

Scaling Up Solar in ISA Member Countries

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BloombergNEF

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Executive Summary

Thanks to dramatic cost declines, particularly over the last decade, solar power is poised to catalyze the world's transition to a lower-carbon economy.

Photovoltaic technology also has the potential to help lift no less than a billion people out of energy poverty, but only if trillions of dollars in private investment are mobilized and the right policy frameworks are erected.

In this report prepared for the International Solar Alliance, BloombergNEF examines recent solar technology, cost and deployment trends. The study also includes BNEF's short- and long-term projections for new build and examines policy best practices to date. Key findings:

- Solar power today represents the lowest cost, most economic solution for adding new power generation capacity in countries home to well over half the world's population and gross domestic product.
- From 1976 to 2020, the average price of a crystalline silicon photovoltaic (PV) module fell from \$77 per Watt (in 2020 dollars) to just 22 cents per Watt. The price has risen in 4Q 2021 to 25 cents due to temporary constraints in polysilicon and other parts of the supply chain.
- PV's price decline follows a consistent and predictable "learning rate". For each doubling of PV installed worldwide, the cost of making a module falls by approximately 28.4%. BNEF anticipates this trend continuing in the long term despite current price rises, as manufacturers design superior cells that achieve higher efficiencies and make other improvements.
- A current typical cost of an installed Watt (DC) of solar capacity in a utility-scale project is \$0.62. BNEF projects that to sink to \$0.50 by 2025. The drop will be driven by further reductions in the costs of modules, and by better technology and lower installation costs.
- Global electricity demand doubles in the next three decades. In the 80 less developed nations in ISA's "Beneficiary" classification, demand nearly triples. Strong sun and poor access to fossil fuels make these markets particularly fertile for solar development.
- PV used in mini-grids, solar home systems or other off-grid applications has the potential to be transformative in developing nations. However, the build-out of such capacity is contingent on cooperation from local authorities, including regulators and state-owned utilities. New off-grid activity and investment appeared to be hurt by the Covid-19 pandemic and slowed in 2020.
- Installed solar capacity stands at over 788GW today and BloombergNEF expects that to quadruple to 3.2TW cumulatively installed by 2030. This rate of growth will not be nearly fast enough to put the world on a path to net-zero CO2 emissions by 2050, however.
- BNEF has modelled multiple longer-term scenarios. Under BNEF's "Green" scenario, governments dramatically strengthen policies to meet the goal of achieving net-zero CO2 emissions by 2050, including providing heavy support for the use of hydrogen produced with zero-carbon sources of energy. Under the Green scenario, the world has 5.3TW of solar on line by 2030, both to meet 17% of electricity demand and to power a major ramp in green hydrogen production.

- As solar's share of generation grows, so too does complementary battery capacity, to ensure energy produced from the sun can be used well after dark. Under BNEF's Economic Transition Scenario, which largely assumes the current policy status quo remains, 1.5TW of new battery capacity is built in the next three decades. Netting out projected retirements of batteries over the period, cumulative capacity reaches 1.3TW in 2050.
- The capital requirements to underwrite this massive build-out are substantial. Under the Economic Transition Scenario, from 2021-2030 about \$1,200 billion goes to the construction of 1.6TW of solar while \$151 billion supports 165GW of associated battery capacity.
- Expected build rates must more than double to reach the cumulative capacity of 19.7TW by 2050 under BNEF's Green scenario. This may seem outlandish, given that there is well under 1TW installed today, but the sector has grown both extremely rapidly and somewhat unpredictably to date. As of year-end 2000, just 1.5GW was installed worldwide. By 2010, that had risen to 42.6GW. It totals over 788GW today.
- Feed-in tariffs helped spur solar deployment booms in some countries from 2005-2015. As solar has become more cost competitive, however, policymakers have more often turned to competitive auctions to solicit lowest bids for power delivery from solar projects at a much lower cost than feed-in tariffs. To date, over 190GW of new solar capacity has been added in response to auctions.

This report is divided into six sections touching on the key aspects of the solar industry today and examining the elements required for it to enjoy further growth tomorrow. Section 1 summarizes historical trends in solar technology development that have allowed costs to drop so precipitously over the past four decades. It also includes BNEF's projection of further cost declines over the next decade. Section 2 summarizes BNEF's 2-year projections for energy demand growth worldwide at a high level, including in each of the ISA country groupings.

Section 3 tightens the lens somewhat to look at solar growth rates in the immediate term in ISA nations. It examines the on-grid, off-grid and solar thermal electricity generation sub-segments of the market in further detail. It also looks at the current state of play in the PV manufacturing supply chain. Section 4 illustrates how capital has been deployed to date in support of solar of development. This includes a look at which ISA nations have been most successful in attracting investment and which have lagged. It also spotlights the organizations that have provided financing thus far. Section 5 contains BNEF's long-term outlooks for solar build, battery build and investment levels region by region.

Finally, Section 6 discuss the key policies that have allowed solar to flourish in many countries to date and offers preliminary thoughts on what further work may be needed in this area to accelerate the much faster growth required to meet the climate challenge.

About Us

BloombergNEF

BloombergNEF (BNEF) is a strategic research provider covering global commodity markets and the disruptive technologies driving the transition to a low-carbon economy. Our expert coverage assesses pathways for the power, transport, industry, buildings and agriculture sectors to adapt to the energy transition. We help commodity trading, corporate strategy, finance and policy professionals navigate change and generate opportunities.

Bloomberg on Climate

Led by Michael R. Bloomberg, a global climate champion and Special Envoy to the UN Secretary-General, Bloomberg is tackling the climate crisis from every angle.

Bloomberg Philanthropies is at the forefront of U.S. and global efforts to fight climate change and protect the environment across a key array of issues. Bringing together mayors and other government and business leaders, grassroots partners, and environmental advocates, Bloomberg Philanthropies implements bold programs that tackle the climate crisis and help build a more sustainable, resilient, and equitable economy. Its efforts are accelerating the transition from coal to clean energy, improving air quality and public health, advancing city climate action, protecting and preserving ocean ecosystems, and helping unlock billions of dollars in sustainable finance.

Bloomberg L.P. provides the global financial community with data-driven insights, news, and analysis to help them integrate an ESG lens across the investment process. As a company, Bloomberg L.P. is also leading by example, including committing to net-zero carbon emissions by 2025 and taking action in the communities where its employees live and work. And through Bloomberg's stewardship of the Task Force on Climate-related Financial Disclosures and the Climate Finance Leadership Initiative, Bloomberg is using the power of the capital markets to address climate change and support the transition to a net-zero economy.

Bloomberg Philanthropies

Bloomberg Philanthropies invests in 810 cities and 170 countries around the world to ensure better, longer lives for the greatest number of people. The organization focuses on five key areas for creating lasting change: the Arts, Education, Environment, Government Innovation, and Public Health. Bloomberg Philanthropies encompasses all of Michael R. Bloomberg's giving, including his foundation, corporate, and personal philanthropy as well as Bloomberg Associates, a pro bono consultancy that works in cities around the world. In 2020, Bloomberg Philanthropies distributed \$1.6 billion.

The International Solar Alliance (ISA)

The ISA is a growing international organisation of 80 member countries. ISA supports governments around the world to improve energy access and security by promoting solar energy as a sustainable, affordable and resilient way to transition to a carbon-neutral future.

ISA's vision is to facilitate energy access in every corner of the world by delivering cleaner electricity to all by 2030. ISA's mission is to unlock USD 1 trillion of investment by 2030 by reducing the cost of the technology and its financing, and increasing the skills of people working in the industry. The ISA will help deliver global relevance, local benefit to all countries through collaborations, with its key interventions focusing on readiness & enabling activities, risk mitigation & innovative financing instruments, which will then facilitate the promotion and deployment of technologies in respective target markets.



Section 1. Solar and battery technology, trends and costs

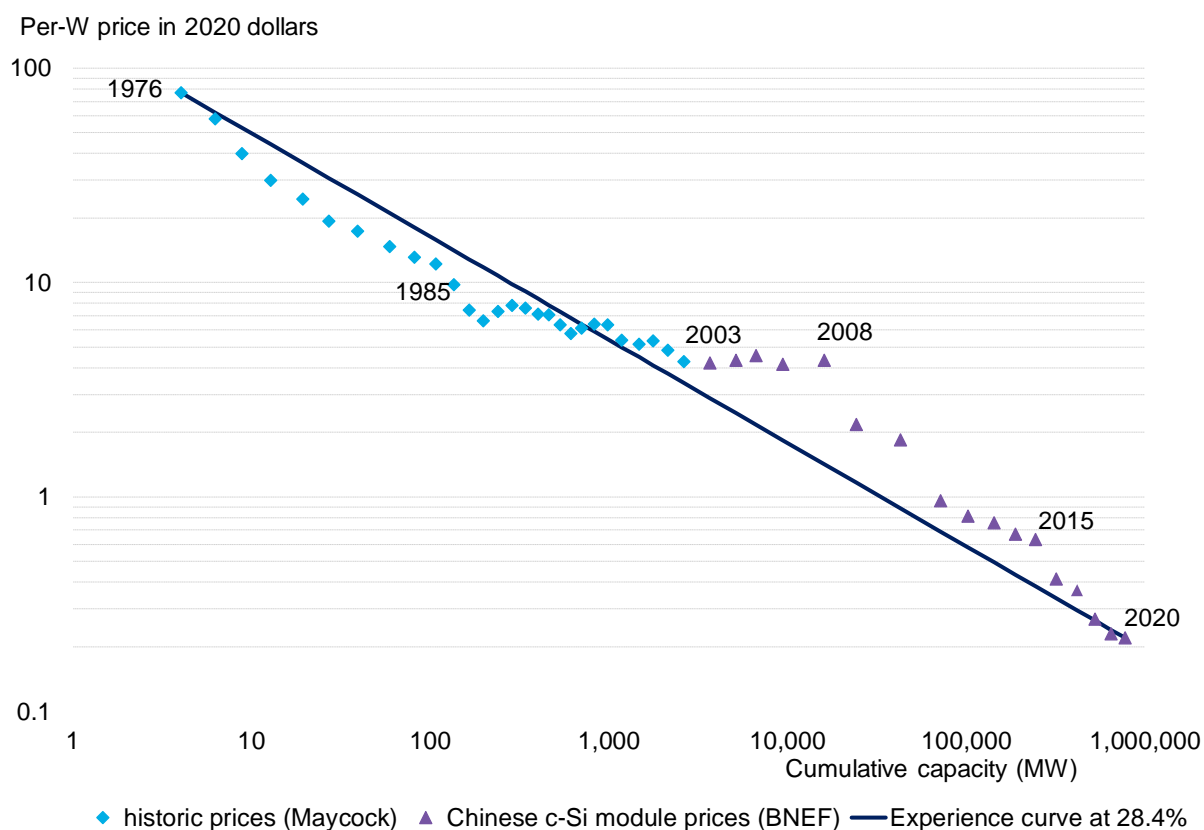
Clean energy market growth is being enabled by rapid falls in the cost of PV modules and lithium-ion batteries. While in the past subsidies mainly drove adoption of solar and batteries, today dramatically lower prices are making both technologies more accessible to ISA countries. PV, in particular, is now cost now broadly cost competitive across most of these nations and beyond.

1.1. Photovoltaics

Since 1976, we have seen a rapid fall in price of crystalline silicon PV modules, from \$77/W (in 2020 dollars) to \$0.22/W for monocrystalline silicon modules at the end of 2020, though as of September 2021 the price has risen somewhat to \$0.24/W due to constraints in the supply of polysilicon. In the long run, we expect the cost reductions to continue because manufacturers are making technological tweaks such as thinner wafers, designing better cells to achieve higher efficiencies, and using conductive pastes more precisely to reduce material use.

This curve follows a learning rate – the cost reduction per doubling of deployed capacity – of about 28.4% (Figure 1).

Figure 1: PV module experience curve



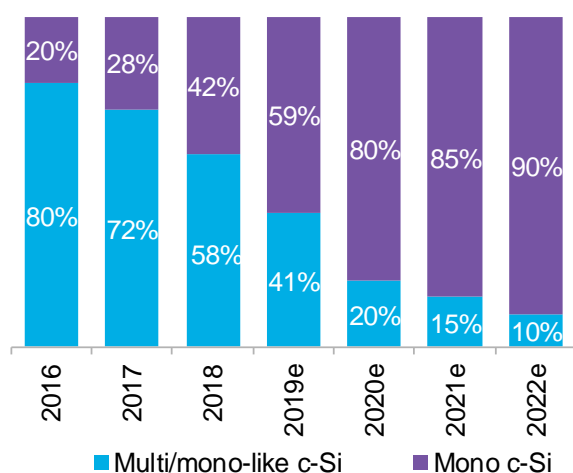
Source: Paul Maycock, BloombergNEF

This learning curve has been made possible by a combination of technology innovation, economies of scale and manufacturing experience. It does not assume any major breakthroughs, such as a rapid uptake of perovskite or other technologies. The learning curve uses price as a proxy for cost, because average price data for solar modules is much more available than cost data and margins are usually slim.

Another factor that has helped to cut polysilicon use and ultimately costs has been a strong shift from multicrystalline to monocrystalline silicon modules since 2016 (Figure 2). Monocrystalline cells have always been more efficient and used less material per watt, but the introduction of diamond wire saws and other manufacturing improvements have lowered mono cell production costs to below those of multi. Much of the shift was driven by one company, Longi Green Energy Technology, a major wafer maker which has dramatically scaled up mono cell and module capacity and proven a competitive advantage. Most of Longi's peers have now followed suit and shifted to mono.

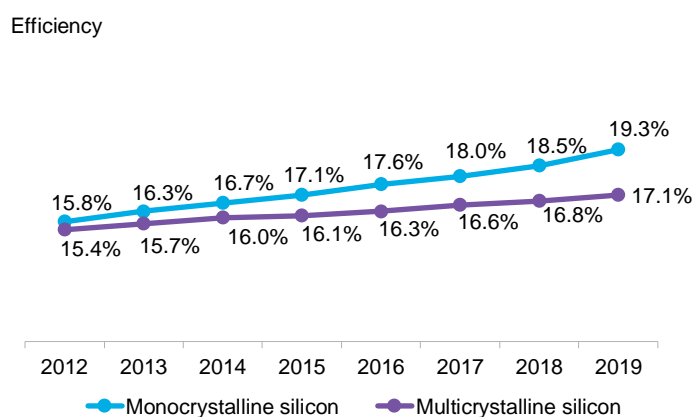
Both mono and multi cells and modules have become more efficient over time, according to a survey of manufacturers BloombergNEF performs every year (Figure 3).

Figure 2: Share of crystalline silicon PV annual sales by technology



Source: BloombergNEF

Figure 3: Average module efficiency of surveyed manufacturers

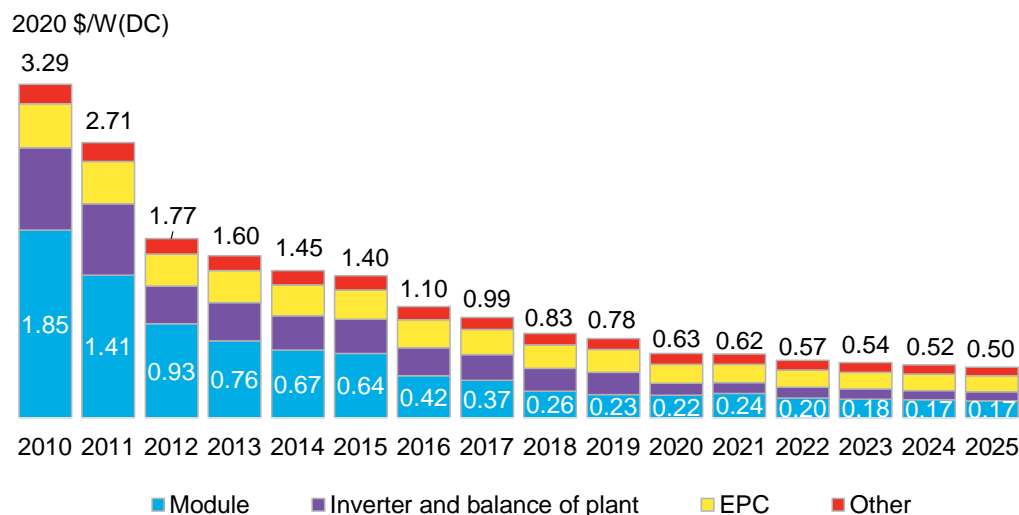


It is more difficult to pinpoint learning rates for the rest of the components that go into a solar project – the inverter, the mounting structure, cables, groundwork and engineering or installation. However, these are also getting steadily cheaper. The other three categories of costs in Figure 4 – balance of plant (BOP), engineering, procurement, and construction (EPC), and development costs (others) – are mostly related to the physical size of the plant or have a fixed cost per project. When more efficient modules are used, these expenses can be averaged over more power, leading to lower per-watt costs.

Engineers tasked with building projects in the field have also innovated to find numerous ways to reduce costs. These include using machines to install modules, shifting utility DC system voltage to 1,500V instead of 1,000V, and tweaking the inverter load ratios to use less inverter per module. For our longer-term projections, BNEF assumes that costs for EPC and balance of plant continue to decline 2% per year on top of the efficiency improvements.

Combining our forecast view of module, inverter, balance-of-plant and engineering costs, we expect the global capex benchmark for a utility-scale PV project to decline from \$0.63/W in 2020 to \$0.50/W in 2025, and \$0.42/W by 2030.

Figure 4: BNEF global benchmark capex forecast for fixed-axis utility-scale PV systems



Source: BloombergNEF

Site-specific factors obviously influence capex, and competition for grid connection adds additional cost. In sunny places, projects are usually designed to track the sun across this sky. This allows a system to generate about 25% more energy for about 5 cents per Watt of extra capex.

1.2. Large-scale battery electric storage systems

Today, most stationary battery electric systems installed globally are located outside ISA countries, with China and the U.S. the leading markets (Figure 5 and Figure 6). The bulk of current capacity is accounted for by utility-scale systems, not those located “behind the meter”(inside homes or businesses). While these deployments are contributing to economies of scale for li-ion batteries, it is the major ramp in electric vehicle demand that is primarily driving down battery costs.



Figure 5: Global energy storage build, historical and forecast, by country

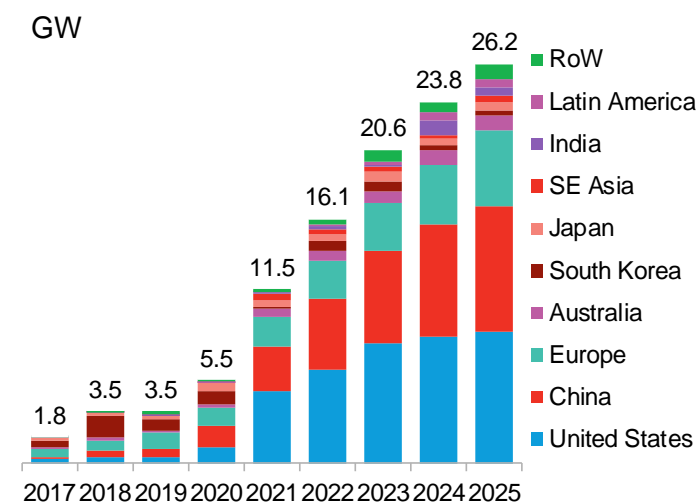
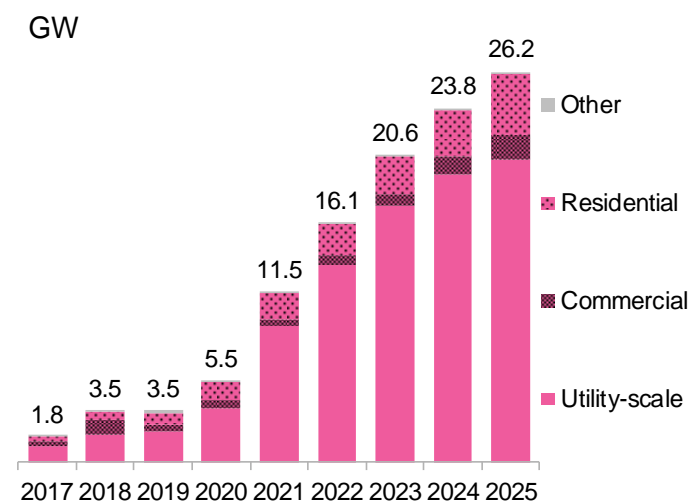


Figure 6: Global energy storage build, historical and forecast, by segment



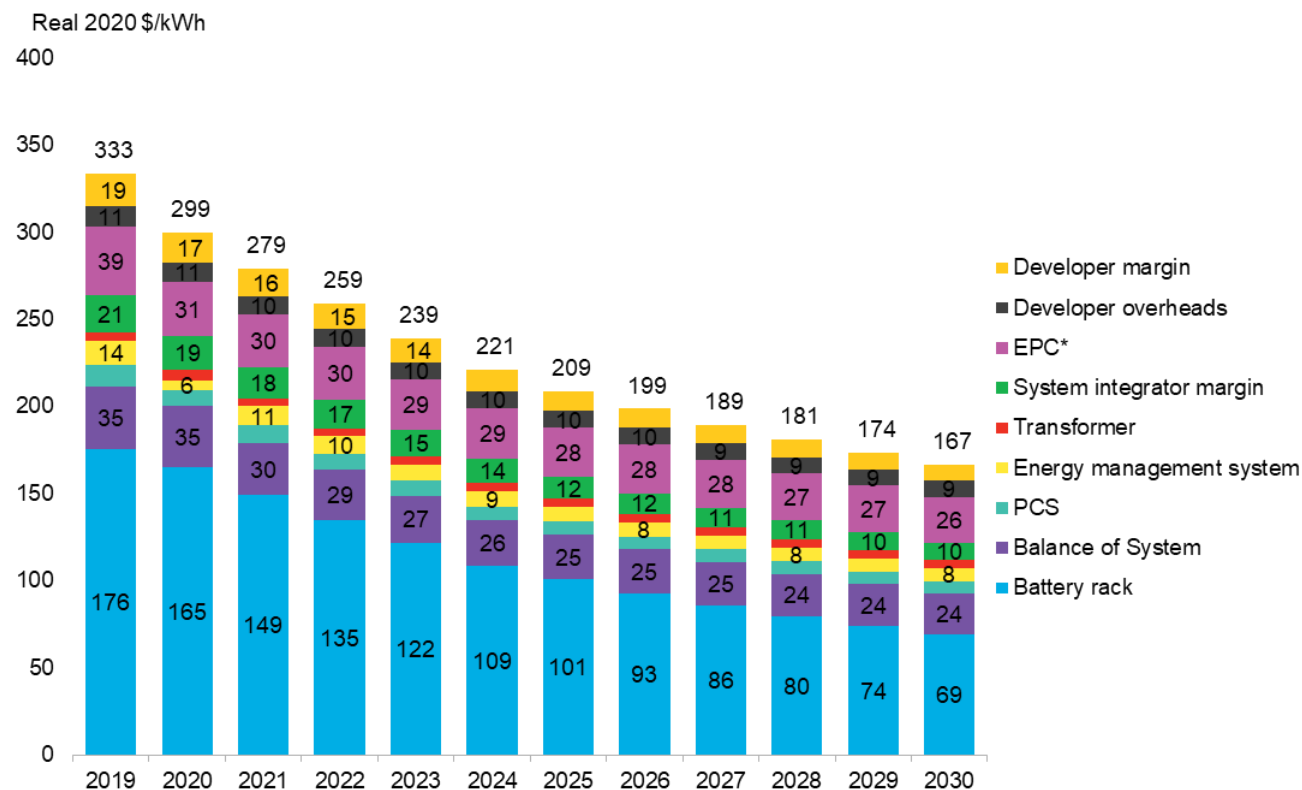
Source: BloombergNEF Note: Includes lithium-ion based and non-lithium-ion based batteries; excludes pumped hydro capacity.

