: 94.3 GW, USA: 37.4 GW, India :20.6 GW), and together be responsible for 60% of the market, an even larger share than in 2022 with 152.3 GW combined, according to our Medium Scenario. Three years later, in 2026, the share of these three is projected to reach 184.4 GW, with China being the only country to install more than 100 GW per year (a level it will reach as early as 2024), the US expected to pass the 40 GW level, and India staying slightly below the 30 GW level. Germany will be the only other country that will install more than 20 GW in 2026.

For the majority of our GMO forecast period until 2026, China will continue to execute on its 14th 5-year plan (2021-2025), which has also set reduction targets for CO_2 intensity and energy. The first year of any new 5-year plan is the time the Chinese central and local government bodies work on policies, setting targets for certain topics. While China's Renewable Energy Development plan is yet to be released, several initiatives have been already announced. This includes the provinces and autonomous regions plans, of which around three quarters had set their five-year targets by March, looking at solar installations up to 420 GW (up to 84 GW per year alone), according to China based consultancy AECEA. Plans for rooftop solar from government buildings to local households and the GW Renewable Energy Base Plan show a solar deployment potential of around 100 GW/year until 2025 in China, estimates Chinese solar market research firm Gessey Research Institute (GRI). Based on our analysis of the Chinese solar developments, the Medium Scenario projects the market to grow to 94.3 GW in 2023, reach 100.4 GW in 2024, and further boost demand to 115 GW in 2026.

The United States will continue on its solar growth path in any case for the coming years despite the discussion on import tariffs, which have been a subject of nuisance for local solar developers in the US for quite some time. Also, the expiration of the ITC in 2023 for residential rooftop systems and a decrease to 10% for commercial and utility-scale in 2024 will not be the end of the growth phase for solar in the US. Demand for low-cost clean power is simply too huge. Our Medium Scenario forecasts the market to grow from 37.4 GW in 2023 to 41.2 GW in 2026, but even our worst-case scenario anticipates 29.3 GW by 2026.

As India will have missed its 100 GW (AC) target of the National Solar Mission by end of 2022, its solar stakeholders will be very busy in 2023 and 2024, the deadline to meet its goal. Our Medium Scenario anticipates India to add 20.6 GW in 2023 and 22.9 GW in 2024, adding up to 124 GW. While the utility-scale sector will continue to dominate solar in India, the distributed segment, which was the main reason for missing its goals, is supposed to finally leave its niche status.

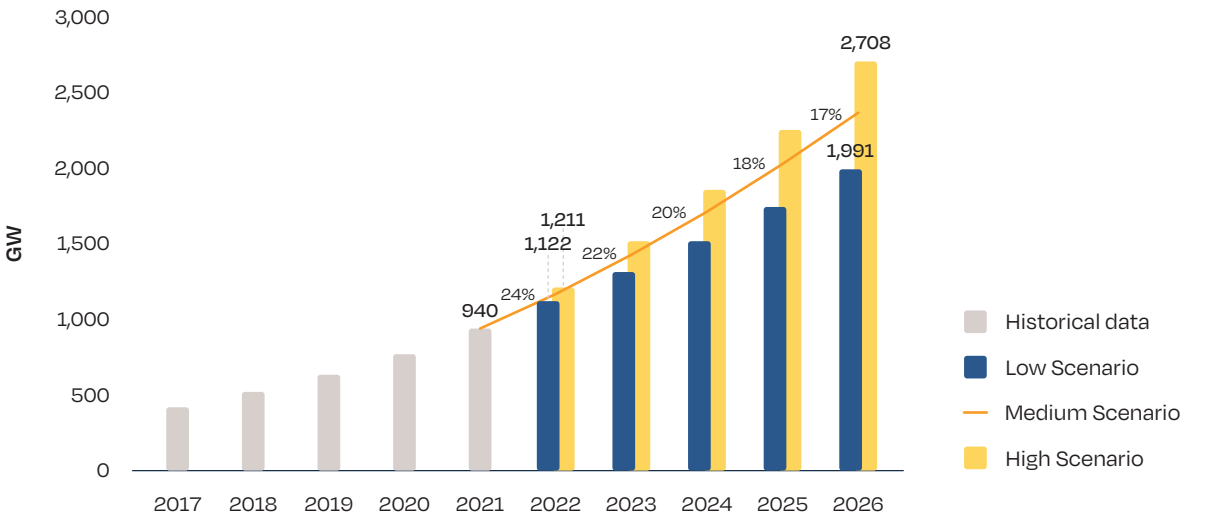
When looking at regional development from 2023 to 2026, China will progressively lose the market share it gained in 2022, basically returning to the 33% annual installation share it owned in 2021. The Americas will be another region to lose shares in this period, decreasing to 18.8% in 2026, from 20.3% in 2022. In the middle of the scale will be APAC excluding China, which will maintain its 20% share from 2022 onwards until 2026, while Europe and MEA will sit on the opposite side. With many of the big projects being built in the Middle East, and Saudi Arabia finally executing on its '40 GW by 2030' target, the MEA region will continue its growth seen in 2022, but on a

path less steep, expected to reach 5.8% in 2026, up from 4.1% in 2022. Europe's growth will continue to rely on the shoulders of the European Union, which is supposed to improve its 2030 renewables targets this year and will bet increasingly on solar to detach itself from Russian energy imports by 2026 the latest, as outlined in its REPowerEU plan. Europe will grow its share to 21.7% by adding 75.2 GW in 2026, up from 17.1% (39.1 GW) in 2022. This will make Europe the world's second largest regional solar market again, after 6 years on rank three.

Less than 10 years after the 100 GW mark was reached in 2012, the total operating on-grid solar power capacity has reached the 1 TW level in early Q2/2022. It will take only a little more than 3.5 years until the world's total grid-connected solar capacity will double to 2 GW by end of 2025, according to our Medium Scenario. Despite today's high prices for raw materials and final PV products, the run on solar continues. Severe concerns about energy security resulting from the Russian invasion of Ukraine will only accelerate the transition to solar in the coming years. In consequence, our Medium Scenario forecasts total installed capacities in 2022 will reach 1,167 GW, which is about 2% higher than in last year's GMO. The final year of our 5-year forecast in the previous GMO ranged between 1,554 and 2,127 GW, with the most likely Medium Scenario resulting in 1,869 GW of total operating solar power in 2025. For GMO 2022, we forecast between 1,747 and 2,248 GW, with 2,021 GW for the Medium Scenario in 2025 — about 8% higher. For the final year of this outlook, 2026, this year's GMO anticipates in our most-likely Medium Scenario that the global solar power fleet will reach 2,368 GW. Under optimal conditions, the world could operate PV generation plant capacities as large as 2.707 GW by the end of 2026. In our Medium Scenario, we now expect that total global installed PV generation capacity will pass the following milestones over the next 5 years: 1.1 TW in 2022, 1.4 TW in 2023, 1.7 TW in 2024, 2.0 TW in 2025, and 2.3 TW in 2026.

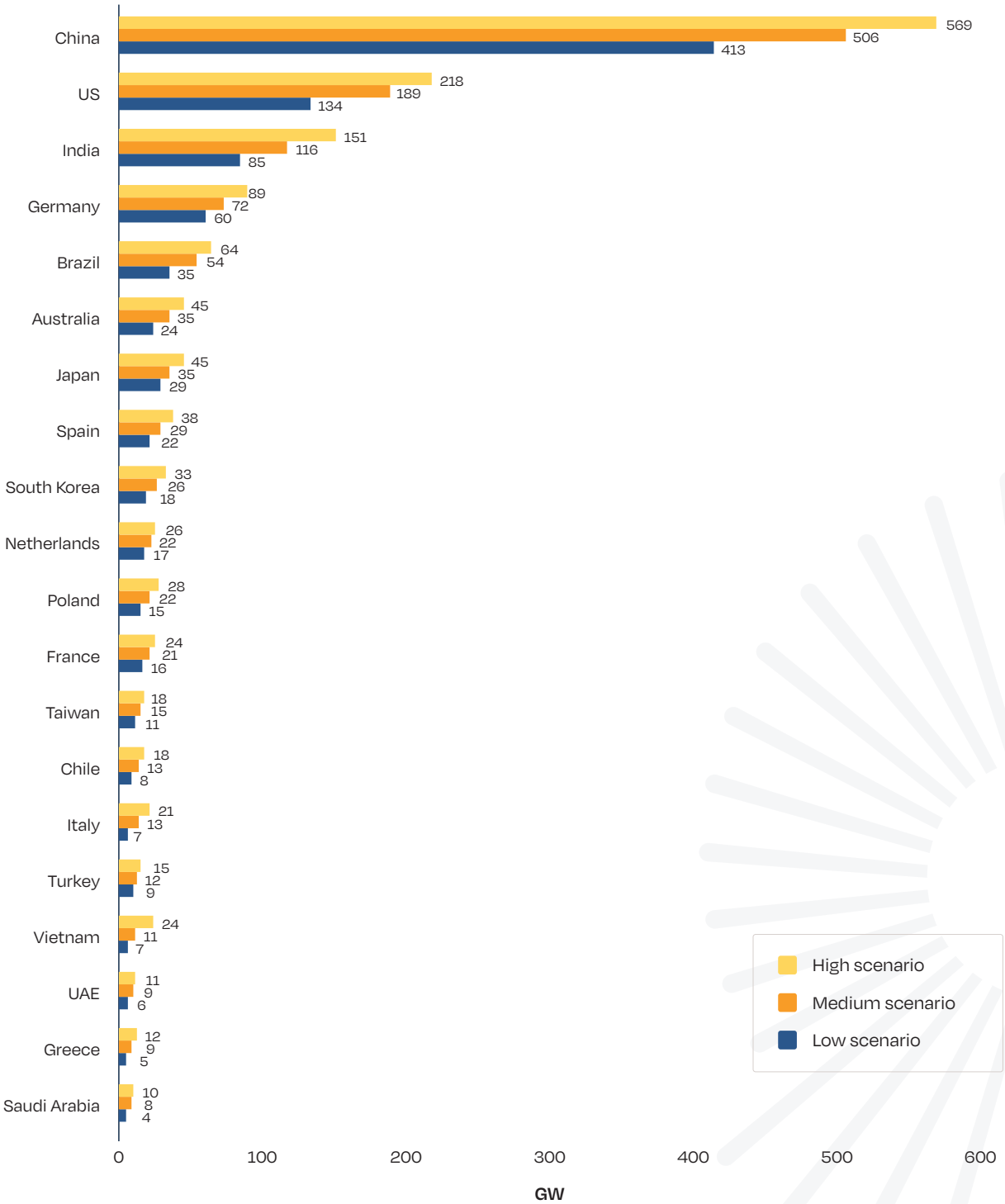
The 20 markets with the highest 5-year installation potential (in the order of Medium Scenario assumptions; see Fig. 17) show a number of changes compared to the 2021 GMO edition. The top four markets remain the same and in the same order — China, US, India, and Germany. This is the first time we expect three countries to install over 100 GW in the Medium Scenario: China (506 GW), the United States (189 GW) and now also India (116 GW). However, the pattern of the markets on this list remains similar, with a few countries installing the bulk of all solar system capacity, though the number of mid-size markets is growing, and stronger than last year. When looking at

FIGURE 16 GLOBAL TOTAL SOLAR PV MARKET SCENARIOS 2022 - 2026



the countries adding at least 20 GW for both high and low scenarios over the next five years, installation numbers are again higher for most markets, and so is the number of those reaching that level, which has increased to 12, from 9 in the last edition, now also including Brazil, Poland and France.

FIGURE 17 TOP 20 MARKETS SOLAR PV ADDITIONS 2022-2026



17 of the top 20 markets are expected to install at least 10 GW each between 2022 and 2026, according to our Medium Scenario, with new capacity additions in this group showing a large spread, now ranging from 505 GW for the first, China, to 8 GW for Saudi Arabia; that is more than 100 GW larger than in last year's edition.

Newcomers on this year's Top 20 list are from three different continents: Saudi Arabia (#20), Greece (#19), and Chile (#14), which replace Denmark, Mexico, and the UK. This time, higher capacity volumes are needed to enter the Top 20 market prospects, with at least 8 GW compared to 6.8 GW last year.

Altogether, the 20 solar markets listed are estimated to install a total of 1,218 GW until 2026. This is much more than in our previous GMO, when we had estimated this group to install 938 GW over the coming five years in our Medium Scenario.

A sensitive analysis for the top 20 shows additions of 1,459 GW over the next five years until 2026 in the High Scenario, and 924 GW in the Low Scenario — up by 303 GW and 238 GW, respectively, from our GMO 2020 5-year assumptions. A close look only at the top 5 shows that these markets combined are anticipated to deploy 1,092 GW until 2026 in the High Scenario and 727 GW in the Low Scenario, covering a share of around 69% and 62% of total grid-connections in that period (74% and 77%, respectively, in GMO 2021).

With severe weather phenomena becoming more frequent and the effects being felt by more and more people around the world, politicians are increasingly forced to take the challenges of Climate Change more seriously than ever. Recognised publications, like the April-published IPCC report, are finally acknowledging the outstanding role solar could play in reducing global emissions. Solar power is not only being recognised for its potential to help fight climate change, but also as a very effective means to create attractive local jobs, and provide energy security, protecting citizens and the industry from high fossil fuel prices and import dependencies from autocratic states that own a large share of the world's oil and gas reserves. For the 5-year period of this GMO, our weather forecast is sunny for 16 of the top 20 countries, with all but one of them expected to show double-digit annual growth rates.

The country with the largest 5-year growth rate expectations in this group is a newcomer among the top 20, Saudi Arabia, with an impressive expected level of 60% CAGR. While still small, we expect the first GW-scale project to be built in Saudi Arabia soon, after financial closure was reached for the 1.5 GW Sudair project last year, and kick-start the country's journey towards its 2030 goal of 40 GW. Again, on the other side of growth expectations for this top 20 group is Japan, with a compound annual growth rate of only 8%. This makes Japan the only country on this list with a one-digit CAGR, which is already 1 percentage point less than the year before in this edition. Our growth projections for Japan over the next 4 years translate into additions of only around 35 GW or an average of 8.75 GW/year in the Medium Scenario, which means the 7th rank, down 2 places from GMO 2021. Still, we consider the political support prospects sunny as the Japanese government has increased its 2030 target up to 147 GW, is implementing new support schemes, and working on policy measures to ease permitting.

The only country on our list with a rainy forecast is Vietnam, despite a 10% CAGR and 11.1 GW of new installations expected for the next 5 years. Vietnam's government is fuelling uncertainty for the solar sector as it has still not implemented its FiT3 scheme and a PPA programme after the end of an over-generous FiT2 programme that had turned the country, quite unintentionally, into the world's third largest solar market in 2020.

Last year, the weather forecast for Vietnam was considered cloudy, like the political support prospects for Mexico and the UK, which are no longer among the top 20 prospects of this GMO anymore. Another cloudy-tagged country, Italy, is still listed. While demand in Italy did slightly increase in 2021, due to a COVID-19 recovery backed residential tax credit for energy efficiency measures that includes solar and storage, the country, one of the EU's largest economies with plenty of space and sunshine, still remains a sub-GW level annual market. Although its 2030 solar targets are ambitious, requiring an additional 50 GW to be installed, the policy framework has not enabled investors to realise solar project developments, while the government is working on procedures to ease permitting. For Turkey, the second country with a cloudy forecast, it is not so much the policy framework that causes uncertainty. Incentive schemes, like net-metering and tenders, are well established and a 20% CAGR looks promising, but the country suffers from a dramatic financial crisis and very high inflation that

make project financing very difficult. Although somewhat strange at first sight, we also see some clouds on the horizon for the USA, the world's second largest market with 189 GW of new capacity to be added until 2026, according to our Medium Scenario.

But the anti-circumvention investigation of Chinese modules might dramatically reduce demand. The US solar association SEIA warned that, as a result of the trade case, 24 GW of solar capacity planned in the next two years might not be built.

FIGURE 18 TOP SOLAR PV MARKETS' PROSPECTS

Country	2021 Total capacity (MW)	By 2026 Total capacity Medium Scenario (MW)	2022-2026 New capacity (MW)	2022-2026 Compound annual growth rate (%)	Political support prospects
China	308,284	814,105	505,821	21%	
United States	122,861	311,414	188,553	20%	
India	60,113	176,488	116,375	24%	
Germany	60,599	132,887	72,288	17%	
Brazil	13,100	67,241	54,141	39%	
Australia	27,045	62,134	35,089	18%	
Japan	77,624	112,474	34,850	8%	
Spain	18,960	48,251	29,291	21%	
South Korea	21,328	47,723	26,395	17%	
Netherlands	13,991	36,108	22,117	21%	
Poland	7,670	29,197	21,527	31%	
France	13,220	33,739	20,519	21%	
Taiwan	7,706	23,111	15,405	25%	
Chile	4,683	17,944	13,261	31%	
Italy	22,127	35,322	13,195	10%	
Turkey	7,915	19,878	11,963	20%	
Vietnam	18,604	29,759	11,155	10%	
United Arab Emirates	3,170	12,369	9,199	31%	
Greece	4,162	13,050	8,888	26%	
Saudi Arabia	847	8,894	8,047	60%	

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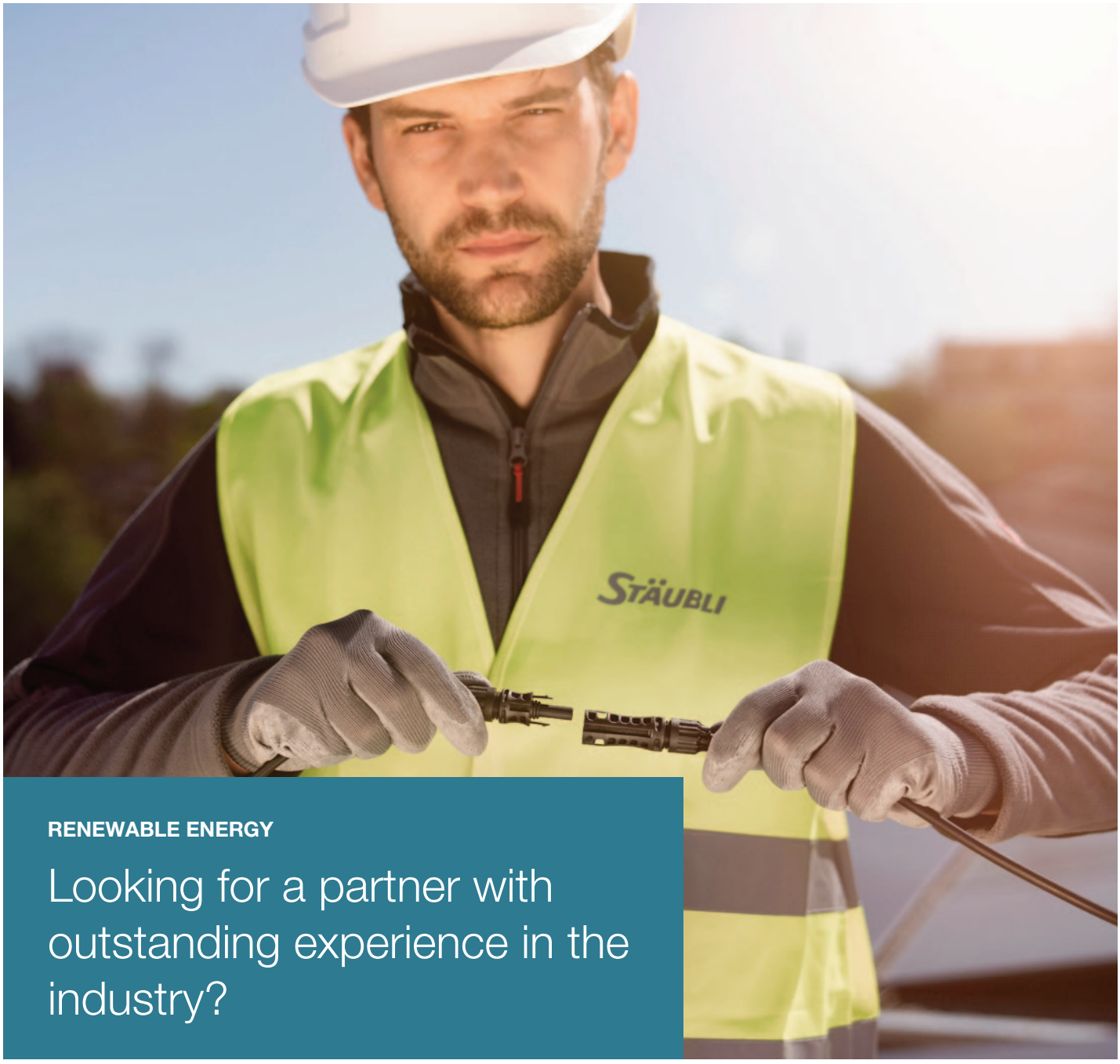

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In summary, driven by Climate Change and now also geostrategic considerations, the policy environment for solar power is getting brighter, and so is the investment climate over the coming years. This doesn't save the solar sector from disappointments, even in larger markets, like Mexico, where a current fossil fuel friendly government has been able to slow down solar dissemination. The other example is Vietnam, where the government put the brakes on after an over-generously designed support programme went so much out of control that this earlier insignificant solar market suddenly turned into a global top 3 solar destination. But these are exceptions over the coming years; the overall weather forecast for solar power is very sunny.

SEGMENTS 2022 – 2026

Both the rooftop and the utility-scale segments grew along with a growing solar market in 2021. However, the two segments have evolved following quite different market dynamics. At 77.2 GW, rooftop additions grew by 26% compared to 61.2 GW the previous year. By contrast, utility-scale installations grew by a smaller percentage (16%), reaching 90.7 GW, although they still remain the main contributor to total annual capacity (54%). This was partly the impact of solar systems' high prices on business conditions, which hampered the economic viability of large-scale solar parks and caused delays in project completions.

In China, the rooftop segment experienced its sharpest growth to reach 29 GW and 53% of installation, a record-high performance that is almost twice as much as last year, when rooftops accounted for 32% of installed capacity with 15.4 GW. It is the first time in the country's history that the rooftop segment has outperformed the utility-scale segment. The reason behind this accomplishment is found in the small commercial and residential segment. The utility-scale segment, by contrast, was not under the same hard deadlines for subsidised large-scale systems that drove the segment up in 2020.

A more balanced trend is observed in the United States, where the 42% increase in annual solar PV installations was more evenly distributed across the different segments, which kept market shares more or less steady from 2020. The market remains skewed towards the utility-scale segment, which contributed 72% of new installations with 19.7 GW, while rooftop represented the remaining 28% with 7.6 GW. Following a surprising extension of the deadline for the ITC at the end of 2020, the rooftop segment grew from 5.4 GW in 2020 to 7.6 GW in 2021. The market shares are poised to change in the coming years as the solar ITC will be significantly reduced — to 0 for certain residential systems in 2023 and to 10% for commercial and utility-scale systems in 2024. We are therefore expecting a surge of rooftop installations in 2022 and 2023, but utility-scale will steadily remain the main segment of the country anyway.

In India, following the major downtime in 2020 due to grid connection issues, tender renegotiations and the severe impacts of the pandemic, the utility segment more than regained its pace in 2021 at above 250%. It represents 81% of installations with around 11.5 GW of newly added capacity, while rooftops accounted for 19% of the total additions with 2.6 GW. The off-year that India experienced in 2020 therefore has not changed the structure of the market, which is fully dominated by the large-scale segment. This development, however, is not in line with the national ambition, which aimed to install 40 GW of rooftop by the end of 2022 — an objective that seems completely out of range now considering that the country has only reached 6.47 GW so far. It is expected that India will set out policies to encourage the expansion of the rooftop segment, although it is likely that in the next phase of its solar programme it will focus much more on large-scale solar for the following reason.

Deploying large volumes of utility-scale solar is much simpler than creating a distributed PV rooftop market, which requires a substantial period of time and a lot of effort to educate consumers, while setting up an effective platform with the right financing instruments and technical standards. That's a major part of why emerging markets usually begin their foray into solar with tenders for utility-scale solar and frequently struggle to set up the distributed rooftop segment, even if politicians generally prefer PV on rooftops as it avoids any potential conflicts on land use. However, in 2021, the rooftop segment gained 2% percentage points of total market share and reached 46% of global installations. This can be attributed primarily to two forces. First, the high solar system prices caused delays in the finalisation of big utility-scale project developments. Second, many residential and C&I customers opted to install rooftop solar as a means to reduce their electricity bills. In parallel, on the

utility-scale side, the lack of new ultra-large solar project completions in the Middle East also played a role in the reduced growth of the segment.

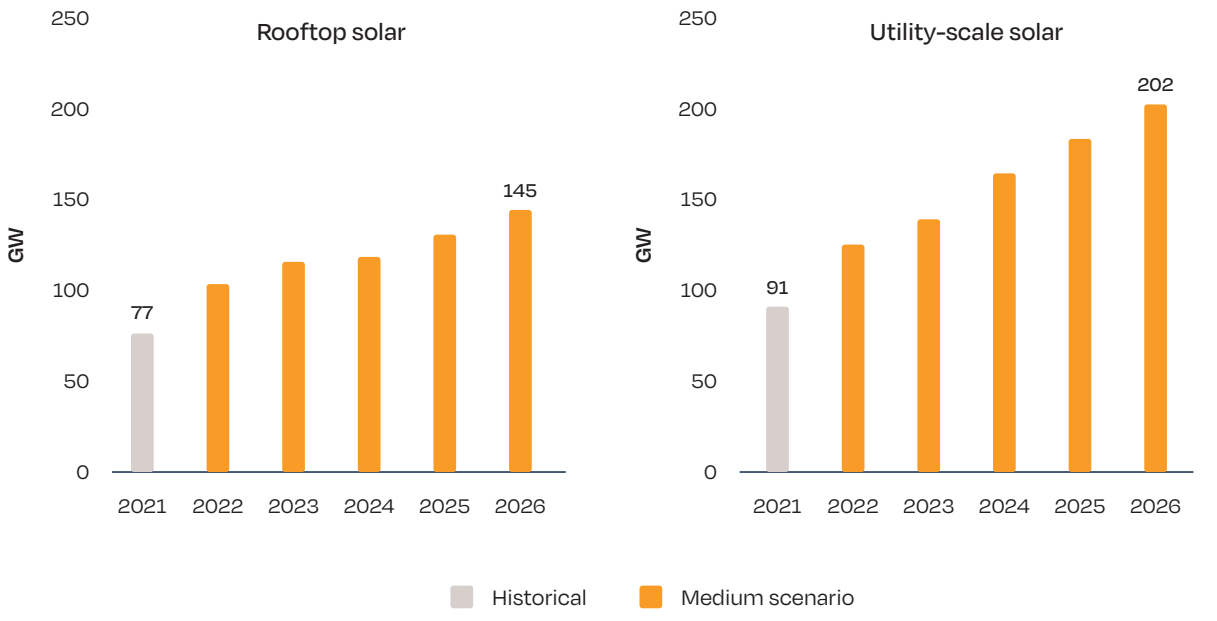
The rooftop segment followed different paths across the other top 10 markets. Several of the more advanced rooftop solar markets — Australia, Japan, Germany, South Korea — installed less distributed capacity than the year before, whereas countries that so far have seen limited distributed solar growth — Brazil, Poland and Spain — all increased by a large margin. All in all, the growth of the segment was not only supported by the top markets China and, to a lesser extent, the United States, but also by contributions from mid-sized European countries, a region in which more than half of the annually installed capacity was made up of rooftop systems.

The renaissance of ground-mount systems observed in 2020 in long-established solar markets like Europe is still ongoing. The trend towards tenders has been providing the basis for a big wave of ground-mount PV plant installations, like in Spain or Germany, which has increased its tender volume significantly to help reach its ambitious target. Only for 2022, 6 GW of solar tenders are scheduled. Also in Holland, one of Europe's most densely populated countries, there is a boom for ground-mount installations, based on technology neutral tenders, though land and permitting issues are increasingly limiting growth. The country is now looking also into floating solar or agri-PV as alternatives to conventional land, a trend that is also starting in a number of other countries.

The cost competitiveness of solar enabling merchant/PPA solar systems also drives the growth of the ground-mount segment. According to Bloomberg NEF's latest data from April 2022 solar is now the largest technology used in renewable global corporate PPAs. In 2021, 18 out of 30 GW was supplied by solar, and in the first quarter of 2022, almost 80% of the 8.5 GW of corporate PPA systems installed were solar related.

While the US has been the largest market for RE corporate PPAs, there is growing interest in Europe as well. Three of Europe's very sunny and spacious countries, Spain, Portugal and Italy, have multi-gigawatt pipelines for such subsidy-free PV power plants. With solar's competitiveness further improving across the board, the PPA segment will become a major driver for ground-mounted solar.

FIGURE 19 SOLAR PV ROOFTOP AND UTILITY-SCALE SEGMENTS SCENARIOS 2022-2026



After the utility market reached 90 GW in 2021, we expect this segment to reach 125 GW with a share of 55% in 2022, which could be even higher if the high silicon and module prices had not caused delays in planned projects. For 2023, we anticipate the utility-scale segment to reach almost 140 GW. For the following years until 2026, it is forecasted that utility-scale's share will slowly increase to make up about 58% of the total annual installed capacity, representing more than 200 GW globally in 2026. What could tilt the balance even more towards large-scale, ground-mounted power plants are green hydrogen related solar power generation capacities that have been announced in several locations around the world, Australia in particular. That trend, however, is probably going to become visible only towards the second half of the decade.

Nonetheless, the recent combination of high electricity prices and the Ukrainian war has reshaped the plans of several states and citizens, with distributed solar seen as a way to increase energy independence now more than ever. The EU-27 region in particular needs a fast response to cover the gap left by the phaseout of two thirds of Russian gas by the end of 2022. Utility-scale solar has proven resilient during the pandemic, but takes longer to install than rooftops, which can provide a timely contribution already by next winter. With the high-price module phase still ongoing, distributed solar is therefore likely to remain a big part of the plan in EU-27 over the next 2 years.

In addition, both residential and commercial power consumers are also evolving more and more into prosumers, solar panels will turn into building materials, and smart cities will want to employ the advantages of distributed small-scale solar in combination with storage and digital solutions. California's decision of making solar a mandatory part of new-build homes as of 2020 has been followed by several other sub-national actors. In Germany, following the states of Hamburg, Bremen and Baden-Wurttemberg, in June 2021, the city of Berlin established a mandate to install rooftop PV on all new and renovated buildings in the coming years. As of May 2022, the first of these solar obligations in Germany is going into effect in Baden-Wurttemberg. For all these reasons, our forecast for the development of solar rooftop is more upbeat than in previous years. As a result, we are seeing the rooftop share remaining stable around 46% until 2023. In a longer-term perspective, starting from 2024, rooftop solar will slightly drop to 42%, as most of the increased tendered capacity will start to come online. Still, in absolute terms, the market for rooftop solar is supposed to expand significantly over the coming years, reaching 145 GW in 2026 from 77 GW in 2021.

CONCLUSIONS

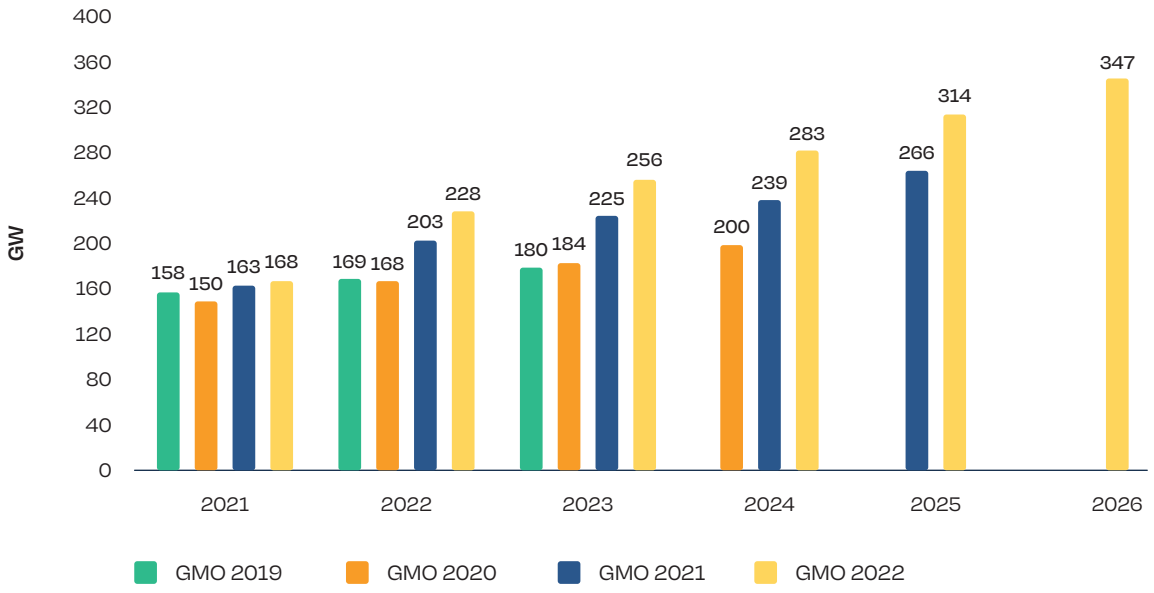
The coming years will see much more PV capacity come online than anticipated in the GMO 2021, which was published in a time of uncertainties about the aftermath of a prolonged pandemic with severe effects on health, economics, supply chains, and even individual movement.

Just as our 2021 Global Market Outlook last year was constantly above the too pessimistic expectations in GMO 2020, in this GMO 2022 we forecast a larger growth in each of the years that we can compare with last year's expectations (see Fig. 20). The deployment assumption is 12% higher for 2022, still somewhat limited by the sustained high component prices, the short-term supply chain bottlenecks, and logistics issues. Last year, our expectation for 2023 could have already appeared quite ambitious; yet we have increased it by a further 14%. Our Medium Scenario outlook for 2024 and 2025 is also 18% higher than in GMO 2021.

Like last year, we expect to reach 200 GW level by 2022; though at 228 GW, in this edition it is 25 GW higher. But unlike last year, now we also have the 300 GW mark in sight, to be surpassed by 2025. We expect 314 GW to be installed versus 266 GW in the previous GMO. To put it into perspective, only five years ago, in 2016, this was the world's total installed solar power generation fleet.

Our increasingly positive view is based on solar's impressive resilience, its recent market and technical developments, and the new geostrategic component that had little to no influence on solar investment decisions before. Despite and because of the uncertainties of the Russian invasion of Ukraine and the resulting energy price hikes, solar is now increasingly considered key to true energy independency. No other power generation source can compete with solar's versatility: from large-scale

FIGURE 20 COMPARISON MEDIUM SCENARIO GMO 2021 VS GMO 2022



power plants to onsite commercial and residential rooftops, to building-integrated, off-grid, and mobile power solutions. Combined with batteries and heat pumps, solar is even capable of satisfying energy needs beyond the power sector.