Nearly all elements of building a large battery system are coming down (Figure 7). While a typical capex for a four-hour system over 100MWh was about \$333/kWh in 2019, it has already dropped and is expected to hit \$167/kWh in 2030. In 2020, the dominant technology was lithium iron phosphate technology.

Prices for energy storage systems vary substantially depending on the power-to-energy ratio, the size of the project, its complexity, the level of built-in redundancy and local regulations.



Figure 7: Capex for a large four-hour duration AC energy storage system



Source: BloombergNEF. Note: We consider a large project to be over 100MWh. Excludes warranty costs, which are often paid annually rather than as part of the initial capital expenditure. These costs do not explicitly include any taxes, although due to a lack of transparency in the market, some may be unknowingly included. This is for a brownfield development so excludes grid connection costs and includes a 5% EPC margin. It does not include salvage costs or project augmentation. 2019 figures adjusted for inflation to convert to real 2020 \$.

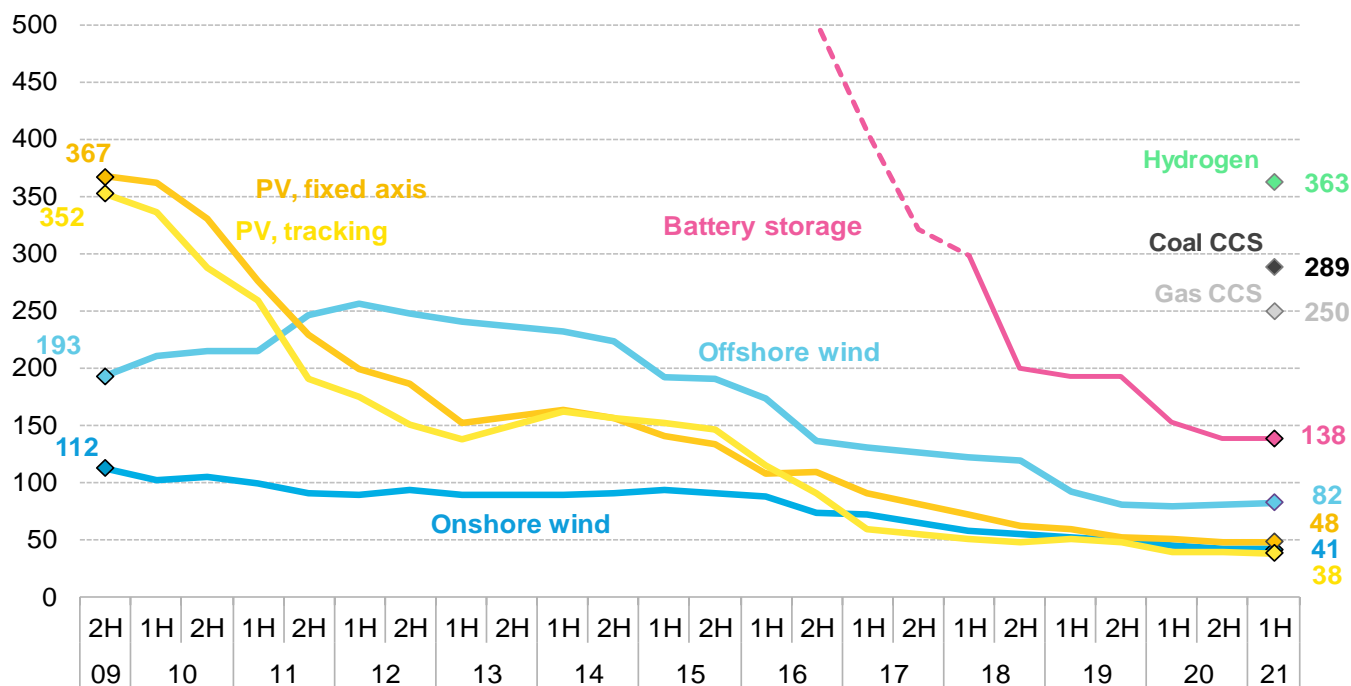
1.3. Levelized cost benchmarks

BloombergNEF attempts to benchmark the cost of generation (Figure 8), although this varies widely across different climates, system designs and specifications and uses, and cost of capital. The levelized cost of PV on a per-MWh basis has come down about 87% since 2009, and the cost of battery electric systems about 54% since the first systems started to be added in 2018.



Figure 8: Global Levelized Cost of Electricity (LCOE) benchmarks for selected low-carbon technologies in the power sector

LCOE (\$/MWh, 2020 real)



Source: BloombergNEF. Note: The global benchmark for PV, wind and storage is a country-weighted average using the latest annual capacity additions. For hydrogen-fired power, coal- and gas-fired power with carbon capture and storage (CCS), it is a simple global average. The storage LCOE is reflective of a utility-scale Li-ion battery storage system with four-hour duration running at a daily cycle and includes charging costs.

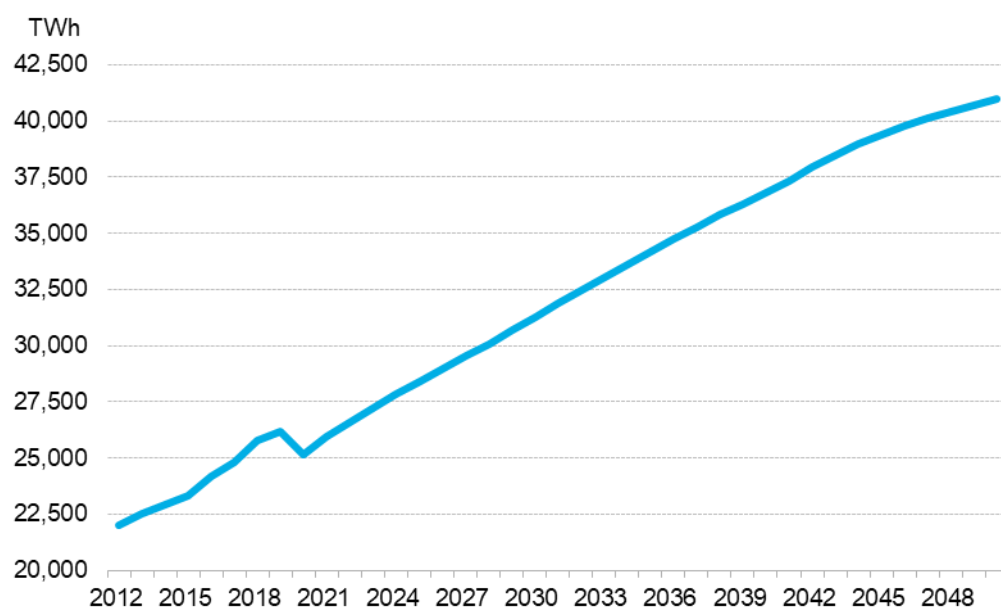


Section 2. High Level Energy Demand Forecasts

As the world's economy and population grow over the next three decades, electricity demand will double, BloombergNEF projects (Figure 9). Among individual nations, China and India are the two biggest sources of growth on an absolute basis, consuming 4,167TWh and 3,069TWh more power annually by mid-century than they did in 2019. In less developed nations, the pace of growth will be even faster and in “Beneficiary” nations, which are low income countries with solar markets that are less than 100MW annually, in particular, demand growth will be torrid. In ISA “partner” nations, which are middle income countries with solar markets greater than 100MW annually, demand should grow 83% by 2050 while in the smaller, Beneficiary countries it will nearly *triple*.

Among those nations designated as “Facilitators” in the ISA membership, which are high-income countries with solar markets larger than 100MW annually, electricity use grows far more slowly. However, given the relative size of these nations and their economic status, 19% expansion through 2050 will create substantial additional demand in absolute terms. BNEF expects rapid electrification of transportation, followed by heat and potentially other sectors will place greater emphasis on power generation in such countries though this will be partly offset by improving energy efficiency.

Figure 9: Global electricity demand



Source: BloombergNEF New Energy Outlook, Economic Transition Scenario 2020

Underlying our demand outlook are two fundamental drivers: population and economic output. Electricity consumption tends to increase with an expansion of these two, most notably in economies with low to medium GDP per capita. Economies at advanced stages of development

tend to experience much slower demand growth or even a decline in electricity consumption as their GDP continues to expand (Figure 10).

Two factors explain this dynamic at a country level. The first is economic development. The second is improvements in energy efficiency. Agrarian economies with the lowest GDP per capita, many of which are Beneficiary countries, consume relatively little electricity per unit of economic output. This is because in these countries, electrification rates tend to be low and a large fraction of the economic output relies on the direct combustion of fossil fuels and biomass. In contrast, industrializing economies with intermediate GDP per capita (many of the Pivotal countries) tend to have relatively high electricity intensity, consistent with the energy-intensive industry and manufacturing. Economies with the highest GDP per capita (Facilitator), have relatively low electricity intensity, consistent with a dominant service sector that uses much less power per unit of GDP (Figure 11).

Figure 10: Electricity demand in ISA countries, by region, 2010-2050 (TWh)

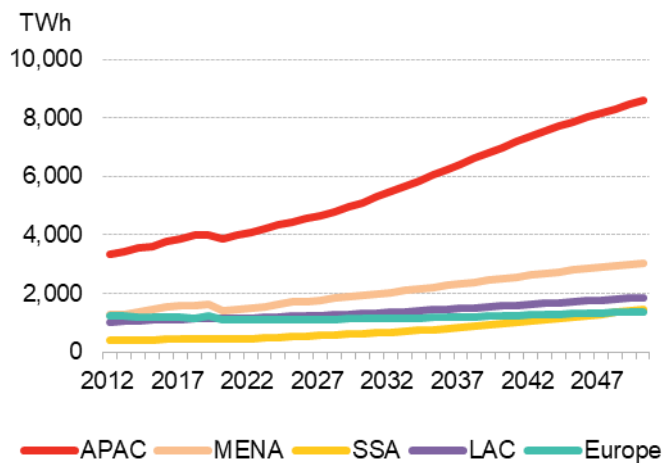
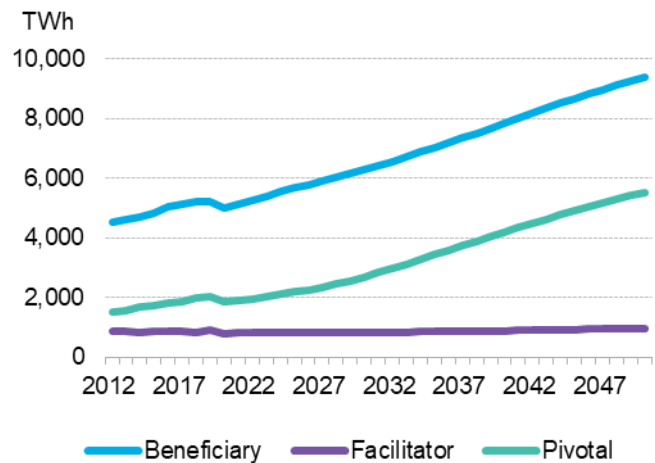


Figure 11: Electricity demand in ISA countries, by country group, 2010-2050 (TWh)



Source: BloombergNEF New Energy Outlook, Economic Transition Scenario 2020. Note: See Appendix A for ISA country list.

To avoid the most catastrophic impacts of climate change, most if not all this new demand will need to be met with zero-carbon power – a formidable challenge requiring an unprecedented build-out of new capacity. For instance, to meet the higher electricity demand in ISA Beneficiary nations entirely with solar would require about 2,700GW of new PV capacity¹. To put that in context, PV capacity was 788GW as of year-end 2020. Higher demand from Pivotal countries would require a further 2,000GW PV capacity.

Photovoltaic build has been rising rapidly and totalled 144GW in calendar year 2020, up from 56GW in 2015 and 18GW in 2010. Still, a massive ramp would be required in ISA nations to meet projected new demand. Furthermore, due to the intermittent nature of solar power production, such build would need to be accompanied by massive deployment of new battery capacity.

¹ Assuming a 20% capacity factor for projects.



Section 3. Near-term solar outlook for ISA member nations

The heterogeneity of ISA nations has created very different opportunities for solar power to flourish, tailored to local conditions. This section examines recent activity in multiple areas of the solar industry across the ISA nations with a look at potential growth over the next decade.

It examines first the recent activity in the “on-grid” segment of the solar market for PV, including utility-scale projects and those located on rooftops of grid-connected homes and businesses. It then turns its attention to “off-grid” with special attention on countries where the desire to expand energy access to all citizens is driving uptake. Recent trends in the solar manufacturing supply chain are then scrutinized, including how manufacturers have sought to keep pace with strong demand for equipment. Finally, this section looks at solar thermal electricity projects and their progress in recent years.

3.1. On-grid PV

As prices for solar have plummeted, the volume of installed on-grid PV has skyrocketed. This has included the build of conventional, utility-scale projects typically located in large open spaces and connected via transmission lines, or systems on rooftops of buildings connected to the grid.

On-grid PV capacity today is about 18 times what it was just a decade ago and totals approximately 788GW. The volume of new build PV added to grids worldwide has risen every year since at least 2005 (Figure 12 and Figure).

The utility-scale segment has led the way with the most gigawatts added, but small-scale solar has also made important contributions. Both segments of the market are expected to grow strongly, with national or local policies likely to influence the exact build mix.

Today, utility-scale PV is considerably larger than rooftop solar, partly because the average size of utility-scale plants has grown so dramatically in recent years. While the biggest solar plant in 2010 was a 70MW phase of the SunEdison Rovigo PV Plant, today there are two projects of about 1.2GW (ADWEA’s Noor plant in Abu Dhabi, and the Qinghai Upper Yellow River Hydropower Hainan Gonghe Talatan UHV PV Plant 1 in China), and 14 more plants over 500MW. In 2020, utility-scale PV was 58% of new solar capacity built.²

² We consider small-scale to be rooftop plants and those primarily intended for on-site self-consumption, with a nominal size cutoff of 1.5MW.

Figure 12: Global cumulative installed PV capacity, by market segment

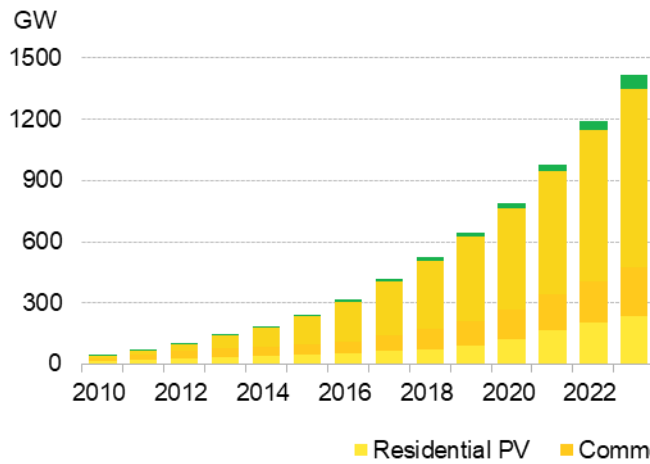
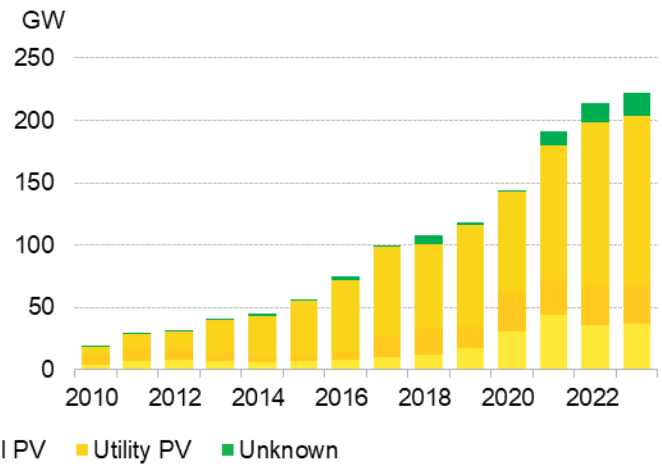


Figure 13: Global annual new PV capacity additions, by market segment



Source: BloombergNEF Note: Forecast as of September 2021.

In the small-scale section of the market (residential and commercial PV), commercial rooftop has historically accounted for the majority of new build. However, in 2020, the split between the two sub-segments was about even (Figure 14 and Figure). BNEF projects that residential solar will be the majority of new rooftop build over the next few years, on current trends.

Figure 14: Global cumulative small-scale PV, by market segment

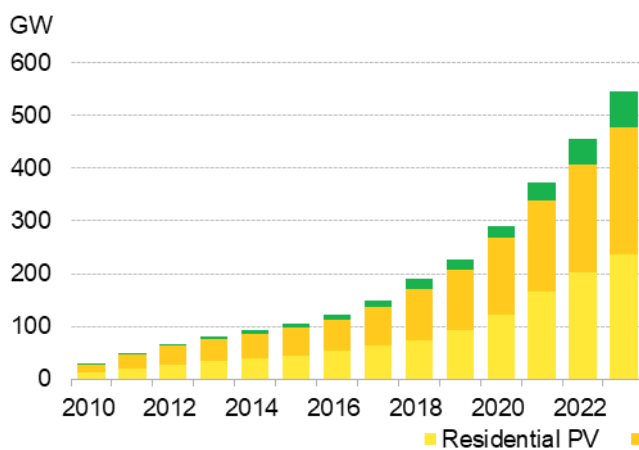
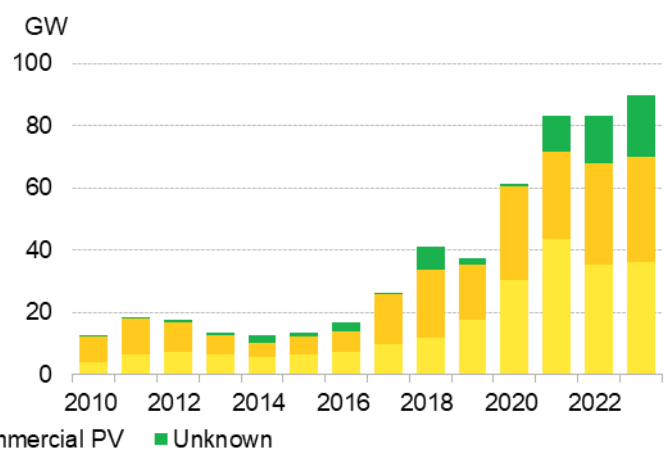


Figure 15: Global annual small-scale PV capacity additions, by market segment



Source: BloombergNEF

ISA on-grid PV snapshot

ISA countries were home to about one-fifth of all grid-connected solar online worldwide as of year-end 2020 and capacity has grown steadily each year over the last decade. However, build in ISA nations slowed in 2020 as Covid-19 stalled activity (Figure 16 and Figure 17). Among the ISA

regions of countries, Asia-Pacific (APAC) – particularly India - has typically accounted for the majority of new build, so it was perhaps unsurprising that activity fell most sharply in that region.

Within the ISA APAC countries, Japan and Australia have historically been the primary growth engines, but that is changing. In India, we expect solar build to rise 57% in 2021 vs. 2020 and to expand at an average pace of 17% annually until 2023, BNEF projects. By contrast, new build in Japan will sink 55% in 2021 compared to last year and then continue to shrink by an average of 36% per year through 2023, because the market is stabilizing after a long but unsustainable subsidy-driven boom. From 2021 on, Australia and India will be the biggest markets for new build among APAC ISA nations.

Among ISA Beneficiary nations, Myanmar was until quite recently a standout for solar build. However, a recent coup in the country has called all predictions about the country into question. In a tender held May 2020, 1GW of projects won contracts to deliver power in 2021. Completion of those now appears very much in doubt; just \$11.17 million of solar equipment – translating to about 46MW of capacity – was exported from China to Myanmar in 1H 2021, according to Chinese Customs data collected by Sinoimex. In August 2021, Myanmar's Ministry of Electricity and Energy (MOEE) issued an invitation for proposals for a second tender. BNEF projects 150MW of new solar capacity to get completed in Myanmar in 2021, but even this may turn out to be optimistic. The market could get back on track if the current political uncertainty passes.

Among the ISA Facilitator cohort, countries in the Europe Middle East and Africa (EMEA) region, notably the Netherlands and France, have built large volumes of solar in the past. Both are poised for further growth, but new markets such as Nigeria and Saudi Arabia are emerging quickly.