Even with temporary price hikes, solar's cost leadership improved further in 2021, again outcompeting fossil fuels and nuclear in any unsubsidised investment case, and it will continue its cost-reduction path for many years to come. Again, many product innovations across the value chain — as highlighted in our chapter on technology trends — further support solar's leading role in the energy generation field.

With the most for more waves of COVID-19 seemingly behind us in most of the regions across the world, our new outlook is consistently above our earlier forecasts from GMO 2021 and GMO 2020, but also much higher than the predictions of our pre-COVID-19 report, GMO 2019. Despite its resilience, solar has lost precious time in the fight against Climate Change due to the widespread effects of the pandemic, which are still negatively impacting the solar sector, like many others.

In conclusion, we still need to be more ambitious when it comes to solar deployment with more support from policymakers, in order to implement better policy frameworks that enable solar to reach its full potential. Although at first sight it is impressive that the solar power fleet has just reached the TW level, and will double it in less than 4 years, it needs to get to much higher dimensions to keep the world on a 1.5°C Paris aligned trajectory and provide local and regional energy independence as soon as possible. While it is still remarkable that solar continues to add larger year-on-year power generation capacities than any other technology, its contribution to the global power output is only 3.7%. There's still huge potential for solar to tap!

2 Focus: The Latin American solar market

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Introduction

Latin America is usually associated with warm weather and bountiful sunshine. The region is gifted with a favourable climate and abundant natural resources, including exceptional solar irradiation. Combine that with relatively high electricity tariffs in the region, and it provides fertile grounds for investments in solar, from both local and international investors. The past decade has proven this right with the interest in solar PV in Latin American markets growing substantially. The region has had GW-level solar markets for several years now — one of its countries among even in the solar Top 10 — and both support and demand for solar are quickly growing.

In 2021, as part of the global efforts to avoid the worst impacts of climate change and keep global warming below +1.5 °C, an increasing number of Latin American countries announced commitments to reduce greenhouse gas emissions. Additionally, many countries from the region are working towards increasing its local energy security and reducing dependency on imported fuels (with volatile and unpredictable prices) for electricity generation. The falling costs and increasing competitiveness of renewable energy technologies made them prime candidates for supporting this transition, particularly solar PV. Furthermore, solar PV adoption is closely linked to empowering electricity consumers (homes, small businesses, rural communities and public buildings), local job creation and economic development, thus benefitting from strong popular and governmental support in Latin America.

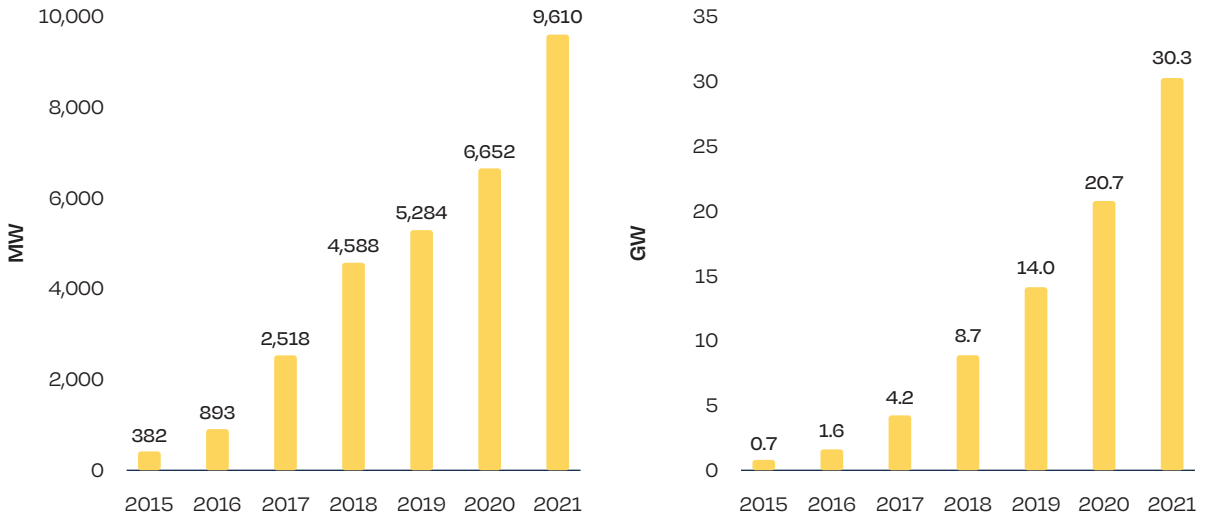
LUT University's energy system modelling assesses that, in order to follow a Paris-compatible global energy transition pathway, the installed capacity of solar PV in South America must reach 424 GW in 2030 and 2.25 TW in 2050.[1] While it appears a very long way away, current market performance indicates a bright future for the technology in the region, especially given the factors discussed at the outset, plus the positive legal and regulatory frameworks in place in many Latin American countries .

During the last decade, the region saw a rapid and more diversified development of renewable energy technologies. In this context, solar PV has a significant advantage in terms of competitiveness, simplicity and public support. These combined factors led to a strong surge in solar PV installed capacity in Latin American countries.

In 2021, solar PV capacity in the region increased by 44%, installing a total of 9.6 GW of new PV systems (see Fig. 21). The market expansion in 2021 has been much higher than in the previous years. In 2019 and 2020, when investment conditions were less favourable, the market grew only 15% and 26%, respectively.

1 Bodganov et al (2021): Low-cost renewable electricity as the key driver of the global energy transition towards sustainability. Available at: https://www.sciencedirect.com/science/article/pii/S0360544221007167

FIGURE 21 LATAM ANNUAL AND CUMULATIVE SOLAR PV MARKET 2015-2021



In terms of cumulative solar installations, Latin America had an operating solar fleet of over 30 GW by the end of 2021. This is almost four times the total solar capacity deployed three years ago at the end of 2018, and over 40 times the generating capacity in 2015.

Distributed solar developments

The deployment of rooftop solar PV systems has amplified significantly in recent years, especially due to favourable support from public policies, such as net metering, net billing and fiscal incentives. In many cases, such policies make solar PV solutions more attractive to end consumers than buying electricity from the grid. The competitiveness of distributed generation is backed by its low installation costs and monthly savings of up to 90% on the electricity bills.

For another year, Brazil maintained its leadership as the largest solar PV market in Latin America. In fact, in 2021, the country registered record growth of solar PV distributed generation (rooftop and ground-mounted systems with individual capacity of up to 5 MW) through its national net-metering program. This record may well be surpassed again in 2022. According to projections from the Brazilian Solar Photovoltaic Energy Association (ABSOLAR), Brazil's market is headed for a strong boom this year, especially after the approval and official publication of a long-awaited distributed generation law (Law No. 14,300/2022) that brought more legal certainty, stability, predictability and transparency to the market. During 2022 and beyond, solar PV distributed generation is also expected to experience a strong growth curve, due to the combination of rising electricity prices in the country and falling system prices worldwide.

In Mexico, small-scale solar PV growth was based on a net-billing scheme, a market-based compensation mechanism in which prosumer's compensation is based on the market value of the kWh consumed or injected into the grid. Although less favourable than net-metering, net-billing also contributes to improve grid integration of renewable electricity, increasing the system's flexibility by engaging the prosumer and providing savings on electricity bills.

In Chile, most of the distributed generation capacity has so far been installed through Pequenõs Medios de Generación Distribuida (PMGD), which are projects of up to 9 MW. In addition to that, a net-billing scheme that supports small rooftop projects was amended in 2019 and the upper threshold raised from 100 kW to

300 kW, with an option to increase this limit further to 500 kW in the near future. Although the rooftop segment provides a minor share of annual installations today, the government aims to reach 500 MW of net-billing installations by 2026.

In the other Latin American PV markets, less favourable supporting frameworks and investment conditions result in a lower pace of growth of distributed solar. However, as households and businesses become familiar with the versatility and cost-competitiveness of solar energy solutions, further market diversification is expected across the region.

Large-scale solar developments

Latin American countries are increasing the diversification of their national electricity matrices, as well as improving local policy and regulatory environments to stimulate economic recovery from the impacts of the COVID-19 pandemic, as well as to accelerate their energy transition and decarbonisation.

In this context, electricity auctions held in countries such as Brazil, Chile, Colombia, Mexico, and Peru have helped accelerate the deployment of gigawatts of large-scale solar PV projects. Latin American governments were amongst the first in the world to hold electricity auctions, as part of a strategy to develop and catalyse renewable energy deployment locally, a strategy that rapidly spread to countries in other regions of the planet. The auction mechanism awards long-term contracts (between 10 and 25 years) to electricity sellers (power producers) that offer the most competitive (lower) prices. The revenue streams from those contracts are then used as a financing guaranty to mobilise investors (financial institutions and private capital firms) for the project. This facilitates the implementation of renewable energy capacity throughout the region.

In Brazil, the largest Latin American market in 2021, two types of renewable energy auctions are usually held: (i) to meet the electricity demand of utility companies; and (ii) to ensure grid stability and reliability. Competition between electricity sellers promotes cost-effective expansion, thus contributing to reduce electricity prices for consumers. This auction model has also been successfully implemented in Chile, Peru and Colombia.

Despite delays and other challenges brought on by the COVID-19 pandemic, electricity auctions remain a key driver for large-scale solar PV development. However, uncertainties about future demand in auctions and disappointments due to low volume of new contracts auctioned by governments in recent years forced large-scale solar PV market players to search for other ways to enable new projects. One of the promising mechanisms to do so is through bilateral PPAs in the free electricity market and self-electricity generation by direct ownership or lease of large-scale solar PV power plants.

The use of bilateral contracts to deploy solar PV is increasing in the region, especially in Brazil and Chile. There are many successful cases of direct ownership or lease of large-scale solar PV power plants by large consumers (e.g., industries, shopping malls, agribusiness companies, etc.) in open electricity markets, allowing them to reduce electricity prices and increase business competitiveness. Usually, these power plants are built and operated by a generation company in a joint venture with the consumer, allowing the latter to remain focused on its core business.

Opportunities in Latin America's solar PV markets are being highlighted around the world. According to the Global Solar Council (GSC), the outlook for solar PV in the region is optimistic, particularly given the increasing number of power purchase agreements being signed. However, to give it an impetus, investors expect clear targets from governments and regulatory certainty.

In this regard, policy and regulatory uncertainties, notably in the case of Mexico, where the government has been trying to make retroactive changes to the support framework, remain challenges to market growth in the region, while greater investment in transmission infrastructure will be important to avoid project delays caused by system constraints, as well as to avoid limitations to the amount of electricity that can be injected into and transported by the grid.

Prospects 2022-2026

If 2021 set a new record for annual PV installations in Latin America, 2022 is expected to see even more significant achievements. Under SolarPower Europe's Medium Scenario, the capacity deployed in the current

year will hit the double-digit GW scale and total 14.6 GW, growing a stunning 52% year-on-year (see Fig. 22). In the best policy and investment conditions, or the High Scenario, it could reach as high as 17.2 GW. In the worst-case Low Scenario, installations would still surpass the 10 GW mark. While Brazil and Chile, the most prominent markets, are poised for sustained expansion, several smaller countries around the continent will contribute to this growth as they find an affordable and versatile solution to their energy needs in solar. An overview of the market dynamics in the top 10 Latin American markets is provided in the following section.

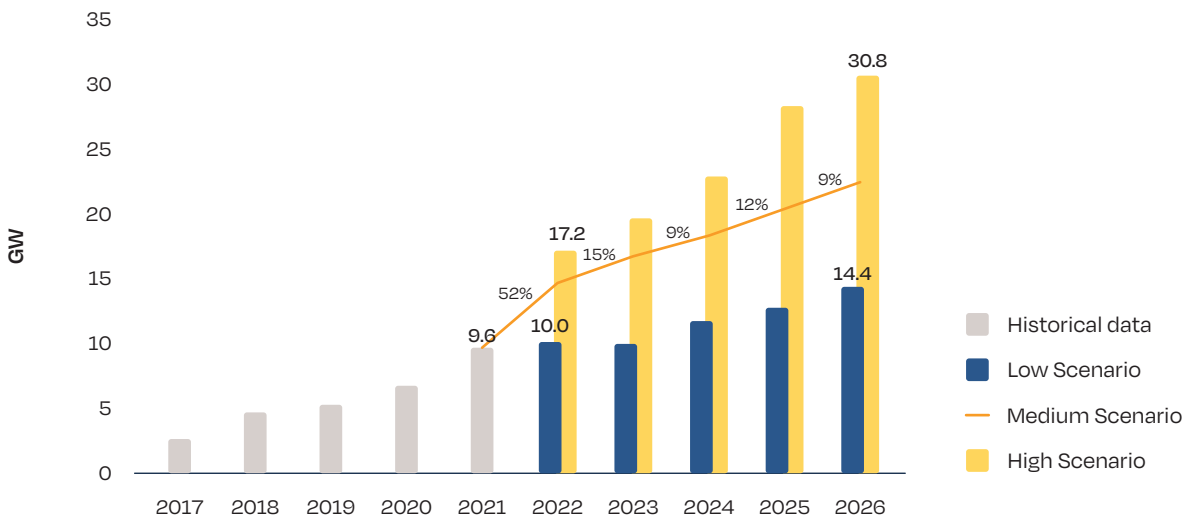
After an exceptional 2022, we expect solar markets to slow down in the period 2023-2026. The restructuring of key regulatory frameworks will pave the way for a new phase of market expansion, with annual growth levels in the 2023-2026 period trending towards the low double-digit range. At the end of the forecasting outlook, the annual market could be as low as 14.4 GW or as high as 30.8 GW, with the Medium Scenario playing out at 22.4 GW.

Capacity addition projections for solar PV in Latin America indicate positive developments for 2022 and beyond, but not without challenges.

Financing availability and costs for solar PV projects in Latin America have always been important factors, because of the specific macroeconomic and microeconomic characteristics of the region. This also requires a specific evaluation of the economic aspects of each country, in order to understand and factor into the projects aspects such as local interest rates, currency fluctuation, taxation, risks and expected returns on investment. Additionally, the current scenario of the COVID-19 pandemic brings new challenges to governments, entrepreneurs and investors interested in the region.

The growth prospects for solar PV across Latin America also face hurdles related to equipment costs, freight and access to raw materials, such as steel, copper and glass, which recently caused some level of disruption in the international solar supply chain. Solar PV market in Latin America is still dependent on imports of equipment, especially modules and inverters, while local companies are usually able to supply most other components also used in other sectors. The development of local manufacturing faces several difficulties, from qualification of workforce to labour laws, and lack of policies to promote the industry, as well as a series of purchase

FIGURE 22 LATAM ANNUAL SOLAR PV MARKET SCENARIOS 2022-2026



taxes and fees that burdens local manufacturing. Thus, Chinese companies are currently responsible for most of the photovoltaic equipment installed in Latin America and probably will keep that leading position in the following years. Yet, even with some challenges ahead, the use of solar PV for electricity generation is expected to keep growing fast in the region, a trend that is projected to continue unchanged in the short, mid and long terms.

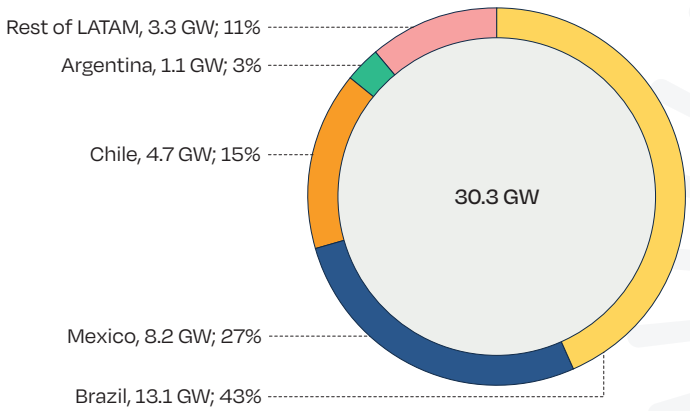
Undoubtedly, the average selling prices of equipment and the resulting levelised cost of electricity (LCOE) of solar PV is steadily decreasing, another positive trend that should continue. Technology improvements in solar cell and module efficiencies, as well as better industrial processing and economies of scale will ensure that solar power becomes even cheaper in coming years. This scenario will not only have a positive impact on the environment and the fight to prevent the worst impacts of climate change, it will also help Latin American countries in their transition to cleaner and local energy sources.

Therefore, countries from the region will have the opportunity to reduce their dependence on the use of fossil fuels for electricity generation. This, in turn, will help decrease the share of fossil fuels in their respective energy matrixes, by increasing solar PV and other renewable energy technologies in the country's energy matrix, making Latin America a strategic destination for solar PV companies in search of promising and expanding markets.

Top 10 Latin American Solar Markets

Latin America has experienced exponential market growth and deployment of solar technology, mainly led by four countries: Brazil, Mexico, Chile and Argentina. Combined, they accounted for almost 90% of the region's solar PV power capacity as of the end of 2021 (see Fig. 23). Each of these countries have already surpassed 1 GW of operational power from solar PV, while the other markets of the region like Colombia, Peru, Dominican Republic, El Salvador, Panama and Cuba trail by quite a margin. The three markets that reached the GW scale in 2021 — Brazil, Mexico, and Chile — operated a solar fleet of 26 GW as of the end of 2021, accounting for 86% of the total 30.3 GW deployed in the region.

FIGURE 23 LATAM CUMULATIVE SOLAR PV CAPACITY 2021



BRAZIL

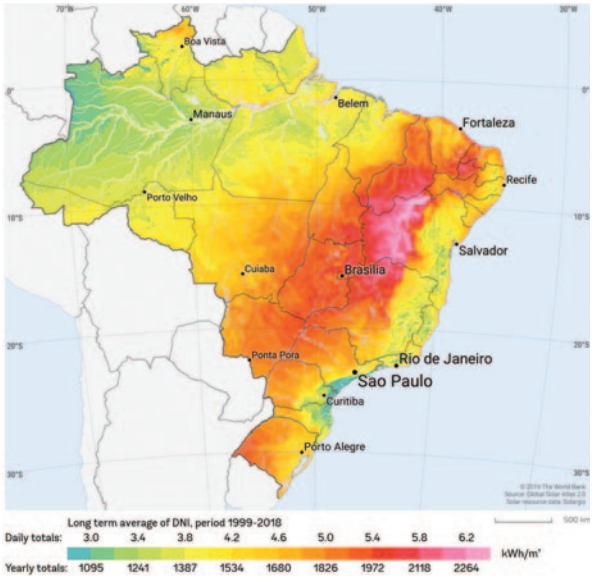
Brazil, with a total landmass area of 8,515,800 km², is the largest country in Latin America, equivalent to the eastern European continent in size. It also has the largest population in the region with 211 million inhabitants, as well as the largest economy with 1.84 trillion USD. The country is one of the leading markets for renewable energy in the world and ranks number one in Latin America.

At the end of 2021, Brazil's installed solar PV capacity was over 13.6 GW, combining the contributions of the centralised and distributed generation market segments, adding more than 5 GW of capacity in 2021 alone. Solar's share in the country's electricity mix reached 7.2% last year (see Fig. 24).

The country has great potential to generate electricity by using photovoltaics; there are some regions in Brazil where solar resources can reach more than 2,200 kWh/m²/year.

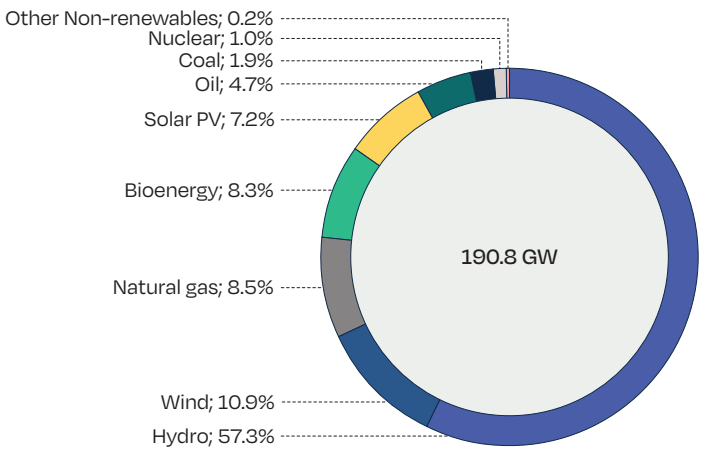
With enormous solar potential, the country has been experiencing strong growth in the renewable energy market for several decades, initially with large-scale hydropower, then with biomass, wind power and small hydropower, and more recently with a boom of its solar PV market. The government has been successfully establishing a positive legal framework, as well as regulating specific policies to attract foreign investments into the country. In terms of solar PV, as of the first week of April 2022, Brazil has surpassed 15 GW of total solar PV installed capacity. Large-scale solar PV power plants account for 5 GW and distributed generation systems have an installed capacity of 10 GW.

FIGURE 25 BRAZIL'S DIRECT NORMAL IRRADIATION



SOURCE: SolarGis 2022. © SolarGis.

FIGURE 24 BRAZIL'S ELECTRICITY MATRIX IN 2021



SOURCE: MME (2022). © SOLARPOWER EUROPE 2022

According to the Brazilian Solar Photovoltaic Energy Association (ABSOLAR), which represents national and international companies from all parts of the sector's value chain, more than 78.5 billion BRL has been invested in solar PV in the country between 2012 and the beginning of April 2022, creating over 450,000 jobs over this period.

A record number of new centralised generation projects were registered at the Brazilian Electricity Regulatory Agency (ANEEL) last year, most of them targeting the open electricity market (private bilateral PPAs). The growing competitiveness of solar PV has resulted in a pipeline of more than 34.9 GW of projects under development in the country. However, not all of these projects have already signed contracts; therefore, a part of this pipeline is considered prospective.

In 2021, solar PV distributed generation registered its largest historic growth in the country. However, this record may well be surpassed in 2022. Brazil's solar PV market is poised for strong growth, especially after the passage of a long-awaited distributed generation law (Law No. 14,300/2022), that brought more legal certainty, stability, predictability and transparency to the market. During 2022 and in following years, solar PV distributed generation is expected to experience a strong growth curve, due to the combination of rising electricity prices and falling system prices. This makes Brazil one of the most promising markets not only in Latin America, but globally.

ABSOLAR's in-depth analysis of the Brazilian market is available in the GW Markets chapter (see p. 80).

MEXICO

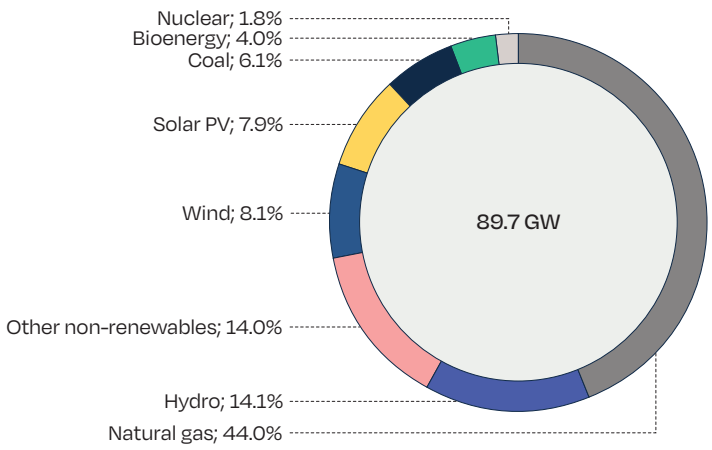
Mexico has a total landmass area of 1,964,400 km², is home to nearly 128 million inhabitants and is the second largest economy in Latin America with a GDP of 1.26 trillion USD. One of the world's leading oil producers, Mexico's electricity sector is still very dependent on fossil fuels, especially natural gas thermoelectric plants, which has been the main power source during the past decades.

At the end of 2021, Mexico's installed solar PV capacity surpassed 7 GW, combining the large-scale and distributed generation market segments. Overall, the country added 1.5 GW of solar PV capacity in 2021 alone, resulting in solar claiming a 7.9% share in electricity production (see Fig. 26).

The country has one of the best potentials in the world to generate electricity using photovoltaics, with an annual average irradiation of 5.5 kWh/m²/day. Depending on the location and time of the year, the value may go from 3.0 to 8.5 kWh/m²/day, making solar radiation a potentially unlimited energy source.

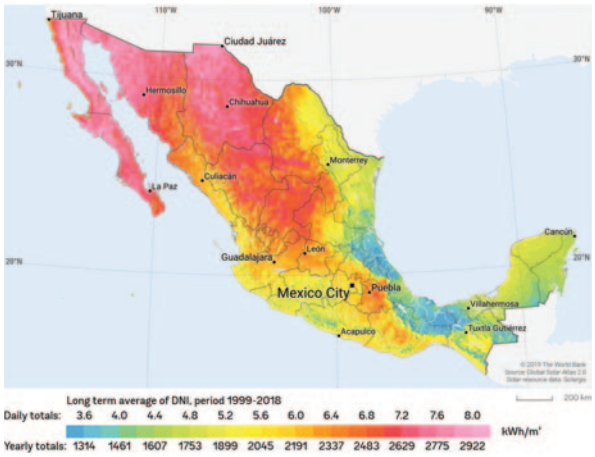
The rapid expansion of solar PV is not a product of specific technology choices by the government, as the auction system under which they are introduced

FIGURE 26 MEXICO'S ELECTRICITY MATRIX IN 2021



SOURCE: SENER (2021), BASED ON CENACE DATA.

FIGURE 27 MEXICO'S DIRECT NORMAL IRRADIATION



SOURCE: SolarGis 2022. © SolarGis.

to the market is technology-neutral. Rather, it reflects the good fit for renewable energy sources with the market design introduced under Mexico's power sector reform, which has built-in mechanisms to increase the share of clean energy in the mix.

The first two auctions for new power supply, held in 2016, demonstrated strong private readiness to invest in new solar PV projects, validating the innovative choice of market design. Investments to strengthen the grid and reduce network losses, combined with initiatives to reduce the reliance on expensive fossil fuel generation, have helped keep the costs of electricity supply in check, providing a boost to Mexico's industrial competitiveness. This context also provides a good opportunity to reduce the costs of subsidies for residential electricity consumers.

According to IRENA's analysis and forecasts, large-scale solar PV is expected to lead power capacity expansion in the country, adding 4.3 GW by 2026. However, this forecast has been revised downwards from last year, because of negative policy environment changes in Mexico. The current government is trying to centralise the country's energy market and favours fossil fuels over renewables. The cancellation of the green certificate auctions in 2018, proposed policies to change dispatch criteria in 2019 and uncertainty over the newly proposed electricity market rules and regulations in 2020 and 2021 have all created a scenario of uncertainty for local and international solar entrepreneurs, which in turn has reduced investor confidence.

Meanwhile, solar PV distributed generation is expected to add more than twice its current installed capacity by 2026, especially driven by net-metering and net-billing policies, coupled with growing demand and rising electricity tariffs.

The Mexican solar association ASOLMEX provided an assessment of the Mexican solar market in the GW Markets chapter (see p. 106).

CHILE

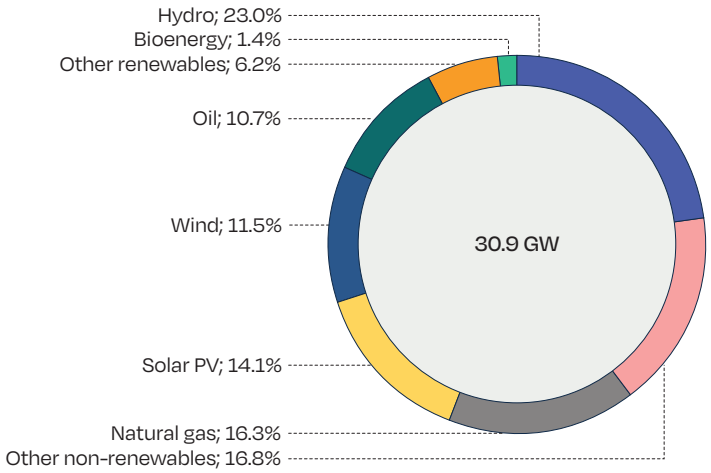
Chile has a total landmass area of 756,121 km^2, hosts a population of close to 19 million and a GDP of 282.3 billion USD. The geography of the country consists of mountain ranges running from the north to the south, stretching 4,337 km and creating a wide variety of climate zones. The Atacama Desert, mainly located in the northern regions, is one of the driest and sunniest places on earth, making it a growing attraction for the solar PV industry in recent years. In addition, with the country's dependence on imported fossil fuels with rather volatile and unpredictable prices, Chilean electricity tariffs are amongst the highest in the world to end consumers, in the range of 15 USD/kWh.

As of the end of 2021, Chile's solar PV installed capacity surpassed 4.3 GW, combining the large-scale and distributed generation market segments. Overall, the country added 1.3 GW of solar PV capacity in 2021 alone, claiming a 14.1% in the country's power mix in 2021 (see Fig. 28).

The country has undisputedly one of the highest solar irradiations in the world. The north of the country, due to its high altitude, prevalent cloudless conditions and relatively low columns of ozone and water vapour, is one of the best locations on earth for the use of photovoltaics. Annual average irradiation exceeds 2,000 kWh/m^2 in most parts of the Chilean territory and can surpass 10.0 kWh/m^2/day depending on the location and time of the year.

Chile displays a large array of "solar climates", offering excellent opportunities for greater energy independence and the chance to establish a more sustainable electricity matrix. In the past several years, Chile has been

FIGURE 28 CHILE'S ELECTRICITY MATRIX IN 2021



SOURCE: CEN (2022).

very successful in stimulating growth of renewable energy. According to Climatescope 2020 by BloombergNEF, Chile is ranked first among the most attractive countries for investing in renewable energy out of 108 emerging countries and 29 developed countries.

Chile has a large pipeline of late-stage projects, as new ones continue to be added throughout large-scale power plants and small-scale distributed projects, which have a capacity of less than 9 MW. The country expects to see 2.9 GW of solar PV newbuilds in 2022.

The main barriers to renewables in the forecast are the availability of transmission and distribution infrastructure, given the rapid increase in variable renewable capacity. The expansion of renewable electricity generation technologies calls for a robust grid with good coverage. The slow pace of expansion of transmission infrastructure in Chile has caused project delays in the past and could be a factor over the forecast period. Additionally, considering the relatively small population of the country and its national economy, Chile's electricity demand is somewhat constrained by macroeconomic factors.

An analysis from ACESOL on the status of the Chilean solar market is available in the GW Markets chapter (see p. 109).

FIGURE 29 CHILE'S DIRECT NORMAL IRRADIATION

SOURCE: SolarGis 2022.

ARGENTINA

Argentina is the second largest country in Latin America, with a total landmass area of 2,780,400 km², a population of 44.9 million inhabitants and a GDP of 451.9 billion USD. The southern country of the American continent is one of the largest natural gas producers in Latin America, but the production has been in decline since the beginning of 2000s.

At the end of 2021, Argentina's installed solar PV capacity was close to 1.1 GW, combining the large-scale and distributed generation market segments. In 2021, the country added 0.3 GW of solar PV capacity, with solar providing only 2.5% of total power needs.

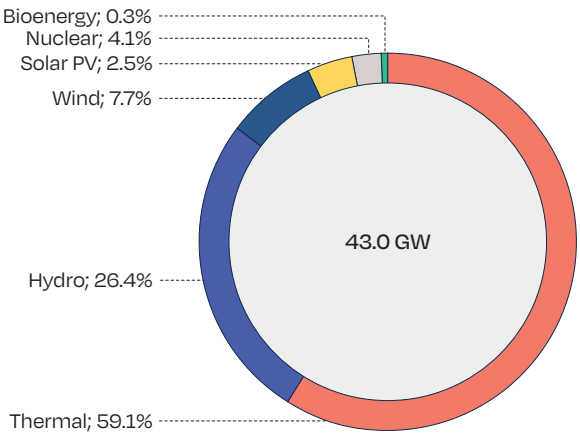
More than half of Argentina's territory receives average sunlight of over 4.5 kWh/m²/day, which means an extensive available land area with very good solar resources that makes solar PV a technically feasible and attractive option to match the country's electricity demand. However, solar energy utilisation has struggled with political and economic hurdles that are very specific to Argentina.

In order to diversify its energy matrix and to reach environmental commitments, the Argentinian government has passed a Renewable Energy Law in 2006, later amended in 2016, setting targets and establishing support mechanisms to reach 20% renewable energy by 2025.

FIGURE 31 ARGENTINA'S DIRECT NORMAL IRRADIATION

SOURCE: SolarGis 2022. © SolarGis.

FIGURE 30 ARGENTINA'S ELECTRICITY MATRIX IN 2021



SOURCE: CAMMESA (2022). © SOLARPOWER EUROPE 2022

Argentina is privileged with high solar irradiance, especially in the north-western region, which has been attracting local and foreign investors. Nevertheless, and despite the success of the energy auctions to expand renewable capacity in Argentina, the sector faces macroeconomic challenges that inhibited the growth of many sectors in the country, including: (i) high interest rates; (ii) necessity to hedge risks of the volatile local currency; (iii) restrictions on transmission infrastructure; and (iv) artificially low electricity prices due to subsidies, reducing the benefits for, and interest from, end consumers on the net-billing policy available for solar PV distributed generation.

The recent economic crisis and the COVID-19 pandemic have brought further financing challenges to Argentina, which delayed the commissioning of several renewable energy projects. Only half of the solar PV projects contracted in previous auctions had become operational by mid-2021. Almost a quarter of the auctioned projects missed their commissioning deadlines and were at risk of losing their contracts. Additional projects could still be impacted and cancelled due to such financing challenges. The country's renewables share has reached 13% by end of 2021, leaving 7% to go to reach its 20% target in 2025.

Currently, Argentinian business representatives are proposing a change to the distributed generation mechanism applied to the country, either by adopting a higher limit per system or by applying new rules similar to the Brazilian net-metering approach (limited to 5 MW per system). The strategy aims to accelerate solar PV growth in the country, as observed in neighbouring countries such as Chile and Brazil. The Argentinian private sector is in discussions with the government to find options to improve the current net-billing mechanism, to obtain better results and reach the goals established in the National Energy and Climate Change Plan.

COLOMBIA

Colombia has one of the cleanest energy matrices in the world thanks to a large hydropower capacity representing 95% of all the renewable capacity in the country. However, the country has excellent solar irradiation throughout the year at average sunlight of 4.5 kWh/m^2/day and can easily take advantage of this. After adding 382 MW last year, Colombia's total solar PV installed capacity reached 593 MW. The primary drivers of the market include government initiatives, like net-metering, to promote renewable energy, reduce greenhouse gas emissions, and have a more sustainable energy supply. Several auctions are also launched in order to assure the proper development of solar. The latest took place in October 2021, awarding 796 MW of solar PV. Awarded projects will sign a 15-year PPA and must come online by 2023. The Colombian solar PV market is projected to grow further due to an increase in the country's electricity demand.

PERU

Peru has favourable conditions for the development of solar PV projects, but the country's solar potential has not been significantly exploited yet. The greatest potential for solar power generation in Peru is found in its southern regions because of its combined proximity with the equator and the high altitude of the region, above 6,700 meters. The higher you get, the fewer ozone molecules are blocking sunlight; for this reason, the country experiences irradiation as high as 7.2 kWh/m^2/day. In 2021, the total solar PV installed capacity in the country reached 509 MW, after adding 78 MW in the same year. Peru's federal government has set specific energy targets for renewable energy, which should meet 60% of the total energy consumption by 2025, up from 32% at the end of 2020. Solar PV energy will play a key role in reaching this target, with several projects above 800 MW already under development across the country. More recently, the Ministry of Energy and Mines also announced in January 2022 its plan to tender 2 GW of renewable across two different auctions. The latest auction was held back in 2016 and awarded 185 MW of solar PV.

DOMINICAN REPUBLIC

Dominican Republic is one of the fastest growing economies in Latin America, resulting in a growing energy demand and, consequently, increasing greenhouse gas emissions. After adding 164 MW in 2021, the island reached a total installed capacity of 400 MW, which represents 30.2% of the total solar PV capacity installed in the Caribbean Islands. The country has a huge solar pipeline of nearly 1 GW, a large part of which is expected to be installed in 2022 and 2023.

According to IRENA, Dominican Republic has the potential to cover 63% of real-time demand by solar PV and wind energy; besides, it also recommends including the installation of batteries for frequency support and new transmission lines and upgrades to existing infrastructure. In April 2022, the country also engaged with the Inter-American Development Bank (IDB) to insist on the need to diversify its energy sources and discuss ways to achieve a 25% share of renewables in the energy mix by 2025, and 30% by 2030.

EL SALVADOR

El Salvador already has experience with large projects over 100 MW and is continuing on its path with a 115 MW tender launched in November 2021, to be installed in two blocks of 57.5 MW each. In 2022, several projects have already been announced to add at least 38 MW of solar PV capacity to the country's total. Thanks to those developments, solar PV reached 386 MW at the end of 2021 and is the second source of renewable energy in the country, behind hydro. According to IRENA, the country has around 66% of its energy coming from renewable sources in 2020. The country is also undertaking a long-term energy policy with the help of IRENA to reduce its electricity tariff and support the development of renewable in the country. This will help improve the socio-economic conditions of the country and increase its dependency, knowing that in 2019 more than two thirds of energy came from imported fossil fuels.

PANAMA

Panama has taken a new step in 2021 with the grid connection of the 150 MW Pénonomé solar project, located in the province of Coclé. Announced as the largest plant in Central America, it opens the door for further development of large-scale PV in the country, which already counts several PV plants under construction combining more than 300 MW. This could more than double the country's total capacity, which stood at 271 MW at the end of 2021. In its 2019-2024 Strategic Plan, the government is also counting on distributed solar to diversify its electricity mix and estimates the technical potential for self-consumption in the country at almost 4 GW. In a longer perspective, Panama's National Energy Plan 2015-2050 establishes that 15% of its generation capacity will come from renewables by 2030, and 50% by 2050. Even if three quarters of the country's electricity mix is already provided by renewables (among which 66% by hydro), the total energy supply is still dominated by fossil fuels by over 80%.

CUBA

Cuba is the largest island in the Caribbean Sea with a total landmass area of 109,884 km^2. The country, with a population of around 11 million, is still using the renewable energy sources at its disposal very sparingly for electricity generation. Nevertheless, the Cuban government intends to reach 24% of renewable energy in the total electricity mix by 2030, up from 15% today. In 2021, Cuba grid-connected 80 MW, resulting in a total solar PV installed capacity of 267 MW, representing less than 4% of the country's total generation capacity. Solar PV deployment will keep growing in the island nation during the next years – notably with a 900 MW tender that has been launched in January 2022. As member of the International Solar Alliance (ISA), the Ministry of Energy and Mines has also requested the support of the organisation to develop more solar PV capacity on the island.

To the present date, the remaining countries have experienced limited solar PV development. Combined, their total operating solar capacity represents only 3% of the region's installed solar capacity. This, however, may evolve swiftly, as solar energy's versatility and competitiveness continue to evolve and mature faster than previously anticipated by market analysts and technology experts.

Authors: *Dr. Rodrigo Lopes Sauaia & Rafael Francisco Marques,* Global Solar Council & ABSOLAR.

CASE STUDIES

SOLAR PV COMBINES ENVIRONMENTAL CARE, WELLBEING AND ECONOMIC DEVELOPMENT IN MEXICO

Name: Guajiro Solar Plant
Location: Nopala de Villagrán, Hidalgo, Mexico
Size: 129 MW

The power plant is located in Nopala de Villagrán, in the State of Hidalgo in central Mexico and has a capacity of 129 MW, which is equivalent to generating approximately 300 GWh annually.

Guajiro Solar Plant contracted a long-term PPA with the state-owned utility Federal Electricity Commission (CFE), awarded in Mexico's first auction held in March 2016. The project reached commercial operation on 1 May 2019 and according to the owner, Atlas Renewable Energy, the plant's generation provides clean energy to more than 120,000 families per year. Atlas Renewable Energy has invested more than 118 million USD, with the participation of Bancomext, providing 88.5 million USD in long-term financing

The power plant has more than 370,000 panels, and spans over 410 hectares, which is equivalent to 220 football fields. More than 36,000 trees and almost 7,000 non-tree species were planted within the project's area. It is estimated that Guajiro's operation will prevent the emission of 215,000 tonnes of CO_2 per year, which can be compared to removing 46,000 cars from circulation during the same period. As part of the deployment process, the developer partnered with The Pale Blue Dot, a Mexican organisation that promotes educational programs through the use of technology in schools and community centres. The implementation of the project allowed more than 400 students from the communities near the Guajiro Solar Plant to have Internet access and an educational platform.

GRID-INTELLIGENT SOLAR PARK IN CHILEAN DESERT

Name: Luz del Norte Solar Plant
Location: Atacama Desert, Chile
Size: 141 MW

Located in the Atacama Desert in Chile, the Luz del Norte PV plant built in 2016 enjoys one of the best solar irradiance conditions across the globe. The PV park, one of the largest in Chile, is built 58 km northeast of Copiapó, and spans over 478 hectares of land. The owner, U.S.-based thin film manufacturer First Solar, announced that the plant financing was provided by the U.S. Overseas Private Investment Corporation (OPIC) and IFC, which is a member of the World Bank Group.

Chilean grid operator CEN has added the Luz del Norte PV plant to its list of approved generators providing grid services. CEN uses a combination of bids and auctions to award the provision of frequency regulation services among the eligible operators.

Tests for ancillary services provided by this PV park have shown that large-scale solar plants are able to ensure and provide grid stability as ancillary services. The performance test analysed the plant's SMA inverters, which offer advanced grid management functions. In addition to the testing of a number of functions, such as Rapid Frequency Control and Rapid Voltage Control, the PV power plant's connection to the Automatic Generation Control (AGC) system of the National Electric System was simulated. The test was carried out by Engie Laborelec Chile, a leading expertise and research center in electrical power technology, and by First Solar, a global energy solutions provider.

129 MW, Guajiro Solar Plant. Hidalgo, Mexico. © Atlas Renew able Energy

141 MW, Luz del Norte Solar Plant. Atacama Desert, Chile. © First Solar

CASE STUDIES

SOLAR PV PROVIDES CLEAN AND RELIABLE ELECTRICAL SUPPLY IN COSTA RICA

Name: Solar Huacas PV plant
Location: Huacas, Santa Cruz de Guanacaste, Costa Rica
Size: 7.24 MW

The largest Solar PV power plant in Costa Rica is currently under construction in Huacas city by Advanced Energy and its local partner HiPower. The 7.24 MW system in Huacas is scheduled to go operational in June 2022 and will generate around 12,277 MWh per year, equivalent to the consumption of some 3,800 Costa Rican homes, which is a milestone for the Central American country, offering great potential for the expansion of solar energy.

The power plant will connect to the decentralised electrical network of Rural Electrification Cooperative of Guanacaste RL, aiming to make available as much renewable energy as possible to its customers to provide a clean and reliable electric supply to residents and businesses in Huacas.

7.24 MW, Hacuacas Solar Plant. Costa Rica. © SMA Solar Technology AG

GENDER INCLUSION IN SOLAR DEPLOYMENT IN BRAZIL

Name: Lar do Sol – Casablanca II Solar Plant
Location: Pirapora, Minas Gerais, Brazil
Size: 239 MW

The Lar do Sol – Casablanca II Solar Plant, currently under development in the region of Minas Gerais, Brazil, follows the signing of a long-term PPA contract between solar developer Atlas Renewable Energy and corporate offtaker Unipar, which is one of Brazil's largest chemical companies. The project will support Unipar's electricity needs to generate chlorine for water treatment operations. The developer has secured a 76 million USD loan from Brazil's Northeastern Bank, the largest regional development bank in Latin America. The solar park will span over 700 hectares, with a capacity of 239 MW.

In accordance with its sustainability requirements, the project aims to contribute to the development of the local community. Lar do Sol – Casablanca II Solar Plant is set to contract about 1,200 workers in the peak of its activity and part of them comes from the female workforce program "we are all part of the same energy". The program focuses on the promotion of inclusive practices by empowering the local female workforce through training. This initiative will allow local women to have access to new job opportunities within the project's construction, generate an opportunity for their economic stability and enhance their skillsets and potential by integrating them into more technical jobs.

Atlas Renewable Energy, Female workforce program, Brazil. © Atlas Renewable Energy

TRENDS

What's cool in solar

1.2 MW, Wadenoijen, the Netherlands. © BayWa r.e.

Over the last decade, not only have prices for solar modules decreased by around 90%, solar PV technology as a whole has made big leaps in terms of development. Although a typical solar module is still based on the same components and so is a solar PV system, a look below reveals that what's below the hood is very different — materials were improved, new solar cell technologies implemented, and cell, module and inverter efficiencies augmented. In particular, over the last 2 years, the trend towards very large wafers and much higher module power ratings have had knock-on effects on further developments of inverters, mounting systems, and the entire system design.

© LONGi Solar

With solar now on the minds of many investors and policy makers as the key to the energy transition, and as solar power capacity deployment is gathering pace, we see solar expanding into new fields. Although solar has already become the lowest cost power generation technology in many applications and locations, there is still much room for further developments in order to continue reducing costs to make the technology even more competitive and open to new frontiers. For instance, combining solar with battery storage on massive scales or producing the only true sustainable hydrogen solution, green hydrogen, or co-locating solar with agriculture are just few of many innovation opportunities to tap solar's versatility.

SolarPower Europe has taken a look at the latest solar technology developments in the value chain — starting from wafering until the system level and its applications — that have all collectively helped the segment grow and will continue to do so.

Wafers

Mono — The Only Choice:

Monocrystalline silicon has become the material of choice for wafers over its casted multicrystalline variant (also called polycrystalline). With fewer defects than multicrystalline, mono supports higher cell efficiencies. It was only 5 years ago, in 2017, that multi dominated the segment, while mono's share of the market was only about 40%. Fast forward to end of 2021 and mono had captured close to 90% of the market, and is expected to only grow stronger. The mono variant is at the core of all new capacity expansions of silicon ingot crystallisation for ingot and wafer fabs. For example, LONGi Group, the world's largest integrated solar module manufacturer, has been the primary advocate of monocrystalline wafers, increasing its capacity from 85 GW in 2020 to 105 GW in 2021, and targeting 150 GW by year end. TZS, the other global leader in this field with capacity nearing the 100 GW mark, grew even faster from close to 40 GW in 2019 to 88 GW by end of 2021, and a goal of 140 GW by year end. Other vertically integrated major module manufacturers have also been expanding their wafer output, with new entrants also joining in — and all these wafer capacities are based on monocrystalline silicon. Multicrystalline has now been restricted to just serving niche markets and applications and is expected to fade away over the coming years.

The PV industry's increased focus on high efficiency crystalline silicon cell technologies has resulted in yet another monocrystalline wafer variant being introduced to the market: the 'n-type', or negatively doped products. Doped inversely to today's standard p-type substrates, these wafers are the preferred choice for high efficiency crystalline cell technologies, such as interdigitated back contact cells (IBC), heterojunction (HJT) and passivated contacts, often referred as 'TOPCon'. With a few companies now producing these advanced cell architectures in volumes, n-type wafers gained close to 10% market share in 2021, but are expected to be even stronger in the coming years — increasing to around 20% in 2022, and over 70% by 2032, according to the 13th edition of the International Roadmap for Photovoltaic (ITRPV) released in April 2022.

Increasingly larger wafer formats

A low hanging fruit in augmenting module power without switching to a whole new cell technology is to use larger wafers. Module power, being a function of size, gets a boost by adopting larger silicon substrates. But unlike designing larger modules with a higher number of cells, this improvement in power does not involve increasing the voltage, thereby lowering the balance of system (BOS) costs. Said simply, building high-power modules using larger wafers is an effective way to reduce PV system costs. The benefits are so

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compelling that the entire solar process manufacturing and supply chain has been adapted to facilitate the deployment of very large wafer-based PV products.

'M0 wafers' (6 inch or 156 x 156 mm side length) were more or less the only mainstream wafer size for many years. In 2017, a new format took over, called M2 (156.75 x 156.75 mm). In 2018, the first companies introduced G1, a full square 158.75 mm format. The same ingot used for producing G1 can also be used for making M6 wafers with a larger area and side length of 166 mm, but in a pseudo-square format, resulting in a better cost-performance ratio. Starting in 2019, and for a short period of time, it appeared that M6 was going to be the largest wafer size for the foreseeable future. But within a mere span of a few months, a full square format with 210 mm side length called G12 was introduced, which is the largest commercially available wafer size today. By the end of 2019, modules based on this size had started marking their presence. In 2020, another alternative size was introduced, the M10, with a side length of 182 mm and in a pseudo-square format. During the initial days as these new formats came into being, the market was flooded with multiple wafer sizes. Today, M6, M10 and G12 are considered mainstream sizes. And while it is almost certain that the M6 is going to fall off the mainstream soon, its successor remains undecided yet — M10 or G12. Integrated companies are generally promoting M10 and companies with no strings attached to wafer production are usually jumping directly to G12.

According to ITRPV 2022, M10 wafers will become the dominant species this year with a share of greater than 30%. G12 is supposed to reach a 20% share this year, taking over the lead at the beginning of the next decade, by which time no smaller formats than the two will be available anymore. The roadmap anticipates the introduction of even larger formats than G12.

Cells

Increasing efficiency and reducing costs are the two key topics that govern technological innovations at the cell level today. The PV industry has been evaluating several advanced cell technologies such as HJT, TOPCon and IBC to strike the right balance between cost and performance to move beyond today's incumbent, PERC.

PERC – still the state of the art

With basically all recent gigantic solar cell manufacturing capacity expansions based on Passivated Emitter Rear Contact (PERC), this cell architecture has been the state-of-the-art technology for the last few years. A considerable price drop for PERC production equipment paved the way for multi-GW scale expansion in China. PERC progressed at a rapid pace in terms of cell-efficiency improvement of greater than 0.5% absolute per year until it slowed down recently. The mainstream commercial efficiency of several leading cell manufacturers is about 23.2%, marginally higher than what is stated as "above 23%" in last year's edition. With the flexibility it offers in using larger wafers, PERC has further strengthened its position as the technology of choice. Another bonus is its bifaciality, as it is very simple to tweak PERC into a cell that produces power from both sides without adding to costs. With that said, the bifaciality of this technology is on the lower side among the crystalline solar cell varieties.

Another interesting development that is relevant for PERC cells is gallium doping. The historically positively doped (p-type) nature of ingots for monocrystalline wafers, mostly with boron, has been the root cause for a degradation mechanism called light induced degradation (LID), an issue not seen in negatively doped wafers (n-type). Using gallium instead of boron helps p-type overcome this inherent disadvantage, resulting in gallium to become the new standard and now reaching a level of around 98%, according to ITRPV 2022.

PERC has everything – a well-established supply chain, high throughput, efficient production equipment, and compatible process consumables. The technology is at its peak in terms of process optimisation, providing the best cost performance ratio today. Despite the little improvements over last year, PERC is hitting its commercial efficiency limits; there is no clear pathway to improve the efficiency beyond current levels in the industrial production environment. While record PERC cell efficiencies do reach around 24%, such production practices are not cost effective for mass production, at least not yet. However, PERC still offers some cost reduction potential, especially on the equipment side. Some manufacturing processes still have room for further improvements to reduce CAPEX and/or OPEX, and efforts to squeeze out the latest

efficiency potential are ongoing. But the big question today in terms of trying to go beyond the current cell efficiencies is: What next?

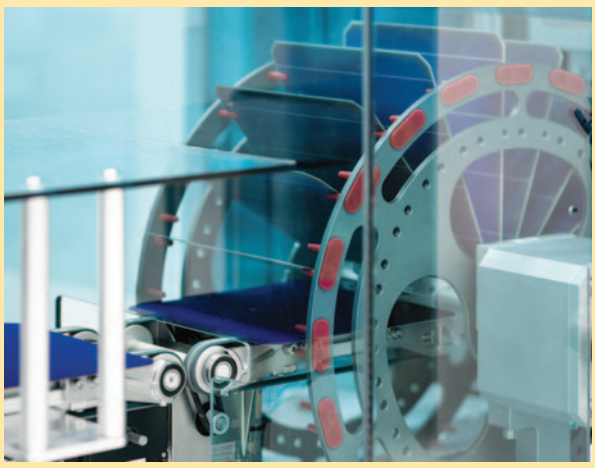
Passivated contacts (TOPCon) – a logical successor to PERC

The next evolutionary step in solar cell technology following PERC is likely to be Passivated Contact cells (a passivated contacts technology developed at Germany's Fraunhofer ISE), or TOPCon as it is often referred to. These cells use a sophisticated passivation scheme adapted to advance cell architectures with an aim to reduce recombination in the electrical contact region. Implementing TOPCon requires only a few additional processing tools over PERC. Theoretically speaking, TOPCon shows the highest ultimate efficiency potential of all crystalline silicon (c-Si) cells at 28.75%. But in practice, research institute ISFH has achieved a record performance level of 26.1% with its POLO structure, which is passivated contacts in combination with IBC architecture adapted on a p-type base wafer in lab scale. In the industrial environment, JinkoSolar remained at the top in record efficiencies for commercial cell size last year, reaching 25.25%, and even 25.4% in October. While Trina Solar topped this level with an efficiency record of 25.5% in late March 2022, Jinko reclaimed the crown in April, reaching 25.7%. When it comes to industrial implementation, TOPCon has only a handful of followers so far, as there were issues with certain production equipment. Now, not only are there workarounds besides the new tools that have been developed to overcome those limitations, the machines are also capable of processing larger wafers. With these developments in place, TOPCon is seeing new traction. Next to TOPCon cell pioneer Jolywood, the most prominent proponent is JinkoSolar, which is targeting 16 GW of cell/module production capacity by year-end.

Heterojunction – fewer production steps to high efficiencies

Heterojunction technology (HJT) has demonstrated the highest crystalline silicon cell efficiency so far — set by Kaneka in 2017, it continues to hold the overall cell record for silicon solar cells at 26.63%, based on a combination of HJT and IBC. When it comes to the pure HJT structure, the highest efficiency for commercial sizes was 26.3% reported in October 2021 by LONGi. This was followed by a series of announcements, but in different categories. LONGi also holds the top in p-type HJT at 25.47% and 25.4% for indium-free HJT cells. Recently, Chinese production equipment supplier Maxwell announced a certified efficiency of 25.62% for another HJT variant — a low indium and silver coated copper gridlines-based cell.

Many industry players have expressed significant interest in taking the HJT path, about 80 GW globally towards the end of 2021. The actual production capacities, though, have been much lower, in single-digits. In early 2022, Meyer Burger announced the construction of a 400 MW cell/module line, to be completed by the end of year in Arizona. This is in addition to its 400 MW capacity in Germany, which is being expanded to 1 GW during 2022. One of the most recent developments in the HJT arena is Enel Green Power's (EGP) 118 million EUR grant agreement with



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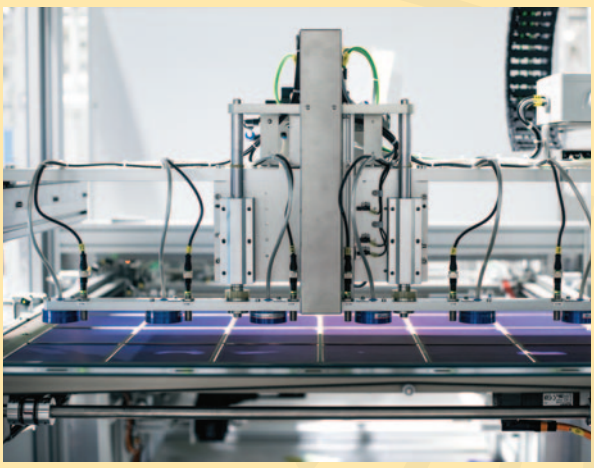

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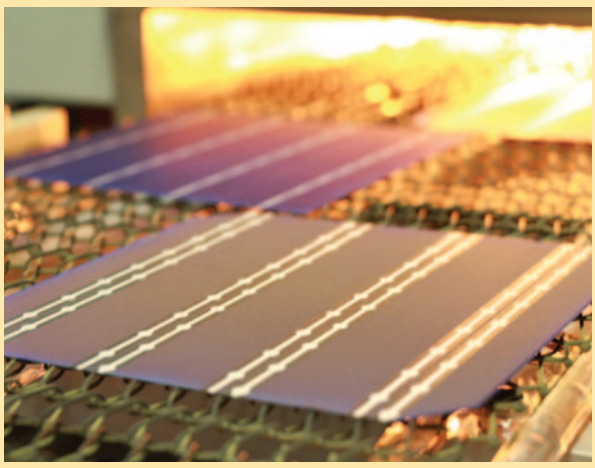
the European Commission. This agreement will contribute to the Italian company's 600 million EUR expansion of its 200 MW 3Sun HJT cell and module solar panel fab to 3 GW by July 2024. While a few companies, such as HuaSun, have entered commercial production with HJT in China, several leading Chinese module manufacturers have also started R&D and process development lines with HJT. The latest HJT news comes from India's Reliance which, after acquiring Norway's REC last year, has now gone on to order 4.8 GW HJT cell production equipment from China in April.

HJT has several advantages over traditional crystalline solar cells — a leading low temperature coefficient, the highest bifaciality of all cell technologies and much fewer production steps. But requiring a completely new line, the CAPEX involved is considerably higher than for baseline PERC. With several Asian tool vendors venturing into the development of deposition equipment for HJT, investment costs have already started to come down. The technology also suffers from higher operating costs, mainly due to higher silver usage vis-à-vis PERC. Alternatives, such as using copper coated silver particles instead of pure silver that can reduce manufacturing costs, are in the final stages of evaluation.

IBC – hiding contacts on the rear for record efficiencies

IBC is another advanced cell technology that has been around for quite some time. The technology has been the long-time efficiency champion among crystalline silicon solar cells. The concept is all about moving the entire metallisation scheme of the solar cell onto the rear of the cell, including fingers and busbars. That means, the front surface of the cell has no shading at all, while the rear of the cell features contacts of both polarities. The US company SunPower was the pioneer in this cell technology segment. Its IBC cell — now manufactured by Singapore based Maxeon Solar, a SunPower spin-off and JV of its parent company TotalEnergies and Chinese wafer manufacturer TZS — reaches a production efficiency of 24.9%, while the commercial potential is at around 25.5%.



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The most active challenger in this cell segment is the German research institute ISC-Konstanz, which developed a less complicated IBC cell design. Its Zebra cell essentially works as a line of extension to PERC in a sense that production lines used for PERC can be upgraded to process IBC cells, while it is adapted onto n-type wafers. ISC first commercialised the process with the Chinese company SPIC, reaching an efficiency of around 24%, and is now expanding with partners in Europe. The solar module with the highest commercial module efficiency of 22.8% is based on IBC cells from Maxeon Solar.

Tandem – Towards 3rd Gen PV cells

Not only PERC, but all single-junction crystalline cell efficiencies as a whole will reach their practical efficiency limits soon. Considering that HJT's best commercial cells are at around 24.5% today, the practical limit of around 26% will be reached in a few years. At that time, the industry must be ready with the next generation of multi-junction technology, where different materials are stacked to harvest a larger part of the light spectrum. There are many different options for choosing materials and combinations. As of today, the most promising candidate seems to be a c-Si/Perovskite tandem cell structure. Oxford PV is very active in this area, and in 2021 has finished building a first 100 MW manufacturing unit for c-Si/perovskite tandem cells in Germany to commercialize the technology, targeted to start full production in 2022. The British company is also a long-time efficiency leader in this field: Oxford PV demonstrated the latest world-record efficiency of 29.52% at the end of 2020 and held it until November 2021, when Germany's Helmholtz-Zentrum Berlin (HZB) took over with a 29.8% cell. The tandem structure offers the potential to exceed efficiencies beyond 35%.

Modules

Using high efficiency cells has been the major means of improving module performance. However, a few advanced module technologies have enabled improved module performance independent from the cell level. This can be attained by improving the light management and/or reducing resistance losses. While light management often involves changing the BOM, the effort to reduce electrical losses requires modifications in module making. Alternative approaches that have evolved are advanced module technologies — half cells, more busbars, multibusbars (MBB) and shingling.

Half cell — cutting down the losses involves cutting a cell into two pieces. The logic behind the approach is that the cell's current, which greatly influences resistance losses, gets reduced proportionately to the number of slices a cell is cut into, thus reducing the losses. Due to the simplicity of its implementation and final gain in module power, which is about 5 to 6 W, half-cell technology has emerged as a standard in state-of-the-art module fabs. With the trend to very large wafer sizes, a solar cell's current is rising accordingly, thereby augmenting its losses, so slicing the cell is becoming even more compelling. An industry-wide practice to slice cells is applied to all larger formats starting from M6. Slicing cells also leads to edge losses and the effect is more pronounced in high efficiency cell technologies such as HJT. To overcome this limitation, PV manufacturers are seriously evaluating processing of half wafers, i.e., instead of cutting a fully processed cell, the wafer is sliced into half and then processed into half cells. The half-cell term might just become a figurative term as PV producers are evaluating slicing a cell into 3 or even 4 pieces.

MBB – more and more busbars

The multi-busbar (MBB) approach in principle is an extrapolation of the 'more busbars' concept. Here, a higher number of wires (currently 9 to 12) is used instead of flat solar ribbons to electrically connect the solar cells in a module. The advantages are many: reducing resistance losses, lowering current density carried by each busbar, better optical properties enabled by the round shape of the interconnection, and higher tolerance to cracks in cells. Employing MBB makes busbars so close to each other that the finger width can be reduced significantly, thereby reducing silver paste consumption. While the current practice is to still use busbars on cells, MBB in principle also enables replacing the busbars with small soldering pads, which paves the path for further reduction in silver paste consumption. The shift towards MBB has become much more apparent with the industry's move towards larger wafer formats.

Mind the gap – improving space utilisation

Increased wafer and module size calls for better utilisation of the module area. Packing solar cells as densely as possible makes sense in order to reduce the module area to the maximum possible extent, and thus positively impact module efficiency.

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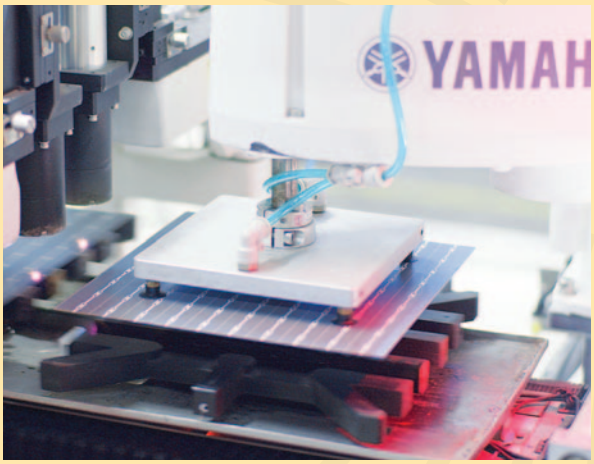

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Shingling is one approach that eliminates the spacing between the cells in a solar module completely, while providing the panel with a stunning homogeneous optical appearance. In addition to aesthetics, this approach also enhances module performance. The benefit comes from two ends — eliminating the dead areas as well as slicing cells into several pieces, the latter of which is a superlative of half cells and its benefits, in principle. Shingling involves slicing the fully processed cell into 5 or 6 strips that are interconnected by overlapping at the edges, like roof tiles. However, the technology is mostly protected by patents owned by SunPower and Solaria. This is why companies started looking for workarounds.

Tiling Ribbon (TR) is one such approach commercialised by JinkoSolar. In this alternate approach, a round ribbon, similar to the one used in the MBB approach, is pressed flat exactly where it would bend in order to connect the top of the next cell. Instead of placing the cells side-by-side, the cells slightly overlap. The technology is very similar to shingling as far as overlapping is concerned, but it uses an interconnection media and, at the same time, avoids laser stripping of cells into several pieces, even though JinkoSolar uses half-cells.

If not eliminate the inter-cell spacing completely, the majority of the module manufacturers are trying to reduce it. The approach closely follows on the heels of Tiling Ribbon up to the level of interconnects that are pressed flat between the cells. However, instead of overlapping, the gap between the cells is narrowed considerably. While the traditional cell layout maintains a cell gap of 2 mm, the latest module products of several leading module companies have reduced this gap to between 0.6 and 0.9 mm.

Reducing reflection – optical enhancers to augment solar absorption

While the above approaches actually are means to boost the electrical performance of a solar module, there are also methods to enhance optical performance. While using circular copper wires is helpful in reducing the optical shading footprint of the interconnection, employing **reflective ribbon** may even add to optical gains. The fundamental principle is simple: by making the interconnect surface reflective, the light is reflected back onto the active module area. While some European ribbon manufacturers have commercialised such products in the past, LONGi recently started employing its proprietary triangular segmented ribbon in its latest module range using M10 wafers.

Employing **antireflective coated glass**, which has been a standard for many years, is also part of enhancing a module's light management. Using **white EVA** on the rear side supports this effort. White EVA is used as the bottom encapsulation layer, which in a finished module increases the light reflection from the cell gaps, resulting in power gains of up to 5 W. The effect is more pronounced when using bifacial cells in the monofacial module configuration.

Bifacial – power from front and back

The bifacial module design enables power production from the front as well as from the rear side of a PV device. Bifacial capabilities depend on the cell technology, but it requires more optimisation at module level compared to cell level. Beyond PERC cells, which can be tweaked into bifacial without any additional costs, every advanced cell architecture, including IBC (Zebra), are naturally bifacial. The prerequisite at the module level is to replace the opaque backsheet with a transparent rear-cover, be it glass or transparent backsheet, both of which are fully mature and available commercially; however, the glass-glass configuration is the preferred option today.

Bifacial, mostly used in utility-scale PV plants, helps in improving the power yield of the solar system and ultimately reducing the LCOE. The power gain varies from 5% to 30% depending on the solar cell technology used, location, and system design. According to the latest ITRPV edition, bifacial module's share of around 28% in 2021 is expected to increase further to 60% in 2032, while the share of glass-glass modules is anticipated to grow from 25% in 2021 to above 50% in 2032.

All about power – towards higher wattages

One of the most important trends in today's PV world is realising higher module power using larger wafers. While building modules with 600 W+ panels on a multi-GW scale was the topic last year, modules with power ratings as high as 700 W are already on the

market. In addition to employing larger wafers, module makers are also implementing a blend of advanced technologies in a single product to increase output, such as bifacial design, cut cells, MBB and narrowed cell gaps, or no gaps (see above). At the same time, module companies are increasingly including downsized versions of the new breed of modules in in their product portfolios aimed at rooftop applications. While also employing very large and half or third cut cells, the cell number in these products is reduced to enable production of smaller panel formats that still have high power ratings of around 400 W but can be lifted by craftsmen, much like the earlier rooftop module generation. With the advent of larger wafers, the variety in module configurations with different cell counts has increased to 78, 72, 66, 60, 54 and even 40, or to be precise, the equivalent (if a 72-cell configuration is cut in half, the module has 144 cells, for example).

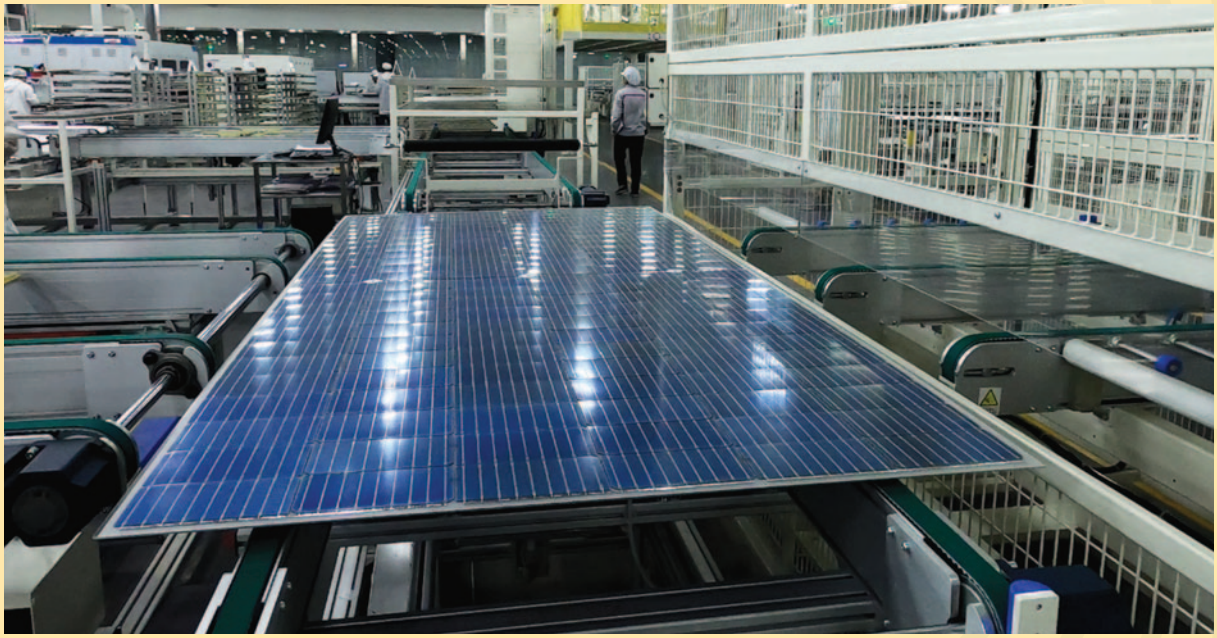
Thin and large – a CdTe solar story

While there are several thin-film technologies, including CIS in solar is mostly represented by CdTe technology, produced primarily by US company First Solar. The company's latest and top-of-the-shelf product is its Series 6 Plus with a large form factor and up to 470 W, a superior temperature coefficient, better spectral response, a true tracking advantage as shading has less impact on thin-film modules, and reduced soiling, which results in high energy yields and low LCOEs. First Solar, with a total production capacity of around 8.4 GW in 2021 in the US and Malaysia, has plans to increase capacity to 16 GW by end of 2024. Its Series 7 fab in Ohio is currently under construction and expected to start initial production in H1/2023 and the first India fab is supposed to be launched by the end of 2023. First Solar's Series 7 will be 570 W monofacial panels.