Among the ISA nations in the Americas (AMER) region, several have expanded solar capacity dramatically in recent years, including Brazil and Chile. Although activity in Brazil's utility-scale PV sector has slowed due to economic contraction and a lack of tenders for new power-delivery contracts, it has a generous net metering regime which drives strong growth in the residential and commercial segments. Chile uses capacity incentives to encourage increased capacity. In 2018, the country implemented a net metering policy for systems smaller than 300kW.

Figure 16: Cumulative grid-connected PV in ISA countries, by region

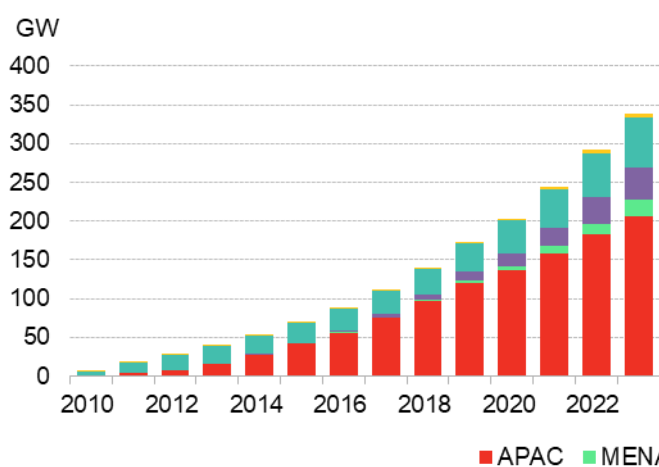
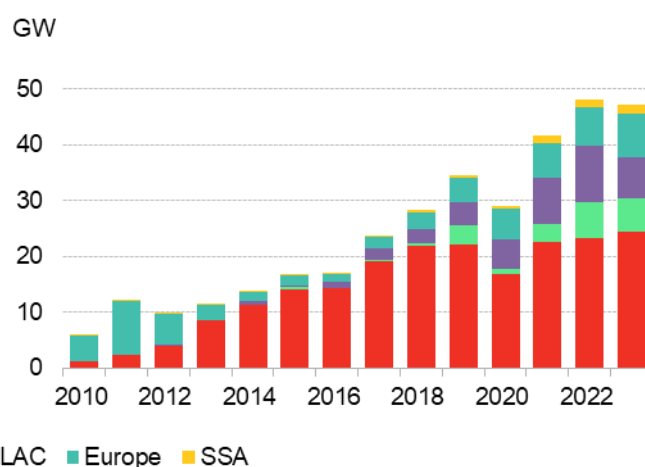


Figure 17: Annual grid-connected PV capacity installed in ISA countries, by region



Source: BloombergNEF. Note: SSA = Sub-Saharan Africa; MENA = Middle East and North Africa; LAC= Latin America and Caribbean; APAC = Asia Pacific. Note: See Appendix A for ISA country list.

Installed solar should rise across all three ISA country classifications at a collective annual rate of 30%, BNEF projects. Facilitator countries will continue to make up the majority through 2022, after which Pivotal countries will make up 56% of total global solar capacity, which will continue to grow into 2023 (Figure 18 and Figure 19).

As solar prices have declined, the technology has become cost competitive across countries in all three ISA nation classifications. That stands in clear contrast to pre-2016 when only Facilitator countries saw significant build, enabled by direct subsidies. In Pivotal countries, capacity has grown significantly since 2011, but annual year-on-year growth rates have actually slowed. From now through 2023, BNEF expects an average annual year-over-year growth rate of 42%.

In Facilitator countries, demand is also growing but more slowly than in Pivotal nations. We expect annual year-over-year growth 2021-2023 for these countries of about 5%. This trend is due in part to the fact that these nations have large installed bases of solar already. Beneficiary countries had seen very little solar build until 2019 when 1GW was added. We predict that the annual year-over-year growth rate from 2021-2023 for these countries will be about 39%.

Figure 18: Cumulative solar PV in ISA countries, by country group

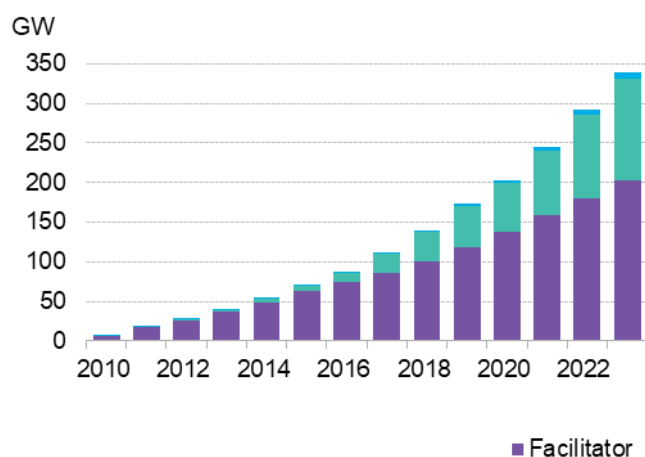
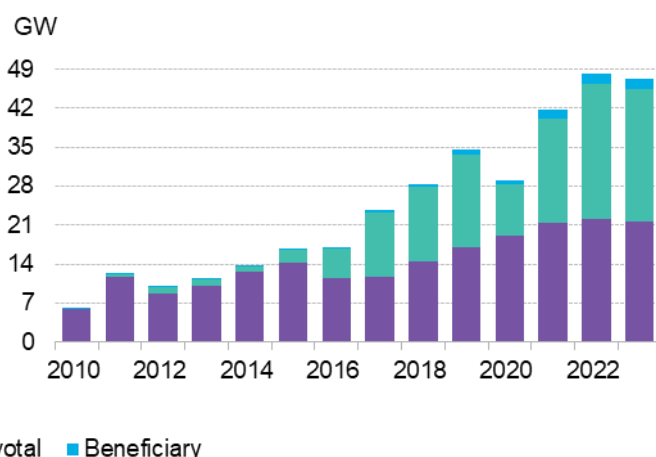


Figure 19: New solar PV build in ISA countries, by group



Source: BloombergNEF. Note: See Appendix A for ISA country list.

Activity by sub-segment

Utility-scale build slowed in 2020 due to the pandemic. Activity in India in particular dipped after the government extended a deadline for when projects needed to be completed. However, utility-scale build appears to be rebounding in 2021, with build resuming in India and an increasing number of big projects due online in African countries in the next two years.

By contrast, small-scale solar build has proven generally resilient in the face of Covid-19, particularly in Facilitator countries.

Utility-scale PV

The pace of utility-scale solar capacity additions slipped substantially in 2020. Among Pivotal countries, the drop was about 8GW, led by India where new build fell from 10GW in 2019 to 3GW. However, specifically in Middle East and North Africa (MENA) Pivotal countries, results were mixed. Oman and Morocco boosted utility-scale build, while Egypt's additions nearly disappeared. Brazil, another country that had consistently been adding utility-scale capacity, also saw additions

slip in 2020. Across all the Pivotal nations, BNEF expects this dip was temporary and capacity additions should rebound in 2021 and continue rise 2022 and 2023 (Figure 20 and Figure).

Beneficiary countries, which account for a far smaller share of activity in any given year, saw new build drop from 0.64GW to 0.54GW. Activity in some of these nations is often sporadic year to year. Zambia, for instance, added 150MW in 2019 but built nothing in 2020. BNEF anticipates that utility-scale build rates will rebound in Beneficiary nations in 2021 and continue to grow year-on-year for the foreseeable future.

In Facilitator countries, utility-scale build remained strong in 2020. This was primarily due to Japan where capacity additions rose from 5GW in 2019 to 7.5GW. Markets such as Australia, United Emirates, and Saudi Arabia are projected to expand, in the latter two countries due to large government auctions for solar build. Australia's utility-scale solar market is more chaotic and involves a combination of merchant, corporate procurement and state policy drivers.

Figure 20: New build utility-scale solar in ISA countries, by region

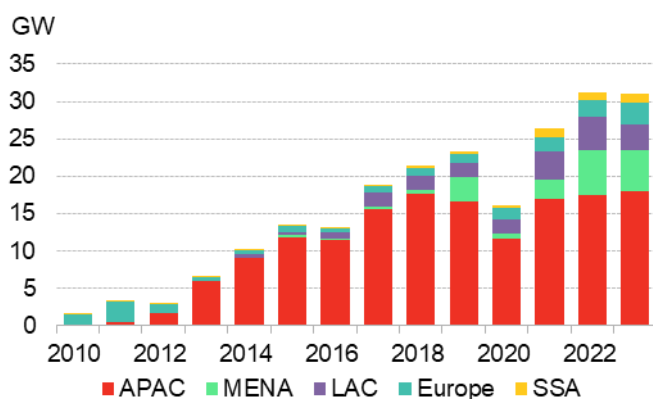
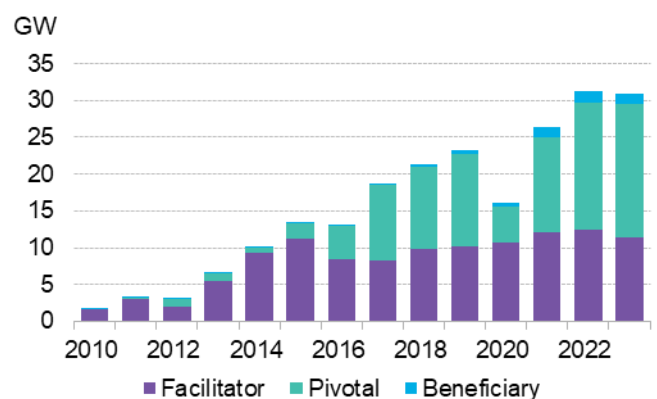


Figure 21: New build utility-scale solar in ISA countries, by classification



Source: BloombergNEF. Note: See Appendix A for ISA country list.

Small-scale PV

Pivotal and Facilitator countries are primarily where grid-connected small-scale PV exists today within ISA nations. Beneficiary countries have small-scale solar, but much of it is not connected to the grid and overall volumes are relatively low, given low use of electricity of any sort (Figure 22 and Figure).

Among the Pivotal countries, Brazil is the largest market with approximately 3GW of new small scale solar added in 2020 alone. This is a drastic change from earlier in the decade when India was the largest small-scale market, although the types of systems are very different. In 2010, the country's 1GW total capacity accounted for effectively all such capacity among Pivotal countries. India continued to invest heavily in small-scale and remained the dominant country until 2018 when Brazil offered net metering and kicked off its small scale solar market. BNEF expects Brazil's domination of small-scale solar build among these nations to continue well past 2023, though the net metering is expected to be made less generous.

Among Facilitator nations, the Netherlands and Australia are the largest markets with both poised for further growth. In earlier years, others were at the head of the pack. In 2010, for instance, France was among the biggest players in small-scale build, but activity there has slowed. We

expect most countries, even Saudi Arabia and the United Arab Emirates, to run some small-scale solar programs like Dubai's net metering.

Facilitator countries added about 8GW of small-scale grid-connected capacity in 2020. This is larger than both Facilitator and Beneficiary countries, which added about 4.5GW and 0.25GW respectively. Italy and the Netherlands have especially large markets for small-scale solar and are projected to continually increase into 2023.

Figure 22: ISA country grid-connected small-scale PV build, by region

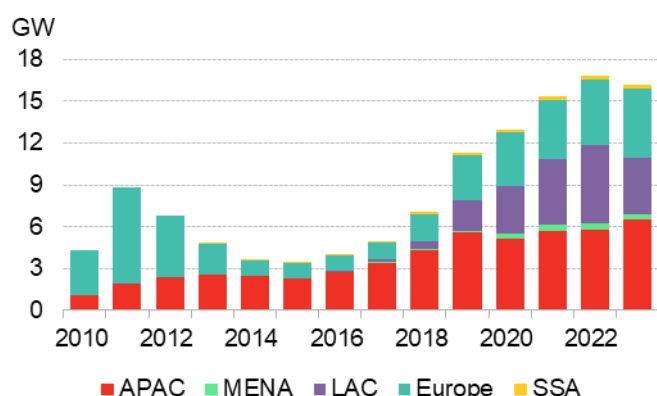
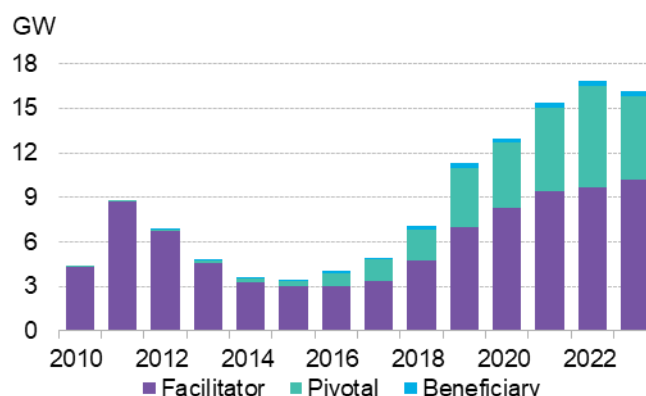


Figure 23: ISA country grid-connected small-scale build, by ISA classification



Source: BloombergNEF. Note: See Appendix A for ISA country list.

ISA countries to watch

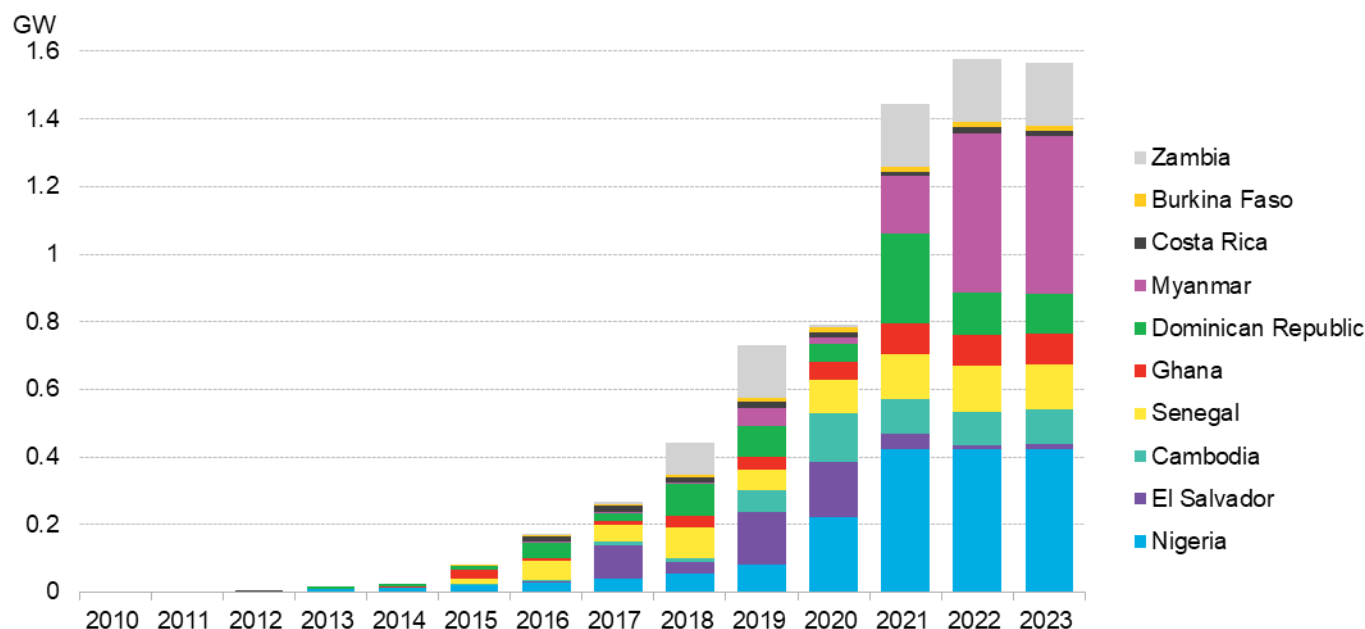
Beneficiary countries

Because Beneficiary countries are also rapidly developing countries, they are poised to accelerate solar adoption (Figure 24). Among them, Myanmar is a potentially very large market, but is plagued by deep uncertainty in the wake of a military coup in February 2021. While Nigeria has only added 0.46GW of solar capacity since 2010, BNEF expects another 1.26GW by 2023, due to a series of supportive policies implemented in the nation since 2018, including a mini-grid plan, auctions, and tax incentives.

El Salvador built a few projects in 2017, 2018 and 2020, main driven by tenders. The country has added a total of 0.45GW since 2010, with 0.32GW of that added in 2019 and 2020. PV now accounts for over 20% of the country's total power generating capacity.



Figure 24: New capacity added in top 10 new-build Beneficiary countries, 2010-2023



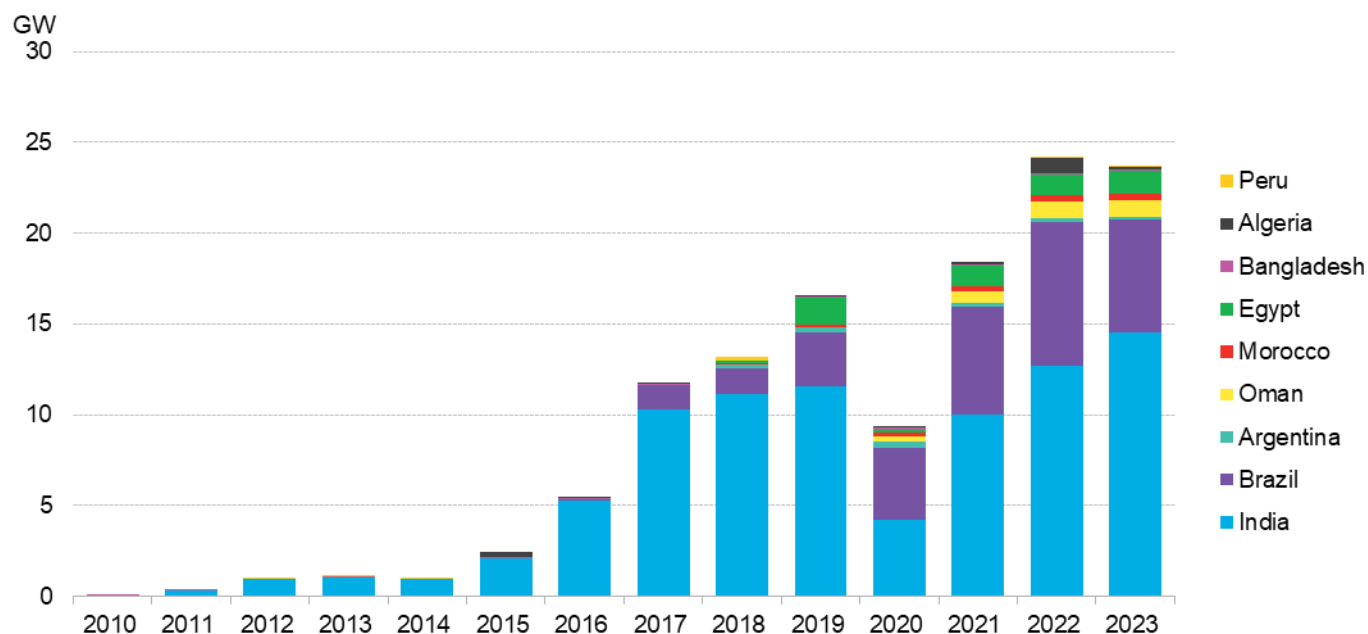
Source: BloombergNEF. Note: Charts portrays performance in the top 10 nations in 2020 to attract new build. Note: See Appendix A for ISA country list.

Pivotal countries

Brazil and India remain the largest solar markets among Pivotal countries (Figure 25). Smaller markets, such as Egypt and Morocco are also making large strides. Egypt has added 1.7GW of solar since 2010 with 1.4GW of that in 2019 alone. This was driven in part by a 2018 renewables auction that helped bring the 200MW Kom Ombo PV project on line. Egypt is projected to add another 3.5GW of solar by 2023.



Figure 25: Top 10 Pivotal countries for solar capacity additions, 2010-2023



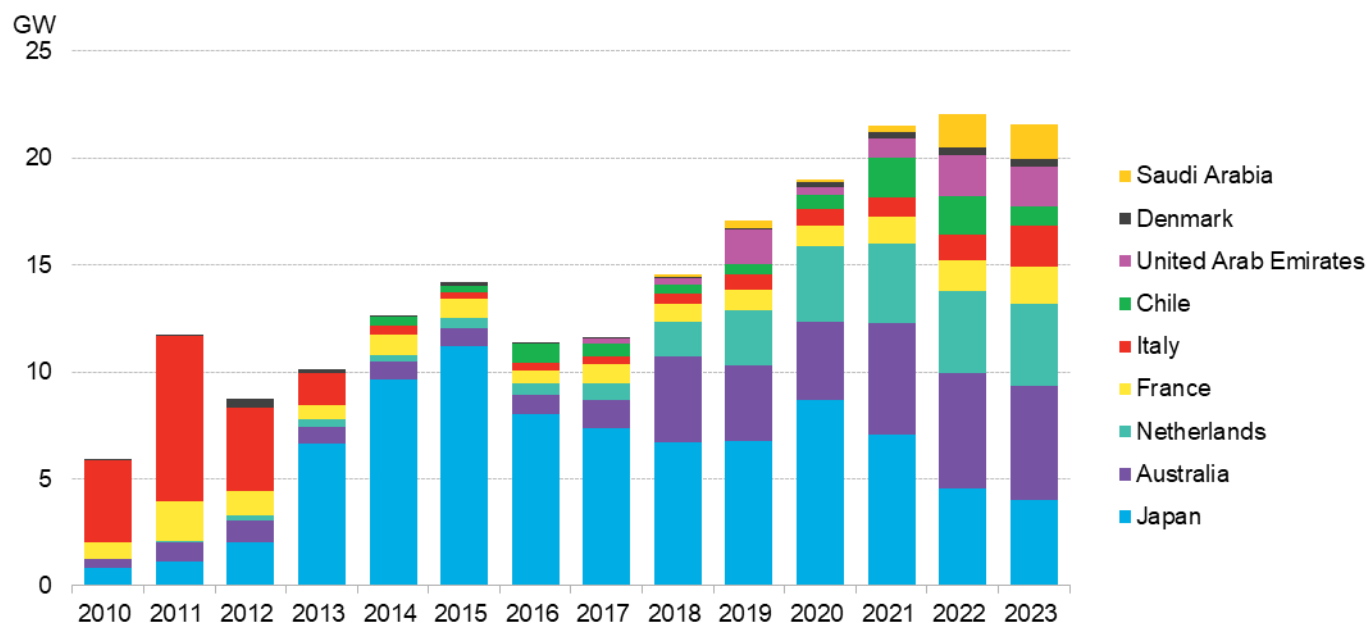
Source: BloombergNEF. Note: top 10 nations determined by total build in 2020. Note: See Appendix A for ISA country list.

Facilitator countries

Japan and Australia are the largest new solar markets among Facilitator countries (Figure 26). Japan has a major, generous and sustained feed-in tariff which has been attracting new solar investment consistently since 2013, with 2015 the largest year with 11.16GW capacity added. It is expected to slow down, as easily developed sites are becoming rare, curtailment in some regions is a problem, and the government is using auctions to put pricing pressure on developers. The Australia market set a high-water mark with 4GW added in 2018, influenced heavily by a key policy unveiled in 2016. It is projected to have record new capacity additions in 2021 and continued growth into 2022.



Figure 26: Top 10 Facilitator countries for solar capacity additions, 2010-2023



Source: BloombergNEF. Note: top 10 nations determined by activity in 2010. Note: See Appendix A for ISA country list.

3.2. Off-grid PV

Over the last two decades, developing countries have made massive strides in expanding access to electricity. As recently as 2000, just 73% of the world's citizens enjoyed electrification, according to the International Energy Agency³. By 2019, the figure had risen to 90%. From 2018 to 2019 alone, the number of people lacking electricity access dropped from 860 million to 770 million. Along the way, particularly in the past five years, off-grid PV in its many forms – mini-grids, residential systems, or micro devices such as lanterns – has played a key role in electrifying even the most far-flung communities.

While BNEF is still collecting 2020 data, it does appear that progress in improving electrification rates slowed last year as Covid-19 and the associated economic fallout took hold. Rising poverty may have resulted 100 million people in Asia and Africa losing electricity access, the IEA estimated in its 2020 World Energy Outlook⁴.

As the delta variant of Covid-19 continues to spread, uncertainty remains in many emerging countries on when and how they will recover. Governments in less developed countries have faced a lack of financial resources, prompting them to redirect funds that might otherwise have gone toward energy access initiatives to other areas, such as healthcare. Others have boosted tax rates or changed tax rules in an effort to compensate for lost revenues due to slower economic activity.

Meanwhile, local currencies have depreciated against the U.S. dollar, increasing the cost of imported energy equipment as local companies rely on revenues in these currencies. The

³ <https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity>

⁴ <https://www.iea.org/topics/energy-access>

pandemic served as a painful reminder of how often healthcare facilities in developing nations lack sufficient access to electricity.

Due to combined effects of lockdown measures, economic downturns and job cuts, payments for energy services have become significant cost burdens for consumers using energy access services. In May 2020, 63% and 57% of surveyed consumers did not pay for energy access services in Uganda and India, respectively (Figure 27 and Figure 28). In September, the majority of the respondents were able to pay for their energy services, possibly because governments lifted lockdown measures, improving household financial status.

Figure 27: Consumer payment levels, May 2020

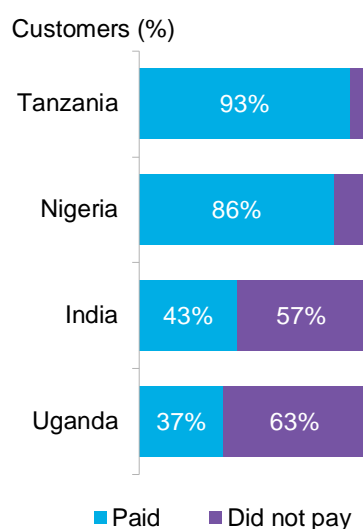
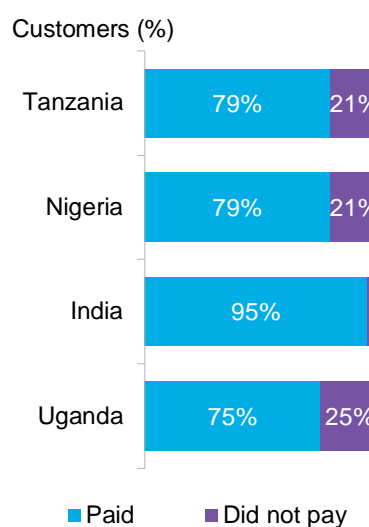


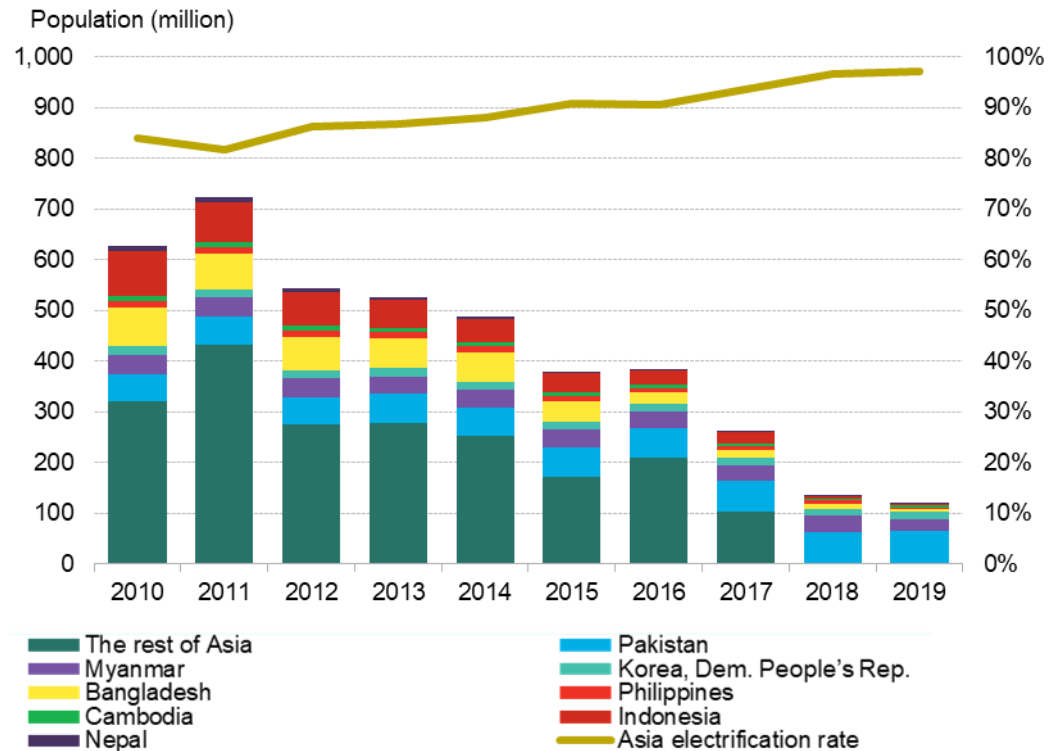
Figure 28: Consumer payment levels, September 2020



Source: 60 Decibels, BloombergNEF

In sub-Saharan Africa, the electrification rate grew from 31% to 44% from 2010 to 2019. However, as population increased faster than electrification, the estimated number of people without electricity access actually increased by 2.2%, from 602 million to 615 million between 2010 and 2019. According to UN estimates, the population in the region will reach nearly 1.4 billion by 2030, up from the current 1.09 billion, although the rate of growth is likely to slow. This suggests a population of 463 million (or 92 million households) who will fall into the group living without electricity access in 2030 based on the trajectory in the last decade. This also means that Nigeria, Democratic Republic of Congo and Ethiopia will be the three largest addressable markets for the energy access sector with estimated populations without electricity access of 93 million, 79 million and 39 million, respectively in 2030.

Figure 29: Asia population without electricity access

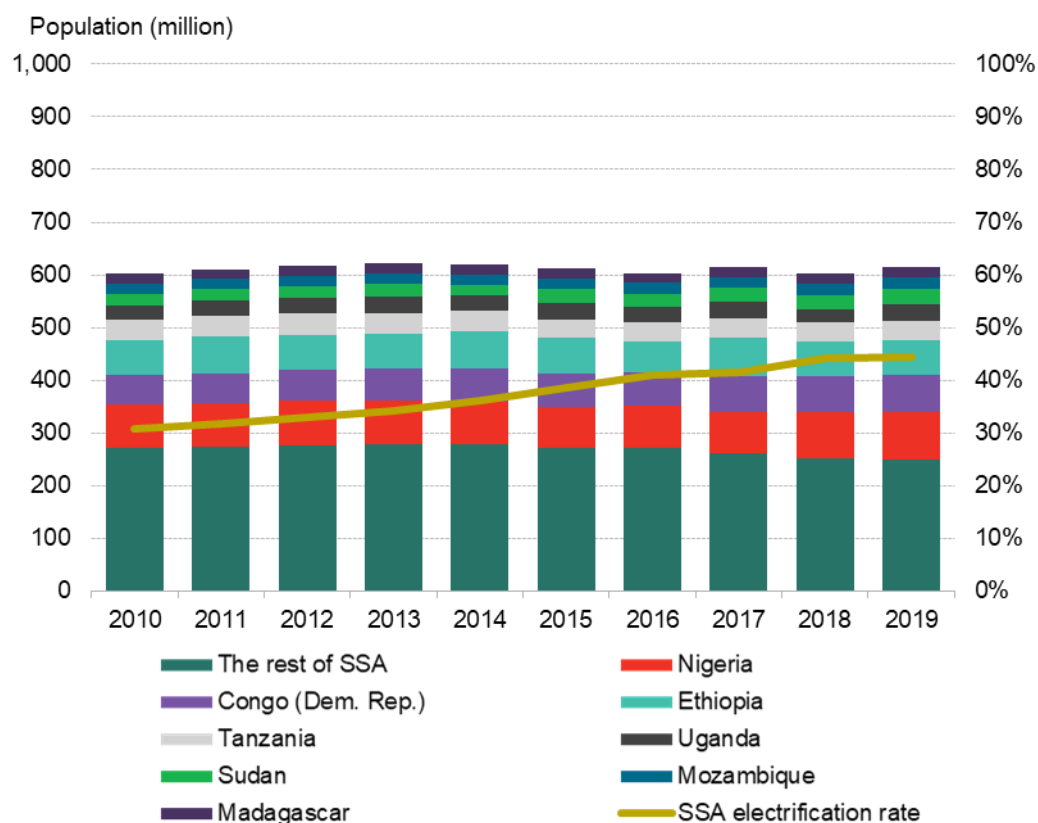


Source: BloombergNEF, Climatescope 2020, World Bank.

Asia overall has made remarkable progress improving energy access in the last decade, with India, Myanmar and Bangladesh being standout successes. The annual population growth rate in the last 10 years was 1.1% and 1.3% in South and Southeast Asia, respectively, while it was 2.7% in sub-Saharan Africa (Figure 29).

However government statistical figures of electricity access do not always take into account connections to individual households, but may regard those within villages where poles and wires exist as 'connected'. For example, the Indian government has claimed 99.9% of its citizens enjoy electricity access, but local experts argue the actual number is lower. Reliability challenges, which are not captured in these figures, also remain even if the grid is reached. In Pakistan, 80-90% of the country's power was interrupted in early January 2021.

Figure 30: Sub-Saharan Africa population without electricity access



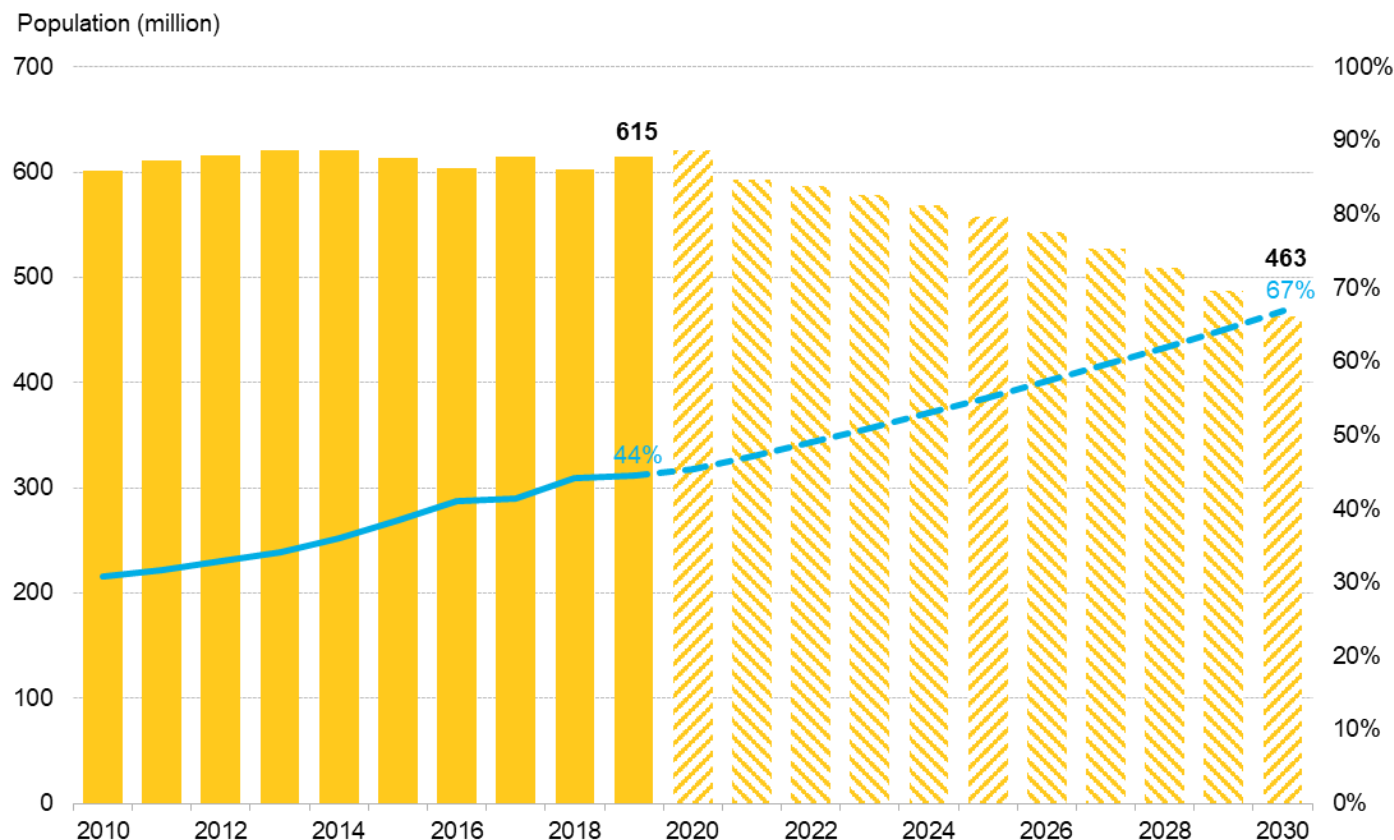
Source: Source: BloombergNEF, Climatescope 2020, World Bank. Note: SSA = sub-Saharan Africa. Congo (Dem. Rep.) = Democratic Republic of Congo.

Sub-Saharan Africa remains the region with the lowest access rates though the situation is projected to improve over the next decade (Figure 30 and Figure 31), in part due to the proliferation of low-cost solar power options.

In addition to low electrification rates, both Asia and Africa have households with access to electricity, but the access is unreliable. From 2010-2019, the global electrification rate (ie, percentage of population with electricity access) rose from 79% to 90% thanks to new power plants, grid expansions and distribution of decentralized energy technologies such as solar home systems and microgrids. On the flip side, at the end of 2019, one in 10 people remained without initial access to sufficient electricity to use basic energy services.



Figure 31: Projected population without electricity access in sub-Saharan Africa (left-hand axis) and electrification rate (right-hand axis)



Source: BloombergNEF, Climatescope 2020, World Bank, UN. Note: The electrification rate from 2020 onward is forecast based on the electrification trajectory from 2010 to 2019.

Among ISA countries, Myanmar, Mali and Haiti made the greatest leaps, with millions gaining electricity access for the first time in 2019. Cameroon followed (Figure 34).

The growing role of solar home systems in off-grid environments

Global sales of solar home systems totalled approximately 3 million during the first half of 2020 (the latest period for which BNEF has complete data), down 26% from the year-earlier period (Figure 32). East Africa and South Asia saw notable drops.

In East Africa, “pay-as-you-go” solar companies and other retailers sold just over 1.4 million systems in the first half of 2020, marking a 12% lower growth rate than the year prior, as the Kenya, Ethiopia and Uganda markets struggled.

However, sales grew elsewhere including in Tanzania and Rwanda. In Ghana, sales during the first half of 2020 more than quadrupled from the same period a year earlier to reach 73,000 systems. Growth did not appear to be driven by any specific new policy but may be related to the rise of distributors PEG Africa and Zola Electric. Off-grid solar distributors were allowed to travel within the country even with lockdown restrictions in place, which may have helped sales, according to the Global Off-grid Lighting Association, a trade organization representing off-grid

solar companies. Half-year sales plateaued around 350,000 in West Africa. The volume of new systems installed in Nigeria shrank 24% year-on-year for unclear reasons.

In South Asia, off-grid system sales sank by approximately 0.5 million units, or 57% from the year-prior period, primarily due to market contraction in India. The country's recent successes connecting far-flung communities to the grid for the first time may have dented demand for off-grid solutions. However, access remains spotty even in many areas the government now regards as grid-connected due to frequent outages.

Figure 32: Solar home system sales in ISA countries (million)

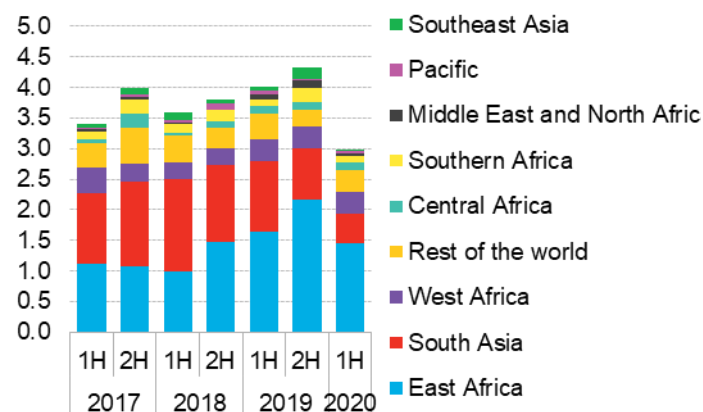
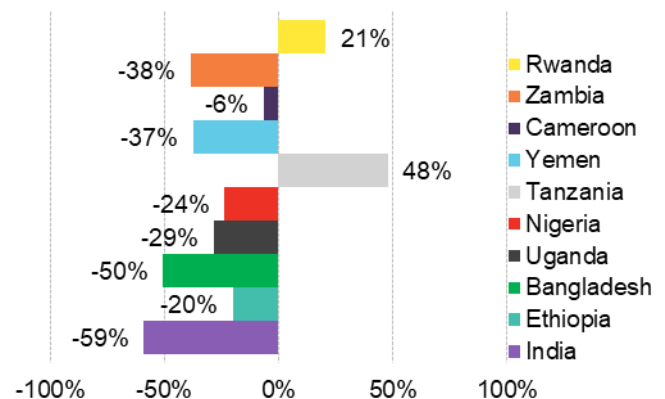


Figure 33: 1H 2020 vs 1H 2019 sales of solar home systems in the 10 ISA countries with highest demand

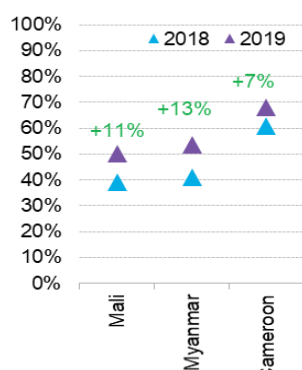


Source: GOGLA, BloombergNEF. Note: Solar home systems include solar lanterns.

BNEF expects stronger growth in West African markets such as Senegal and Mali where the governments introduced VAT exemptions for PV equipment. In December 2020, the Nigerian government initiated an electrification program to roll out 5 million solar home systems with support from the World Bank. In May 2021, the Nigeria Infrastructure Debt Fund announced a 1.8 billion naira (\$4.6 million) investment in solar minigrid supplier Havenhill Synergy for 22 minigrids. This is expected to provide electricity to over 70,000 people, plus businesses, in rural communities.



Figure 34: Top ISA achievers in improving national electrification rate, 2018-2019



Source: BloombergNEF, Climatescope 2020

Top performing ISA Beneficiary countries in improving energy access

While some state-run utilities and central governments have resisted the development of off-grid solar and distributed energy resources, others have embraced them. Among the more forward-looking ISA nations to date have been Myanmar and Mali, which have implemented policies explicitly to grow energy access through expanded distributed resources (Figure 34). Such efforts have been accompanied by financial support from development finance institutions (DFIs) and donors.

The five countries that made most progress improving national electrification rates 2018-2019 are:

- Myanmar** (41% → 54%): The country's 2019 National Electrification Program aims for universal electrification by 2030 and appears on track to hit its goal of 55% access by year-end. The country has adopted a 'least-cost' electrification approach, aiming to keep end user costs in check as much as possible. It has successfully attracted domestic and international businesses to its decentralized energy market. Yoma Micro Power, a joint venture between Yoma Strategic Holdings and AC Energy, has rolled out over 250 solar-hybrid microgrids since March 2019. Myanmar is also the fastest growing off-grid solar market in Asia with about 208,000 systems sold in 2019, more than doubled the 2018 tally. However, in the first half of 2020 sales did fall. Further progress is now very much up in the air after the military staged a successful coup in February 2021 and declared martial law.
- Mali** (39% → 50%): The country's National Renewable Energy Action Plan (PANER) states that off-grid renewable energy technologies should serve two-thirds of the country's rural population by 2030. That is an aggressive goal, given that as of year-end 2019, just 21% had such access, though that was up from 19% as of year-end 2018. Meanwhile, the country's urban electrification rate has jumped to 96% from 86% the year prior. There are multiple government rural electrification programs to roll out solar-hybrid microgrids and solar home systems in the market, with financial assistance from DFIs such as the World Bank and the Islamic Development Bank.
- Cameroon** (61% → 68%): Cameroon's improvement was primarily due to rapid progress in urban electrification, boosting the national electrification rate from 74% to 83% in 2019. Rural electrification stagnated, with only 21% of population having access as of the end of 2019. The government's Rural Electrification Master Plan (PDER) aims to provide energy access to all areas in Cameroon by 2035, with new connections to 500 localities every year. In all, there were a total of 135 installed microgrids in the country as of October 2019, the U.S. Agency for International Development found. Several microgrid developers (eg, Schneider Electric, Renewable Energy Innovators Cameroon) and off-grid solar companies (eg, BBOX) are active in the decentralized energy market.