Inverters

Big, small, and very small

The importance of the inverter's role in PV systems has only been increasing with the arrival of digitalisation in the solar sector. Primarily used in the past as a means of converting DC into AC power, today, inverters are the true brains of solar PV systems. They cope with all varieties of storage systems, are a key tool for efficient solar power plant operation & management, also regarding grid services, and are a partner of intelligent energy management systems in homes or the solar mobility world.



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In terms of size, inverters are getting bigger on the one hand, with central inverters now available over 5 MW to address the needs of ultra-large utility-scale plants. At the same time, producers of string inverters are offering increasingly higher power solutions as well. While the maximum power rating used to be around 250 MW in 2020, the largest products now reach up to 350 MW, designed to compete in the field of large-scale power plants.

An important development for string inverters is their compatibility with the new module generation featuring very large cells, which have different needs regarding current and voltage. The typical increase in current with larger wafers such as M6, M10 and G12 is 9%, 28% and 75%, respectively, compared to the earlier 156 mm wafer 'standard'. The earlier generation of inverters with a 13 A maximum current limit were only compatible up to M10 modules, but not so compatible with G12 modules. Now every leading inverter supplier has a high current variant that can manage different configurations of G12 modules.

There is also the popular concept of commercial-size inverters with power optimisers to operate a solar system more efficiently, which has found new proponents; while module-integrated micro-inverters are also seeing increased traction, as bifacial modules and a growing rooftop market with a focus on safety provide the grounds for a stronger growth of module-level power electronics. Probably the most visible trend in the residential rooftop segment is the hybrid inverter for solar & storage systems, which basically every inverter manufacturer has added to its product portfolio as the prosumer idea quickly gains in popularity.

Mounting systems

Following the Sun

Trackers have become a standard for large utility-scale solar power plants in southern regions but are increasingly used in less sunnier areas. They operate reliably and, depending on the location, the investment over fixed mounting systems is more than compensated by lower LCOEs. Moreover, they are also interesting from a power market perspective as trackers enable solar systems to supply solar electricity more evenly over the course of a day.

After trackers were re-designed a few years ago to handle bifacial modules, so that they have open access to the grounds, in order to be able to generate power unhindered on their back-side, the latest updates have been much sturdier tracking systems to resist stronger wind loads as they have to carry the very large module formats with power ratings of 600 W+.

Solar systems and innovative applications

With developments in module making having hit the fast track, and demand for solar quickly increasing, the industry is finding increased applications for PV to address the need for the vast amounts of space that solar will need in the future. Building integrated PV (BIPV), agricultural PV (Agri PV), Floating solar (FPV) and PV integrated into vehicles (VIPV) are multi-functional solar applications, offering the feature of power generation and other benefits through co-location. These applications have specific requirements for PV products in terms of weight, format, size, shape and even colour. Though still niche, there is huge interest from the industry and policy in these non-traditional solar applications.

Floating PV – PV on water

A quickly growing application for PV is to make use of water as an installation site instead of land. This approach is called floating solar (FPV) — the system setup is somewhat like ground mounts, except for the fact that all panels, and often the inverter, are fixed on a floating platform with an anchoring system. While this approach costs a bit more to build, it has several advantages: it saves on land for PV installation, and is especially beneficial for locations where land is scarce. The benefits are even more apparent when combined on commercially-used water sites for drinking water, fishing, hydropower generation sites — the floating systems help reduce water evaporation and improve water quality and, in the case of hydropower plants, can even use the transmission infrastructure. The setup also promises higher power yields compared to ground-mounted systems due to the cooling effect from the water underneath and a higher power when using bifacial, benefiting from the reflection from the water. According to a 2018 report from the World Bank, even under conservative assumptions, floating PV can grow up to 400 GW if only 1% of the potential area is used. Indeed, FPV systems are beginning to sprout across the globe — growing both in number and size. In January 2022, the world's single largest floating solar power plant with 320 MW was grid-connected in China, and

gigantic FPV projects larger than 2 GW each are being developed in both Korea and Indonesia.

The World Bank has also published a Floating Solar Handbook for Practitioners, to set up best practices in FPV deployment and offer practical guidelines. Building on this, in 2021, technical advisory DNV, which expects a FPV pipeline of over 10 GW by 2025, has released, together with an industry consortium, detailed practical recommendations for FPV project development. These recommendations focus on 5 key topics, namely site conditions assessment, energy yield forecast, mooring and anchoring systems, floating structures, permitting, and environmental impact.

Building integrated PV – solar in architecture

Though direct integration of solar modules into a new building makes a lot of sense from a cost and aesthetics perspective, and special products for this have been offered for many years, the enormous potential of BIPV remains largely untapped. Only a few small module manufacturers have been successfully serving this segment. Architects and developers have shown little interest in solar power. With prices for solar modules having come down dramatically, the interest in rooftop solar quickly growing also in Asia and the first governments making solar mandatory for new buildings, it seems BIPV's time in the sun, so to speak, is not too far. A sign for this next chapter of BIPV could be globally leading module manufacturers starting to offer commercial BIPV modules, research institutes having developed module products that can be made in literally any colour.

Agri PV – double usage of land

Any strategy to utilise the space required for a solar installation more efficiently is welcomed by more than just the solar sector. Agro-photovoltaics, or Agri-PV, is a fairly new mounting technology and method, which enables the use of agricultural land for both food production and solar power generation at the same time. Like Floating PV, the initial costs with Agri-PV are higher to start with, as the mounting structures are much more sophisticated, but it does offer many benefits. In addition to increasing the resource efficiency thanks to dual-land use, Agri-PV also enables farmers to diversify their income, thus helping to work against the rural population exodus. For farmers, it actually means a triple-win, as the shading of the PV system enables higher crop yields, lower water use and clean energy generation. Although in its very early stages, the potential is huge; pilot Agri-PV projects are being developed in an increasing number of countries, many companies are working on product solutions and project developers are beginning to look seriously into this co-location concept for solar power.

Vehicle-integrated-PV – electrifying transport

As the name suggests, **Vehicle-integrated PV (VIPV)** is the segment where PV panels are integrated into vehicles, now especially electrical cars. Like with buildings, there is also a subsection of this segment, which is vehicle attached PV, where the PV panels are attached to the roof of vehicles, usually buses, trucks, or even trains. However, VIPV is much more complex as it has to take the exact shape of the component it

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is replacing, typically the car roof. German research institute Fraunhofer ISE has developed such a solar car roof, integrating solar cells with an output of around 210 W/m² that enable generation of sustainable electricity onsite for a daily range of about 10 km with an average electric car on a sunny day.

Solar & battery storage – a perfect match

Stationary battery storage is quickly gaining in popularity in an increasing number of solar markets; in particular, in established residential PV rooftop markets, where the technology already supports the dissemination of solar self-consumption systems, and soon will be crucial to bring solar penetration to the next level. This trend is visible with most of the major inverter makers now offering their own batteries with their hybrid inverters. Solar & storage of course offers savings on high retail power costs, guaranteeing low cost and clean power with increasing electricity needs, among others for electric cars. Combined with a heat pump, it also allows to electrify heating, posing a green hedge against high prices of fossil fuels (gas and oil), which have skyrocketed in Europe in the winter 2021/2022 as a result of Russia's invasion of Ukraine.

Green Hydrogen – renewables are the only way to a sustainable hydrogen economy

Regions, countries and a quickly growing number of companies around the world have discovered hydrogen as the next big thing for the energy transition. But due to its comparatively low efficiency, it makes sense to prioritise direct and lowest cost electrification whenever possible, such as replacing ICE cars by electric vehicles. Yet, hydrogen for decarbonisation of the so-called 'hard-to-abate' sectors — heavy industry (cement, steel, chemical), heavy-duty transport (shipping, aviation) — is the appropriate solution, if generated with renewable energy. Multiple GW of renewable hydrogen facilities have been announced over the last year, in particular in Australia, MEA, and the European Union, which has set a green hydrogen target of at least 40 GW by 2030. One example for today's hydrogen hype was a June 2021 announcement about plans for a 30 GW hydrogen facility based on 45 GW solar & wind in Kazakhstan, a country with a little more than 1 GW of solar installed so far. However, this year, two of the largest solar markets also published their green hydrogen roadmaps. In February, the Indian government officially announced the country's Green Hydrogen/Green Ammonia Policy, aiming for 5 million tons of green hydrogen by 2030. In March, the world's largest solar power market, China, released its hydrogen policy under which, by 2025, it targets to produce a very modest amount in the range of 100,000 to 200,000 tons of green hydrogen annually. However, the Russian invasion of Ukraine, which is also fought about supply of fossil fuels, has intensified the discussion about accelerating green hydrogen developments in Europe, which is likely to have knock-on effects in other regions as well.

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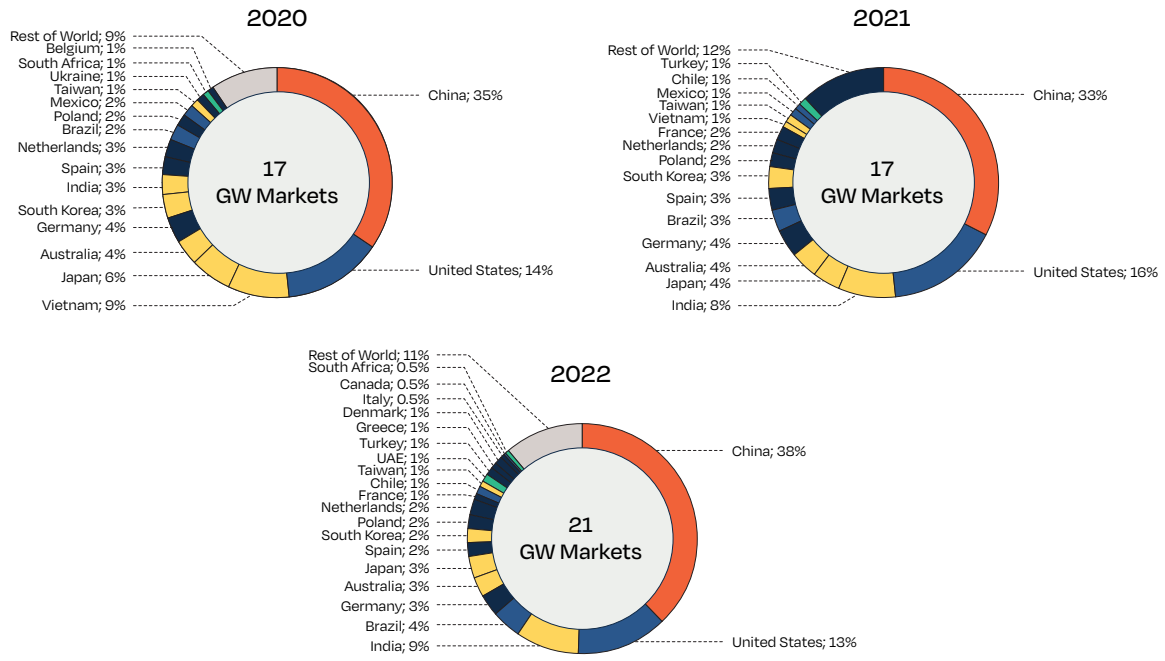
4 GW-scale markets

4.5 MW, Tombeboeuf, France. © TCO Solar.

In 2021, 17 countries installed more than 1 GW of solar; a draw with 2020's number, when 17 GW-scale solar markets were also counted (see Fig. 32). Last year's GMO announced 18 GW markets in 2020, however the annually installed capacity in France turned out to be less than what was expected, and is therefore not included anymore.

FIGURE 32 GW-SCALE SOLAR PV MARKETS 2020-2022



When comparing 2021's number with last year's forecast, it appears we were optimistic as we anticipated 20 GW markets for 2021. The lower number of 17 GW markets can be attributed to various causes, the most apparent being the sustained high solar price throughout the year, which delayed several installations across the globe. Our outlook, however, remains positive. The strengths of solar PV remain, and more countries are turning to renewable sources to shield their economies from high electricity prices caused by natural gas, as well as to increase their energy sovereignty, after the invasion of Ukraine has reshaped the dynamics in energy geopolitics. Based on this outlook, we expect growth to continue, reaching 21 GW-scale markets in 2022, 29 GW-scale markets in 2023 and at least 34 GW-scale markets in 2024.

Like in the previous Global Market Outlooks, national solar associations from markets that have added more than 1 GW in the previous year have been invited to present their local expert views on their home markets (which sometimes differ from our estimates that are based on several sources). Many of these associations, like our organisation, are members of the Global Solar Council (GSC), which is a long-time supporter of the Global Market Outlook. For the GW-scale countries for which we did not receive contributions from local associations (this time, Germany, Japan, South Korea, Taiwan, United States), we have written the overviews based on our SolarPower Europe research.

1.	**CHINA** China Photovoltaic Industry Association (CPIA)
2.	**UNITED STATES** SolarPower Europe
3.	**INDIA** National Solar Energy Federation of India (NSEFI)
4.	**JAPAN** SolarPower Europe
5.	**AUSTRALIA** Smart Energy Council
6.	**GERMANY** SolarPower Europe
7.	**BRAZIL** Brazilian Photovoltaic Solar Energy Association (ABSOLAR)
8.	**SPAIN** Unión Española Fotovoltaica (UNEF)
9.	**SOUTH KOREA** SolarPower Europe
10.	**POLAND** Polskie Stowarzyszenie Fotowoltaiki (PSF) & Polskie Towarzystwo Fotowoltaiki (PV Poland)
11.	**THE NETHERLANDS** Holland Solar
12.	**FRANCE** Syndicat des Énergies Renouvelables (SER)
13.	**VIETNAM** GIZ Energy Support Program Vietnam
14.	**TAIWAN** SolarPower Europe
15.	**MEXICO** Mexican Association of Solar Energy (ASOLMEX)
16.	**CHILE** Chilean Solar Association (ACESOL)
17.	**TURKEY** GÜNDER

1. China

Overview of PV developments

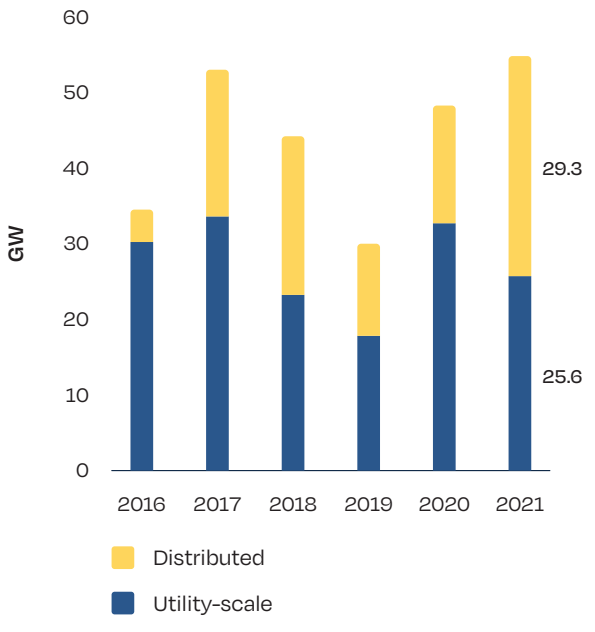
China installed 54.88 GW of new photovoltaic capacity in 2021, a year-on-year increase of 13.9%. While it was lower than initially expected, it still set a new world record by beating the 53 GW installed in 2017. By the end of 2021, China's cumulative photovoltaic grid-connected capacity had exceeded 300 GW.

China's PV manufacturing continued to expand in 2021 despite the impact of price fluctuations throughout the supply chain. In 2021, the country produced about 505,000 tonnes of polysilicon, a year-on-year increase of 27.5%; silicon wafer production reached 227 GW, a year-on-year increase of 40.6%; cell production totalled 198 GW, a year-on-year increase of 46.9%; and module output stood at 182 GW, growing 46.1% over the past year.

Targets

China's Action Plan for Carbon Dioxide Peaking Before 2030 aims to increase the consumption of non-fossil energy to about 20%, reaching 25% by 2030, while its total installed wind power and solar energy capacity is planned to exceed 1.2 TW. In order to achieve its goals of carbon peaking and carbon neutrality, China plans to establish and improve an economic system for green, low-carbon and circular development, and incorporate carbon peaking and carbon neutrality into the overall layout of ecological construction of civilization.

FIGURE GW1.1 CHINA ANNUAL SOLAR PV MARKET 2016-2021, BY CPIA



SOURCE: CPIA. © SOLARPOWER EUROPE 2022

Driver for solar Growth

As the move towards renewable energy gathers pace around the world, the society as a whole continues to turn towards PV as the most reliable source of renewable energy, in turn creating a conducive environment for the development of the sector. Solar has entered a stage of large-scale, high-proportion, and high-quality development, while its business model has become more diversified, driving the enthusiasm for photovoltaic installations.

Utility-scale vs. distributed & rooftop solar development

At 29.28 GW of capacity installed, the distributed sector accounted for 53.4% of total new installations in 2021, exceeding 50% for the first time in history. Residential capacity increased 113.3% year on year with total installations of 21.6 GW — a 39.4% share of new capacity added in 2021. Looking ahead, the distributed sector is expected to be the bright spot in the solar story.

Challenges

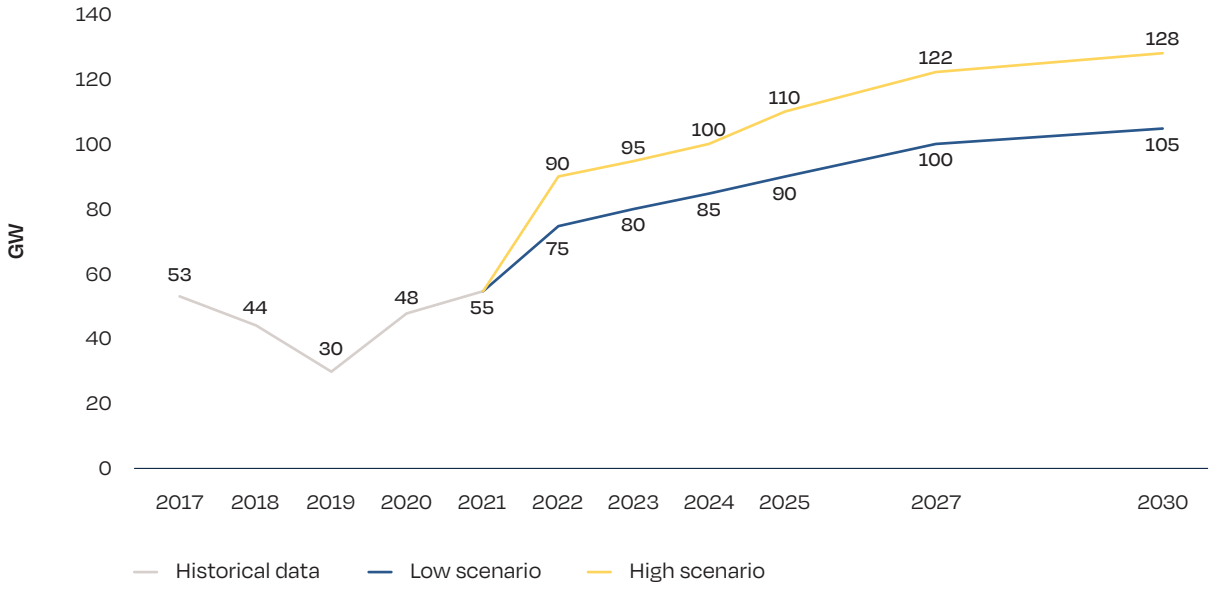
In 2021, the PV supply chain has been majorly impacted by price increases. On the one hand, the global commodity price inflation has resulted in various levels of price increases at all stages of the value chain. On the other hand, some components have experienced supply and demand imbalances, especially with regard to polysilicon. This supply shortage has driven polysilicon prices up by more than 200%.

Over the past decade, investment costs for PV systems have steadily declined in China. In 2021, however, with the price increases across the supply chain, the prices of PV systems and components have also increased. Reducing solar investment costs while keeping it competitive is a challenge that needs to be solved.

Outlook

Today, "zero carbon" or "carbon neutral" are part of almost every country's climate goals, and the role of photovoltaics in this move towards renewable energy is one of note. Looking into the future, the application of solar power will grow in scope and the application mode more diversified, as the utilisation levels also scale new heights. The global PV market is expected to maintain its trend of rapid growth.

FIGURE GW1.2 CHINA PV MARKET SCENARIOS 2022-2030, BY CPIA



SOURCE: CPIA.

China expects its policy guidance and market demand will help continue the development of both centralised and distributed sectors in the future. In terms of centralisation, in order to promote the realisation of carbon peaking and carbon neutrality, China will vigorously develop renewable energy, and accelerate the planning and construction of large-scale wind and solar projects in desert areas. In February 2022, China's NEA and NDRC released *Opinions on Institutional Mechanisms and Policy Measures for Green and Low-Carbon Technologies*, a policy document which specifies that the administration establish a land and space management mechanism to develop and utilise low-carbon energy in desert regions. With distribution, the aim is to install PV on at least 50% of new public building rooftops by 2025. Backed by these ambitious targets, CPIA assumes that the market will reach up to 90 GW in 2022, before crossing the 100 GW annual installation threshold in 2024 in a High Scenario and in 2027 in a Low Scenario.

Author: China Photovoltaic Industry Association (CPIA).

2. United States

US Solar overcame COVID-19 but is now facing international trade challenges

Overview of solar PV development

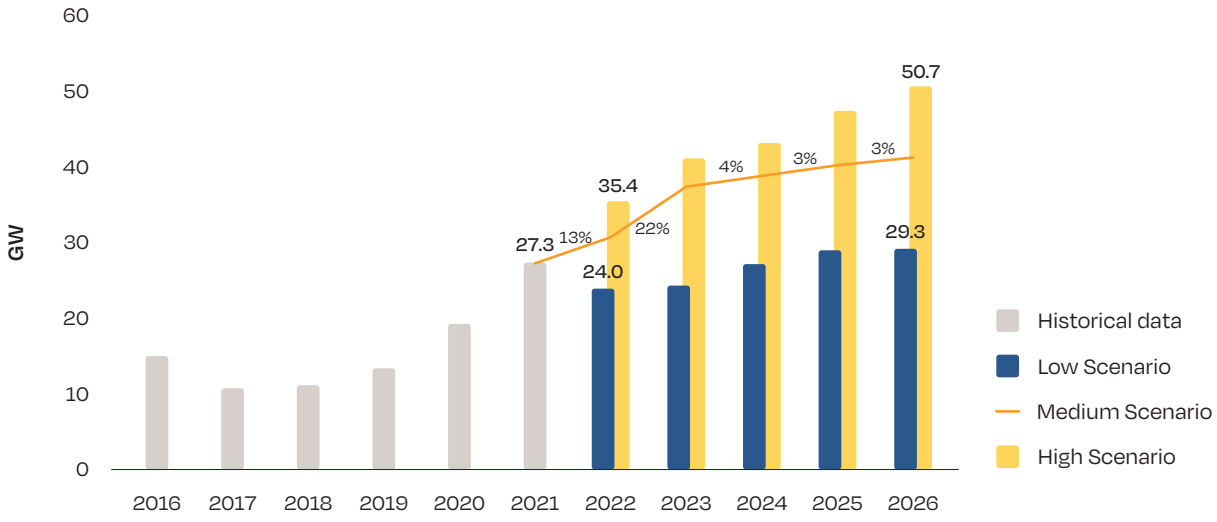
The US solar sector has shown strong resilience in the face of COVID-19, installing a record 27.3 GW in 2021, a 42% year-on-year growth from 2020. Solar power accounted for 46% of all new power installations in the country, making it the third year in a row that solar holds the first spot.

Utility still remains the major segment for installations in the country with 19.7 GW installed, up from 14.2 GW added in 2020. Supply chain disruptions and the ban on solar panel components coming from the Xinjiang region has only had a slight impact on the sector's growth so far, although there continues to be uncertainty about how these factors are going to play out in the future. The total pipeline is experiencing continued growing, standing at a record level over 80 GW at the end of 2021. However, prolonged uncertainty in terms of module price and availability of equipment is forcing several developers to delay their installations by several quarters. Interestingly, Texas has dethroned California as the number one solar state of the country for the first time, thanks to the strong growth of its utility segment.

If the large-scale segment still takes the lion's share of newly added capacity, it is the residential sector that experienced the sharpest increase with a 51% year-on-year growth to reach 4.9 GW, from 3.2 GW in 2020. On the other hand, the commercial segment remains the smallest in the country in absolute numbers as well as in growth, with only 2.7 GW installed, though up 18% from 2020. Both segments have been heavily supported by the Investment Tax Credit (ITC), which offers a 26% tax credit on solar projects. With this incentive decreasing to 22% in 2023 and all the way down to 0% for residential and 10% for commercial installations in 2024, it is still unsure how these segments will evolve with their primary driver gone.

If the reduction of the ITC will decrease solar's attractiveness, the indefinite postponement of the California Net Energy Metering (NEM) 3.0 proposal, which suggested to reduce the amount received for exported electricity, is a win for the development of the sector in the second biggest solar state of the country. A similar victory was celebrated in Florida in April where Governor DeSantis vetoed a law looking at reducing net metering.

FIGURE GW2 UNITED STATES ANNUAL SOLAR PV MARKET SCENARIOS 2022-2026



Our market forecasts for the next five years remain more optimistic than most solar analysts (see Fig. GW2). Under our Medium Scenario, we anticipate the market to increase 13% year-on-year and reach 30.8 GW in 2022, followed by another year of strong growth to 37.4 GW in 2023. Despite the progressive reduction of solar support mechanisms, we expect the market to stabilise at single-digit growth levels, exceeding 41 GW of annual installations in 2026.

Challenges ahead for the US solar market

The very positive outlook is being put at risk by the current investigation carried out by the US Department of Commerce (DOC) looking into imposing anti-circumvention tariffs on crystalline silicon PV modules and cells coming from Cambodia, Malaysia, Thailand and Vietnam. DOC is considering imposing a 50 to 250% tariff on solar products coming from these Southeast Asian countries. Considering that 65% of all module imports and 50% of cell imports originate from these countries, the solar sector could be severely impacted. A large number of companies have already reported project delays and cancellations, voicing concerns that over 70% of their pipeline could be cancelled following the introduction of such tariffs. With no domestic production for silicon solar wafers and cells today, and less than 5 GW of module production, mostly thin-film panels from First Solar, the US market is strongly relying on external production, whose level can only be assured by Chinese actors today. The US solar association SEIA warned that, as a result of the trade case, 24 GW of solar capacity planned in the next two years will not be built. While we remain somewhat more optimistic than most analysts, the danger of a strict anti-circumvention policy is well reflected in our Low Scenario, whose installation levels are lower than in the Medium Scenario by 6 GW (-22%) in 2022 and by 13 GW (-35%) in 2023.

On top of import tariffs, the solar industry in the US, like in other regions, is vulnerable to the general price increase that affected the whole value chain: from polysilicon to freight costs, prices continuously went up and were significantly higher than in 2020 for all segments.

Trade issues can also come in the way of US solar developers. In February, the Biden Administration extended the Section 201 tariffs on imported solar modules and cells for another 4 years, but increased the amount of tariff-free cell imports from 2.5 GW to 5 GW. In addition, US developers still have to deal with the June 2021 issued Withhold Release Order (WRO), which enables US Customs and Border Protection to detain solar module imports using silica from a Xinjiang based producer. While several MWs of detained solar modules were reportedly released earlier this year, uncertainty persists.

The form in which the Senate-stalled Build Back Better Act finally passes, if it does at all, could also mean big consequences for the solar sector, which has hoped to see an extension of the ITC that will end in 2023 and 2024.

Author: *Christophe Lits, Raffaele Rossi, Michael Schmela,* SolarPower Europe.

Austin, TX (United States).

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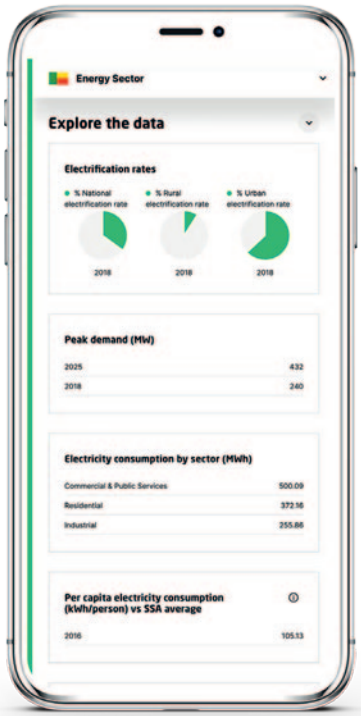

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3. India

Overview of PV developments

The average solar radiation in India is approximately 4-7 kWh/day for about 300 days each year. To utilise this vast potential, the Union Government of India has identified solar as a key pillar for its power supply strategy. India is engaged on the path to climate neutrality now more than ever. At the COP26, Indian Prime Minister Shri Narendra Modi pledged to cut India's total projected carbon emissions by 1 billion tonnes by 2030 and achieve net-zero carbon emissions by 2070.

Prior to this, under the Paris Agreement, the country's Nationally Determined Contribution (NDC) for the period 2021-2030 targets a reduction in the emission intensity of its GDP by 33-35% by 2030 from 2005 levels, as well as achieving about a 40% share of non-fossil fuel electricity generation capacity by 2030, with the help of technology transfer and low-cost international finance. The new and updated commitments include installing a non-fossil fuel electricity capacity of 500 GW by 2030, sourcing 50% of energy demand from non-fossil fuel sources by 2030, and achieving a 45% carbon intensity reduction over 2005 levels by 2030.

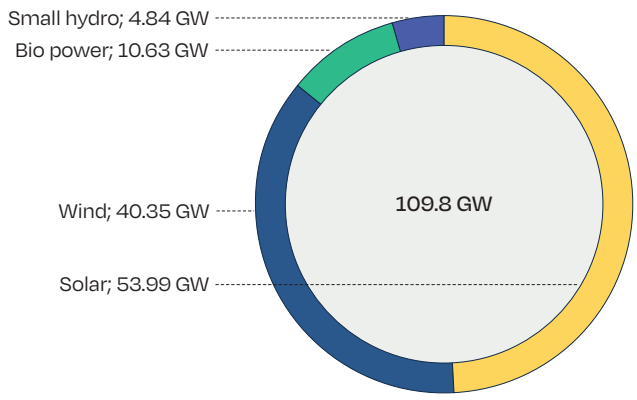
India's installed renewable energy capacity expanded by more than 2.5 times between April 2014 and January 2022. During the same time span, installed solar power capacity has increased by 19 times. India is now ranked fourth in the world in terms of renewable energy capacity, fourth in wind power, and fifth in solar power. Over the past 7.5 years, India has installed around 50 GW of solar. With an annual capacity addition of 14 GW of solar energy in calendar year 2021, India is expected to add around 26 GW of solar in 2022-23. By March 2022, the country reached a cumulative installed capacity of 54 GW.[2]

Solar/RE target

By the end of 2030, India's government targets total installations of 500 GW of non-fossil fuel based energy resources, of which more than 280 GW will be from solar power (utility and distributed), and around 140 GW from wind. India is on track to meet these objectives with a total installed renewable energy capacity of 109.8 GW (excluding large hydro), of which 12.76 GW was added between April 2021 and March 2022.

In the shorter term, the country has set the objective of reaching 100 GW solar capacity by the end of 2022, broken down into 40 GW of rooftop installations and 60 GW of large-scale projects. The Indian government's resolve for ambitious targets has already started paying dividends; however, in order to meet its 2022 target, it needs to install nearly 50 GW by the end of the year.

FIGURE GW3.1 RE-POWER MIX OF INDIA, BY NSEFI



SOURCE: NSEFI.

2 All installed capacity data in this article on India are AC capacities.

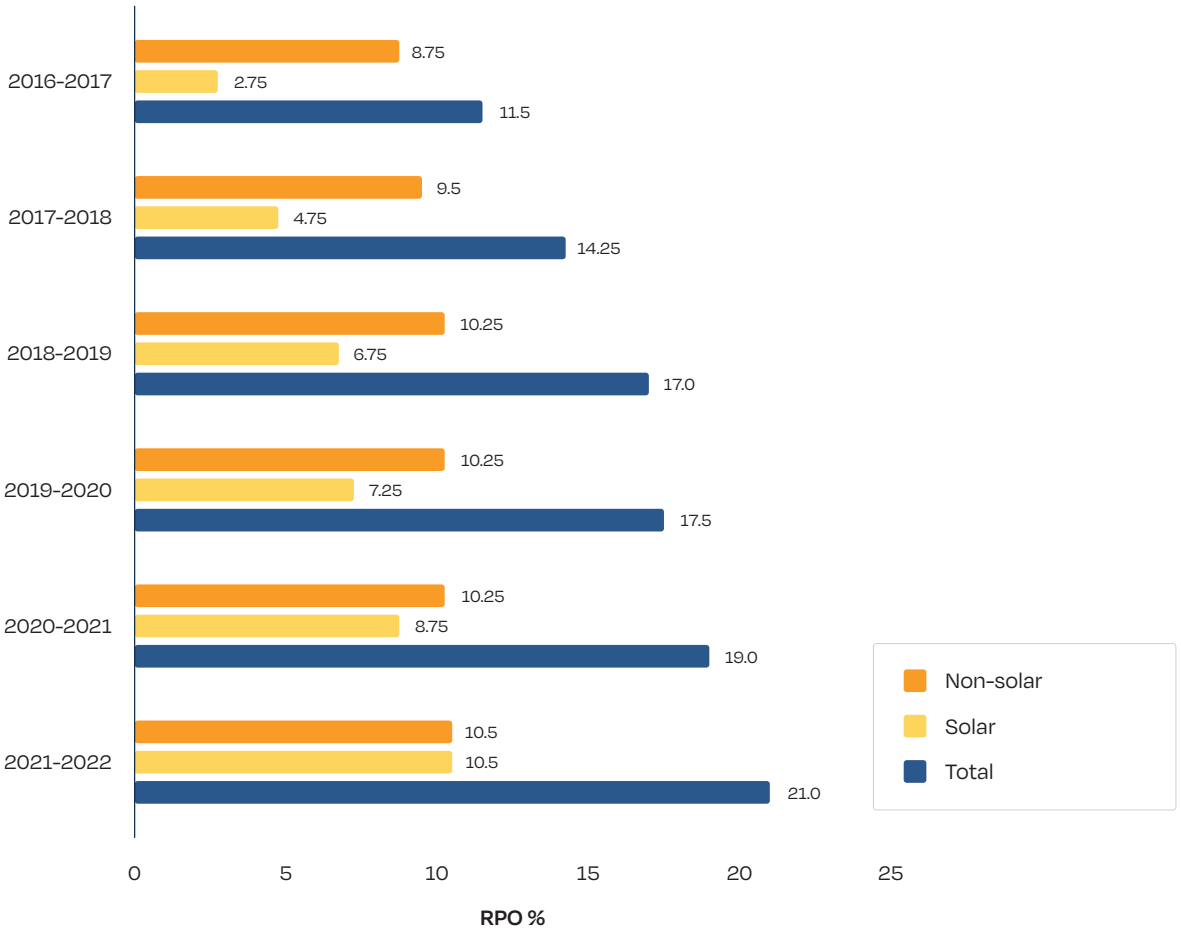
Such goals have triggered a strong deployment of solar energy in the country. While missing its 2022 target seems more than likely, India needs to install around 30 GW of solar each year in order to achieve its 2030 target. It is envisioned that by 2030, 40% of India's power needs — projected to reach 15,280 TWh — will be covered by renewable energy, up from 21.4% in 2019. India has Renewable Purchase Obligation (RPO) targets till 2022 while RPO targets till 2030 are currently under development.