Top clean energy microgrid markets in ISA countries

BNEF identified 900 clean energy microgrids installed across the world as of year-end 2020. Among these, the average capacity was over 100kW. Figure 35 shows the top ISA markets in terms of installed systems, while Figure shows the split of projects by ISA country type. Microgrids installed in emerging markets mostly serve rural and island communities where electricity demand is currently low, so the average system size is much smaller than in OECD countries or China.

For the purposes of this report and BNEF's previous research in this area, BNEF defines a microgrid as a group of interconnected distributed energy resources (DERs) plus load(s) or a

single DER plus load(s) within clearly defined boundaries. The main feature of mini-grids is their ability to operate independently, either in remote locations not reached by the main grid (isolated mini-grids) or in grid-connected areas where the electricity supply from the main grid may be interrupted (grid-connected mini-grids). Mini-grids can incorporate either a single generation source (e.g., a diesel generator) or multiple DERs (e.g., PV and battery storage), and supply electricity to more than one building. Solar home systems and energy generation plants installed at customer premises to supply electricity to just one customer are not considered to be mini-grids in this report. There is no minimum or maximum generation capacity threshold. Systems are larger when more customers, particularly large power consumers, are connected.

Figure 35: Count of installed clean energy microgrids

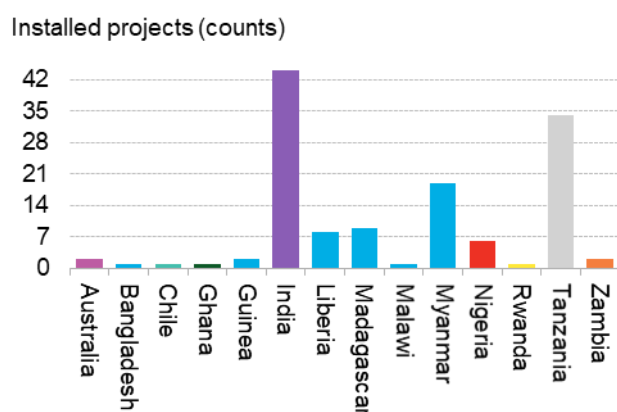
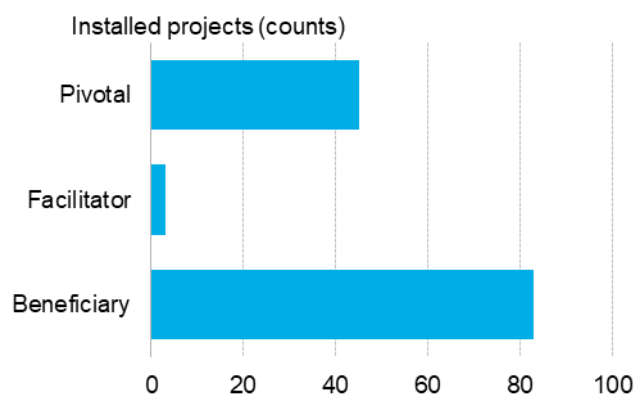


Figure 36: Count of installed clean energy microgrids by type of ISA country



Source: BloombergNEF. Note: Charts cover microgrids with aggregated generation capacity over 100kW or unknown, and use clean energy technology. 'Community microgrids' serve residential customers and other small communities like local shops and buildings. 'Other' includes airports, healthcare facilities, agriculture, and test facilities for microgrid technology development. Some projects do not have information of installed capacity.

The largest microgrids built in ISA countries to date have come in Australia, which added 18MW of such capacity in 2020. India has deployed many small projects, with fewer in 2020 due to Covid-19.

Total financing from leading DFIs for energy projects or programs was \$8.69 billion in 2020, down slightly from \$8.79 billion in 2019 (Figure 37). Of this, funding explicitly to promote energy access (ie, deploying microgrids, solar home systems and clean cooking) and grid extension/improvement was \$3.35 billion, or 39% of the total for the year. This was up from 32% and 25% in 2018 and 2019, respectively. The 'other' category, which includes various objectives such as improvement of fiscal status of state-owned utilities and reforms of the power sector and policies, recorded \$1.58 billion. These sectors are important enablers for scaling solar. This segment also includes financial assistance programs to mitigate the impact of Covid-19 on state-owned utilities.

From 2018-202, the World Bank Group approved nearly \$1.34 billion in support for this area (Figure 38), 88% of which was directed to sub-Saharan Africa. Of this, Burundi received \$160 million, and Rwanda, Cameroon and Madagascar each got \$150 million. In 2021, Ethiopia received \$500 million from the World Bank to support the country's goal of universal electricity

access by 2025. The financial support is intended for Ethiopia's electrification program and expanding the grid network coverage to nearly 60% of towns and villages. Geographies covered by other DFIs tend to be complementary to those covered by the World Bank. The Asian Development Bank (ADB) approved \$146 million for energy access while the Asian Infrastructure Development Bank (AIIB) has made no announcement of funding in this segment.

Most of the solar and storage large mini-grids in planning in ISA countries today are pilot or in some way experimental. However, the market is expected to grow, enabled by better and cheaper battery technology as well as solar.

Figure 37: DFI-approved funding for energy projects or programs (\$billion)

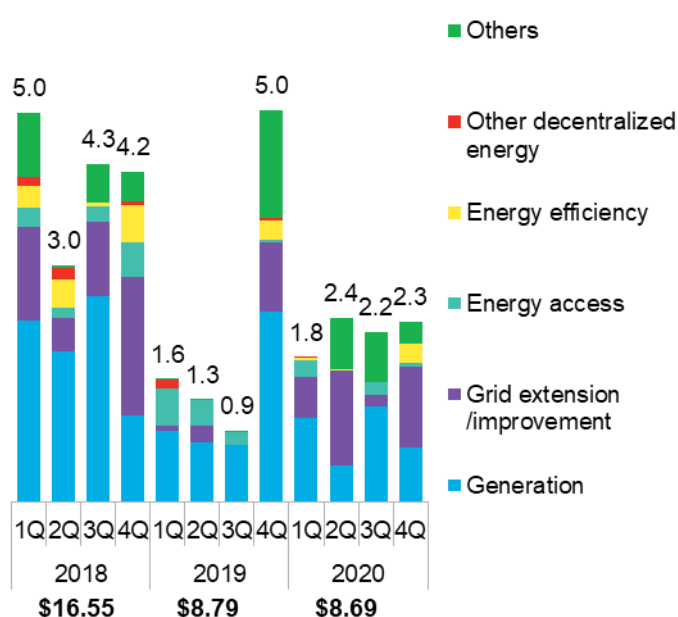
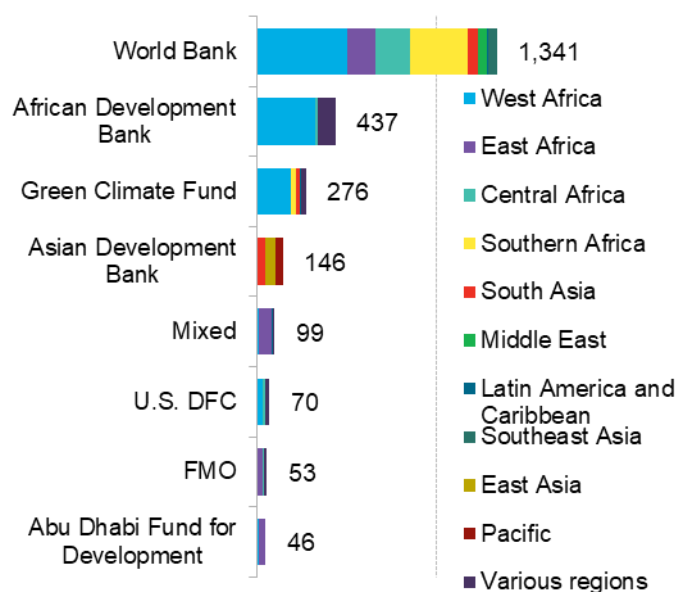


Figure 38: DFI-approved funding for energy access, 2018-2020 (\$billion)



Source: BloombergNEF, development finance institutions. Note: Includes data from Abu Dhabi Fund for Development, African Development Bank (AfDB), Asian Development Bank (ADB), Asian Infrastructure Development Bank (AIIB), Green Climate Fund (GCF), Inter-American Development Bank (IDB), Nederlandse Financierings-Maatschappij voor Ontwikkelingslanden N.V. (FMO), New Development Bank, Proparco, U.S. International Development Finance Corporation (DFC), World Bank Group. 'Mixed' refers to funding from multiple organizations including ADB, Africa Growing Together Fund, GCF and the Government of Australia.

Co-located solar and storage

To date, most large projects that combine solar and energy storage technologies have been built in the U.S. and China. However, falling battery costs have attracted interest from ISA country governments and state-run utilities. Combining solar with storage can be particularly valuable in areas with weak grids. India's distribution companies ("discoms"), for example, are experimenting with different auction schemes to encourage combinations of renewables with batteries (Table 1) to reduce the intermittency of renewables or improve their dispatchability.

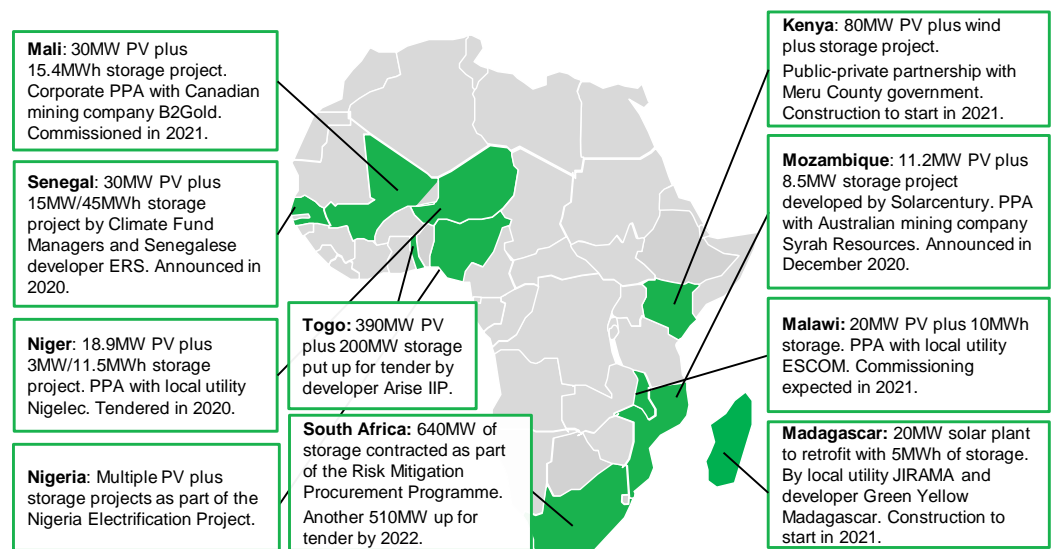
Table 1: India's complex auctions for renewables with storage, 2021

Auction	2021 update	Outlook
Round-the-clock (RTC) renewables (80% annual capacity factor)	SECI <u>signed</u> the PPA with ReNew Power for 400MW. ReNew will develop 900MW wind, 400MW solar and undisclosed storage capacity.	With the first such PPA signed, demand from other discoms may lead to more such auctions. IPP participation may be higher as the first-mover risk no longer exists.
Standalone energy storage (2GWh) tender	SECI's tender is <u>expected</u> to come out in August 2021.	The use cases, revenue streams and terms of tender will determine the extent of industry participation.
Tender for RTC renewables paired with other technology	SECI continues to <u>tweak</u> its 2.5GW tender for round-the-clock power from renewables paired with any other source (including coal and storage)	Bid submission expected to close in 3Q 2022. If this unique auction is a success, more such tenders could be quickly rolled out.
New 1.2GW wind-solar hybrid auction (SECI Tranche IV)	Winners were NTPC (450MW), Ayana (450MW), NLC (150MW), and Azure (150MW) at weighted average tariff of 2,341 rupees (\$31.55)/MWh.	Almost 6GW of bids received indicates that IPPs will compete aggressively in future hybrid auctions.

Source: BloombergNEF, Solar Energy Corp of India (SECI), news reports, ReNew Power press release.

There are widespread plans for solar and storage auctions in sub-Saharan African countries, including many ISA ones (Figure 39).

Figure 39: Selected utility-scale PV+storage projects and opportunities in Sub-Saharan Africa



Source: BloombergNEF

3.3. The PV supply chain

The global PV manufacturing supply chain today is highly concentrated in China. In 2020, China-headquartered companies made 77% of the world's polysilicon, nearly 100% of wafers, 83% of

cells and 74% of modules. Several companies that are not headquartered in China also make most of their cells and modules in the country.

Few ISA Beneficiary or Pivotal partner nations are home to any meaningful amount of PV manufacturing. The one exception is India, which has implemented various policy measures aimed at increasing local manufacturing. At present, India has cell and module factories but imports wafers made in China, mostly made from Chinese-produced polysilicon.

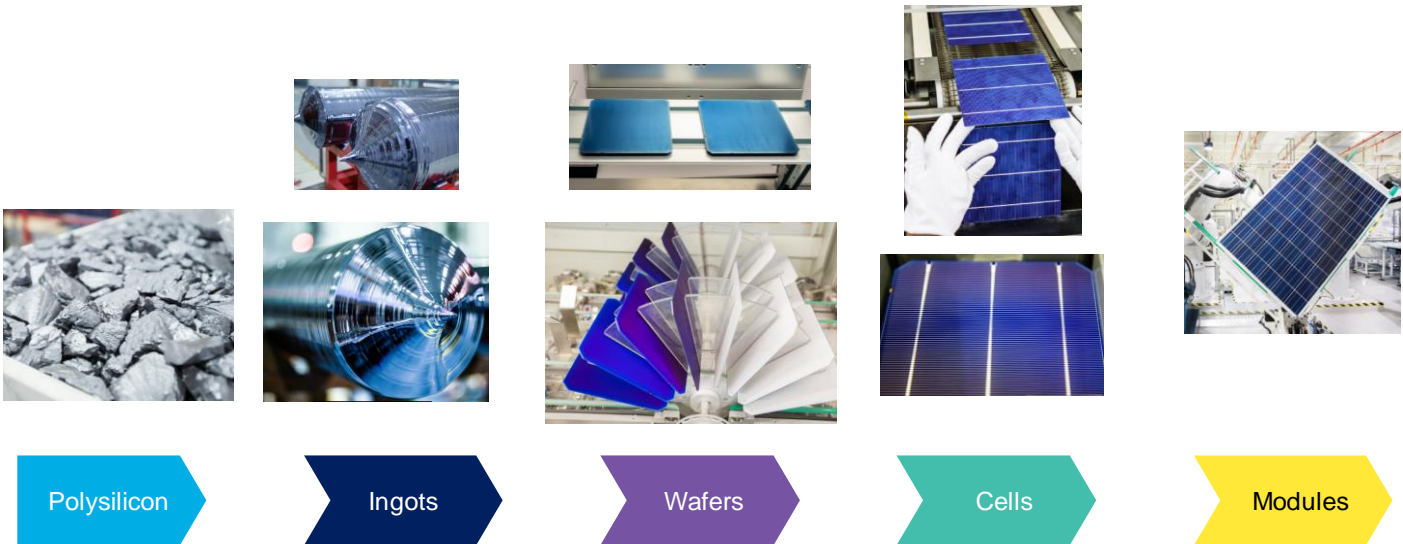
The fact that ISA Beneficiary nations, many of whom are among the least developed on Earth, have not participated in making PV equipment is arguably for the best. Wafer, cell and module factories tend to be technologically obsolete within five years, often before they have recouped their capex. Developing countries could stand to benefit most from the declining costs for solar simply by being consumers.

In this section, we review the main segments of the manufacturing value chain and then look in depth at solar manufacturing in India, the only ISA country to have significant activity.

Overview

The PV manufacturing value chain has main components: polysilicon, ingots, wafers, cells and modules (Figure 40). The production of each of these components requires very different processes and competencies. A variety of specialized materials and equipment are used in each of the five steps of the value chain.

Figure 40: The solar PV manufacturing value chain



Source: BloombergNEF, Longi

Table 2 provides a summary of key characteristics of the solar PV sector.



Table 2: Summary of PV supply chain characteristics

	Number of factories	Largest manufacturer	Market concentration (by country)	Market concentration (by company)	Adjacent industries	Barrier to entry	Value
Overall	1,215	China	High	High	Power, silicon, glass	Med	High
Polysilicon	77	China	High	High	Power, silicon metal	High	High
Wafers	158	China	High	High	Crucibles, wire saws	High	High
Cells	363	China	High	Med	Silver, aluminum	Med	High
Modules	617	China	High	Med	Glass, aluminum	Med	Med

Source: BloombergNEF. Note: Does not include standalone ingot factories, most ingot production is made within wafer plants.

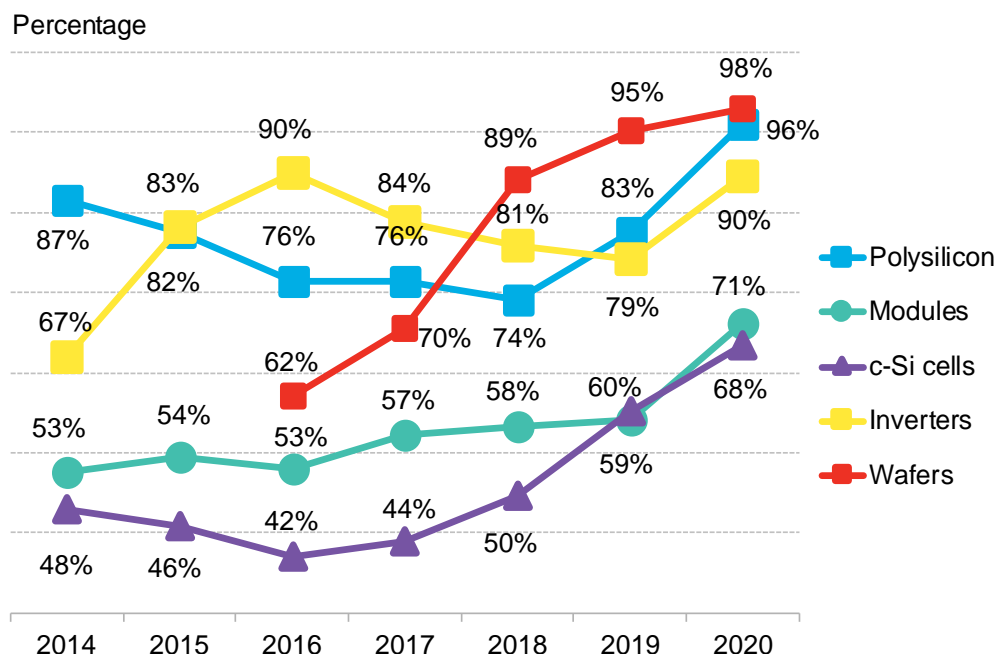
The solar value chain starts with metal silicon – basically sand cooked up with coal – which is processed by an energy-intensive set of chemical and physical reactions into polysilicon, which is cast into ingots and sliced into wafers, then made into cells and modules.

While only polysilicon to modules is really solar-specific, metal-grade silicon production has come under increasing scrutiny in 2021 as the U.S. has set trade restrictions on production from the Chinese province of Xinjiang. It is likely that, where necessary, polysilicon producers will be able to switch non-Xinjiang sources of metal silicon quite easily.

Manufacturers in Xinjiang province also make about half the world's polysilicon due to Chinese industrial policy and cheap electricity from local coal. This polysilicon is usually blended into ingots and made into wafers in China, which has nearly all the world's wafering capacity.

Generally speaking, the further up the PV production chain, the more consolidated the market is (Figure 41). The top ten polysilicon and wafer firms supplied 96% and 98% of the market in 2020, respectively. Polysilicon factories are capital and energy intensive and require a high level of technical expertise to build and to run effectively. Ingot and wafer factories are less capital and technology intensive than polysilicon plants, but more difficult than cell and module plants. The last can be set up with turnkey manufacturing equipment or even second-hand equipment, although the newest machines are not exactly cheap and older machines will not produce state-of-the-art products.

Figure 41: Percentage of market supplied by the top 10 firms at each step of the photovoltaic module value chain, 2014-2020



Source: BloombergNEF

Large solar manufacturing companies often have some degree of vertical integration. The module assembly giants of 2020 – Chinese firms Longi Green Energy Technology, Trina Solar, Jinko Solar and Canadian Solar – all have some wafer and cell capacity too. Most polysilicon companies are large chemical firms not otherwise involved in the downstream solar industry.

India's bid to become a PV manufacturing hub

India's energy policy-makers have long aimed to improve citizens' basic energy access while maintaining or improving energy security.

Compared to wealthier, Western nations, India's PV market got off to a late start, largely because PV on an unsubsidized basis was higher cost than conventional coal generation on a levelized basis. The country saw installations of approximately 50MW per year of PV in 2008 and 2009.

A number of India's first utility-scale projects used equipment imported from regional rival, China. This was due both to aggressive pricing offered by Chinese module makers and the fact that India itself had limited manufacturing capacity online at the time. Indian policy-makers did not at all relish the idea of a promising new industry being beholden to foreign suppliers, least of all Chinese suppliers.

The National Solar Mission

Launched in 2009, India's National Solar Mission aimed to create a domestic PV market through the build-out of capacity and through the expansion of a domestic supply chain. The Mission set installation goals regarded as ambitious at the time. It also outlined local content requirements intended to ensure that new projects would use PV equipment produced on Indian soil.

Specifically, the policy originally sought to have 20GW of grid-connected solar power operating in India by 2022, to create “favourable conditions for solar manufacturing capability” and to reach “a 4-5GW equivalent of installed [manufacturing] capacity by 2020”.

To create demand for that equipment through the addition of operating capacity, the Mission established a series tenders for power-supply contracts exclusively for solar developers. On the manufacturing supply side, the Mission put in place rules requiring developers to use locally-made PV equipment in their projects. The two policies were intended to work hand in hand.

To qualify for a particularly favorable categorization in the tenders, developers had to demonstrate their projects would use certain volumes of domestically-made equipment. During the first phase of the program from 2010-12, the local content rules only applied to crystalline silicon (c-Si) technologies. The program sought to work up the c-Si value chain, starting with the segment deemed easiest to fulfil domestically – the assembly of finished PV modules. During the first “batch” (tender), projects needed only to use locally-made modules; the cells contained in those modules could be imported. In the second batch of Phase 1, developers had to use both modules and cells made in India. Importantly, none of the Phase 1 rules applied to projects that used “thin-film” modules, which are made from cadmium telluride, not c-Si.

In Phase II, which included four more batches, the rules tightened while also giving developers flexibility. Developers participating in a “domestic content requirement” (DCR) segment of the tenders’ process had to source both their modules and cells locally. Alternatively, they could take part in the “Open” category where local-content rules did not apply. Or they could take part in both by submitting separate bids. For the first time, projects seeking to use thin film modules were subject to local content requirements as well (Table 3).

Table 3: India's local content rules for on-grid PV under the Solar Mission

	Phase I (2010-12)		Phase II (2013-17)
	Batch I	Batch II	Batch I-IV
Capacity	1-2GW on-grid, 200MW offgrid	4-10GW ongrid, 1GW offgrid	20GW on-grid, 2GW offgrid
Crystalline silicon	Locally manufactured modules. Cells may be imported	Locally-manufactured modules & cells	<i>DCR category:</i> locally manufactured modules & cells <i>Open category:</i> no requirements
Thin film	May be imported		<i>DCR category:</i> locally manufactured modules & cells <i>Open category:</i> no requirements

Source: India Ministry of New & Renewable Energy

The program also had explicit targets that it hoped would help India achieve its long-term installed capacity goals. It was hoped that Phase I would result in 1-2GW of new build, followed by 4-10GW in Phase II. A later, Phase III from 2017-2022 would add another 20GW

Market impact

When the auctions kicked off, the local content rules in Phase I essentially favored thin-film products as they were exempt from the requirements, tended to be cheaper and could be procured by developers affordably thanks to low-cost international financing. Thin-film modules offered lower efficiency than crystalline-silicon (c-si) equipment, but were considerably less expensive on a dollar-per-Watt basis. They are also quite suitable to regions with particularly strong sun, including many parts of India.

Arizona-based First Solar, the world's largest manufacturer of thin-film modules, saw opportunity in India and used support from the U.S. Export-Import Bank and the U.S. Overseas Private Investment Corporation. The two U.S. credit agencies offered cut-rate loans to Indian developers to buy First Solar equipment for the projects. The interest rate was reportedly approximately 3% and denominated in dollars. By comparison, local banks were offering developers rates as high as 14% on loans issued in rupees. In 2010-11, the U.S. Ex-Im Bank lent \$248m to Indian companies to buy thin-film module from First Solar.

India had only a tiny volume of domestic thin-film module manufacturing at the time, and all of it was amorphous or microcrystalline silicon, a technology that has not stood up to technical performance trials. Indian developers using domestic thin film silicon modules also could not access U.S. Ex-Im financing. As a result, half of installations in Phase I Batch I used thin film. That rose to 59% in the following batch. By comparison, the share of thin film in solar plants developed globally during those years was around 14%. Some of the thin film silicon modules made in India have since been replaced, for example at Adani's Kutch plant, due to performance problems.



Figure 42: Crystalline silicon cell manufacturing capacity on Indian soil

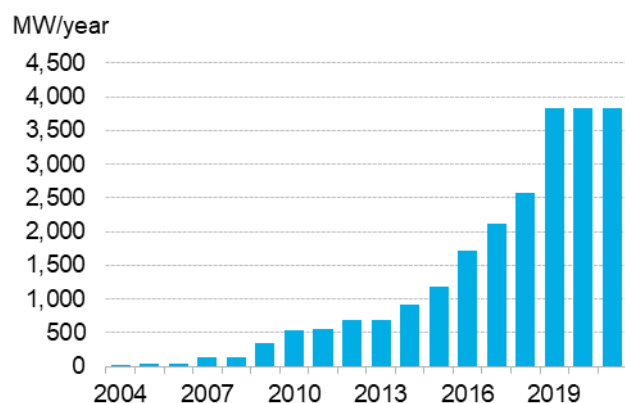
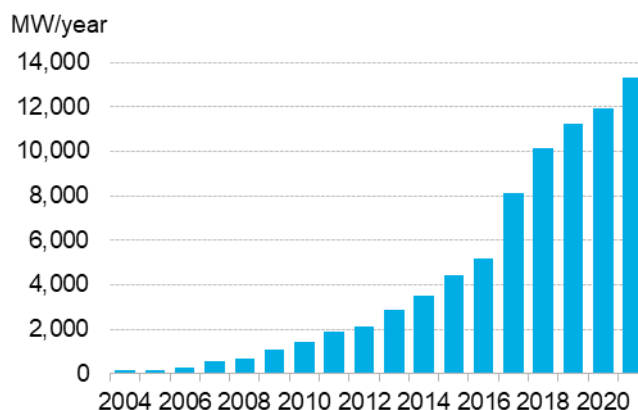


Figure 43: Crystalline silicon module manufacturing capacity on Indian soil



Source: BloombergNEF Note: India also had some thin film silicon module makers, but all of these are now essentially defunct.

Overseas manufacturers objected that India's domestic-content rules ran afoul of World Trade Organization rules. In February 2013, the U.S. filed a complaint, invoking the General Agreement on Tariffs and Trade to press the case that India's domestic content requirements granted Indian manufacturers "certain benefits and advantages, including subsidies through guaranteed, long-term tariffs for electricity, contingent on their purchase and use of solar cells and modules of domestic origin."

Three years later, in February 2016, the WTO sided with the U.S., ruling that India's local content requirements under Phase I and II (Batch I) unfairly discriminated against imported cells and modules. India said it would implement the WTO's findings but would not revisit contracts awarded to earlier projects.

The Mission and accompanying local content rules spurred growth in India solar manufacturing and the country does today have a significant presence in the production of finished PV modules and, to a lesser degree, in the manufacturing of PV cells (Figure 42 and Figure). These represent the last two segments of the PV manufacturing value chain. However, the country still lacks almost any manufacturing capacity in higher value segments further up the value chain. It has virtually no polysilicon, ingot, or wafer production capacity.

The current situation

As a result of its supportive policy, India has more domestic module makers than any other country except China. Since April 2021, government auctions can only procure modules from an approved list, which only has Indian manufacturers on it (Table 4).

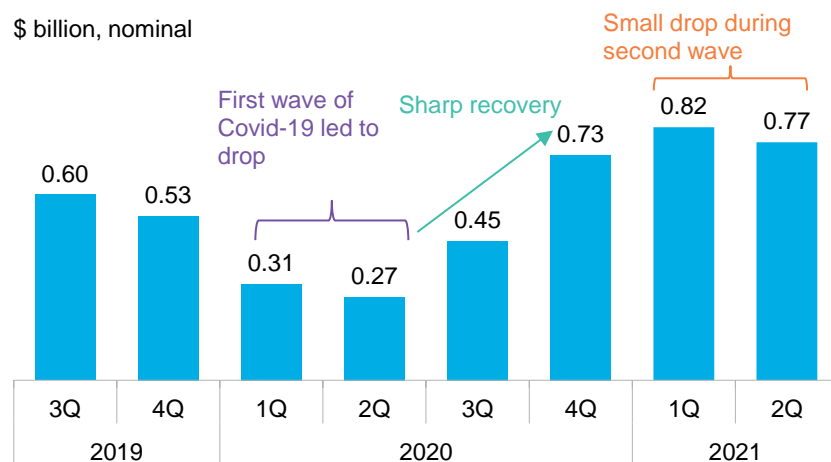
Table 4: List of solar module makers approved to supply Indian government-approved projects

Manufacturer	Module manufacturing capacity (MW/year)	Manufacturer	Module manufacturing capacity (MW/year)
Australian Premium Solar	50	PV Power Technologies	200
Bharat Electronics	10	RenewSys India	750
Central Electronics	0	Saatvik Green Energy	240
Emmvee Photovoltaic Power	500	Solex Energy	45
Goldi Solar	500	Sova Solar	240
Icon Solar-En Power Technologies	125	Swelect Energy Systems	140
Jakson Engineers	0	Tata Power Solar Systems	300
Mundra Solar (Adani)	1,100	Topsun Energy	100
Navitas Green Solutions	100	Vikram Solar	970
ORB Energy	50	Visaka Industries	30
Patanjali Renewable Energy	0	Waaree	2,000
Premier Energies	482	Websol Energy Systems	250
		Total	8,182

Source: BloombergNEF, India's Ministry of New and Renewable Energy. Note: MW/yr indicates number of megawatts per year of PV equipment capacity a plant can produce. Australian Premium Solar is an India-based company.

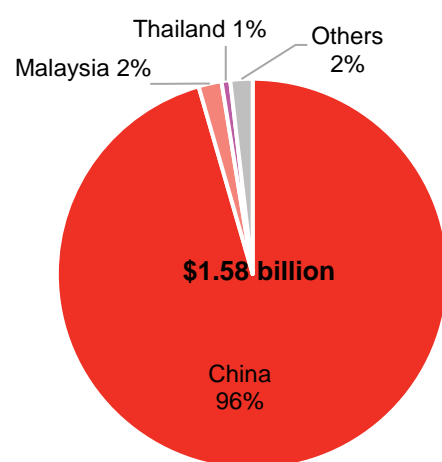
However, in non-government auctions developers are still free to import modules (Figure 44), and most still choose Chinese products (Figure 45). Total imports of \$1.58 billion worth in 1H 2021 are equivalent to about 6.9GW of modules, compared with expected Indian installation in 2021 of about 10GW, and about 13GW in 2022.

Figure 44: India's quarterly PV import volumes



Source: BloombergNEF, Sinoimex, Ministry of Commerce and Industry. Note: Data shown includes PV cells and modules under HS code 85414011 and 85414012 respectively.

Figure 45: 1H 2021 PV imports by country





Major policy updates during 1H 2021 (Table 5) are aimed at supporting and expanding India's solar manufacturing companies.

Table 5: India policy updates to incentivize domestic manufacturing

Target	Policy	Next steps/ impact
Cells and modules	\$600 million in subsidies to be awarded over five years to shortlisted firms. Scheme favors backward/ upstream integration and large capacities	Winners are due to be announced in September 2021.
Modules	The list of approved module models and manufacturers (designed to be a product certification) does not <u>include</u> any foreign manufacturer	All bids submitted after April 10, 2021 for government auctions can only procure modules from this approved list, as it stands on the date of procurement. IPPs face uncertain supply and foreign manufacturers risk being shut out of the market
Cells and modules	Import <u>tax</u> of 25% on cells and 40% on modules from April 2022	Increases price competitiveness of domestic products, but supply in the short term may be insufficient to meet India's demand.
Cells and modules	Another import tax (anti-dumping duty) is under consideration.	The progress of the investigation is slow. No official proposal has been made on tax rate and duration of the measure.
Inverters	In February 2021, the import tax on solar <u>inverters</u> was raised from 5% to 20%	This policy benefits foreign manufacturers with factories in India, such as Sungrow, TBEA, Sineng Electric, TMEIC and Fimer
Solar glass	Textured tempered glass originating in or exported from <u>Malaysia</u> is taxed in the range of 9.71% to 10.14% from March 9, 2021	Malaysia's share of India's glass imports will fall from 2020 level of 60%. This will boost prospects of domestic glassmakers, such as Borosil Renewables.

Source: BloombergNEF, Ministry of New and Renewable Energy, Directorate General of Trade Remedies, Ministry of Finance.

Indian government support has created module manufacturers which supply its domestic market, and even exported \$50 million worth of solar product to the U.S. in 1H 2021 (about 1% of U.S. solar imports, which mostly come from Malaysia, Vietnam and Thailand due to U.S. tariffs on Chinese products). However, they are not yet able to compete with Chinese products without support.

3.4. Solar thermal electricity generation

As of 2021, there is only a handful of countries still building solar thermal electricity generation (STEG) plants around the world. Some high-profile tower and heliostat solar thermal plants like Crescent Dunes and Ivanpah in the U.S. have underperformed, and this has impacted the bankability of new designs. Photovoltaics is cheaper for delivering bulk electricity, although solar thermal offers the potential to store energy efficiently in molten salt to generate after the sun goes down. Three of the countries most active in new solar thermal are ISA countries.

Morocco: NOORo and NOOR Midelt

Morocco is currently the world's most interesting market for solar thermal, with 500MW commissioned (Table 6) and another 800MW from the PV-hybrid plant, NOOR Midelt I, tendered at a winning price of 680 Moroccan dirhams (\$70)/MWh. All of these plants used concessional debt from the World Bank, African Development Bank, KfW, European Investment Bank, and Agence Francaise de Developpement.

The 500MW of NOORo solar thermal plants in Morocco make up the largest solar thermal complex in the world. As far as we know, it is operating successfully.

Table 6: Key features of NOORo (Ouarzazate, Morocco)

	NOORo I	NOORo II	NOORo III
Type	Parabolic trough	Parabolic trough	Tower and heliostat
Generation capacity	150MW	200MW	150MW
Storage capacity	3.5 hours	7 hours	7 hours
Commissioned	2013	2018	2018
Capex	\$841 million	\$1.1 billion	\$862 million
Capacity factor	35.7%	34.2%	38%
Power purchase agreement (PPA)	\$189/MWh (peak hour)	\$130/MWh for 25 years	\$150/MWh for 25 years
Land area	450 hectares	680 hectares	550 hectares
Stakeholders	Owned by Masen, turnkey construction by Aries Ingenieria y Sistemas, TSK, Sener, Acciona, and ACWA Power; O&M by ACWA	Owned by Masen, turnkey construction by Sener, ACWA Power, Acciona, and TSK; O&M by Masen and ACWA	

Source: BloombergNEF

The next phase of Moroccan solar development, NOOR Midelt, was auctioned in May 2019 as 800MW of solar thermal and PV capacity with a minimum of five hours storage capacity. It was won by a consortium of French electricity giant EDF EN, Abu Dhabi clean energy investor Masdar, a local firm called Green of Africa and German engineering firm Ferrostaal. It began construction at the end of 2019 and is intended to be built by 2022.

Chile: Cerro Dominador

The Atacama Desert in Chile has some of the strongest sunshine in the world, and relatively little seasonal fluctuation in resource, which makes solar thermal plant design easier.

As part of Chile's 2013 Power Tender, Abengoa successfully submitted a bid to develop a plant with 100MW PV and 110MW tower and heliostat capacity (Table 7). It has a power-purchase agreement (PPA) in place at \$114/MWh for 950GWh of annual generation because the combination of PV and solar thermal capacity allowed it to compete in multiple slots. The project also benefited from a \$20 million subsidy, government-loaned land, and concessional debt from intergovernmental organizations that the Chilean government helped secure.

After delays due to Abengoa's financial troubles, the project was transferred to clean energy private equity firm EIG. In May 2018, EIG signed a financing package with a group of local banks and international financial institutions worth \$758 million.

Cerro Dominador was fully commissioned in 2021, and signed an additional PPA to sell 65 GWh/year in August 2021. Another Chilean solar thermal plant by EIG reportedly won 390MW capacity in an August 2021 auction at a price of \$39.99/MWh, but the terms are uncertain and if true, the plant may have other revenue streams.

Cerro Dominador has a planned capacity factor of 81%.

Table 7: Key Features of Cerro Dominador (Maria Elena, Atacama, Chile)

	STEG	PV
Type	Tower and heliostat	PV
Generation capacity	110MW	100MW
Storage capacity	17.5 hours	-
Status	Under construction (2020)	Operational
Capex	\$1.1 billion	\$300 million
Capacity factor	81%	20%
PPA terms	\$114/MWh for 15 years for combined generation	
Land area	700 hectares	300 hectares
Stakeholders	Owned by EIG Global Energy Partners LLC; turnkey EPC by Abengoa and Acciona; O&M by Abengoa	

Source: BloombergNEF

U.A.E: Al Maktoum IV

With 700MW of capacity under construction, as well as 250MW of PV, the Al Maktoum IV plant in Dubai stands to be the largest STEG complex in the world upon commissioning, which is scheduled for 4Q 2021. The plant is also noteworthy for its PPA price, a record low of \$73/MWh despite relatively low insolation. An ACWA-led consortium is developing the plant for Dubai Electricity and Water Authority (DEWA), which required the use of tower and heliostat technology. The project will have the world's highest tower (260 meters), but most of the project (600MW) is the more proven parabolic trough technology. As well as being part owner, Chinese Shanghai Electric Guangyuan Thermal Engineering is the EPC provider and has subcontracted the construction and technology provision of the tower to Brightsource and of the parabolic trough to Abengoa (Table 8).

The low PPA price may be partly due to the unusually long duration of 35 years, and the use of debt finance sculpted to match the revenue profile of the project, including leeway in the early years for an extended ramp-up phase.

Table 8: Key Features of Al Maktoum IV (Dubai, U.A.E.)

	Tower	Trough
Type	Tower and heliostat	Parabolic trough
Generation capacity	100MW	600MW (3 x 200MW plants)
Storage capacity	15 hours	10 hours
Status	Under construction (2021)	Under construction (2021)
Capex	\$3.9 billion for the two solar thermal plants (plus \$400 million for 250MW of PV)	
Capacity factor	56% for the combined plants	
PPA terms	\$73/MWh for 35 years for combined the combined plants	
Land area	3,750 hectares in total	
Stakeholders	Owned by ACWA and Shanghai Power; EPC by Abengoa, East China Electric Power, Shanghai Power	Owned by Silk Road Fund, ACWA and Shanghai Power; EPC by Abengoa, East China Electric Power, Shanghai Power

Source: BloombergNEF



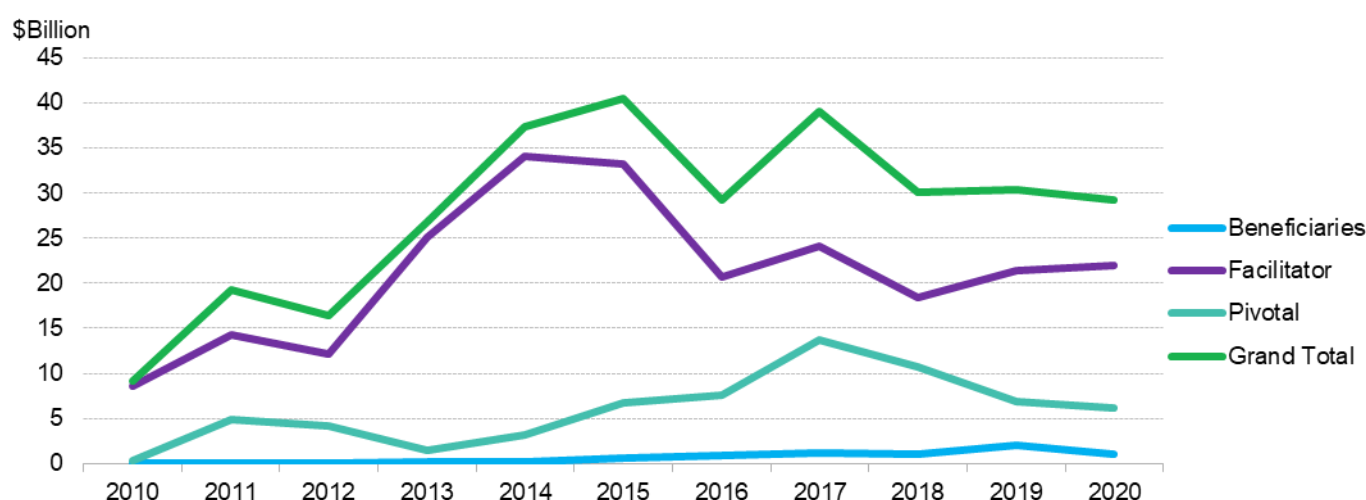
Section 4. Asset finance for solar

BloombergNEF sees keen interest from institutional investors in taking equity and debt stakes in solar projects, provided the projects can meet minimum risk requirements. Historically, Facilitator countries have been better able to offer projects with lower risk, long-term revenues and have attracted most financing. However, investors' hunger for yield, rapid rates of growth in developing countries, and diminishing risks associated with solar technology should push more investment toward Beneficiary and Pivotal countries in coming years.

4.1. Investment inflows

Figure 46 shows historical flows of capital into solar assets (ie PV projects, rather than companies). Total cumulative investment inflows over the decade is \$308 billion. This includes investment from both commercial and public sources. Most solar projects have to date been built in richer countries, so it is not surprising that over \$25 billion per year has been invested in Facilitator countries since 2013. Facilitator countries brought an average of 81% of total investment from 2010 to 2012, while in 2018 to 2020 the countries only attracted an average of 69% of global investment. While Facilitators still attract the majority of investment, more investment has been flowing into less wealthy countries. Pivotal countries averaged 19% of total investment from 2010 to 2012, but made up an average of 26% of total investment from 2018 to 2020. Beneficiary countries made up an average of 0.3% of total investment from 2010 to 2012. In the period from 2018 to 2020, Beneficiary countries made up a much larger proportion of total investment at 4.7%. Totals have dropped since a boom in 2013-2015, largely because solar equipment prices have fallen meaning it requires less capital to build the same volumes of capacity⁵.

Figure 46: Solar asset finance in ISA countries by country group



Source: BloombergNEF. Data includes asset finance for new build large-scale PV, small-scale PV and solar thermal projects. Note: See Appendix A for ISA country list.

⁵ However, in 2021, equipment prices have ticked up due to a short-term polysilicon supply pinch.