Drivers for solar growth

Over the last year, the government has launched key initiatives to accelerate solar deployment. The Central Electricity Regulation Commission (CERC) released the draft regulation for General Network Access to Interstate Network in order to facilitate connectivity, provide non-discriminatory access and resolve challenges in availing long-term access to power plants. The draft regulation will further revamp Renewable Energy Certificates (RECs) in the country and promote new capacity installations. In addition, under the draft rules, consumers with a load of 100 kW or more are eligible for buying renewable electricity through open access. The government has also revamped the implementation of the KUSUM scheme for the installation of solar pumps and grid-connected solar power plants by farmers, targeting around 25,000 MW of distributed solar installations.

India's National Action Plan on Climate Change (NAPCC, 2008) includes the objective of intensifying solar energy deployment and advices RPOs to be set at 5% of total grid purchase and to increase by 1% each year

FIGURE GW3.2 RENEWABLE POWER OBLIGATION (RPO) TARGETS IN INDIA, BY NSEFI



SOURCE: NSEFI.

for 10 years. The plan also includes RECs, which were introduced in 2011, and enhance renewable energy capacity by levelling inter-state divergences of renewable energy generation and the requirement of obliged entities to meet their RPOs with differentiated prices for solar and non-solar. The RPO currently states that, by 2022, 21% of total power consumed by each state should be from renewables, excluding hydro power generation, with half of it coming from solar power generation. The Ministry is yet to specify the RPO targets until 2030 but it is estimated to be around 24% of the total electricity demand by FY 2026-27.

In 2021, the largest tender was launched by the Indian Renewable Energy Development Agency (IREDA) to set up 5 GW of grid-connected solar projects in India (Tranche III) under the Central Public Sector Undertaking (CPSU) program (Phase II). Furthermore, in order to increase large-scale integration of renewable power in the energy mix, the Green Day Ahead Market (G-DAM) was launched in India, in addition to the pre-existing Green Term Ahead market. The G-DAM acts as a marketplace to trade green energy and will ensure that the power from renewable sources is sold in the market, thereby increasing market liquidity.

In parallel with the ambitions in solar capacity deployment, the country is aiming at creating an additional manufacturing capacity of up to 45 GW. The government highlighted its interest in issuing "Sovereign green bonds" for mobilising resources for green infrastructure projects deployed in public sector.

Utility-scale vs. distributed & rooftop solar development and plans

India's solar market is driven by large-scale ground-mounted projects. The segment accounts for 42.8 GW of operating solar capacity, while solar rooftop reaches 6.47 GW. With many utility-scale projects in the pipeline, this trend is likely to continue. Ground-mounted solar projects, which predominantly operate under the Solar Parks and Ultra Mega Solar Power Projects scheme, are tendered by the government through a reverse bidding process.

India's consistent success in attracting foreign investors has also resulted in low prices of solar electricity. The lowest tariff of around 1.99 INR/kWh (0.024 EUR/kWh) was discovered in the tenders auctioned during late 2020. However, due to disruptions and an increase in costs of raw materials caused by COVID-19, the lowest tariff discovered in 2021 was 2.14 INR/kWh (0.026 EUR/kWh).

Rooftop solar is yet to pick up in India. Commercial and industrial clients contribute the major chunk of rooftop solar installations. Meeting the 40 GW solar rooftop target by the end of the year that was set by the National Solar Mission is now impossible. However, for the proliferation of rooftop solar in the coming years, many new progressive steps have been taken up by the government. A part of the initiatives is the Central Financial Assistance, an entity that is poised to provide a subsidy for the installation of rooftop solar plants in the residential sector. Many states have also brought

750 MW, Rewa Ultra Mega Solar power plant in Gurh, Rewa, Madhya Pradesh (India).

new policy instruments such as Virtual Net Metering (VNM), Group VNM, Community VNM and bulk VNM. At the same time, a few states have also been trying to promote peer-to-peer trading of rooftop energy credits in addition to the net metering benefits.

Challenges

There are at least three major challenges that India's solar industry is currently facing:

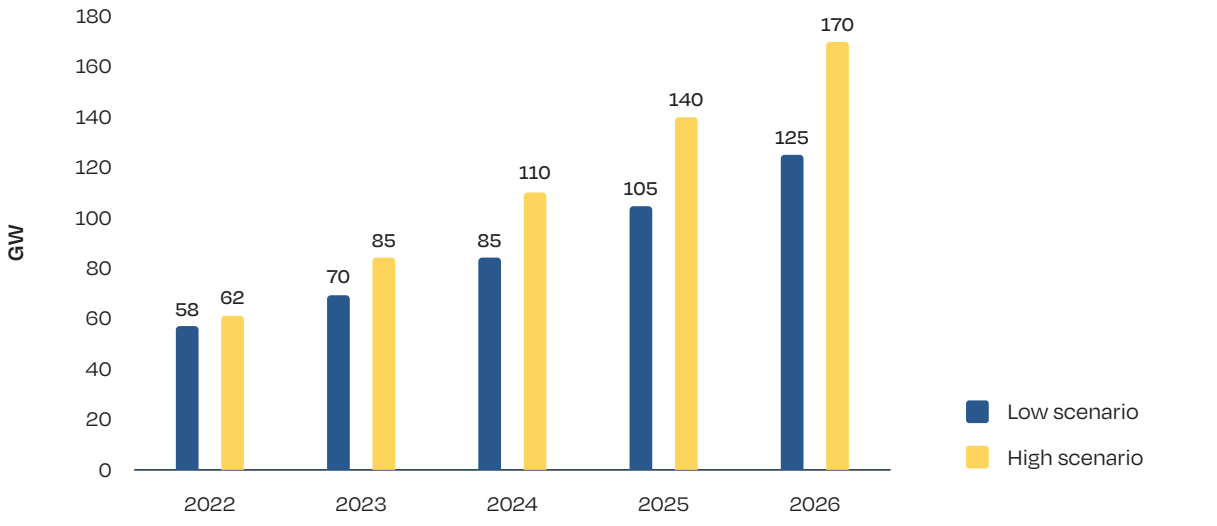
1. **Goods and Services Tax (GST):** The change in GST rates has resulted in adverse impacts on solar developers. In September 2021, the Ministry of Finance issued Notification No. 8/2021 to amend the earlier Notification No.1/2017-Central Tax (Rate) and increased the GST on Renewable energy devices and parts to 12% from 5% ("GST Notification"). The GST Council has clarified that the GST on specified Renewable Energy Projects can be paid in terms of the 70:30 ratio for goods and services, respectively for the past period.
2. **Approved List of Modules and Manufacturers (ALMM):** Under the current scheme, the procurement of solar modules is restricted to only specific manufacturers listed in the ALMM. The ALMM restriction is applicable on all solar projects biddings under central government schemes. This will lead to serious financial loss and unforeseen hardships for solar developers.
3. **PPA renegotiations:** Power distribution companies (DISCOMs) are the largest power offtakers in the Indian renewable energy sector, engaged to purchase power under long-term PPAs at pre-decided tariffs. However, due to liquidity constraints, there have been instances in which the DISCOMs of Andhra Pradesh, Karnataka, and Uttar Pradesh attempted to renegotiate or cancel signed PPAs with solar and wind power developers. Mitigating this risk by public decision-makers requires long-term structural fixes aimed at solving the systematic failures of the four utilities sectors through coordinated efforts by DISCOMs and the central and state governments.

Outlook

Despite several challenges, strongly exacerbated by COVID-19, the Indian solar sector remained strong and installed a record 14 GW of solar capacity in 2021. The outlook for the next 5 years also looks promising with at least 60 GW of capacity additions in our Low Scenario and 110 GW in the High Scenario, resulting in total operating PV fleets of 125 GW and 170 GW, respectively, by 2026.

Authors: *Ayush Shukla*, Manager, & *Subrahmanyam Pulipaka*, CEO, National Solar Energy Federation of India (NSEFI).

FIGURE GW3.3 INDIA CUMULATIVE SOLAR PV INSTALLATION FORECASTS 2022-2026, BY NSEFI



SOURCE: NSEFI.

4. Japan

Overview of PV developments

Having achieved record capacity addition of 10.8 GW in 2015, the Japanese PV market has been on a downtrend following the reduced FIT support for solar PV. In 2021, Japan installed around 6.4 GW of new solar PV capacity, resulting in a cumulative fleet of 77.6 GW by the end of 2021. While the trend seemed to have changed with the country adding 8.2 GW of new capacity in 2020, 2021's additions were the lowest in the last 9 years, proving it only an anomaly. The approved new FIT projects had dropped to 1.9 GW in 2020, indicating that further market contractions were likely in the future. In our 2021 GMO edition, the PV market was expected to return to a state of small growth in 2022. Instead, our new forecast anticipates that the sector's negative development will last for at least one extra year before returning to a stable one-digit growth rate. Japan's emissions reduction target of 46–50% by 2030 will require a big jump in the share of renewable energy, in particular for solar PV.

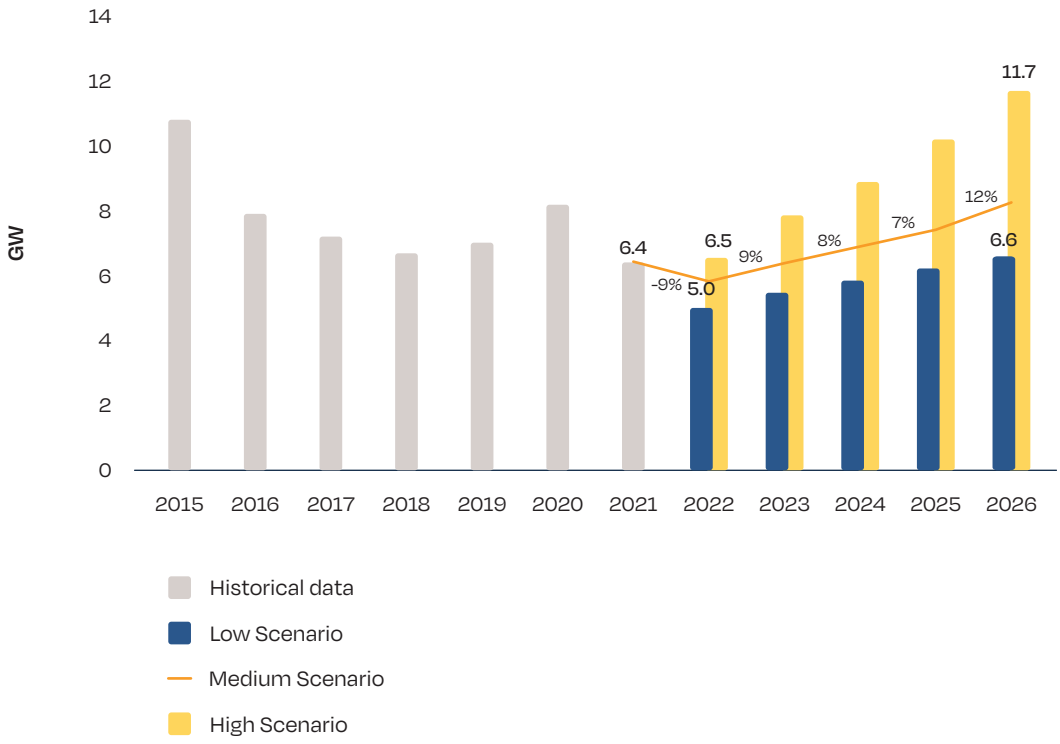
Japanese solar and renewable energy targets

- **The government's PV target:** According to the 'Long-term Energy Supply and Demand Outlook' (Energy Outlook) published by the Ministry of Economy, Trade and Industry (METI) in 2015, the cumulative installed PV capacity target for 2030 is 80 GW. This 'old' target was increased by METI to around 147 GW in its most ambitious scenario to meet the new ambitious carbon reduction target of up to 50% by 2030. According to Japanese consultancy RTS Corporation, this target would be met under a BAU scenario, whereas under an Accelerated Scenario, total installations could reach 180 GW by 2030.
- **Renewable Energy Target:** In July 2021, METI announced new plans to significantly increase the renewable part of its energy generation mix to 36-38%, from 20-22% before.

Drivers for solar growth in Japan

- **The FIT** scheme has been the strongest supporter of solar PV's growth in Japan since its introduction in July 2012. However, this FIT scheme has now come to an end, and a more market-oriented **Feed-in Premium (FIP)** has been introduced in April 2022. Instead of setting a fixed feed-in tariff rate, the FIP scheme allocates a certain amount of premium in addition to the wholesale electricity price. In this manner, the remuneration level is connected to the current electricity prices. The new FIT/FIP scheme, enforced through the Acts for Establishing Resilient and Sustainable Electricity Supply Systems, is expected to be a new driver for solar demand. Under the new framework, larger projects will be subject to the FIP remuneration, while the FIT is maintained for smaller systems. With the new scheme, the government aims to enter a new phase of solar development, which will see the next 60 GW of solar deployed.
- **The new national carbon reduction target of 46–50% by 2030** can be considered a game changer for the government's energy policy, and solar PV's accelerated deployment is the key success factor to meet this target. The expected government support will be a strong driver.
- **The "self-consumption business model"** for commercial and industrial users is anticipated to grow in Japan in the coming years. As the LCOE of solar PV is already comparable to variable retail electricity prices for commercial and industrial users, on-site self-consumption PV systems are becoming attractive to corporate users. As a result, in the medium term, it is expected that the majority of solar additions will come from capacities installed outside the FIT/FIP scheme.
- **Auctions:** Japan is also supporting projects over 250 kW through a series of auctions. The latest exercise concluded in March 2022 and awarded 268.7 MW at a record low price of 9.99 JPY/kWh (0.07 EUR/kWh). Across the 11 auctions held since 2017, it is the first time that the price dropped below 10.0 JPY/kWh, with a lowest bid offered at 8.99 JPY/kWh (0.065 EUR/kWh). However, as it recurrently happens in the country, the auction was slightly undersubscribed. A total of 675 MW of PV was awarded across the auction scheme in 2021. Importantly, the March auction was the last to offer fixed tariffs, as the next auctions will award FIP tariffs.

FIGURE GW4 JAPAN ANNUAL SOLAR PV MARKET SCENARIOS 2022-2026



Utility-scale vs. distributed & rooftop solar development

In 2021, the annual installed capacity for residential solar PV systems below 10 kW was 0.7 GW. We expect this segment to grow slowly in the next 2-3 years before getting stronger, supported by the FIT and various subsidies for net-zero energy houses (ZEH), battery systems, and other drivers.

Distributed solar PV under 1 MW, mostly ground-mounted, is on a downward trend since 2016, mainly due to reduced FIT support. This segment requires a business transformation, for example from a simple ground-mounted system to a self-consumption system integrated with RE users' and/or local community's energy demand. The segment is expected to grow again with the development of business models outside the FIP regime.

Large solar PV systems of 1 MW and above, including utility scale, are also trending downwards. In addition to the FIT termination, power grid constraints and land availability have also contributed to reduced demand. This segment is likely to start growing again in the medium term, as soon as these constraints are overcome and with improved cost competitiveness. Following the introduction of the FIP regime, many investors and developers are preferring to wait due to the large uncertainties about future electricity prices. At the same time, they are turning more and more toward on-site corporate PPAs.

Challenges

- **Smooth transition from FIT to FIP:** FIPs are introduced starting 2022 as mandatory incentive mechanism for large-scale solar PV (1 MW and above) and optional for distributed solar PV (50 kW – 1 MW). One of the biggest challenges for the industry and for policymakers is the smooth transition from FITs to more market-oriented FIPs.

- **Business model transformation:** The role of FIT/FIP will gradually shrink in the coming years. With the emergence of corporate PPA type business models, this decade will see the transition towards a market growth with little reliance on the FIT/FIP regime.
- **Grid constraints:** Limited grid capacity and curtailment risks are the primary causes for the downward market trend in Japan. METI has taken several mitigation measures to maximise grid capacity with existing assets, such as the "Connect and Manage" program for transmission and local grid levels. Moreover, METI has started planning the long-term grid expansion program to accommodate large amounts of renewable energy.
- **Land availability:** New business models without dedicated land space (e.g., on-site self-consumption models), and utilisation of unused/abandoned farmland are a solution to the limited land availability problem. To date, conversion of unused/abandoned farmland to solar farms is very limited as it requires strict legal procedures and local authorities' permission. The government is now tackling those constraints by reforming existing laws and regulations.
- **Cost competitiveness:** The cost of solar PV in Japan is significantly higher compared to average international levels, mainly due to expensive construction and soft costs. Reduced CAPEX (mostly construction costs) and longer life (e.g., from 20-year life to over 30 years) are key challenges for the industry. The FIT for a PV system between 10 and 50 kW was set at 11 JPY/kWh (0.08 EUR) in February 2022 and 10 JPY/kWh (0.073 EUR) for systems from 50 kW to 250 kW. The government targets a PV LCOE of 7 JPY/kWh (0.051 EUR) between 2025 and 2027.

Author: *Christophe Lits, Raffaele Rossi, Michael Schmela*, SolarPower Europe.

Hyogo, Japan.

5. Australia

Overview of PV developments

By the time many of you read this report about the Australian PV market in 2021, we will have had an election (21 May 2022) which will be pivotal for the solar industry: the stark choice is between the continuation of the National government which has been in power for 9 years (and 19 of the last 25 years) and is antagonistic to renewables – including solar – or a progressive Labor Party government that would actively support solar and renewables.

There was an expectation that we might see some increase in PV deployment as vaccinations and other measures slowed the negative impacts of the local and international disruptions caused by COVID-19. In our previous assessment of the evolution of the Australian PV market, we anticipated an increase in rooftop (residential and C&I) over 2020 to about 3.6-4 GW in 2021 and a flat market in large-scale installations of around 2.2-2.5 GW. As it turned out, we were optimistic for rooftop solar and pessimistic for large-scale! The 2021 rooftop sector set another record, for the fifth year in a row, with about 3.2 GW of new capacity added. But the continued impacts of lockdowns and supply constraints meant the growth tapered off early in the year. Installed rooftop solar is now over 16 GW, which added to utility-scale capacity constitutes a total operating solar PV fleet exceeding 25 GW. In contrast, large-scale solar deployment in 2021 was 3 GW, a catch-up from the 2 GW installed in 2020.

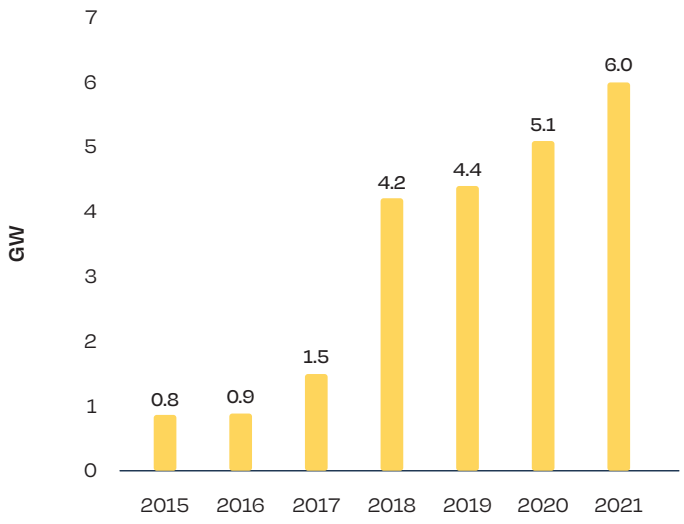
Solar/RE targets

The residential rooftop market remains well supported by the federal government's Renewable Energy Target. Although now in the wind-down stage to end in 2031, this is still a healthy incentive for PV systems under 100 kW. The simple payback period for the most common system size (~7 kW) is under 6 years. There are still no-interest loans for solar PV & batteries with most, but not all means tested.

Drivers for solar growth

Although solar's increased penetration (more than 32% of residences are equipped with a PV system) has reduced wholesale prices in the market, this has been offset by increasing retail prices due to the unreliability of an aging coal generation fleet and higher network costs. That drives more sales with the self-consumption value increasing even with fixed daily service charges.

FIGURE GW5 AUSTRALIA ANNUAL SOLAR PV MARKET 2015 - 2021



In the C&I segment, corporate interest in ESG ramped up prior to COP26 and saw PPA growth as well as national deployments on premises by large companies in the food & grocery business, in white goods, as well as for international brands such as IKEA. Rooftop solar is now a self-sustaining market with the next 30% of rooftops expected to have solar installed before 2028. Greenfield housing developments are increasingly shunning fossil gas infrastructure and commonly PV mandated in all-electric suburbs. EV sales in Australia are just 2% of the total — again because of the national government's policy failure: due to a lack of fuel efficiency standards, there is no incentive for OEMs to ship to Australia. There is a high correlation between EV owners & PV installations that will become another strong driver for uptake in residential and C&I systems, as soon as EV sales move towards international norms.

A big change in 2021 was the creation of Renewable Energy Zones (REZs) in New South Wales (5 zones), Queensland (3 zones) and Victoria (6 zones) — with significant funding for combining renewable generation, transmission and storage into the grid. These three states constitute more than 80% of Australia's population. The New South Wales auction for its first REZ of 3 GW received bids of more than 27 GW — the majority were solar PV projects. The mega-scale projects referred to last year's article[3, 4] have mostly scaled up, while it has been announced the new Western Green Energy Hub, with about 30 GW solar PV and 20 GW of wind.

Challenges

As mentioned at the outset, the political constraints at the national government level continue to add uncertainty and suppress the financing of grid-scale PV. The Australia-China relationship at a government level is the worst it has been for decades, which is an additional impact. In 2021, we reported on the failure of regulatory institutions — there seem to be some changes in approach, but they too will need a change of government to get the impetus needed for serious reform. Supply chain impacts, especially related to China, continue to cause anxiety in the market.

Outlook

The first quarter of 2022 saw flat installation numbers in rooftop solar. Prices of systems and components have increased for the first time in many years and business conditions are uncertain — suggesting a likely rollout of 2.5-2.7 GW of rooftop PV in 2022. Large scale is likely to be again at around 3 GW in 2022, but will be highly dependent upon the election outcome.

Author: *Steve Blume*, President, Smart Energy Council.

1.9 MW, Bowmen Solar Farm, Australia.

3 https://asianrehub.com
4 https://suncable.sg

6. Germany

Towards a double-digit GW annual market soon

Overview of solar PV developments

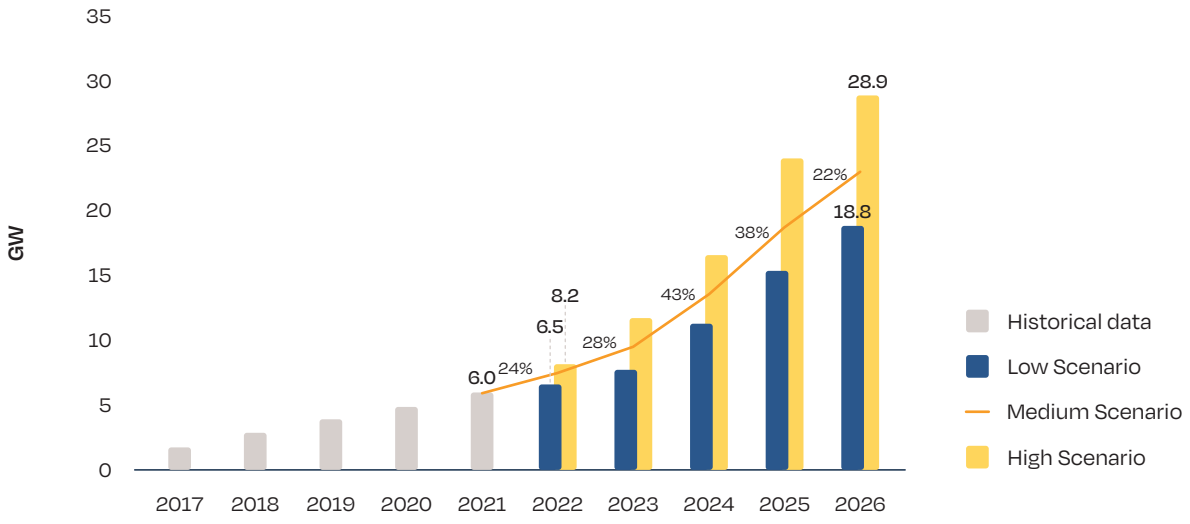
Germany installed 6 GW of solar PV capacity in 2021, a 23% growth compared to 2020, when 4.9 GW was added. This growth rate is slightly below the 26% between 2019 and 2020. While the country did experience record-high installation rates of 550 MW per month during March and April 2021 — due to a rush created by changes in the EEG scheme for mid-size rooftop systems — the market saw the monthly rates settle at an average of 420 MW in the second half of the year.

Germany continues to hold on to its top spot as both the largest solar market in Europe and the largest solar PV operator. With a new government coalition in place and the Green Party taking responsibility for the Environment Ministry, the Agriculture Ministry, and the newly created Economic & Climate Ministry, the outlook for solar in the country looks even more promising. The government's draft Easter Package in April, currently under legislative approval process at the time of writing, targets annual solar installations of 7 GW in 2022, 9 GW in 2023, 13 GW in 2024, 18 GW in 2025, and 22 GW from 2026 onwards.

Solar PV targets in Germany

In its agreement published in November 2021, the new German coalition - formed by the Social Democrats (SPD), Greens and Liberals (FDP) - has highlighted the crucial importance of solar in the energy transition. While the Renewable Energy Act 2021 (EEG 2021) set a 100 GW total installed solar PV capacity target by 2030, the new government coalition agreement sees it double to a target of 200 by 2030. This target has been further raised in the 2022 Easter Package to 215 GW, in line with energy independence and security concerns caused by the Ukrainian war. Therefore, with an installed capacity of around 60 GW at the end of 2021, Germany is committed to grow its PV base almost fourfold by the end of this decade. Moreover, post 2030, the new measures outline solar installations of 22 GW per year on average with an aim to reach about 325 GW by 2035.

FIGURE GW6 GERMANY ANNUAL SOLAR PV MARKET SCENARIOS 2022 - 2026



Even amid the war in Ukraine and concerns on energy security following a reduction in Russian gas supply, the coalition agreement confirms its position on the phaseout of nuclear energy as planned. Germany plans to switch off its last three remaining nuclear reactors by the end of 2022. However, whereas the coalition reaffirmed its plan to move forward the coal phaseout from 2038 to 2030, the country restarted old coal power plants in March to ensure continued electricity supply.

In June 2021, the new Climate Protection Act set a binding path to climate neutrality and brought forward the target year by 5 years to 2045. The interim GHG emission reduction target by 2030 was also raised to 65%, and to 88% by 2040.

750 kW hybrid PV & Wind system, Gielert, Germany. © ABO Wind

The new coalition is committed to meeting 80% of its electricity demand from renewable sources by 2030, up from the 65% target previously, and full decarbonisation by 2035. In January 2021, the former government introduced a national Emission Trading System (ETS) for heating and transport fuels, which expands the EU-wide ETS that currently does not cover the fuels used in these sectors. Starting with a fixed and rather low CO_2 price of 25 EUR per tonne, the prices will increase each year to reach 55 EUR in 2025, followed by an auction system with minimum and maximum prices starting in 2026. The new coalition has agreed to make sure that the CO_2 price, which is currently around 60 EUR, will not fall below that level anymore for longer periods, and will implement price control measures if needed.

Drivers for solar growth

To support the achievement of its renewable energy targets, in 2018, the previous government coalition agreed to organise **extra tenders** over 3 years, accounting for a total solar capacity of 4 GW (2019: 1 GW; 2020: 1.4 GW; 2021: 1.6 GW).

Today, within the context of **large-scale auctions**, Germany has two types of tenders that involve solar: a technology-specific tender for **ground-mounted** projects between 750 kW and 20 MW and a solar **rooftop tender** for systems between 300 kW and 750 kW.

Specific to ground-mounted projects, three tenders took place in 2021, each for a volume of 617 MW (March), 510 MW (June) and 509 MW (November); the latest round concluded with an average price of 0.05 EUR/kWh. In 2022, a total of 3.6 GW will be auctioned in three rounds. The first one launched in March for 1,107 MW resulted in 1,084 MW being awarded in April. The two to follow this year are scheduled for June and November.

There were two rounds of auctions for solar rooftop projects in 2021. The first tender, held in February 2021, was oversubscribed; a total of 213 MW of bids were accepted against the initially tendered 150 MW. The second tender for rooftops concluded in January 2022 with a total of 154 MW being awarded at an average price of 0.0743 EUR/kWh. Three rooftop tenders are planned for 2022 in April, August and December, each for a capacity of 767 MW or 2.3 GW in total.

In addition to ground-mounted and rooftop tender types, a third **technology-neutral innovation tender** took place in August 2021, where solar and storage projects were awarded 155.6 MW out of the 250 MW tendered capacity. In the previous round in March 2021, solar & storage projects were awarded all the 258 MW of capacity tendered.

Lastly, Germany's Federal Network Agency launched a 50 MW **innovative solar tender** for floating solar, carports and agri-PV in October 2021, with a bidding deadline set for April 2022.

With the Climate Protection Act, the former government agreed to give a short-term boost to renewable deployment through higher tender volumes for 2022. Auctioned solar PV capacity will jump from 1.9 GW to 6 GW, with the extra capacity equally divided between utility-scale and rooftop systems. Starting from 2023, tenders for solar are planned to stay around 2 GW per year. However, with the 2022 Easter Package increasing the 2030 solar target to 215 GW, there has also been an increase in tender volumes announced for the period up to 2028-2029.

The **self-consumption** regime underwent profound changes with the approval of the new EEG law in January 2021, although additional changes have been put forward in the proposed 2022 Easter Package. If approved in the parliament, some of the most problematic changes introduced in 2021 will be revoked under this package. This includes the limitations to sell electricity to the grid for mid-size rooftop PV systems, which had caused a steep decrease of installations in this segment. Similarly, the Easter Package raises the threshold under which rooftop systems must participate in a tender process. The current 300 kW threshold will be raised to 1 MW. The same discussion applies for ground-mounted installations, for which the threshold will increase from 750 kW to 1 MW.

The new coalition also reached an agreement to abolish the **renewable energy surcharge (the so-called EEG surcharge)** as of July 2022. This comes after the government's decision in October 2021 to slash this levy by 43%, from 6.5 EUR cent down to 3.7 EUR cent per kWh of consumed power. Starting from July 2022, operators of small commercial systems from 10-30 kW no longer have to pay the feed-in tariff (FIT) surcharge for self-consumed solar power. The EEG remuneration will be financed solely by the Federal Energy and Climate Fund. In the future, the government will be counting on the revenues from the Emission Trading Scheme to offset the financial loss of the EEG surcharge to develop renewables.

The FIT digression rates are planned to change as well. Under the new agreement, the previous "breathing cap" system will be abolished and substituted with linear digression rates. This will enable faster deployment of solar capacity without undermining the FIT remuneration values. Moreover, digression rates will be frozen until 2024 in light of the high rate of inflation prevailing in the German economy.

While the new government wants to make **solar installations mandatory on all new commercial buildings**, it also intends to establish solar as a 'common feature' for residential homes, which means there is no consensus on making it mandatory as of now. The solar obligation for commercial buildings builds on several German states deciding to require solar installations for new buildings. Following Hamburg, Bremen, and Baden-Wurttemberg, Berlin decided in June 2021 to make rooftop PV obligatory on all new and renovated buildings with a usable area of at least 50 m2 as of 2023. Baden-Wurttemberg will be the first state to start with mandatory solar installations on residential buildings in May 2022.

The 2021 EEG revision also brought some positive changes for **community solar systems**, a segment that has lagged expectations for years. Among others, operators do not have to supply power directly to the tenant, but also via third parties, like utilities, which is expected to make the scheme more useful. In the most recent package of measures disclosed in April, the government announced that community solar projects below 6 MW can be built without participating in auctions.

As shown in SolarPower Europe's recent *European Market Outlook for Residential Battery Storage 2021–2025*, Germany continues to be the **key European market for home batteries**, with an estimated 121,000 units installed in 2021, which is equivalent to a storage capacity of almost 950 MWh. The latest amendments to the Energy Industry Act in June 2021 included the removal of double charges and levies to battery systems, enabling better utilisation of batteries' flexibility potential in the energy system. For the next

5 years, Germany is expected to remain Europe's biggest market by far for residential batteries thanks to a very strong solar market and very high retail power prices, as well as high demand for EVs and a quickly increasing number of solar systems dropping out of the 20-year long FIT scheme.

Next to capacity generated by the self-consumption regime and auctions, **PPA-based projects** are the third pillar of solar development in Germany. Large-scale merchant solar is an emerging trend in the German market. The country witnessed EnBW inaugurate its largest PV system, a 187 MW subsidy-free solar park, in November 2021. As utilities, large investment funds, and private investors are very active in this segment, we anticipate the PPA market to grow strongly in the coming years.

Challenges

The recently announced regulatory changes in the Easter Package have lifted several barriers to the deployment of solar in Germany. With the threshold for auctions now raised to 1 MW, the removal of the EEG surcharge and the adjustment of the FIT rates, the rooftop segment can become a major contributor to the country's climate and energy independence ambitions.

However, the premium tariff for prosumers' excess solar energy fed into the grid is currently at very low levels and will not be increased, according to the government proposal. Instead, the German Climate Ministry has suggested to raise the full feed-in tariff to a level that will be twice as high as the premium FIT, which is counterproductive to the EU's idea to back prosumers.

Finding areas and receiving permits to develop large utility-scale volumes remains a challenge, even more when especially when considering that agri-PV and floating PV are not sufficiently supported in the tender mechanisms.

The key task will be to get all the pieces of the puzzle together — incentivise investors for rooftop and power plant segments, smoothen permitting, educate a sizeable number of installers, and create local acceptance for 155 GW to be installed over the next 9 years.

Authors: *Christophe Lits, Raffaele Rossi & Michael Schmela,* SolarPower Europe.

7. Brazil

Overview

Brazil has continued its strong solar PV growth in the country's two main market segments:

1. **Centralised generation:** large-scale projects above 5 MW that commercialise their energy through regulated market auctions held by the government or through bilateral PPAs in the free electricity market; and
2. **Distributed generation:** small- and medium-sized projects, equal to or below 5 MW that are eligible for net-metering, according to Brazilian national regulation and the new distributed generation Law no. 14,300/2022.

In 2021, the country reached 13,478 MW of total installed solar PV capacity in operation, surpassing all official government projections. In terms of annual capacity additions, 5,487 MW were installed in 2021, of which 1,539 MW were in centralised generation and 3,948 MW were in distributed generation.

A record number of new centralised generation projects were registered at the Brazilian Electricity Regulatory Agency (ANEEL) last year, most of them targeting the free electricity market. The contracts negotiated in the free electricity market vary significantly in price based on the location of the power plant (due to price variation in different electric subsystems), the type of energy source, the duration of the contract and other factors.

Solar PV distributed generation registered its largest historic growth in the country in 2021, and this record may be surpassed in 2022. Brazil's solar PV market is poised for a strong growth, especially after the passage of the long-awaited distributed generation Law no. 14,300/2022, which brought more legal certainty, stability, predictability and transparency to the market. For 2022 and the subsequent years, solar PV distributed generation is expected to experience a strong growth curve due to the combination of rising electricity prices and falling system prices.

Solar PV targets

According to analysis by the Brazilian Solar Photovoltaic Energy Association (ABSOLAR) and official projections from the Brazilian Energy Research Office (EPE), solar PV could reach between 36.2 GW (Conservative Scenario) and 48.6 GW (Optimistic Scenario) of cumulative installed capacity by 2026. For centralised generation, ABSOLAR considers an average yearly capacity addition of between 2,407

2.45 kW Mundo Infantil Day care center, Rio de Janeiro-RJ, Brazil. © Insolar

MW and 2,870 MW until 2026. For distributed generation, EPE projects between 19.5 GW and 29.6 GW of cumulative installed capacity by 2026. Summing both centralised and distributed generation, the forecast expects between 4.5 GW and 7.0 GW of solar PV yearly added capacity on average between 2022 and 2026.

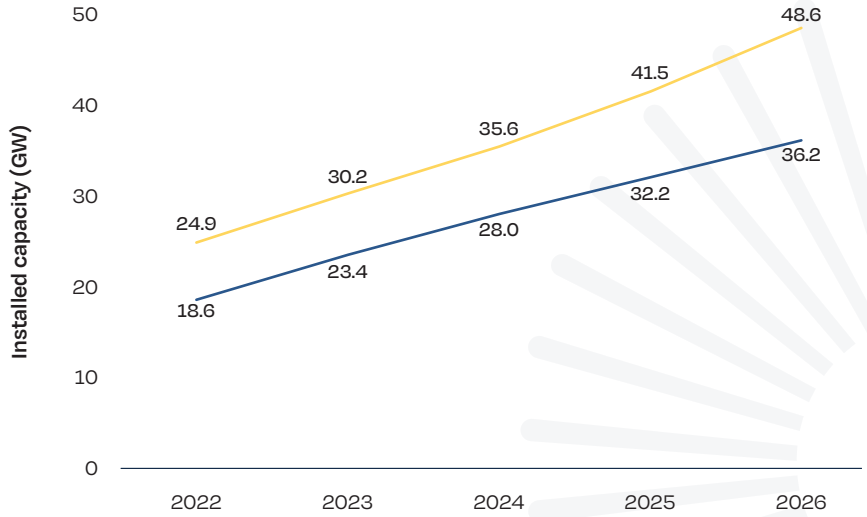
Challenges

Once again, solar PV was one of the most competitive electricity sources in the new energy auctions and contributed to the reduction of Brazilian retail electricity prices. Nevertheless, the auctions held by the Federal Government in 2021 were disappointing and only contracted a small amount of capacity. In response to that, large-scale solar PV market players started to focus on new projects on bilateral PPAs in the free electricity market.

While in 2021 Brazil deployed 1.5 GW of centralised capacity, solar's increased competitiveness resulted in a pipeline of more than 34.9 GW of granted projects across the country. Not all of these projects have already signed contracts; therefore, a part of this is considered prospective pipeline. This shows a growing interest by market players in solar PV electricity, despite challenges related to the bankability and grid connection bottlenecks, topics that ABSOLAR is addressing with the participation of the sector.

Another growing trend is the direct ownership or lease of large-scale solar PV power plants by large consumers (industries, shopping malls, etc.) in the free electricity market, allowing them to reduce electricity bills and increase business competitiveness. These power plants are built and operated by a generation company in joint venture with the consumer, allowing the end-user to remain focused on its core business.

FIGURE GW7 FORECAST OF SOLAR PV CUMULATIVE INSTALLED CAPACITY IN BRAZIL, BY ABSOLAR



	2022	2023	2024	2025	2026
Distributed Solar Conservative Scenario (MW)	10,865	13,992	16,585	18,415	19,515
Distributed Solar Optimistic Scenario (MW)	17,153	20,466	23,417	26,338	29,609
Centralised Solar Conservative Scenario (MW)	7,775	9,408	11,383	13,774	16,666
Centralised Solar Optimistic Scenario (MW)	7,775	9,718	12,148	15,185	18,981
—Total Conservative Scenario (MW)	18,640	23,400	27,968	32,189	36,181
—Total Optimistic Scenario (MW)	24,928	30,184	35,565	41,523	48,590

SOURCE: ABSOLAR (2022) and official projections from EPE (2022).

In distributed generation, 2021 was a record-setting year. The increasing competitiveness of solar PV under the national net-metering regulation led to a total capacity addition of 3,948 MW, compared to 2,767 MW in the previous year, which signals a 43% improvement for the segment.

In this regard, the new distributed generation Law published by the Brazilian federal government introduced clear rules for the market, creating a stable and balanced legal framework for the use of clean and sustainable renewable sources, such as solar PV in homes, small businesses, rural properties and public buildings. The Law ensures that all distributed solar PV systems in operation and all new connection requests performed until the beginning of 2023 will be eligible to full net-metering until the end of 2045. It also introduces a new net-metering regime for connection requests performed from 2023 onwards, gradually introducing grid fees only for the electricity injected into the grid. Although these grid fees will be gradually increased over the years, the Law provides a positive return on investment for Brazilian consumers with distributed generation, bringing more certainty and security to the market.

Energy storage is another relevant technology under development in Brazil, which is expected to experience important opportunities in the coming years. A new regulation is being drafted by ANEEL and has received strategic contributions from ABSOLAR, considering its strong synergy with solar PV. Yet, energy storage still faces high taxes, lack of rules to promote its use, a missing framework on grid connection rules, as well as a lack of support schemes for end consumers.

In the face of these challenges, ABSOLAR will continue to defend Brazil's solar PV sector, developing recommendations to make solar PV a decisive tool to support the sustainable economic recovery of the country, during and after the pandemic.

Authors: *Dr. Rodrigo Lopes Sauaia,* CEO*; Rafael Francisco Marques,* Technical and Regulatory Specialist; ABSOLAR.

8. Spain

The challenges to our ambition

Solar power is entering into a maturity phase in Spain: with 4.9 GW installed in 2021, the country experienced its best year ever for solar PV deployment. During the last 3 years, around 13 GW have been installed, tripling the existing capacity at the end of 2018. The leadership of Spain in the renewable PPA market, the two auctions carried out in 2021, and the growth of rooftop PV, have set the foundation for maintaining the pace of the solar market in coming years. However, both policymakers and the industry have to bear in mind that the maintenance of a GW-size industry will require careful attention.

Drivers of solar growth

Following a process that lasted several years, the Spanish Parliament approved the Climate Change Act in May 2021 fixing a dual target for renewables in 2030: a 42% share in final energy consumption and a 74% share in electricity generation. The law also includes a clause to revise (only upwards) the targets in 2023. In order to meet these targets, the Spanish National Climate and Energy Plan (NECP), also approved in 2021, **foresees a solar PV capacity as high as 39.2 GW in 2030** – more than doubling the current capacity.

In addition to the visibility given by the energy policy, the main driver for solar growth in Spain is **its competitiveness**, in both ground-mounted plants and self-consumption.

In **ground-mounted plants**, the economic competitiveness of the technology (favoured by economies of scale), the terrain and solar resource availability, and the regulatory stability of recent years have fostered a supportive ecosystem that has attracted the interest of different actors: national utilities, European utilities, companies from the oil & gas sector, IPPs, solar developers, investment funds, etc. This situation is acknowledged by international observers, such as market research firm IHS Markit, which considers Spain as the fifth most interesting market in the world to invest in renewables.

As a result of this ecosystem, a considerable number of developers and IPPs have deployed GW-size portfolios that have been sold to newcomers also pursuing brownfield development. Significant activity in mergers and acquisitions (M&A) is making Spain one of the largest sectors in Europe for transactions in renewables. In addition to M&A operations, several companies are considering going public, which speaks to the good prospects of Spanish solar companies.

The pillar behind the impressive development of the previous years has been **PPAs**. All large-scale solar capacity commissioned during 2020 (2.9 GW) and 2021 (3.4 GW) has been developed without any type of public aid or regulatory scheme, and all through PPAs or merchant projects. According to the Renewable Energy Country Attractiveness Index from EY, Spain ranks **world's first in the associated new PPA Corporate index**. Spain is also **the leading PPA market in Europe**, according to corporate renewable energy sourcing platform RE-Source.

The rooftop PV market is not as mature as ground-mounted solar. After the removal of the Sun tax on self-consumption in 2018, the current framework was only achieved in 2020, with the introduction of automatic surplus remuneration, plus collective and through-the-network facilities. Both companies and the end-consumer market have been gradually gaining pace since then.

If installed rooftop power had already been increasing in the previous years (+551 MW in 2019, +715 MW in 2020), the next growth level was reached in 2021, when this market grew 102% year-on-year exceeding the GW-level with 1,444 MW of annual installed capacity. This spectacular growth was particularly strong in the residential segment, which accounted for 32% of the total, compared to 19% in the previous year. The high electricity prices of 2021 and the tax incentives of many municipalities encouraged many households across the country to become self-consumers.

On the policy side, the main driver for the development of the sector is the **Roadmap of Self-Consumption, approved in December 2021**. The document includes measures to foster this segment and estimates the potential of self-consumption in 2030 between 9 and 14 GW.

In addition to policy, it has to be remarked that the Spanish **National Recovery Plan** considers rooftop PV to be one of the main measures to realise the energy transition. In fact, in June 2021 the government approved Royal Decree 477/2021, authorising the transfer of 450 million EUR to Spain's autonomous communities with the aim of giving investment grants to self-consumption in the following segments:

- Industry and agriculture: 150 million EUR
- Commercial: 100 million EUR
- Residential, Public Administrations and Tertiary Sector: 200 million EUR

The program will support self-consumption projects until the end of the funds, or up to 2023. If all the funds are assigned – which is considered certain – the government can double the initial assignment of funds, transferring another 450 million EUR to the regions.

As mentioned, the main driving force for rooftop PV is the high wholesale electricity prices we are seeing since mid-2021, which serves as a **wake-up call** for industrial and commercial players as well as for households. All these segments are looking at solar as a means to decrease their energy bills through the use of affordable and green, self-consumed electricity.

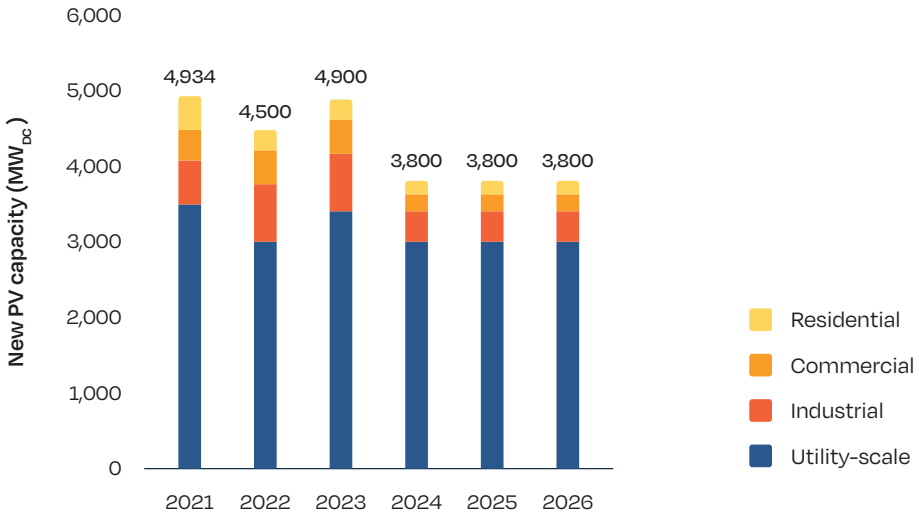
Adding to all the above, as a response to the ongoing war in Ukraine, the government introduced a set of measures in April 2022 to decrease fossil fuel dependency, curb energy prices and hasten renewable deployment. The package of measures includes, among others, a regulatory framework for floating PV, accelerated procedures for PV parks below 150 MW, strengthened distribution grid capacity to absorb 7 GW of self-consumption systems, and regulations for the pipelines of renewable gases, including renewable hydrogen.

In terms of **outlook**, expectations are very positive, with some remaining question marks that need to be followed closely to evaluate their impact.

In the ground-mounted segment, as previously stated, the installed capacity reached 3.4 GW in 2021, in line with our previous forecasts. For 2022, the market will continue to rely upon PPAs and we consider it will develop similarly to 2021. The two auctions carried out in 2021 (January and October) allocating 2.9 GW of new solar PV capacity will increase the figures of deployment in 2023.

For the rooftop PV segment, in 2021 the market grew significantly surpassing the GW barrier. For 2022 we expect a gradual expansion increasing 2021 values thanks in part to the national recovery plan funds.

FIGURE GW8 SPAIN ANNUAL SOLAR PV MARKET SCENARIO 2021-2026, BY UNEF



SOURCE: UNEF.

Challenges

Regarding the **challenges**, and treating first ground-mounted plants, it is obvious that the higher the volume of projects under development, the larger the burden on companies, the authorities, local communities and other stakeholders.

This general effect is increased by the Royal Decree-law 23/2020, which imposes strict deadlines on the plants under development: all projects with network access permits in force when the Decree was approved have to obtain **their environmental authorisation before end 2022**. This deadline is obliging companies to rapidly advance on their permitting procedures and is putting strong pressure on the administrative authorities, who are struggling to process the volume of files.

On the local communities' side, the sheer volume of projects going through local permitting (amounting to 2-3 times the NECP targets), has started to generate a **NIMBY**[5] effect in recent months. Certain local associations are opposing utility-scale renewable plants, requiring a significant communication effort from the companies and UNEF about the benefits and the real impacts of solar power on land use and biodiversity, mitigating the risk of spreading negative misunderstandings.

For rooftop PV the main challenge is the **length of permitting times** (both at the administration and at the network level) due to non-homogeneous processes across municipalities, and the reduced exemptions of network access permits for rooftop PV. In addition, the support program stemming from the national recovery plan is slowing decision making by clients, who are now waiting for the funds to be available in their region.

Conclusions

The high targets of the Spanish NECP and the success of the national solar power market calls for **excellence from all parties: companies, administration and policy makers. In other words, our ambition has to overcome our challenges to maintain the supportive solar** ecosystem that put Spain in the **world's top 10 largest markets.**

On the policy side, it is key to ensure regulatory stability and to eliminate the remaining barriers by streamlining administrative procedures and network access, especially for smaller PV plants and self-consumption projects. On the sector side, companies need to respond to the growing NIMBY effect, presenting projects with the highest standards in terms of environmental sustainability, positive social impacts and transparency.

Authors: *José Donoso,* Director General; *Alejandro Labanda,* Head of Regulation and Studies, Unión Española Fotovoltaica (UNEF).

50 MW, Andévalo, Spain. © Iberdrola

5 Not In My BackYard.

9. South Korea

Overview of PV developments

The solar market in South Korea experienced a slight contraction of 6.6% in new installations in 2021 on the back of a record installation year in 2020. A total of 4.4 GW of new PV capacity was connected to the grid in 2021 versus 4.7 GW in 2020 — the first time in several years that the market has seen a slowdown in its growth rate, as it connected 3.9 GW in 2019, 2.6 GW in 2018 and 1.4 GW in 2017. In total, South Korea had an operating solar fleet of 22 GW by the end of December 2021.

Renewables targets

Under its 2017 plan "RE 3020", South Korea is aiming for 20% of its electricity to come from renewables by 2030. Every 2 to 4 years, Korea publishes an energy plan that acts as a roadmap for the country's power industry. At the end of December 2020, the 9th edition of its Basic Plan for Long-term Electricity Supply and Demand was released, with details for the power sector for 15 years between 2020 and 2034. According to the Basic Plan, the generation capacity from renewables is expected to grow to 34%, from around 15% at the end of 2020. This is a much higher target than the 22% outlined in the 8th edition, released in 2017.

The 9th Basic Plan builds primarily on solar and secondly on wind. By 2030, it strives to reach 34 GW of solar capacity and 18 GW of wind capacity, which would represent 90% of the 57.9 GW renewables target. It is very likely that these numbers will be revised upward again. In October 2020, South Korea's President Moon made a commitment to the national assembly to reach carbon neutrality by 2050, shortly after its biggest local economic rivals China and Japan had announced net zero carbon goals — first China by 2060, then Japan by 2050.

Drivers and challenges: today and tomorrow

The main driver for over 90% of solar demand in Korea remains the Renewable Portfolio Standards (RPS) scheme, which requires utilities with generation capacities larger than 500 MW to supply certain shares of their power from new and renewable power sources: 6% by 2019 and 10% by 2023.

South Korea's strongly regulated market has been an obstacle for low-cost solar in recent years, with the country's Korea Electric Power Corporation (KEPCO) enjoying a monopoly for transmission, distribution and purchase of power. But as of January 2021, domestic consumers are allowed to buy electricity from renewable energy producers through power purchase agreements (PPAs). Following this, a first Korean bilateral PPA was signed in March 2022 between the energy provider SK E&S and Amorepacific, a cosmetic product supplier based in Seoul. Under the 20-year agreement, renewable energy from a 5 MW power plant will be supplied to the corporate offtaker. With South Korea being home to many internationally active corporate heavyweights that increasingly need to care about their ESG ratings, the potential for PPA-based solar systems is huge and we can expect to see many more signed. KEPCO also announced in July 2021 that it had removed a price clause in standardised contracts that prohibited renewable deals to be signed below average industrial prices. But it is still too early to quantify any impacts on solar development as high T&D costs remain a barrier for companies. It is also not clear yet as to how future PPAs will be applied in the allocation process of the Korean Emission Trading System.

South Korea has its own Korean New Deal programme that was announced by President Moon in his October 2020 speech to the parliament. Through this programme, the government committed to invest 160 trillion won (119.6 billion EUR) across three sectors: The Digital New Deal (58.2 trillion won/43.5 billion EUR), the Green New Deal (73.4 trillion won/54.9 billion EUR) and a Stronger Safety Net (28.4 trillion won/21.2 billion EUR). The Green New Deal is aiming at strengthening the country's climate action by fostering green infrastructure, low-carbon and decentralised renewable energy as well as innovation in the green industry. This includes financial incentives for local renewable energy businesses, for projects and to accelerate R&D on the new generation of solar cells, such as high-efficiency tandem silicon-perovskite cells. South Korea's Hanwha Q Cells was the largest non-Chinese solar module manufacturer, placed 7th in global rankings in 2021. The initiatives also encompass support for building the EV charging infrastructure.

On July 14, 2021, the Korean government announced the upgrade of the current programme to become the Korean New Deal 2.0 and increased the budget from 160 trillion won to 220 trillion won (164 billion EUR). Following this change, the Green New Deal is expended to several areas and will push investments to achieve the 2030 Nationally Determined Contribution (NDC).

Utility-scale PV in South Korea struggles with the challenges of finding available swaths of land in a landscape that is mostly mountainous. For that reason, South Korea's government focuses primarily on distributed solar, which is aimed at providing 30% of total power by 2040, up from 12% in 2017, and an interim target of 15% by 2035, with a parallel focus on smart meters and EV infrastructure investments. At the same time, the government is trying to circumvent the issues of land scarcity by looking into alternatives, primarily floating solar and offshore wind. South Korea is currently developing one of the world's largest floating PV projects with a capacity of 2.1 GW, slated for completion in 2025. The country also announced in March 2021 that it will build an additional 2.1 GW of floating PV capacity by 2030. Although utility-scale solar parks are facing land availability challenges, the largest solar park in the country, with a capacity of 150 MW, was inaugurated in Sinan-gun, South Jeolla province, in the beginning of 2022.

As part of its focus on distributed energy, South Korea has been offering incentives and has set sustainability requirements in several programs, such as its Home Subsidy Program, its Building Subsidy Program, and its Public Building Obligation Program. The city of Seoul, for example, has a goal of installing 1 GW of solar on 1 million homes and all public buildings by 2022.

Large-scale power plants also receive government support, by means of a tender scheme that allocated 4.2 GW in two procurement exercises in 2021. The first exercise took place in July and allocated 2 GW of solar PV, from which 1,143 MW are for systems between 100 kW and 1 MW. The second exercise started in October and awarded 2.2 GW of solar PV, with 1,560 MW for systems between 500 kW and 3 MW. It is expected that the government will tender another 4.2 GW in 2022.

Since last year, the Korean Ministry of Trade, Industry and Energy (MOTIE) introduced a carbon footprint assessment system for solar modules. This system classifies PV modules into three categories, based on their embedded carbon emissions on a kg CO_2 /kW basis. Carbon emissions are used in the evaluation of bids in public tenders and have a 10% weight of the total note, in addition to price and commercial considerations.

Samaksan Lake, Gangwon-do, South Korea.

As South Korea has been facing delays with grid connection of renewable energy systems due to the lack of adequate transmission infrastructure, several government agencies have been tasked to solve these issues.

While South Korea's coal and nuclear power will further expand in the short term, peaking in 2024, the country plans to rely on imported gas as a transition and balancing fuel. Battery storage, a strong driver for rooftop solar, only plays a negligible role in the government's plan. It foresees only less than 1% of total storage capacity by 2034, despite the fact that Korea-headquartered LG is a global leader in that field.

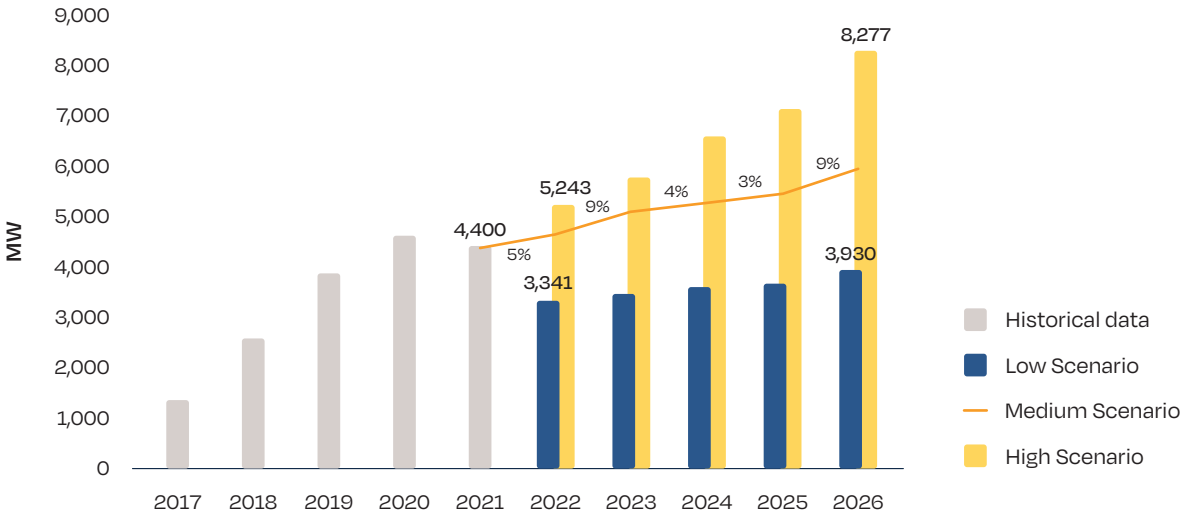
Outlook

The strict land and maritime policies obstructed the deployment of solar PV in 2021, leading to a small market contraction compared to the record set in 2020. Nonetheless, South Korea's PV market is also likely to start growing again in the short term, due to various government initiatives, including two new solar tenders totalling 4.2 GW that are scheduled for 2022.

Originally, the government was looking at a 2 GW level deployment per year in its 2030 policy plan. But that was already proven way too conservative, like the 20% renewables target set for 2030. If the South Korean government is serious about its 2050 carbon neutrality goal, it will have to increase its targets again in the 10th Basic Plan, in particular as it strives to phase out not only coal but also nuclear, and if it does not want to get highly dependent on gas imports in the interim.

Authors: *Christophe Lits, Raffaele Rossi & Michael Schmela,* SolarPower Europe.

FIGURE GW9 SOUTH KOREA ANNUAL SOLAR PV MARKET SCENARIOS 2022 - 2026



10. Poland

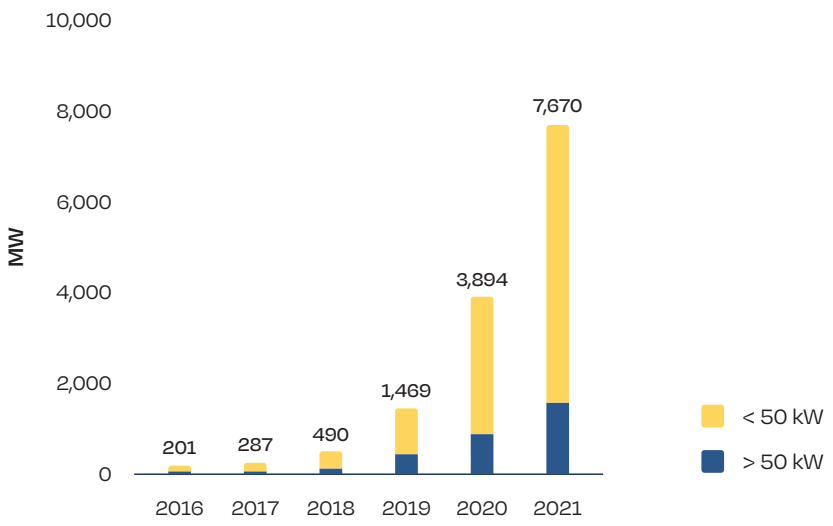
Poland – from small towards large-scale solar

In Poland, we have been observing the dynamic development of PV for over 3 years. All plans and forecasts for the development of this sector in Poland were underestimated. At the end of the year 2021, there were 7.67 GW of PV installed capacity, of which 6.07 GW (79%) is constituted by 857,598 small PV systems below 50 kW (microinstallations). The number of the microinstallations installed by the end of 2021 increased 15 times compared to installations at the end of 2018. This trend is continuing in the current year: in the first quarter of 2022, 2,130 MW were installed, reaching almost 10 GW of cumulative capacity with more than 1 million microinstallations.

This substantial increase in PV capacity has been primarily due to a favourable self-consumption scheme for prosumers, a net-metering system that uses a discount mechanism to balance out across the annual energy that was delivered to, and purchased from, the grid. In 2021, prosumers producing energy in up to 10 kW installations, could feed one unit of energy into the grid, and receive 0.8 units of energy for free. For larger installations above 10 kW this ratio is 1 to 0.7. Moreover, prosumers do not pay the distribution fees for using the grid. An additional support for micro-installations came also from dedicated governmental programs such as the rebate scheme "My Electricity", which provides a maximum 5,000 PLN (1,089 EUR) for home systems sized between 2-10 kW, with the possibility to deduct part of the cost from income tax.

The large growth in the number of micro-installations in Poland proved to be challenging for distribution networks and led to changes in the policy framework. On 1 April 2022, the net-metering system has been replaced by a new net-billing system, whereby the amount of electricity introduced and taken from the grid will be balanced in an hourly settlement using a metering system. Under the new scheme, prosumers are rewarded for surplus energy fed into the grid at the wholesale price, and they pay for the consumed energy just like other electricity consumers. The new system is a significant step back for prosumers and extends the time of return on investment or even makes it unprofitable, depending on energy prices and installation costs. This is the reason why households interested in generating energy of their own rushed the installation of their systems before the new prosumer billing system was launched. We anticipate that this change will drastically reduce the market for small rooftop systems. However, even if the deployment of micro-installations slows, we expect a

FIGURE GW10 POLAND CUMULATIVE SOLAR PV CAPACITY 2016-2021



SOURCE: PSE AND ARE.

strong development of other PV segments: large-scale solar projects, and larger rooftop systems for commercial and industrial (C&I) players.

The growth of the large-scale segment will be primarily driven by national tenders. Auctions are carried out at least once a year by the Energy Regulatory Office (URE), where projects below 1 MW and above 1 MW are placed in different baskets. The first technology neutral auction for projects above 1 MW held in November 2018 was dominated by wind energy, but the situation already started to change by the following auction in December 2019, when, for the first time, large photovoltaic projects were among the winners. In 2020, for the first time in the history of the auction system, PV installations equalled the number of offers and installed capacity with wind farms.

The last auction in December 2021 showed a great solar performance, with 870 MW of awarded PV projects. The first procurement exercise for solar and wind projects above 1 MW attributed to 570 MW of solar, with a lowest winning bid of 207.85 PLN/MWh (44.77 EUR/MWh), while wind energy won 460 MW. The second procurement exercise for renewable projects lower than 1 MW allocated all the 300 MW to solar PV capacity with the lowest bid at 219 PLN/MWh (47.17 EUR/MWh). These results confirm the path of the June 2021 auction, which allocated 1.2 GW of solar PV for projects above 1 MW and all the 1 GW of capacity offered for systems below 1 MW.

Interest in large-scale solar is due to the fact that Poland is already experiencing a shortage in energy production capacity, and this trend is set to become even stronger due to the imminent decommissioning of numerous conventional plants as their lifecycle comes to an end. With regulatory barriers obstructing onshore wind development, PV is currently the only technology that can deliver new energy production capacity within a short timeframe.

The demand for green energy in the coming years in Poland will be driven more than ever by the energy-intensive enterprises who seek to secure access to clean, affordable energy to fuel their production and lower their carbon footprint. This requires the liberalisation of regulations on the construction of energy networks and enabling the deployment of direct lines connecting a PV installation with the end user. Legal changes facilitating such a solution were proposed in the draft amendment to the energy law and the RES Act.

Still, the PV sector in Poland is struggling with a few obstacles, above all the lack of grid connection points for new installations and the current problems with timely implementation of projects, which is a consequence of the global price hikes and supply chain shortages. To address these challenges, the deadline to install the auctioned capacities has been extended from 24 to 33 months and could be further prolonged. Accessing land is also an issue in the country, as solar PV enters in competition with agriculture and the

1 MW, Olecko, Poland. © Corab

development of biofuels. Finally, as a consequence of the war in Ukraine, many Ukrainian installers are unavailable and Polish companies are facing a lack of workforce to support the deployment of solar PV.

As a further consequence of the war, Poland is looking to reduce its dependence of Russian fossil fuel energy sources. While the country has plans to fully stop its gas imports via the Baltic pipeline and increase LNG imports, it is also looking at ramping up domestic coal production. At the same time, no official announcements have been made so far with regard to a more prominent role of renewable energy sources towards energy independence. But given solar and battery storage's unique features, we expect this to be reflected in our government's energy policy actions, like in a number of other European countries.

On the positive side, in the medium term, falling renewable energy costs and new business models in the energy sector – including micro-sources and distributed energy sources – are just some of the trends that will shape the solar market in Poland. All these factors contribute to increasing the societal awareness of environmental issues and improve people's support of the transition to renewables.

Maintaining the pace of new capacity increase would also be facilitated by the implementation of the so-called cable pooling – the possibility of sharing a power line for PV and wind farms. It not only solves the problem of the lack of connection infrastructure, but also perfectly implements the idea of complementing various renewable sources – windmills can provide electricity at night, in autumn and winter, and photovoltaics on summer and spring days.

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11. Netherlands

12 GW project pipeline, solar must now compete in tenders with CCS

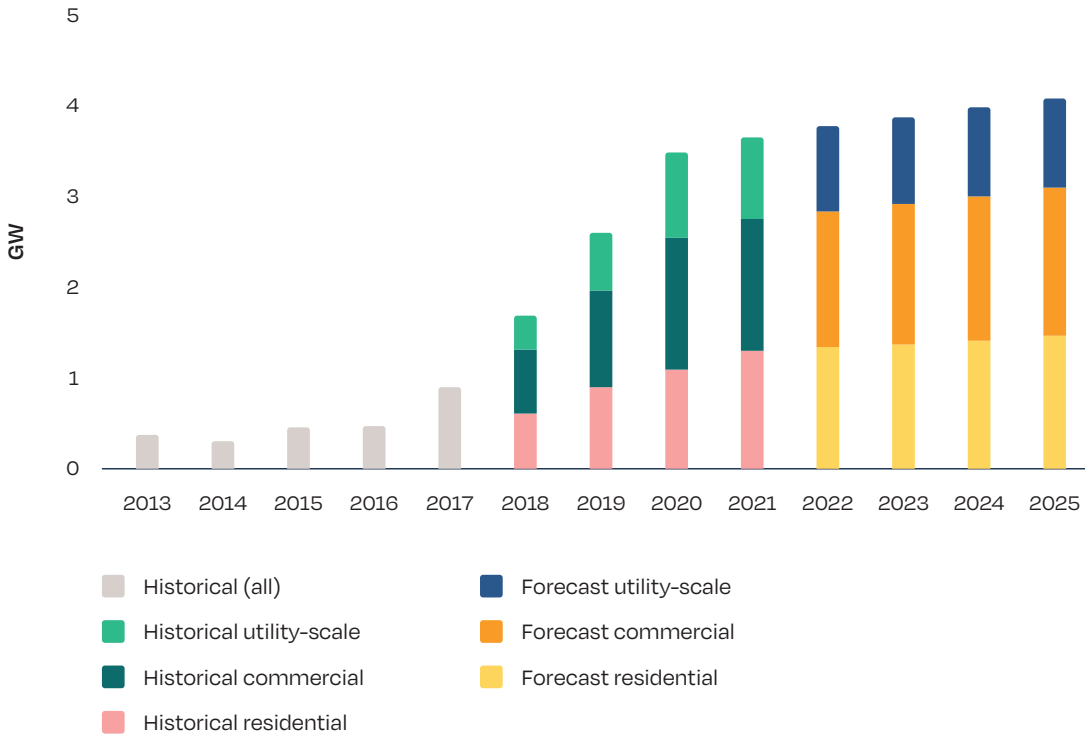
The market in the Netherlands looks sunny, with capacity additions of 3.6 GW in 2021 that have brought the total PV fleet to 14.3 GW. The country also holds a project pipeline of 12 GW with SDE++ subsidy-awarded projects, including both rooftop commercial and ground-mounted projects, with rooftop comprising the lion's share. The main challenge now is to ensure that these projects are built. Currently, around 70% of solar projects reach completion, including a timely grid connection. Many favourable project development areas in the Netherlands are now experiencing grid congestion, which means no new projects can be connected to the grid. Despite this challenge, it is expected that the Dutch solar energy market will continue to grow in 2022 and will surpass 4 GW in 2025 (see Fig. GW11).