Solar asset finance will continue growing in Beneficiary and Pivotal countries as costs continue to decline making fossil fuels less competitive. However, particularly in the short run, such opportunities could be sporadic and dictated by tenders governments and utilities hold for power-delivery contracts.

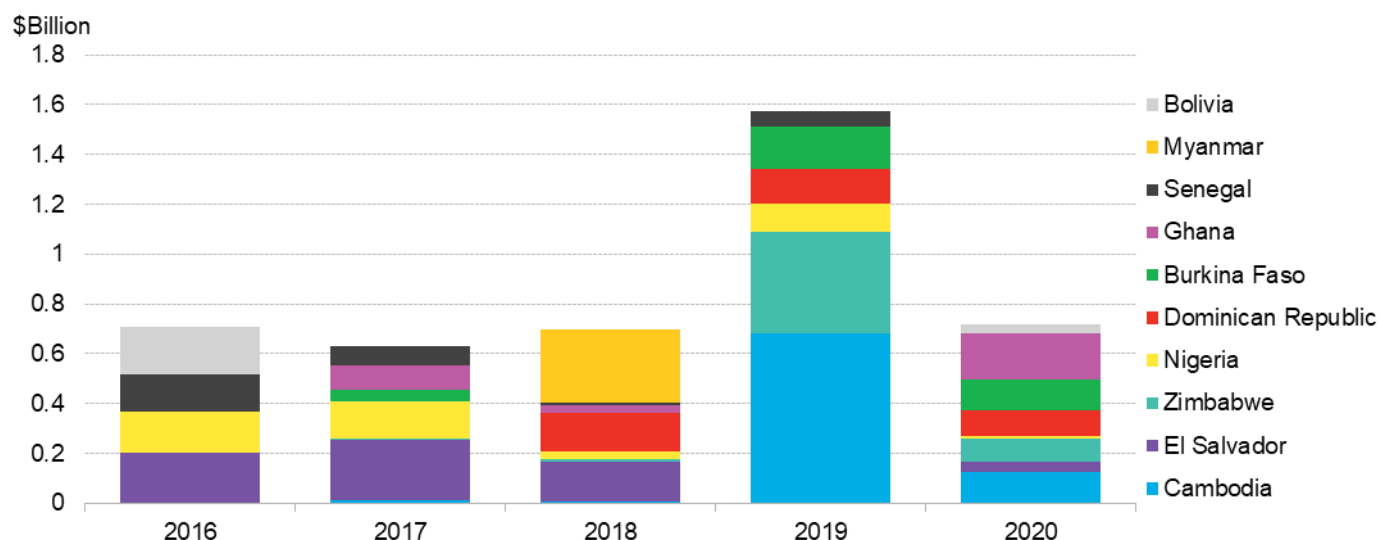
In 2020, Beneficiary countries felt the “Covid effect” as solar investment sank 44% from the year prior. Still, eight such countries were able to secure financing for solar projects for the first time. The continued decline in PV prices and the relatively modularity of technology have helped spread solar to more nations (Figure 47).

In Pivotal countries, investment also fell 2019-2020, but by only 2%. Still, investment into these nations was well below its all-time high set in 2017.

With their size, stability and relative wealth, Facilitator countries have consistently secured the most investment among nations in the three ISA classifications but the trend has generally been flat with some ups and down over the past five years. This is to be expected as these countries, while attractive to investors due to their stability, are not growing quickly. As a result, opportunities to deploy capital within them are limited.

Figure 47 shows the top 10 Beneficiary nations to attract solar asset finance 2016-2020. Several, such as El Salvador and Nigeria, secured funds consistently over the period though the amounts fluctuated somewhat. In others, such as Myanmar, investment levels varied drastically.

Figure 47: Top Beneficiary country recipients of solar asset finance



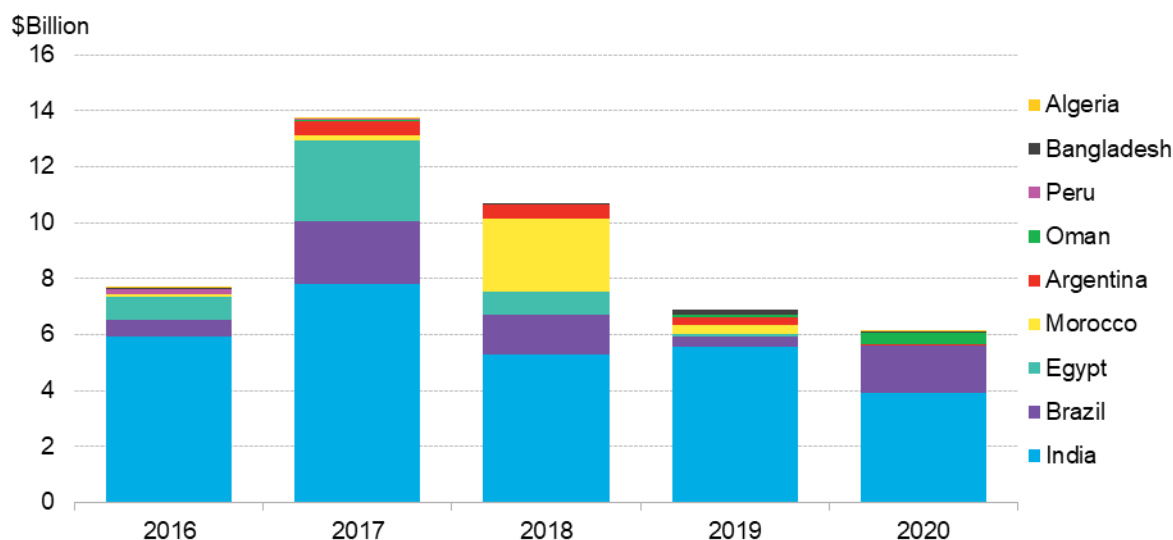
Source: BloombergNEF. Data includes asset finance for new build large-scale PV, small-scale PV and solar thermal projects. Note: See Appendix A for ISA country list.

In Brazil, reverse tenders for clean-power delivery contracts have traditionally driven investment activity. The country pioneered competitive auctions to contract clean energy, which led to 30GW of renewable energy contracted 2009-2019. However, stalled economic growth has slowed demand for new generation. That, in turn, has prompted regulators to hold fewer auctions. The result has been lower investment.



Other countries, such as Morocco and Egypt have each seen sharp spikes in solar investment associated with individual projects. In Morocco, investment jumped after the government approved a major new solar thermal plant under the country's auction scheme. In Egypt, investment peaked in 2017 due to multiple auctions being put in force.

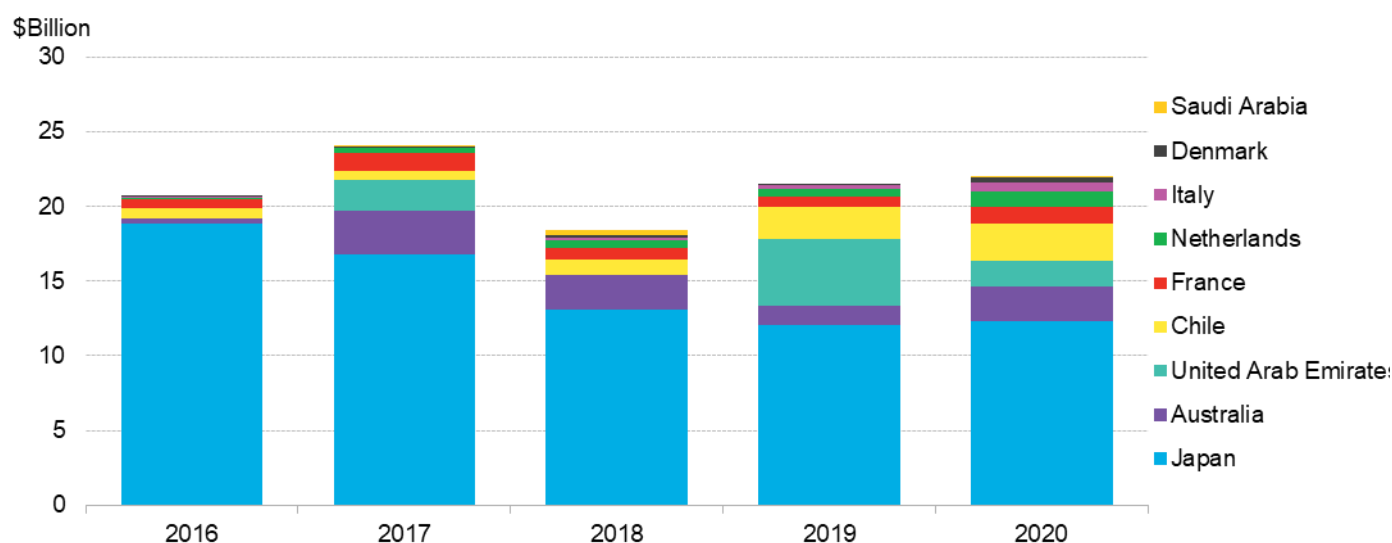
Figure 48: Top Pivotal country recipients of solar asset finance



Source: BloombergNEF. Data includes asset finance for new build large-scale PV, small-scale PV and solar thermal projects. Note: See Appendix A for ISA country list.

Among Facilitator nations, investments levels have varied but the fluctuations have been less dramatic. Of the top 10 countries to attract finance, Japan has been the biggest player with substantial capital deployed for utility-scale projects in recent years (Figure 49).

Figure 49: Investment in solar assets located in Facilitator countries

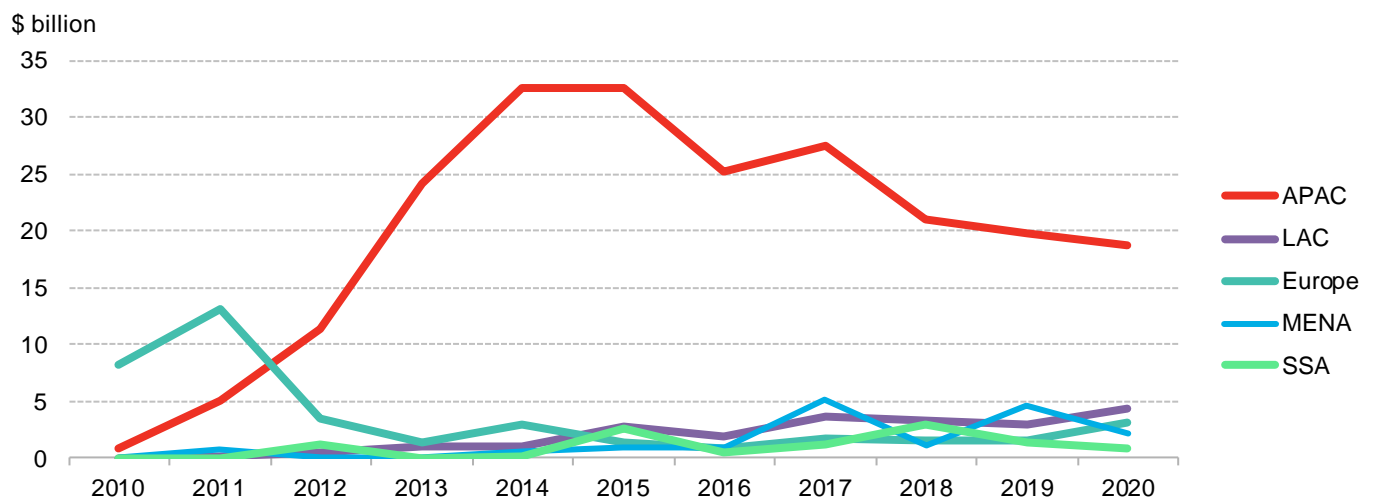


Source: BloombergNEF. Data includes asset finance for new build large-scale PV, small-scale PV and solar thermal projects. Note: See Appendix A for ISA country list.

Comparing ISA nations by region, it is Asia Pacific (APAC) that predominates, driven largely by activity in Japan and India. Investment into ISA countries in the Americas (AMER) has risen consistently over the past five years but continues to trail the other two regions. Brazil, Chile, and Peru have performed particularly well with each featuring relatively strong clean energy policy regimes historically (Figure 50).

In the Europe, Middle East and Africa (EMEA) region, investment dipped sharply in 2020, due both to Covid-related pullbacks. Still, several Beneficiary countries in the region received funding for the first time in 2020, including Ethiopia, Gambia, and Botswana. Ethiopia improved its clean energy policy regime in 2020 with clearer rules on licensing and tariffs for microgrids. The country is also among the three-largest addressable markets for potential energy access improvement. An estimated 39 million people in the country are projected to continue without power by 2030, and policy makers have sought to implement changes to meet this expected increase demand.

Figure 50: Solar asset finance in ISA countries, by region



Source: BloombergNEF. Note: See Appendix A for ISA country list.

Private financing for off-grid firms

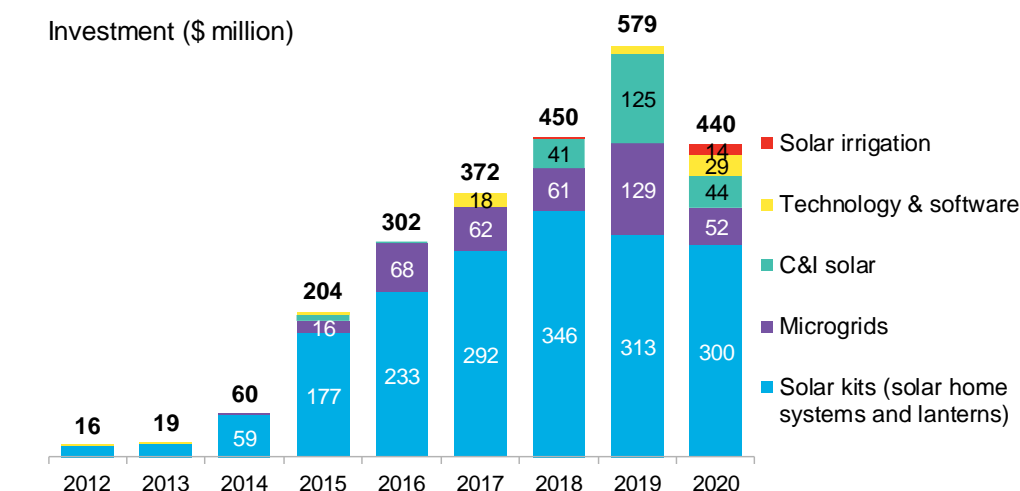
In 2020, financing for energy access startups totaled \$440 million (based on disclosed information), down 24% compared to 2019. It appears the pandemic affected the fall to some extent (eg, investors had difficulty conducting due diligence). These figures do not include relief grants from DFIs and other financiers for energy access start-ups to respond to the pandemic. Some deals were not counted as they were undisclosed (eg, EDF's equity investment in Zambia-based Standard Microgrid, or FMO's investment to Lumos Global) (Figure 51).

The financing for solar kit providers, primarily pay-as-you-go solar companies, fell slightly from \$313 million to \$300 million. Just three companies – Lumos Global, Greenlight Planet and d-light design – accounted for 63% of the \$300 million raised. The commercial and industrial solar sector recorded only \$44 million in 2020. Daystar Power, a Nigeria-based commercial solar system installer raised \$38 million Series B financing from various investors, including Morgan Stanley Investment Management in January 2021.

SunCulture, a Kenya-based solar-powered irrigation system provider, raised \$14 million from several investors, including Energy Access Ventures and EDF, to distribute systems across six countries in sub-saharan Africa. SunCulture also launched a collaborative effort with BBOX and

EDF in December 2020 to roll out systems to thousands of farmers in Togo. BBOXX is already a primary distributor of solar home systems under the Togolese government's rural electrification initiative. For SunCulture, the arrangement allows it to sell its systems through BBOXX's distribution channels. BBOXX benefits from upselling to existing farmer customers, assuming their incomes rise along with improved agricultural productivity.

Figure 51: Disclosed private financing for energy access start-ups, 2012-2020



Source: BloombergNEF, company press releases, news

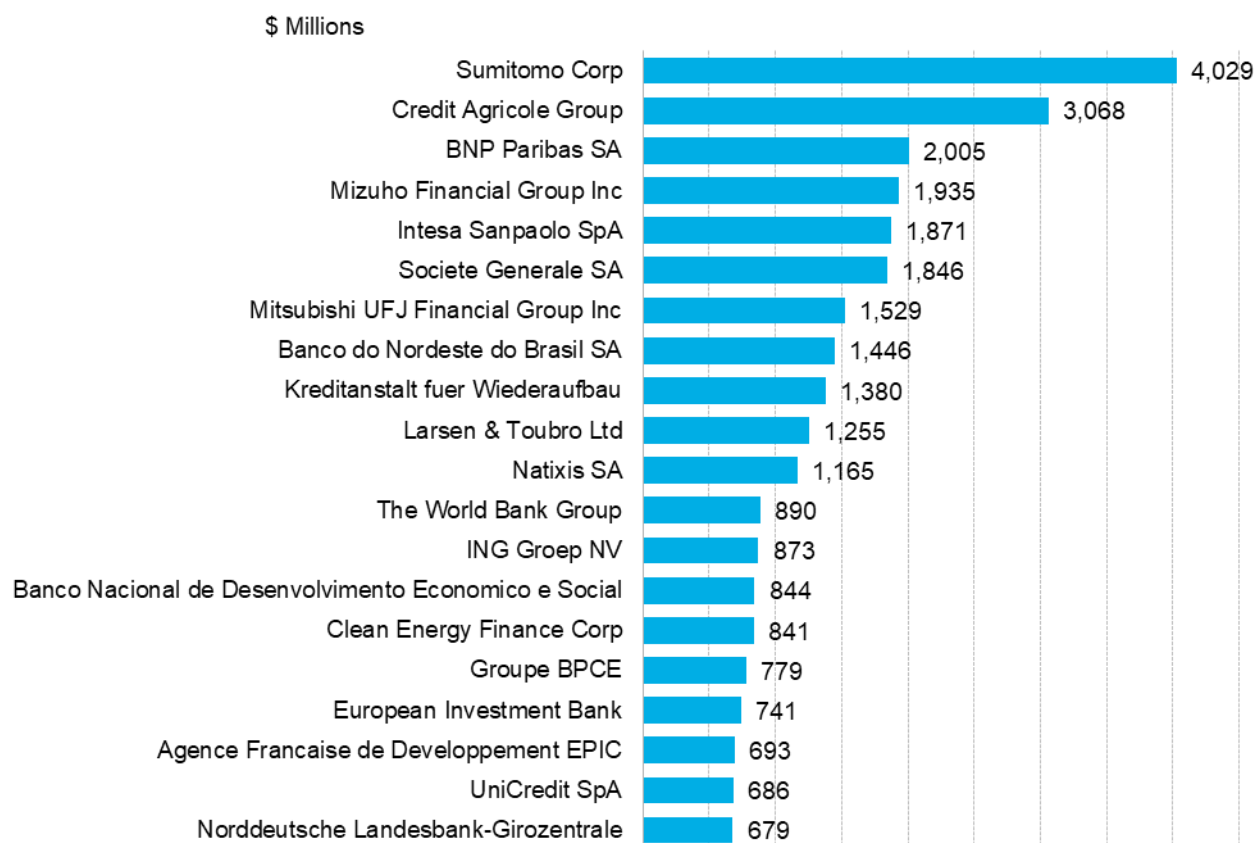
4.2. Investment outflows

ISA Facilitator nations are home to the largest providers of capital for solar assets, both within Facilitator nations and beyond. These institutions have deployed the bulk of their funds closer to home with Beneficiary nations receiving substantially smaller shares. However, efforts have grown to deploy more capital from Facilitators to Beneficiaries in recent years.

At the top of the league table of lenders within ISA nations is Sumitomo Corp., historically a major provider to projects within Japan. However, in the last few years, the bank has begun to lend to projects in Pivotal nations, including to projects in India and Peru (Figure 52).



Figure 52: Top 20 lenders to solar projects across all ISA countries, 2015-July 2021



Source: BloombergNEF asset database. Note: Includes financing for projects at least 1MW in size. Note: See Appendix A for ISA country list.

Development finance institutions, largely based in Facilitator nations, have provided most the bulk of funding for solar in Beneficiary nations. Top providers have included Agence Francaise de Developpement EPIC, the U.S. Development Finance Corporation (formerly the Overseas Private investment Corporation) and the World Bank Group (Figure 53).

In 2020, Kreditanstalt für Wiederaufbau (KfW), the German state-owned development bank, was the largest funder of solar in Beneficiary countries. Most of the organizations that traditionally provide capital to Beneficiary countries did not lend in 2020, changing the overall investment market in Beneficiary countries



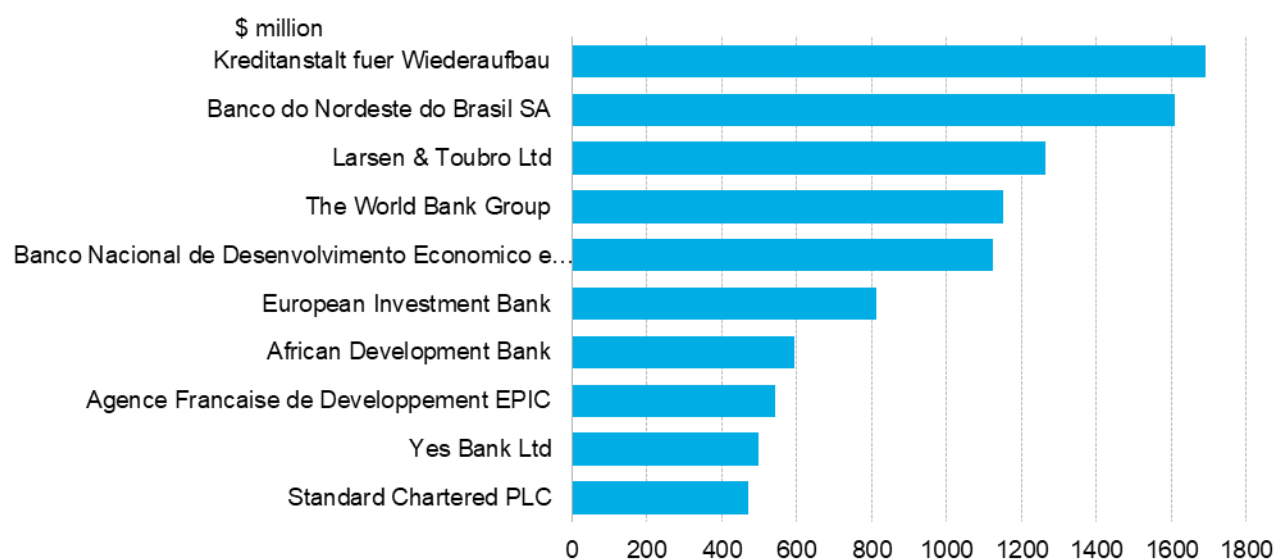
Figure 53: Top lenders to solar projects in ISA Beneficiary countries, 2015-July 2021



Source: BloombergNEF asset database. Note: The U.S. International Development Finance Corporation was formerly named the U.S. Overseas Private Investment Corporation. Note: Includes financing for projects at least 1.5MW in size. Note: See Appendix A for ISA country list.