New system-size records in 2021

In 2021, the biggest market segment in the Netherlands was again the commercial rooftop market with a share of almost 40% (approx. 1.4 GW) of the total market. The residential market had a share of more than 35% (approx. 1.3 GW) while the market for ground-mounted and floating solar PV accounted for almost 25% (approx. 0.9 GW). The residential market kept growing steadily in absolute terms last year (from 1.1 GW to 1.3 GW), and is expected to stabilise at a level of about 1.2 GW per year. Residential solar is an important market segment for the Netherlands, especially when creating awareness and support for the energy transition among citizens, leading to greater acceptance of the spatial consequences that come with introducing ground-mounted solar power plants and wind energy into the energy mix.

In October 2021, a 176 MW solar park was granted subsidy in the SDE++. Once realised, this will become

FIGURE GW11 NETHERLANDS SOLAR PV MARKET SCENARIOS 2022-2025, BY HOLLAND SOLAR



SOURCE: Holland Solar.

the largest solar park in the Netherlands. An increasing number of floating solar projects were also completed in 2021, the largest of them is the Sellingerplas project, with more than 72.000 solar panels –the largest in Europe. This is in line with an increasing interest in multifunctional use of space, like solar carports. In May 2021, a 35 MW solar panel carport was constructed on a festival site in Dronten.

Dutch policy/RE targets

The Netherlands has an impressive solar pipeline of over 12 GW. With this pipeline, and the successful completion of several wind projects, it is likely that the 2030 National Climate Agreement target of 35 TWh/year renewable energy production on land will be met. However, the Dutch National Climate Agreement was agreed upon in 2019 and does not yet consider the higher targets related to EU's ambition of 55% GHG emissions reduction by 2030, nor the impact of the Russian invasion in Ukraine. On top of that, the target does not include a forecast for the increase in demand for renewable electricity for the industry, built environment and mobility. The sector is now discussing what the new national ambitions for renewable energy production on land ought to be. New renewable energy production targets will be needed for the sector to be able to participate in the yearly tender scheme SDE++ after 2023.

Local participation has a more prominent role in Regional Energy Strategies (RES)

As established in the National Climate Agreement, the renewable energy sector is striving for 50% local participation in renewable energy projects. As the pipeline moves up, more and more projects have a significant component of local participation in terms of finance (e.g. local ownership) and spatial impact. In the code of conduct written by Holland Solar and relevant NGOs, key requirements for participation are highlighted and the code of conduct is demonstrating its impact. Not all projects are delivered without hiccups from local residents, but including local companies and residents in development processes shows that a win-win situation can be achieved. Project developers in the Netherlands need supportive local governments that ensure a level-playing field for discussions between the developer and local residents. Smoothing this element of developing ground mounted solar parks is one of Holland Solar's priorities.

38 MW solar & 22 MW wind, Haringvliet, South Holland, the Netherlands. © Vattenfall

Biodiversity label and research lead to double land use

Concerns from municipalities and environmental NGOs have led the Dutch solar sector to set up a large-scale research project to develop ways to maximise existing biodiversity in and around ground-mounted solar parks. The project will allow developers of these parks to request a biodiversity label from an independent certification institution to prove their contributions to nature in addition to producing green electricity. The label will be based on independent scientific research done by the Wageningen University, a renowned institution for nature and biodiversity research. With this new label, the sector has managed to solidify its licence to operate in the Netherlands when it comes to ground-mounted solar parks.

Reducing perceived risks of fire for rooftop solar

In the past few years insurance companies in the Netherlands have become increasingly vocal about the alleged increased risks of fire caused by rooftop solar installations. The discussion incited by the insurance companies has caused the market for large scale rooftop solar to slow down. In November 2021, an independent study initiated by the Dutch government proved that risks of fire are limited. In addition, the sector met with the national fire brigade, insurance companies, and representatives of the insulation industry to create a new code of conduct for large scale solar roofs. This new code of conduct satisfies requirements from insurance companies and ensures that building owners can be confident their commercial solar installations are fire-safe. The code of conduct can be found here.

Drivers for solar growth

The Dutch residential solar market is driven by net-metering. There is no limitation or charge for net-delivery. A proposal supported by the Dutch solar sector to gradually phase out the net-metering scheme, with a 9% decrease every year up until 2031 has not (yet) made it through parliament. This degressive path is based on a seven-year payback time for the prosumer, assuming 30% self-consumption and an optimal situation. In the light of the new Fit for 55 discussions in Brussels, in particular the proposed changes to the Energy Taxation Directive, the current Dutch proposal would become outdated. Therefore, the sector intends to develop a proposal in which a seven-year payback time can be achieved, while the net-metering scheme is also gradually and clearly reduced over the years in order to incentivise more flexibility in the system. Nonetheless, with more than 1.5 million households (about one fifth of all Dutch households) having solar panels – more than any other country on a per-capital base in Europe, this segment is and will remain an important driver for continuous growth in the Dutch Solar sector.

The commercial and utility-scale market in the Netherlands is driven by the SDE++ tendering scheme, where solar energy projects compete with other renewable energy projects and other CO_2 reducing technologies such as CCS. In this tendering scheme different maximum capacities are on offer, depending on technology (wind, biomass, solar), size, and application (ground-mounted, rooftop, floating). The ranking in the scheme is based on Euro per kt of CO_2 avoided. The maximum SDE++ contribution decreases every year, so with increasing module prices and increasing logistic costs there is a chance that, for the 2022 round, this decreasing subsidy level will need to be mitigated. In the 2021 round in December, a total of 4.1 GW solar projects were granted subsidy. About 1.9 GW is ground-mounted and the other 2.2 GW is large rooftop solar. The next round, launched end of June 2022, will have a budget of 13 billion Euros, the largest ever, and also include green hydrogen.

The expectation is that solar energy projects in the Netherlands can be developed without any incentives and based on PPA contracts by 2025 at the latest. Utility-scale solar is estimated to reach grid-parity around 2023, depending on the development of electricity prices.

Challenges

One of the main challenges for the solar energy sector in the Netherlands is to timely secure grid connections. For the coming years, the sector is expected to face serious delays and possibly project non-realisation caused by a lack of grid capacity on the higher and middle voltage levels. Additional reserve capacity will be put into general use by the grid operators in 2022. Legal limitations to cable pooling, which combines solar and wind projects in co-location with batteries, also have to be resolved urgently. The sector is contributing to this discussion by maximising the grid connection per installation to 70% of the maximum capacity. For the years 2022-2025, battery and flexibility solutions provided by the market will require more incentives from grid operators and the Dutch government. A first 60 MW hybrid solar, wind plus battery storage power plant was energised in March by a utility in Haringsvliet.

Another challenge the sector faces is the availability of land, especially for utility-scale projects, as well as social acceptance when it comes to using agricultural land for solar energy projects. So far, it was announced that ground-mounted project will need to include a multi-use component in order to receive permitting, but the nature of that component is still unclear.

Finally, while the newly formed government has shown a good level of ambition in regard to climate change, no specific actions have been announced to support solar PV development.

Authors: *Peter Molengraaf*, President; *Wijnand van Hooff,* General Manager; *Amelie Veenstra*, Policy Director; *Nold Jaeger*, Public Affairs, Holland Solar.

12. France

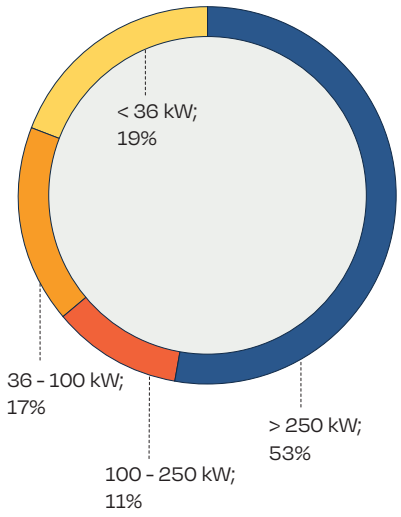
France: The 3 GW level within range

Overview of solar PV developments

The French solar fleet has entered an acceleration phase: for the first time, more than 2 GW were connected in less than a year. With 761 MW connected during the fourth quarter of 2021, solar installations reached 2,687 MW during the year and the French solar fleet amounted to 13.1 GW at the end of last year. These figures show that there has been a significant development in the solar sector in 2021, particularly in the medium and large rooftop segments.

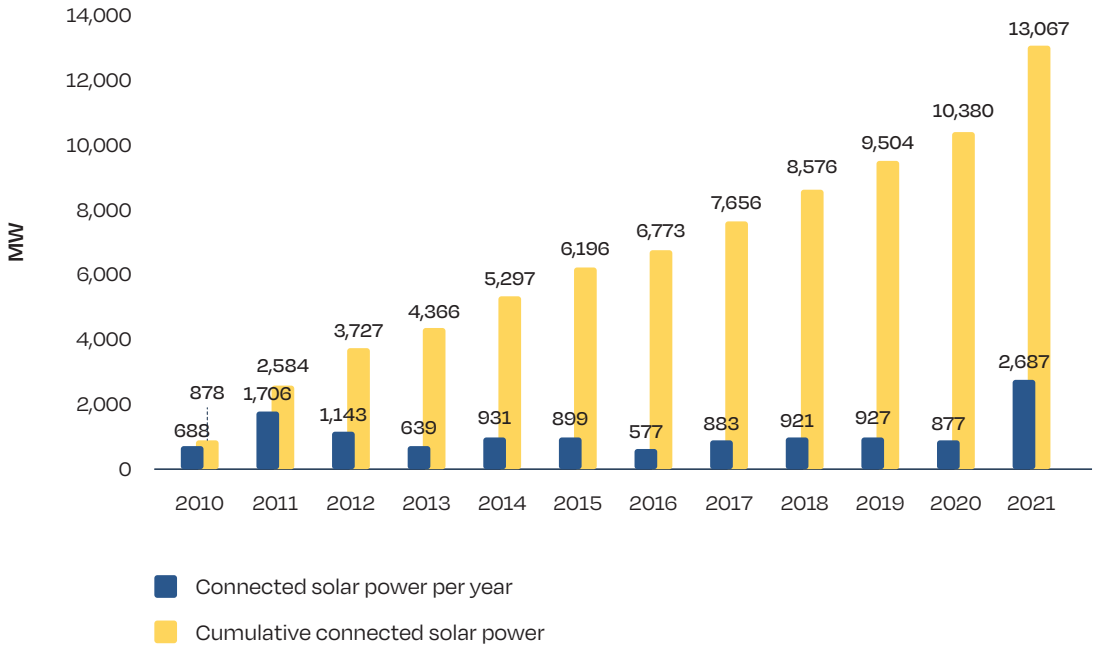
Electricity production from photovoltaic sources stood at 14.8 TWh in 2021, an 11% increase from 2020 thanks to new connected capacities. The coverage rate for electricity consumption by solar energy thus stood at 3.1% during 2021.

FIGURE GW12.2 FRANCE CUMULATIVE SOLAR PV GRID CONNECTED CAPACITY Q4 2021, BY SER



SOURCE: SER.

FIGURE GW12.1 FRANCE SOLAR PV MARKET INSTALLATIONS 2010-2021, BY SER



SOURCE: SER.

Solar PV targets in France

The 2015 Energy Transition for a Green Growth law set ambitious goals for 2030, which were also confirmed in the Climate & Energy Law adopted last year. These objectives have been implemented for each technology through the Multi-Annual Energy Programme (MAEP). This defines clear trajectories and volumetric objectives for the coming 10 years. The MAEP objective for the end of 2023, which requires an operating solar fleet of 20.1 GW, has achieved more than half its goal, currently standing at 64.3%.

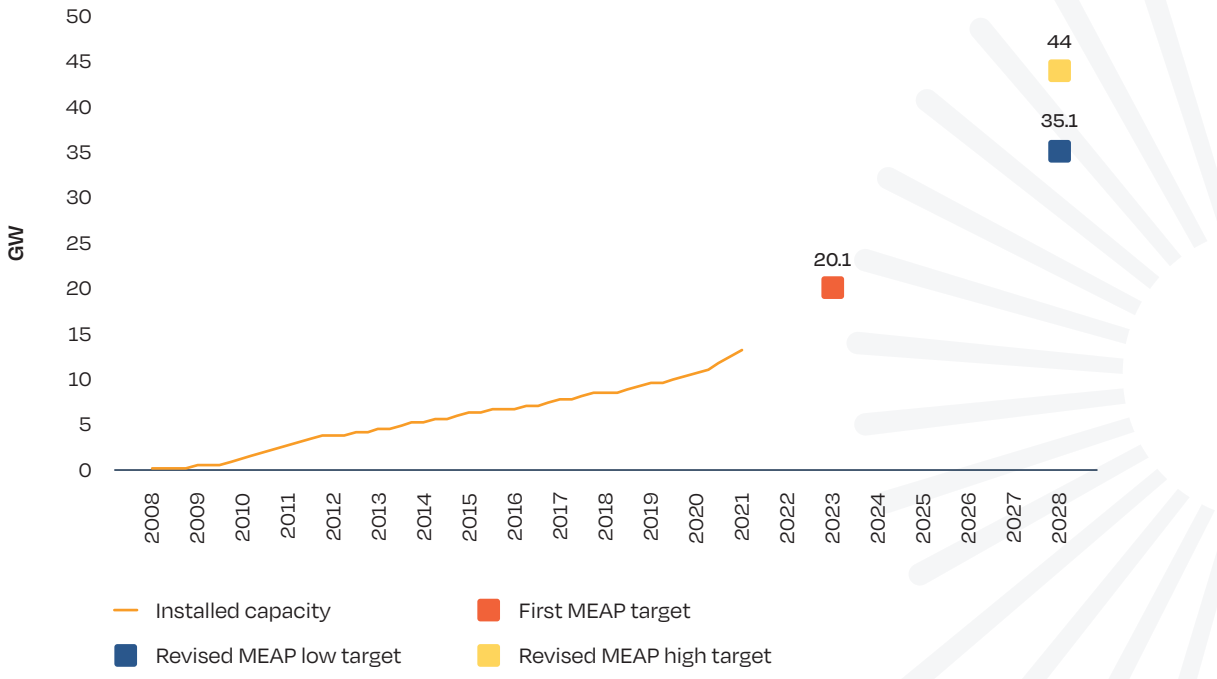
A revised version of the first MAEP, adopted in spring 2020, confirmed the willingness to strongly accelerate the development of the French 'solar park'. The new targets presented for 2028 lie between 35.1 GW and 44 GW in cumulative capacity. These targets suggest that the annual market needs to rise to 3 to 4 GW per year between now and 2028. This means between 330 and 400 km² of ground-mounted PV area will be installed in France, with between 150 and 200 km² of rooftop installations. Therefore, solar power is positioned as one of the most important contributors to the French energy transition.

In a longer-term perspective, French President Emmanuel Macron announced in February 2022 an objective of 120 GW of total solar installations by 2050. However, the MEAP targets for 2033 will be revised in 2023 and will set a trajectory that could be more ambitious. It is also important to note that, in its recently published report which studied six main scenarios to reach carbon-neutrality, RTE (the French transmission system operator) foresees 70 to 208 GW of solar capacity installed in 2050.

Drivers for solar growth

Calls for tenders are the main driver for achieving solar growth targets, with 3.2 GW scheduled every year. Two-thirds of these tenders will be ground-mounted installations. The remaining third will be accounted for by rooftop installations.

FIGURE GW12.3 MULTI-ANNUAL ENERGY PROGRAMME TARGETS



SOURCE: SER.

For many years, the French renewable energy association (SER) advocated that projects for rooftop installations below 500 kW should be exempt from tendering procedures and eligible for a feed in tariff (FIT), in line with the current EU State Aid Guidelines. The new threshold has been implemented in autumn 2021, raising the FIT threshold from 100 kW to 500 kW. This change is making things easier for the mid-size rooftop market segment, where projects were previously limited by tendering procedures. Immediate results from this legislative change have been observed on the market, as the number of installations lower than 500 kW have increased in the last quarter of 2021. A new FIT scheme will also start in 2023 for ground-mounted projects under 1 MW installed on degraded land. Moreover, an ad-hoc decree published in March 2022 reduces grid connection fees for installations under 500 kW. PV installers were paying 60% of the total fee, which is now reduced to 40%. Finally, President Macron announced that he intends to adopt this summer "an exceptional law" to simplify procedures and reduce the deadlines applicable to renewable energies.

Additionally, the self-consumption market for which a dedicated framework has been put in place is growing rapidly, but still represents a small installed capacity. In Q4/2021, 148,022 installations were self-consuming, representing 675.3 MW.

Finally, the country is working on simplifying its procedures and environmental evaluation for systems under 1 MW.

Challenges

Reaching a target of 44 GW of solar power in France by 2028, compared to the 13.1 GW currently installed, means average annual additions of around 4.3 GW, which requires regulatory changes that support the growth of all market segments.

First and foremost, one needs to widen the perimeter of eligible land in calls for tenders for ground mounted projects. Given the 2028 MEAP target, and given that the distribution of major projects remains constant, we can expect almost two thirds of solar power to be installed on the ground. Therefore, a general reflection

87.5 MW, Athies-Samoussy, France. © ENI.

on land use is necessary to take into account the real impact of PV projects on soils and to facilitate their development. In addition, innovative PV projects with especially low land-use impact, such as agri-PV and floating solar, should be encouraged.

Moreover, the development of photovoltaic projects is tightly regulated. Some administrative procedures and architectural planning issues have to be clarified and simplified for all segments. Some local services may have an ambiguous and debatable interpretation of the framework in place. This can sometimes go beyond current regulation, such as fire protection rules. Administrative deadlines also need to be shortened.

France promotes a low carbon footprint solar PV industry. The carbon criterion in the call for tenders is seen as a fundamental pillar of an industrial strategy which should go hand-in-hand with the market development. In line with what SER advocated, the carbon criterion is now set at 550 kg CO_2 e/kW in the new call for tenders' specifications that were published in summer 2021. This criterion is also now required to apply to the new FIT for rooftop installations. Thanks to the work of strong R&D centers (INES, IPVF, etc.), the development of the French industry's innovation capacities and technological breakthroughs will also improve competitiveness. SER also sees great interest of manufacturers setting up solar wafer to module production capacities in France.

Finally, as mentioned above, self-consumption is still a small market for solar PV energy, batteries are hardly used in conjunction with PV systems. The support mechanisms for self-consumption projects need to be adapted so as to enhance the value of all electricity produced, self-consumed, and injected into the grid. This needs to occur at a level that allows the projects to be financially secured. Opening up self-consumption without penalising consumers, who are not always able to consume all of their production, is another way forward.

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13. Vietnam

Overview of PV developments

Following a spectacular 2020, resulting in 11.9 GW of added solar capacity and catapulting the country into the top 3 solar markets globally, the PV sector in Vietnam saw a dramatic collapse in 2021. With the termination of the Feed-in Tariff 2 (FiT2) system at the end of December 2020, the support framework has become much less favourable for solar projects. As a result, slightly less than 2 GW of PV capacity was installed in 2021, an 83% annual decrease from the previous year.

Adding to the legislative vacuum that followed the termination of the FiT2 regime, in January 2022, Vietnam's National Load Dispatch Centre (NLDC) stopped approving any future solar and wind energy projects citing grid constraints arising from the installation of high capacities of renewable sources in recent years. This move is expected to last at least until the end of the year.

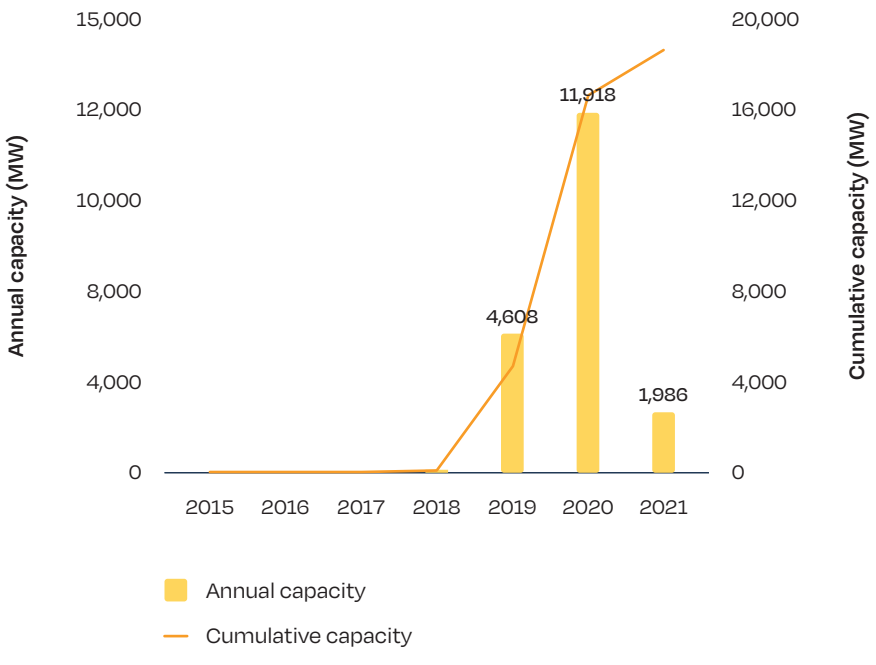
Looking at total installed capacity, the country has a solar fleet of more than 18 GW in operation. The solar installation boom in the recent years has given the country a significant towards achieving its PV targets, which are currently under revision.

Solar/RE targets

At the COP26 in November 2021, Vietnam Prime Minister Pham Minh Chính announced a net zero emission target by 2050 and a coal phaseout by 2040. Renewables and solar PV in particular will play a key role in decarbonising the Vietnamese economy.

Under the draft Power Development Plan VIII (PDP VIII), whose revisions are still ongoing, PV capacity needs to reach about 18-20 GW by 2030 and about 55-72 GW by 2045, representing respectively a base and a high scenario outlined for PV power contributions. Under PDP VIII, only centralised PV parks with a capacity over 1 MW are taken into account, while rooftop solar and renewable capacity for green hydrogen production are not included in this strategy. In either scenario, the growth of large-scale solar capacity is minimal until 2030.

FIGURE GW13 VIETNAM SOLAR PV ANNUAL AND CUMULATIVE CAPACITY 2015-2021



Drivers for solar growth

The major drivers behind solar's impressive growth in recent years have been attractive fiscal and economic incentives. Particularly, in 2020, the FiT2 set very favourable rates for rooftop, floating and ground-mounted solar. Notably, the FiT2 rate for rooftop solar was higher than the average retail electricity tariff, while the rate for utility-scale plants also made the financially viable projects attractive to investors. The feed-in contracts signed under the FiT regulation have a duration of 20 years with the annual payment being determined based on the actual VND/USD exchange rate.

FiT2 was valid from May 22, 2020 to Dec. 31, 2020 and created a rush to develop as many projects as possible before the deadline. New solar capacity installations continued to grow steadily in the third quarter, before experiencing an incredible jump in the last quarter; December, in particular, had record rooftop solar capacity deployments.

At present, not only a new mechanism promoting a shift towards self-consumption has not been introduced; the grid operator has also temporarily stopped the authorisation procedure for any wind and solar projects, due to grid constraints following the recent high PV installation levels. The grid operator cited challenges in stabilising the power system in real time.

Challenges

Considering the current solar PV installed capacity of over 18 GW as of December 2021, the target solar PV capacity for the next 10 years would be negligible, according to the PDP VIII draft. This raises questions about the government's RE development ambitions in the future, despite the COP26 commitment towards net-zero emissions by 2050. Additionally, there are no clearly defined targets specifically for ground-mounted, floating, and rooftop solar categories. These concerns have been raised by various parties and the government has been asked to adjust the solar target in the PDP VIII.

Among various challenges that young solar markets such as Vietnam face, two key barriers affecting the current development are notable:

1. **Very short-term policy that lacks clarity.** The short duration of FiT2 with a validity of only 7 months led to a pressing demand in products, services, delivery, and grid connection. In December 2020, the high demand resulted in a 30% increase in the solar PV system price. Since the expiration of FiT2 on Dec. 31, 2020, no new support policy has been introduced. In the worst case, this gap in policy might cause a medium to long-term market distortion in the coming years or, even in the best-case scenario, a temporary short-term market collapse.

168 MW, Ninh Thuan, Vietnam.

2. **Asynchronous developments of solar PV and grid projects lead to PV power curtailment.** Indeed, the development of solar PV projects outpaced the transmission grid projects, which are defined to be financed, operated and managed exclusively by Vietnam Electricity (EVN) National Transmission Corporation. This has led to the decision to stop new variable renewable projects for 2022 and might result in negative impacts for the sector if not urgently addressed.

Despite the unexpected impacts, both on the investment as well as on grid operation due to the short-term policy, the Vietnamese solar market could still give some positive surprises in the medium term.

Indeed, keeping national energy security and energy independency in view, the opportunity for further development of solar PV is still acknowledged, especially decentralised rooftop solar, the lengthy process negotiation process and limited financial access for big coal-fired and gas-turbine power plants notwithstanding. The pilot direct PPA mechanism will continue to drive the market even without a feed-in tariff in place.

In brief, the installed solar capacity, both utility-scale and rooftop PV, is expected to be very low in 2022, but could experience another up-tick, if well-designed mechanisms that promote a sustainable long-term market are developed and announced in time.

Author: GIZ Energy Support Program Vietnam.

14. Taiwan

Overview of PV developments

Taiwan reached the GW level for the first time in 2019, adding 1.41 GW, which is equal to an annual growth of 45% and results in a total cumulative capacity above 4 GW. While 2020 was expected to follow a similar development, COVID-19 took its toll and only 1.67 GW were installed, missing the 2.2 GW annual target by 24% – a target set up by the Bureau of Energy, Ministry of Economic Affairs (MOEA). When looking at the cumulative capacity target, the miss was a little lower. The 5.8 GW of total PV capacity installed in Taiwan at the end of 2020 meant a 10% miss compared to the 6.5 GW target.

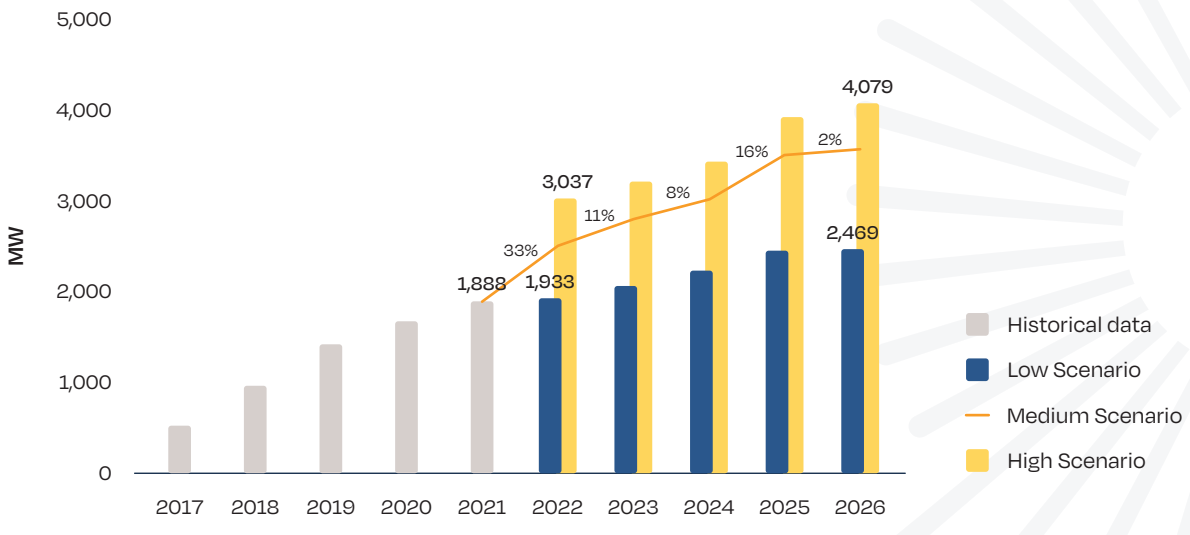
For 2021, the MOEA had reiterated its annual target of 2.2 GW added capacity, which would lead the country to a cumulative capacity of 8.75 GW by the end of 2021. Unfortunately, with 1.9 GW of solar PV added last year, the target was again missed – by 14%, which is still 10% closer to the target than what it was in 2020. On the cumulative side, Taiwan had 7.7 GW of solar PV installation at the end of 2021, 12% short of its target.

Solar PV targets and drivers

Despite the COVID-19 blip, the government maintains its 20 GW solar target by 2025, with 3 GW of rooftop and 17 GW of ground-mounted capacity. Considering the 7.7 GW installed at the end of 2021, Taiwan will have to deploy 12.3 GW in the next 4 years, with average annual installations of 3.1 GW – significantly higher than the installation level in 2021.

On the one hand, Taiwan tried to support its PV industry by extending PV project completion deadlines, granting a three-month grace period in response to the pandemic and the sustained high component prices. On the other hand, the Council of Agriculture implemented restrictions on land-use, which made the job much more difficult for PV project developers. As of July 2020, the new regime specifies that solar projects covering 2-30 hectares of agricultural land must be approved by the council rather than the local government. Moreover, PV projects cannot be built on agricultural and hillside land smaller than 2 hectares.

FIGURE GW14 TAIWAN ANNUAL SOLAR PV MARKET SCENARIOS 2022 - 2026



In June 2021 the Taiwanese Ministry of Economic Affairs decided to leave the feed-in-tariffs for PV installations unchanged, despite the initial plans for the tariffs to be lowered from 3.79-5.67 TWD (11.98-17.94 EUR cents) to 3.73-5.63 TWD (11.80-17.81 EUR cents) per kWh. The decision was taken to help the solar sector recover from the delays caused by COVID-19. Later in December 2021, the ministry also announced that PV projects that received approval in 2019-2021 and would be completed between October-December 2021 will benefit from an additional rate of 0.2245 TWD (0.69 EUR cents) per kWh. The decision was justified to counter the effect of rising energy prices, turmoil caused by COVID-19 and the price fluctuation of raw materials.

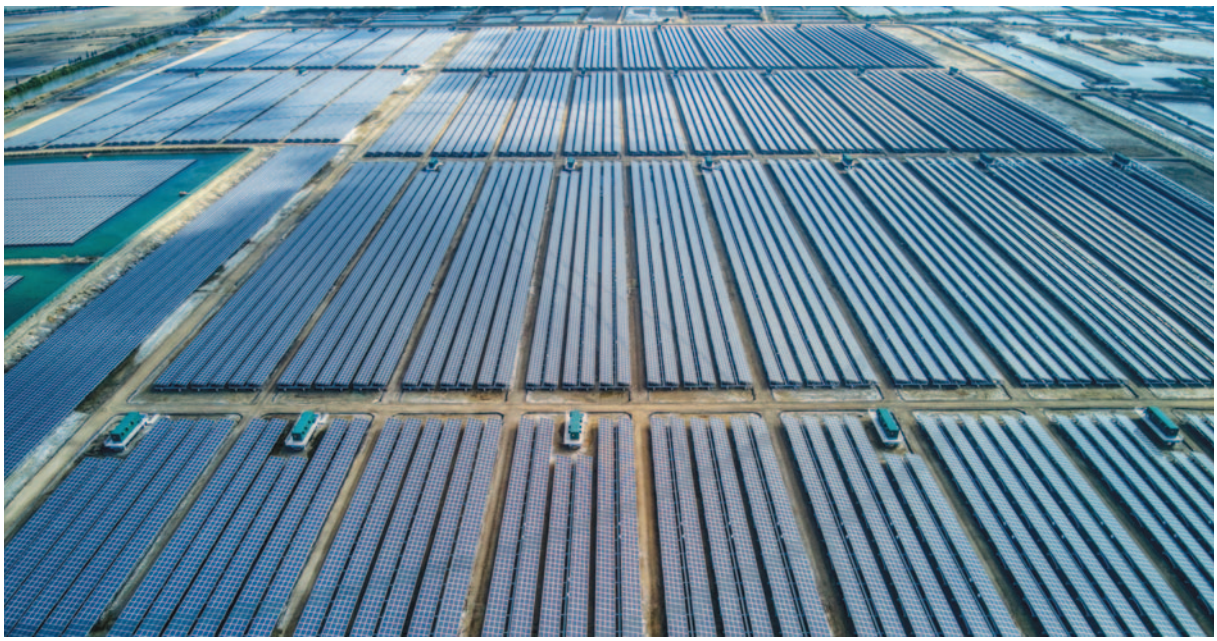
Earlier this year, the MOEA has set the new feed-in tariffs for 2022, which range from 3.8680 TWD (12.25 EUR cents) for ground-mounted projects over 1 MW to 5.8952 TWD (18.66 EUR cents) for residential installations lower than 10 kW. The FiT scheme comprises tariffs for floating arrays larger than 1 MW, solar installations from 1-10 kW, 20-100 kW, 100-500 kW, 500-1000 kW, and for systems over 1 MW. These FiT levels remain the highest in the world and are a major tool that policymakers are counting on to support renewable development on the island. By contrast, a grid-connection fee that was announced in 2021 will also become applicable starting in 2022.

Challenges and perspectives for solar growth

Land availability remains the primary limiting factor to solar deployment in Taiwan. It is one of the most densely populated countries in the world and with two thirds of the island's land constituted by mountainous areas. Therefore, solar developers are facing growing challenges to find suitable locations for their projects. Moreover, the deployment of ground-mounted projects is hindered by hurdles in purchasing land. Often, large-scale projects span across several landowners, which makes negotiations for land acquisition very challenging and lengthy. There is also some resistance in the agricultural sector.

The rules introduced in July 2020 by the Council of Agriculture are stricter than in the past. This limits land availability further and risks slowing down the deployment of solar PV. The situation has been worsened by the November 2020 decision of the Ministry of Finance to stop giving permits for solar system development in ecologically sensitive areas in the County of Chiayi and the city of Tainan. Previous authorisations for PV projects granted in those areas will be revoked.

Nevertheless, project developers in Taiwan have taken interest in setting up large-scale ground-mounted solar power plants. The local solar cell and module player URE was among the first, when it secured two



150 MW, Tainan, Taiwan.

big deals in the country, one for a 193 MW project in 2019 and another for 120 MW of bifacial capacity in 2020. However, one of the largest systems so far is a 150 MW system that went online in March 2021 in Tainan. In early 2022, Thailand's BCPG, the power generation unit of energy conglomerate Bangchak Corporation, announced plans to build 357 MW of solar power plants in Taiwan by 2024, increasing its capacity on the island to 469 MW.

To tackle the space issues, several agencies are looking into ways and technologies to address the land issues. For example, through innovative PV installations such as facilities' roofs, floating PV, using heavily polluted lands, etc. In terms of FPV, Taiwan is operating one of the world's largest FPV plants, the 180 MW Changhua Floating Project, composed of two systems – 88 and 92 MW. However, agri-PV is also very high on the agenda.

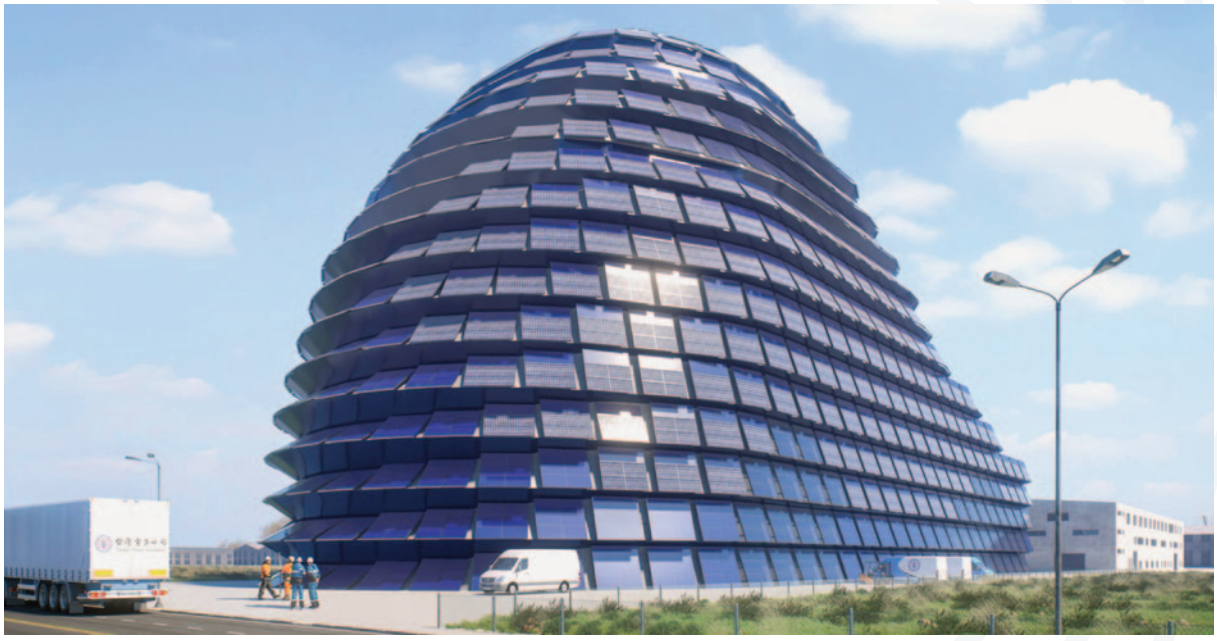
The island is also under pressure from international peers to accelerate its climate transition. With carbon footprint considerations increasingly taken up by stakeholders in the European Union and other countries, Taiwanese products need to lower their overall footprint to remain price competitive when sold overseas.

Rooftop solar is also a focus point of the Taiwan government's agenda. The 2021 edition of the Renewable Energy Law requires large power users to source some shares of their power from renewables. This legislation is anticipated to result in many corporates starting to opt either for onsite solar systems or off-site solar PPAs. Major companies active in RE100 initiative are also further pushing the green electricity demand.

Finally, the country also needs to overcome its interconnection capacity issues. This will help the country to assure stability of its electricity market and avoid a new power outage after the one that occurred in March 2022.

In any case, Taiwan will have to find solutions for adding much more solar in the long run. Under pressure from announcements in the European Union, United States and its close neighbour China to turn climate neutral, its president reportedly emphasised during Earth Day in 2021 that the country cannot fall behind the international trend. The government has started to discuss potential strategies towards net-zero emissions by 2050. So far Taiwan, which relied on coal for 45% of its power production in 2020, has set a target to only halve emissions from 2005 to 2050.

Authors: *Christophe Lits, Raffaele Rossi, & Michael Schmela,* SolarPower Europe.



Sun Rock building (under development), Taichung, Taiwan.

15. Mexico

Overview of PV developments

In 2021, the Mexican solar PV market installed 1.49 GW, a 26% decrease compared to the 2.02 GW added in 2020, and 29% less than the 2.1 GW installed in 2019. Total capacity operating in the country reached 8.17 GW, which constitutes a 22% growth from 2020. This is about 13 times the installed capacity in 2017. Out of the total installed capacity, utility-scale PV represents 75% (6.16 GW) and distributed solar PV 25% (2.01 GW).

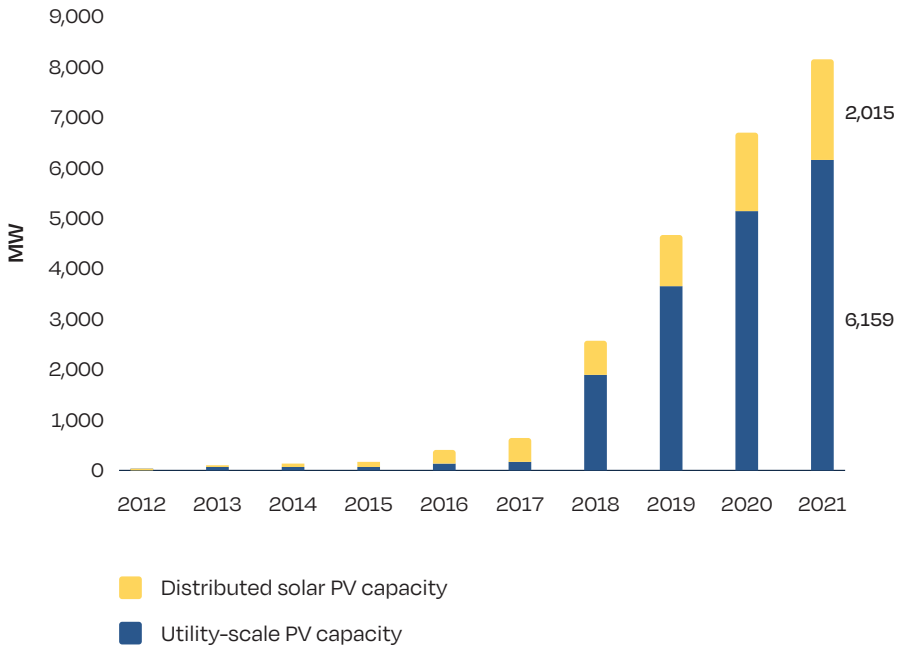
Utility-scale PV added 1.01 GW of capacity in 2021, significantly less than the previous 3 years – 1.5 GW in 2020, 1.77 GW in 2019 and 1.71 GW in 2018. In contrast, distributed solar PV saw an increase of 476 MW, in line with the added capacity in 2020 (516 MW) and notably higher than 2019 and 2018 (335 and 236 MW respectively). Looking at the whole electricity system, utility-scale PV capacity represents 8.2% of total installed capacity (89.9 GW), while 63% of installations belong to fossil-fuel based technologies. In terms of power generation, fossil-fuel based technologies provided 71.4% and solar PV 5.3% of the total electricity generation in 2021, a slight decrease compared to solar proportion in 2020 (5.7%).

Renewable and solar PV targets

In 2015, the Energy Transition Act (LTE) established the targeted share of clean energy in electricity generation: 25% by 2018, 30% by 2021, and 35% by 2024. Based on Ministry of Energy data, Mexico did not meet its clean energy target for 2021 (reaching only 28.6% out of 30%) and due to current legal uncertainty, it is not expected to fulfill the 2024 target.

In order to promote the development of renewable energy and reach clean energy goals, a policy framework for Clean Energy Certificates (CEC) was established, as well as a system of long-term energy auctions held annually by the Independent System Operator (ISO). However, regulatory changes carried out

FIGURE GW15 MEXICO TOTAL SOLAR PV CAPACITY 2012-2021, BY ASOLMEX



SOURCE: ASOLMEX.

over the last 3 years have suspended these mechanisms. At the time they were held, the long-term energy auctions secured nearly 4.7 GW of utility-scale PV capacity, from which approximately 3.3 GW (71%) started operating before the end of 2021 and the remaining 1.4 GW should be in operation before 2024.

Challenges

Before 2013, electricity supply in Mexico was carried out under a vertically integrated monopoly scheme, operated and owned by the State through the Federal Electricity Commission (CFE). After the energy reform of 2013, which included the unbundling and restructuring of CFE, a competitive electricity market was introduced for generation and supply as well as open access to transmission and distribution grids.

Since December 2018, several regulatory changes have been implemented in order to favor the state-owned company CFE. One of the most important was the reform to the Electricity Industry Law in March 2021. These adjustments, legal and regulatory, aimed to: (a) eliminate the economic dispatch of electricity by giving priority to CFE plants; (b) reduce open access to the grid by granting permits in accordance with planning criteria established by the Secretariat of Energy (SENER); (c) eliminate long-term energy auctions; and (d) cancel Clean Energy Certificates. Many of the regulatory amendments have been challenged in court by market participants and environmental NGOs and some of them have become invalid or their implementation has been temporarily suspended.

In order to avoid judicial intervention, in September 2021 the Government proposed a Constitutional amendment which would bring Mexico's entire power supply chain under CFE's control. CFE would be vertically and horizontally integrated as an autonomous government agency responsible for organising and directing the electricity sector, eliminating the ISO as well as the Energy Regulatory Commission (CRE). Fortunately, Mexican Congress rejected the Constitutional amendment on the 17th of April 2022.

The Mexican Supreme Court recently discussed the constitutionality of the 2021 reform to the Electricity Industry Law. However, the Supreme Court was unable to reach a conclusive ruling on this issue and therefore the uncertainty as to the consequences for the market participants remains.

The renewable transition in Mexico is at risk if the state-owned company is to be favoured. The U.S.

170 MW, Santiago, Mexico.

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National Renewable Energy Laboratory (NREL) estimated that giving priority to CFE plants in the dispatch of electricity could lead to several negative impacts, such as a 52.5% increase in electricity production cost, up to 65.2% increase in CO_2 emissions, while curtailment in wind and solar power could reach 90.9%.[6]

Between 2017 and 2021, solar electricity generation jumped from just 0.1% (0.35 TWh) to 5.3% (17.1 TWh) of the country's electricity demand without appropriate investments by the state-owned grid operating company to upgrade and expand the transmission and distribution networks in accordance with this growth. According to CRE, more than 80% of the grid emergencies in 2020 were related to insufficient transmission infrastructure.

Outlook

In contrast to 2020, the business environment for distributed solar PV has been affected by the uncertainty created by the proposed Constitutional amendment recently rejected. For utility scale, the sector has come to a complete halt.

According to the International Renewable Energy Agency (IRENA), given Mexico's major solar resource potential, installed solar PV capacity could reach 30 GW in 2030 (60% utility-scale PV and 40% distributed solar PV), which would require an annual installation growth of 1.5 GW. Between 2017 and 2021 Mexico was able to grow its solar PV capacity at this pace.[7]

Author: *Jaime Pérez de Laborda*, President, Mexican Association of Solar Energy (Asolmex).

6 NREL (2022): Impacts Analysis of Amendments to Mexico's Unit Commitment and Dispatch Rules. Available at: https://www.nrel.gov/docs/fy22osti/81350.pdf

7 IRENA (2015): Renewable Energy Prospects: Mexico, REmap 2030 analysis.

16. Chile

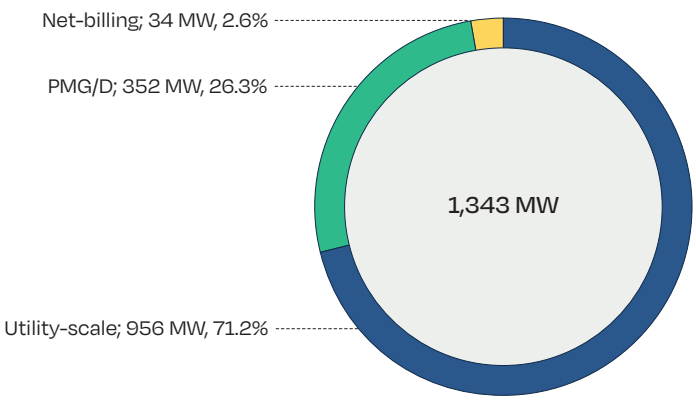
From 2015 through 2020, Chile added an average of around 525 MW of solar capacity per year to its electricity matrix, maintaining steady growth. This growth was almost solely based on utility-scale size projects until 2016. Since 2018, however, distributed solar installations such as PMGD (Pequeños medios de Generación Distribuida, projects up to 9 MW) and net-billing projects (up to 0.3 MW) have been playing a significant role in supporting the annual growth. Between 2020 and 2021, annual installed solar capacity has more than doubled, from 614 MW in 2020 to 1,343 MW in 2021. This is without considering a total of 1,560 MW of solar projects already constructed and still in the commissioning phase, starting their operations in 2022. The 1,343 MW split into 34 MW of net-billing projects (2.56%), 352 MW of PMGD projects (26.25%) and 956 MW of Utility Scale projects (71.18%).

Chile has made a name for itself because of its very good conditions for renewable energy investments. The Climatescope 2021 published by Bloomberg New Energy Finance highlighted Chile as the "best country in America" to invest in renewable energy for the fourth year in a row. The official targets for renewable energy penetration in Chile, demanding 20% of ERNC (Non-Conventional Renewable Energy), have already been met in 2020, 5 years ahead of plan.

In the latest update of the National Energy Policies (PEN), there are several targets that are remarkable. The PEN considers that Chile has to generate 80% of its electricity with zero-emission technology by 2030 and 100% by 2050. The ERNC target is also being updated and will probably aim at 40% of ERNC generation until 2030.

The country has dedicated policies for net-billing projects of up to 300 kW with a clear focus on self-consumption, PMGD projects up to 9 MW, as well as utility-scale projects.

FIGURE GW16.1 CHILE ANNUAL SOLAR PV MARKET 2021, BY ACESOL



SOURCE: ACESOL, based on monthly SEN report April 2022 by CEN (Coordinador eléctrico nacional) and CNE (Comisión Nacional de Energía).

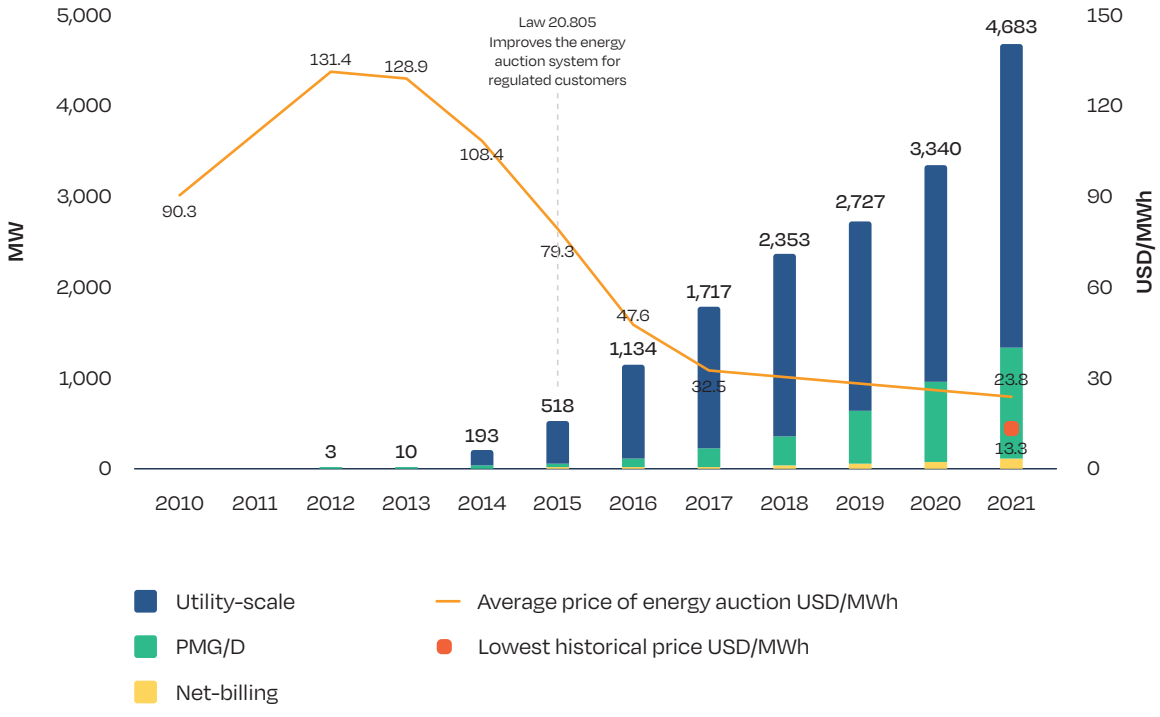
The law for net-billing projects was implemented in 2012 and started operations in 2014. In 2019, the net-billing rules were updated, raising the capacity from 100 to 300 kW and opening doors for remote generation. A new law is currently under discussion, which would raise the capacity again, this time to 500 kW. The net-billing law allows regulated electricity clients to connect self-consumption PV systems to the public electricity grid and repay injected energy at a price that is equivalent to about 80% of the total electricity costs.

The Energy ministry implemented several programs to support solar demand, such as Casa Solar, which subsidised more than 3,000 families in order to implement solar systems; Ponle Energía a tu PYME", or Ponle Energía a tu empresa, which benefit small and medium sized companies with a direct subsidy. Recently, the new government, led by President Boric, announced the intention of raising net-billing installations from about 108 MW in 2022 to 500 MW in 2026.

The PMGD regulation enables solar projects of up to 9 MW to make use of a simplified development process, through which a project can be developed in 12-24 months. Moreover, it establishes a stabilised pricing structure that allows these projects to sell their energy at a fixed price. This price is calculated every six months and avoids the high volatility of spot markets. This pricing structure has recently been revised and prices now vary during the day across 6 blocks of 4 hours each. Before that, the fixed price was calculated without time blocks as a fixed 24-hour price, which enabled a stable pricing structure alternative to traditional PPAs or the spot price.

Utility-scale projects are mainly based on two different commercial approaches. The first is through tenders to supply the energy needed for the regulated clients' demand, while the second is through the establishment of a PPA contract. Tenders are only being initiated if the demand simulation done by CNE indicates its necessity. Projects may also sell their

FIGURE GW16.2 CHILE CUMULATIVE SOLAR PV CAPACITY AND AUCTION PRICES 2010-2021, BY ACESOL



SOURCE: ACESOL, based on monthly SEN report April 2022 by CEN and CNE.

generation directly at the spot market. Since 2015, 1,226 MW of solar capacity has been deployed in order to supply regulated clients under this tender scheme. An additional 2,000 MW of projects have already been awarded in recent tenders, slated to start operation by 2025. The rest of the solar capacity, about 3,300 MW, is supplying energy to independent clients.

Considering that about 1,600 MW of solar projects are already in testing phase, it is assumed that Chile will be able to achieve up to 2.5-3 GW of newly installed solar capacity during 2022, with a focus on distributed generation.

It is assumed that the target for a coal phaseout will be more aggressive under the new government, considering scenarios that include a total phaseout in 2025. In order to replace these thermal power plants, it is estimated that Chile will need about 18,000 MW of new renewable energy capacity from 2022-2025, including 1,000 MW of storage capacity.

Considering the long-term development, in April 2022, the Chilean Ministry of Energy published its updated version of the long-term energy planification (PELP), which still does not consider the accelerated coal phaseout and the target for 100% zero emissions in 2050. Overall, between 2022 and 2025, it can be expected that Chile will add about 5-10 GW of new capacity.

Author: *David Rau,* Vice President, Chilean Solar Association (ACESOL).

145 MW Rio Escondido solar park, Tierra Amarilla, Atacama, Chile.

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17. Turkey

Overview of PV developments

Turkey is one of the fastest-growing energy markets in the world and its total energy demand has been increasing rapidly. In answer to many concerns – climate change, the health effects of air pollution, energy security, volatile oil prices – the country is looking at developing renewable technologies and solar PV comes as one of the pioneers of the future energy mix.

At the end of 2021, Turkey had almost 100 GW of installed electricity generation capacity and solar PV accounted for 7,816 MW. This represents an annual increase of 1,148 MW compared to 2020, which allowed solar PV to reach 7.8% of all Turkish generation capacity.

The breakdown for other generation sources is as follows: 48.3% fossil fuels (natural gas, coal, liquid fuels, etc.), 31.5% hydro, 10.6% wind and 1.6% geothermal. Although the most significant increases in installed renewable power are in the fields of wind and solar energy, almost all natural gas and around 40% of coal were imported. Therefore, Turkey needs to boost its energy self-sufficiency by tapping into its rich potential of renewable energy sources.

'Unlicensed' PV systems – facilities that do not need a licence to operate – have been one of the main factors contributing to the increase in installed solar PV capacity in recent years, accounting for almost 90% of total solar installations. The primary purpose of unlicensed production is to encourage domestic consumption for both households and industrial establishments. The Turkish Electricity Market Law (No. 6446) has created the necessary legal basis for unlicensed electricity generation for the sector players. Under the current regulation, all rooftop PV projects below 5 MW are considered unlicensed systems. By contrast, ground-mounted systems need to have specific applications (e.g., agricultural irrigation) to be included in this category.

This increase in solar energy investments has naturally led to the production of PV modules. In 2021, 22 companies were producing PV modules for a total annual production of 6,500 MW, while around 800 MW of cells are domestically manufactured. Today, Turkey has the only vertically intergrated manufacturer in Europe that produces monocrystalline ingots/wafers, cells and modules. It is expected that this figure will increase rapidly with new investments to be made. Turkish PV manufacturers are mostly focused on the domestic markets in general, but the companies are increasing their exports and country/region portfolios.

Solar/RE targets

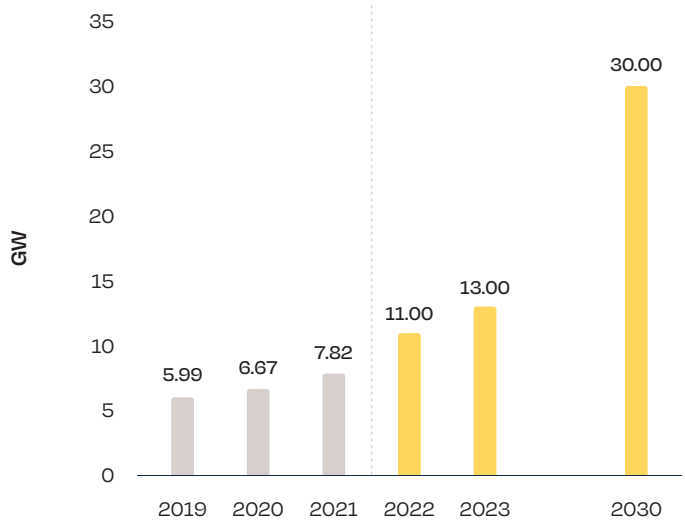
Solar energy is one of the most valuable renewable energy sources, which is still untapped in Turkey with an expected potential of at least 500 GW. In its Strategic Plan for 2019-2023, the Ministry of Energy and Natural Resources (MENR) aims to increase the share of domestic and renewable energy sources from 59% to 65% of the total installed power. This would lead in 2023 to a total of 56.8 GW renewable energy sources, including 10 GW in solar energy, 11.9 GW in wind energy, 32 GW in hydroelectric energy and a total of 2.9 GW in geothermal and biomass.

As GÜNDER, we predict that we will reach between 10 and 11 GW of installed solar power capacity already in 2022. It will continue to at least 13 GW in 2023 and 30 GW by 2030. Under that scenario, sectoral employment and qualified workforce will increase, domestic module technologies and production industry capacity will develop, and all of these will enable Turkey to become the regional solar energy leader. Moreover, the capacity increase in solar energy will be supported by the development of storage systems in Turkey.

Drivers for solar growth

Turkey has been supporting renewable energy sources through several mechanisms such as the Renewable Energy Support Mechanism (YEKDEM) and special auctions for large solar energy power plants with a purchase guarantee for a certain time interval. The YEKDEM mechanism is a Feed-in Tariff (FiT) providing a purchase guarantee for PV electricity since 2011 with a flat price rate of 1.95 TRY/kWh (0.12 EUR cents/kWh). The majority of the power plants installed under the YEKDEM system are operated according to the regulations on Unlicensed Electricity Generation in the Electricity Market.

FIGURE GW17 CUMULATIVE INSTALLED SOLAR CAPACITY AND GROWTH SCENARIOS UNTIL 2030, BY GÜNDER



SOURCE: GÜNDER.

The government introduced a new mechanism called YEKA in 2016. The YEKA system introduced a new tender process to deploy solar and wind energy power plants in pre-specified areas. The government plans to commission 10 GW solar PV capacity in the period 2017-2027, with 1 GW installed each year. The first 1 GW YEKA tender in the Konya-Karapinar region was concluded in 2017 with a purchase guarantee at a price of 1.02 TRY/kWh (6.46 EUR cents/kWh). One of the requirements of this tender was to manufacture all components of the power plant domestically. As a result, a new manufacturing facility with an initial annual capacity of 500 MW for solar ingots, wafers, cells and modules started production in 2020. The Konya-Karapinar 1 GW power plant is expected to be completed in 2022.

Another YEKA tender was concluded in 2021 for 74 distributed small power plants with a total capacity of 1 GW. Due to high competition, extremely low prices down to 0.41 TRY/kWh (2.59 EUR cents/kWh) has been offered by the companies. Two new YEKA tenders are being prepared for 2022 by the MENR.

In May 2019, the government also introduced a new regulation for residential, commercial and industrial applications that allows subscribers to sell the excess generation to the grid at retail price for ten years. The upper limit for the residential has been set at 10 kW, while for commercial, industrial and public applications it goes up to 1 MW.

Utility-scale vs. distributed & rooftop solar development and plans

In 2021, the trend towards rooftop solar energy investments has increased. We anticipate that the rise will continue in 2022 as well. According to industry and public stakeholders, there is at least 20 GW of technical potential for rooftop solar in buildings in Turkey and we expect at least 10 GW to be put into operation in the coming years.

One of the actions that can be taken to increase solar capacity is to ensure the establishment of licensed facilities that do not have a purchase guarantee, but that have the right to sell electricity to the free market through bilateral agreements or Energy Exchange Istanbul (EXIST). Moreover, there is a sectoral expectation for new solar power facilities to be established without competition but with a purchase guarantee.

Challenges

The biggest challenge in the sector is to have access to finance for deployment and manufacturing of solar PV. Renewable energy projects stand out as technology-intensive investments that can be developed primarily with the appropriate legislation and technologies.

The spike in oil, natural gas, and coal prices causes serious cost increases in electricity production. Considering the potential of renewable energy in Turkey, we need to accelerate the development of the solar energy sector and the realisation of investments. The new capacities provided for wind, solar energy and hybrid facilities investments will strengthen this process.

Outlook

The push for decarbonisation of energy-intensive sectors has led to an increased need for renewable and energy efficiency solutions. Several elements will be crucial to realise this transition, such as more investments in low-carbon energy technologies, the development of robust and smart electricity grids, the deployement of storage and renewable hydrogen, as well as a higher penetration of renewable energy sources.

In addition, Turkey ratified the Paris Agreement in October 2021 and solar energy applications are presented as essential to achieve the energy transition. Demand-oriented renewable energy applications with high environmental and economic benefits should be the focus of Turkey's clean energy development.

On a research point of view, most activities are primarily carried out by universities, public and private research centers. The involvement and contribution of the private sector have been weak. A majority of the R&D projects are realised with support from the main funding agency, The Scientific and Technological Research Council of Turkey (TUBITAK). Also, Turkey has been participating in the European Union Framework Programmes supporting R&D projects through many project calls. The latest programme, Horizon Europe, has started in 2021 and will continue until 2027. In 2021, MENR initiated a new research structure called TENMAK, which is an umbrella organisation hosting several research institutes, including the Clean Energy Research Institute. TENMAK is currently preparing roadmaps of R&D activities for its research institutes.

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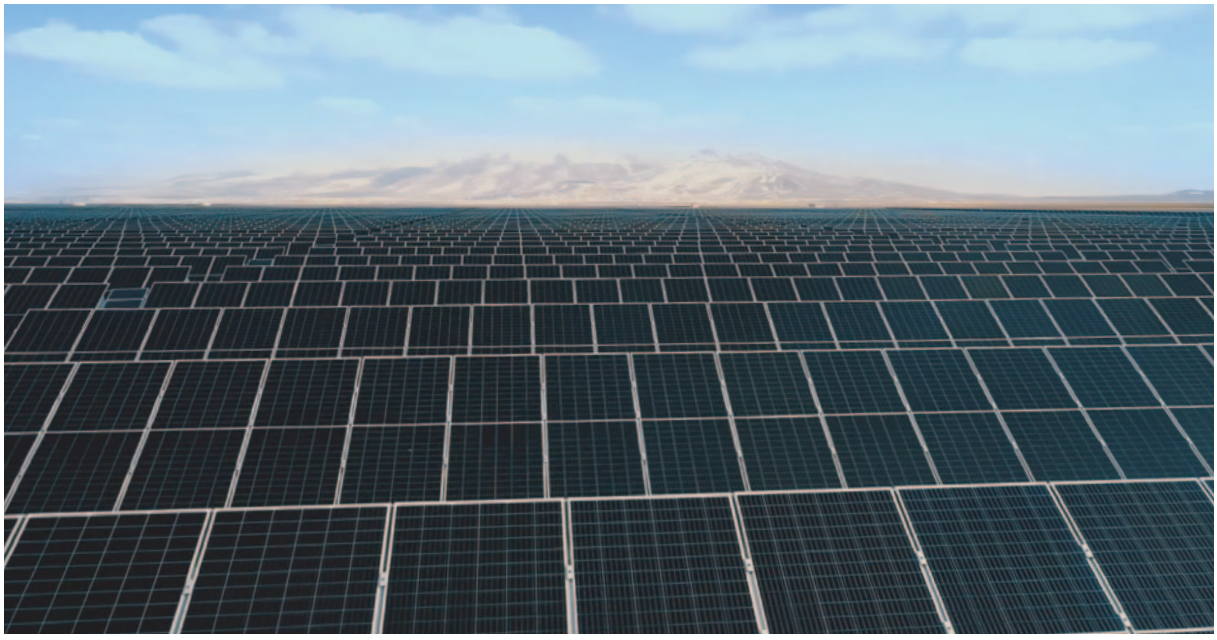

600 MW, Konya Karapinar solar park, Konya, Turkey.

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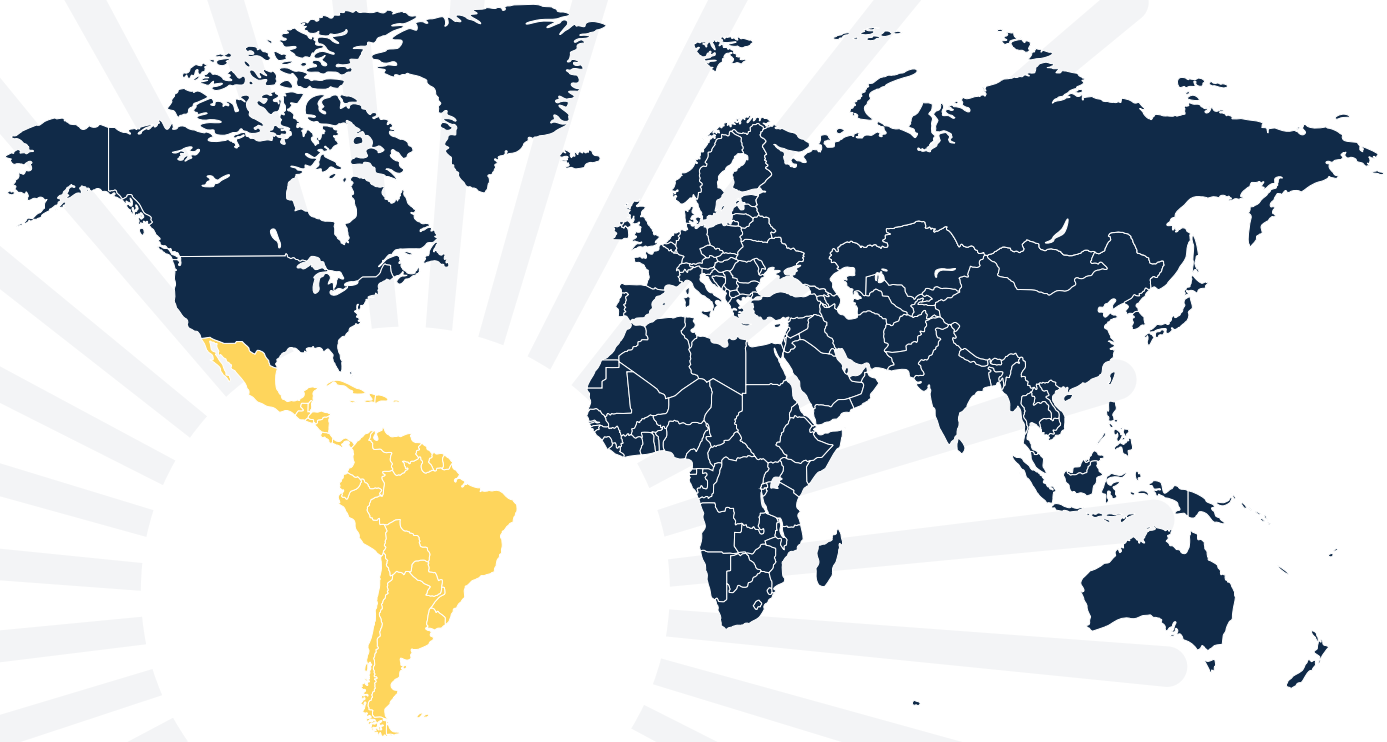

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