In Pivotal countries, solar projects are primarily funded by banks, especially development banks. In 2020, the development banks to contribute significantly to Pivotal countries were Brazil's Banco Nacional de Desenvolvimento Econômico e Social and the U.S. International Development Finance Corp (Figure 54).

Figure 54: Top lenders to solar in ISA Pivotal countries, 2015-July 2021

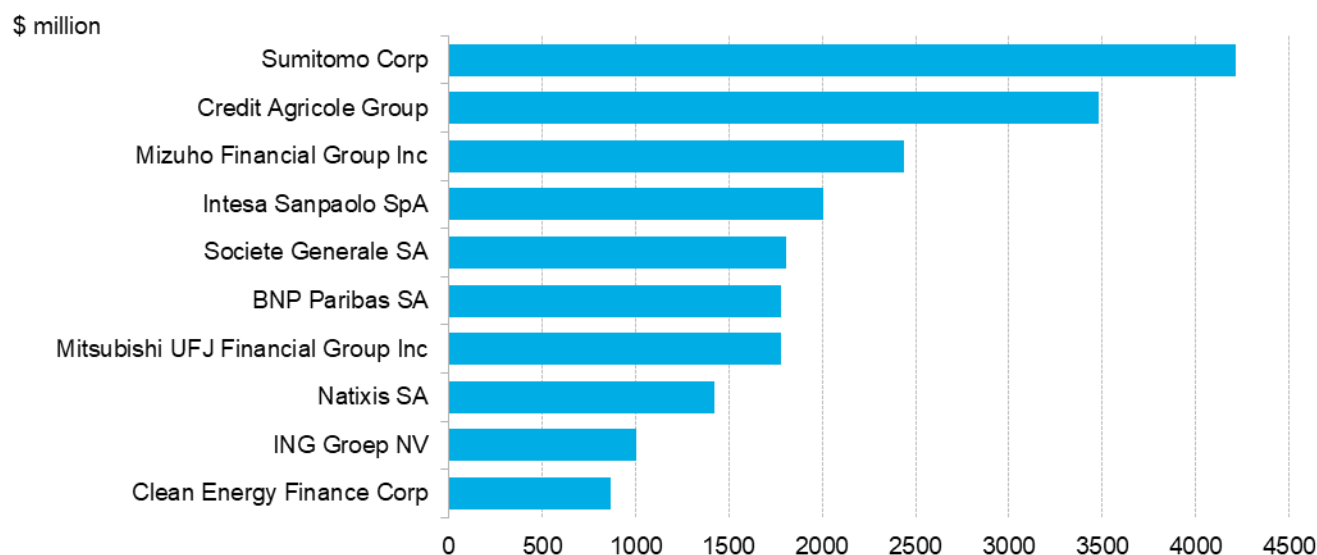


Source: BloombergNEF asset database. Note: Includes financing for projects at least 1.5MW in size. Note: See Appendix A for ISA country list.



Figure 55 shows that most debt to Facilitator countries is provided by commercial banks. Development financing is seldom necessary as the banking industry is mature and solar projects are considered low risk. There are very few cases in which development banks finance is used in Facilitator countries.

Figure 55: Top lenders to solar projects in ISA Facilitator countries, 2015-July 2021



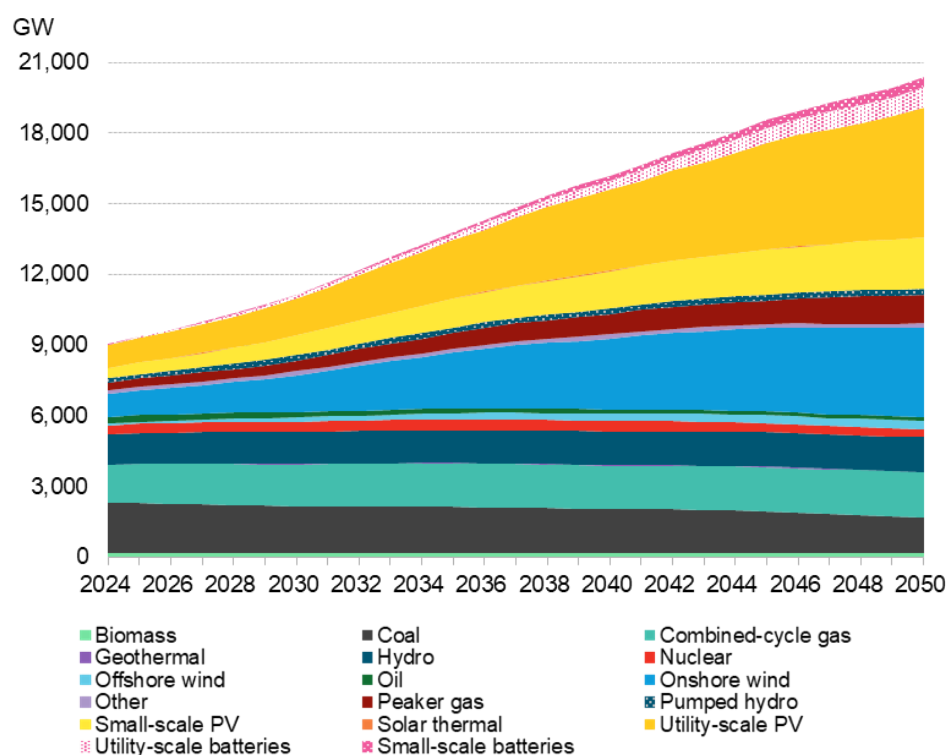
Source: BloombergNEF asset database. Note: Includes financing for projects at least 1.5MW in size. Note: See Appendix A for ISA country list.

Section 5. Global solar build outlooks

Despite extraordinary growth over the last decade, solar today still accounts for only 3% of total global electricity generation. This is expected to change as equipment costs, both generation technologies and batteries, continue to decline. As solar's share of generation grows, so too does complementary battery capacity, to ensure energy produced from the sun can be used well after dark. Wind will grow too, and renewables will reduce fossil fuel burn. However, projections based on economic uptake or even country targets suggest solar and wind would need to grow much faster to set a course for net-zero carbon emissions by 2050.

BloombergNEF thinks about the future of the energy transition through several lenses. BNEF's 2020 New Energy Outlook Economic Transition Scenario (ETS) takes an economic modelling approach to project the next 30 years under what is essentially a business-as-usual scenario in which clean energy costs keep declining at their expected rates but no major new policies are implemented to address climate change. Under the ETS, global gross power-generating capacity more than doubles by 2050 driven by population growth and the economic viability of renewables. Renewables become the majority share of capacity and crowd out coal-fired generation on cost (Figure 56).

Figure 56: Projected global installed power generation capacity, all types, BNEF's 2020 New Energy Outlook Economic Transition Scenario



Source: BloombergNEF 2020 New Energy Outlook Economic Transition Scenario

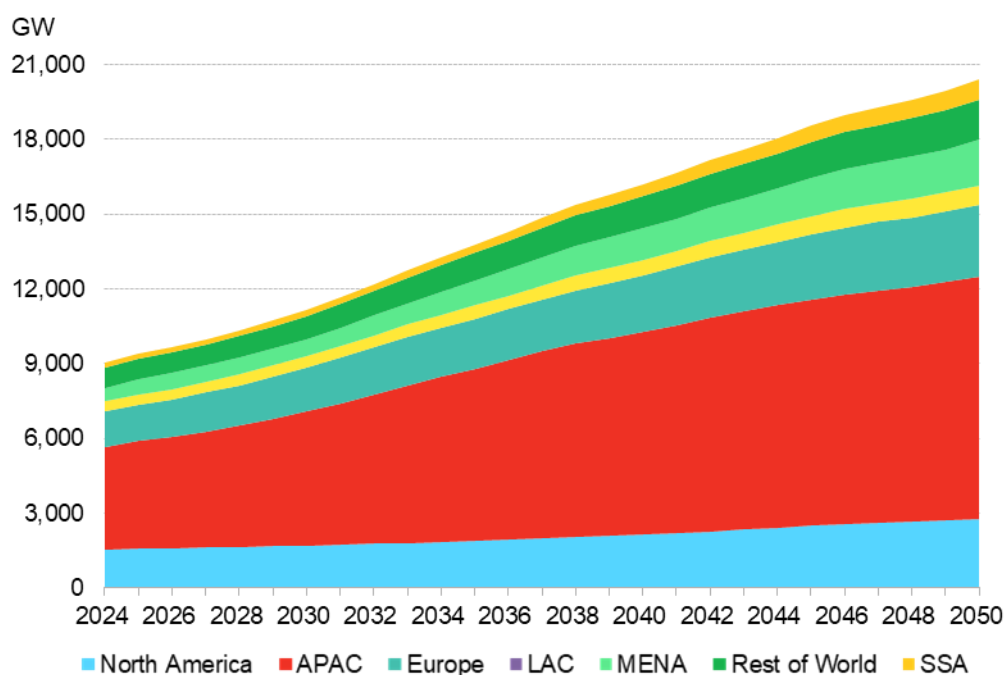
While most of this section focuses on the ETS, in Section 5.4 we also discuss the BNEF Net Zero Pathways scenarios, which assume more policy action gets taken to address climate. We also look at the shorter-term BNEF forecast that extends just through 2030. This is

based on BNEF's assessment of existing project-development pipelines, current economics and policies.

Under the ETS, wind and solar technologies complement each other for a time but eventually compete for an ever-shrinking share of remaining generation. At that point, cost becomes less important than how well resources correlate with demand, or inversely correlate with prevailing weather. This gives wind an advantage, as it can meet residual evening hours more cheaply than batteries added to PV.

Regionally, APAC makes up the majority of added capacity globally largely due to China. However, capacity additions are expected to slow eventually in APAC. Growth is strong throughout the next 30 years in the Middle-East and North Africa (MENA) and Sub-Saharan Africa (SSA) regions (Figure 57).

Figure 57: Global installed power generation capacity, by region⁶, BNEF's 2020 New Energy Outlook Economic Transition Scenario



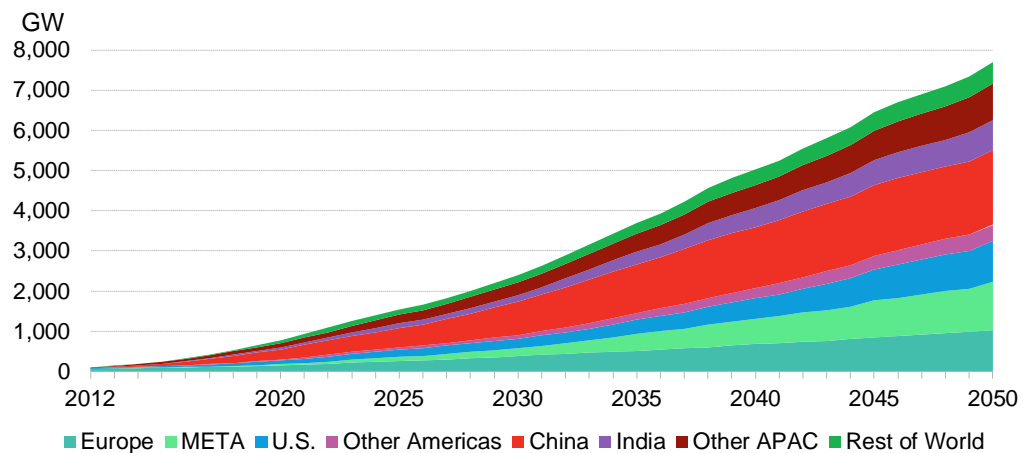
Source: BloombergNEF 2020 New Energy Outlook Economic Transition Scenario. Note: APAC is the Asia-Pacific region. LAC is Latin America and the Caribbean. MENA is Middle East and North Africa. SSA is sub-Saharan Africa.

5.1. Solar and battery outlook

Total global installed PV capacity stands at 788GW today but grows more than ninefold to over 7,700GW by 2050 under the ETS (Figure 58). Nearly three-quarters of all new build comes in the form of utility-scale projects with the balance being small-scale PV. Regionally, APAC is projected to build most and accounts for about half of all new capacity added by 2050. China represents the single largest opportunity with 1.9TW of new capacity to be built by 2050. In the Middle East

Turkey and Africa (META) region as grouped under NEO, installed solar capacity sees more than 30-fold growth. The capacity in the Americas ex-U.S. is expected to reach 407GW by 2050, up from about 30GW today, with 121GW of this in Brazil and 93GW in Mexico.

Figure 58: Global installed solar capacity, by region, BNEF's 2020 New Energy Outlook Economic Transition Scenario



Source: BloombergNEF 2020 New Energy Outlook Economic Transition Scenario. Note: META is the Middle East Turkey and Africa region. APAC is Asia-Pacific.

All segments of solar grow over the next three decades, but at differing rates. Utility-scale PV accounts for the majority of new build each year to 2050 but build fluctuates annually. Small-scale PV installations grow rapidly as well but capacity additions start to slow post-2045. This is in part due to an assumption in the BNEF model about the limits of available roof space for such capacity.

Figure 59: Global cumulative solar capacity additions, by technology, BNEF's 2020 New Energy Outlook Economic Transition Scenario

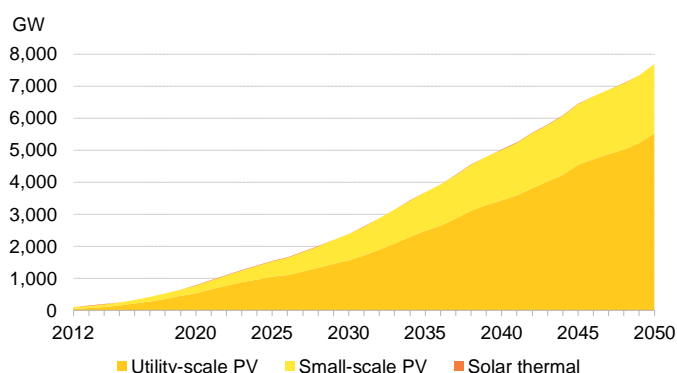
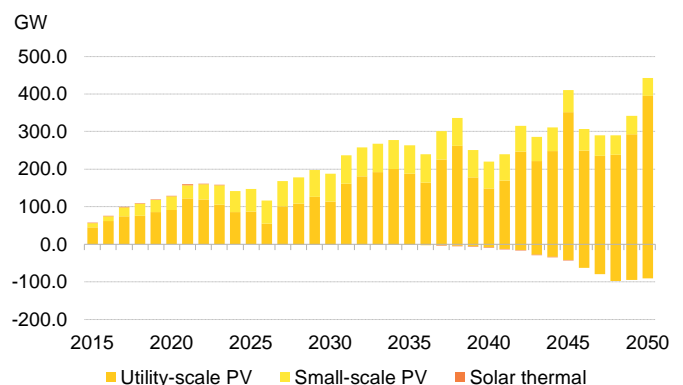


Figure 60: Global solar capacity additions, by technology, BNEF's 2020 NEO Economic Transition Scenario



Source: BloombergNEF Note: Negative additions are retirements.

The APAC region has been extremely active for solar development in the past five years and that trend continues in coming decades with China and India both continuing as leaders. To date, adoption in the MENA region has been defined by utility-scale projects with very little

accompanying small-scale activity. By 2050, META is projected have 589GW of utility-scale solar but only 75GW of small-scale (Figure 63 and Figure 64).

Figure 61: Global cumulative utility-scale solar capacity, by region, BNEF's 2020 NEO Economic Transition Scenario

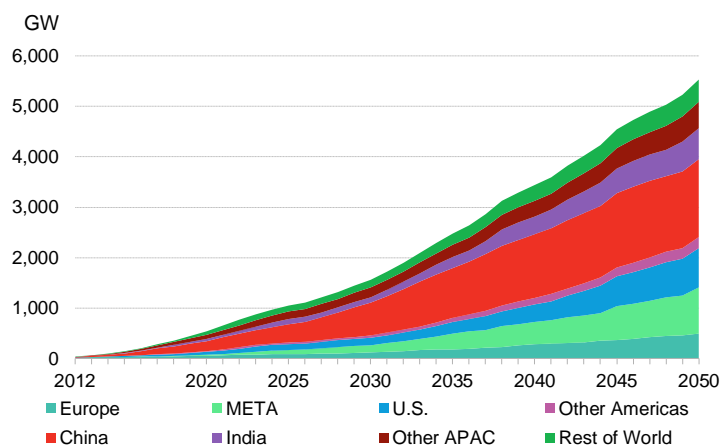
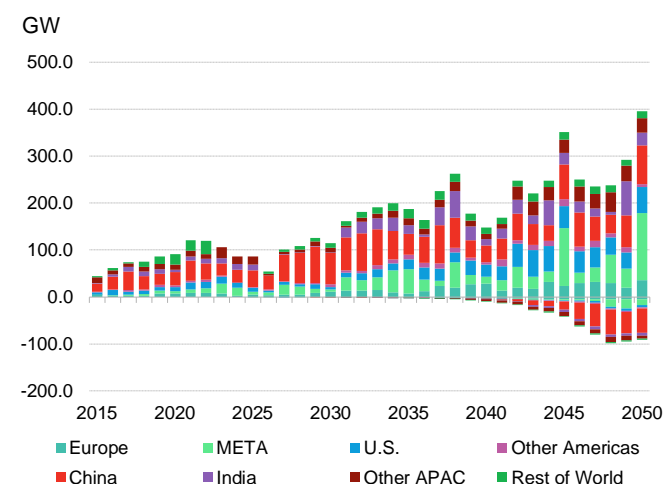


Figure 62: Global utility-scale solar new build capacity, by region, BNEF's 2020 NEO Economic Transition Scenario



Source: 2020 BNEF New Energy Outlook Economic Transition Scenario

In Latin America, Brazil remains the largest solar market both because it is the largest nation in the region but also due to supportive policies. Small-scale build prevails over the construction of utility-scale projects due to the compelling economics behind-the-meter systems offer in the country and the fact that Brazil's hydro-heavy power grid offers somewhat fewer opportunities for renewables to get built. The rest of Latin America follows trends seen elsewhere with utility-scale accounting for the lion's share of new build.

Figure 63: Global cumulative small-scale solar new additions, by region, BNEF's 2020 NEO Economic Transition Scenario

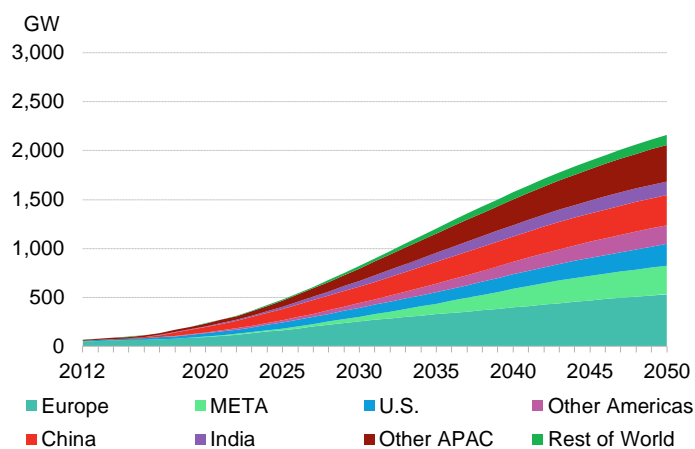
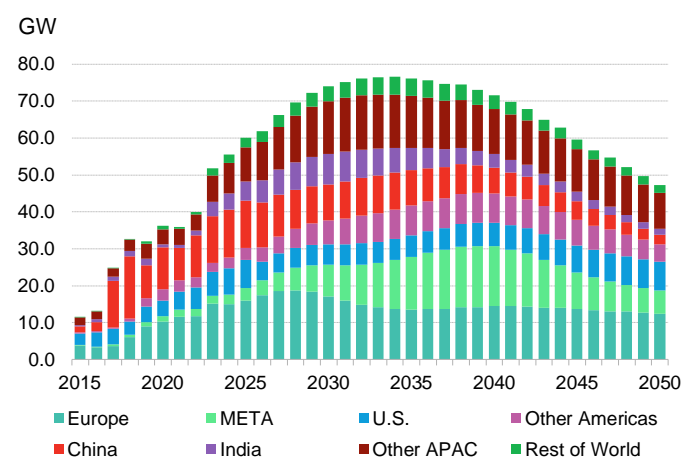


Figure 64: Global small-scale new build capacity, by region, BNEF's 2020 NEO Economic Transition Scenario



Source: 2020 BNEF New Energy Outlook Economic Transition Scenario

As discussed in Section 1, battery prices have fallen dramatically in recent years and BNEF projects them to continue declining at a relatively predictable rate over the next three

decades as further economies of scale are achieved. To a large degree, this will be driven by how fast electric vehicle demand accelerates as that is a far larger market for such batteries. EV adoption plus battery costs reductions creates mass opportunities for deploying batteries both on the grid or behind the meter in businesses or homes.

Already, solar and battery (“PV+storage” or “PV+S”) projects are beginning to be built in developed nations where policy is supportive or power markets offer lucrative opportunities at hours of peak demand. Batteries take advantage of peakier intraday net load curves, pairing with PV in sunny regions to meet demand after the sun sets. This is particularly true where other types of peaking capacity are expensive and where wind resources are strongly seasonal. We project significant battery deployment in the Middle East, Southeast Asia and Japan under the ETS. Overall, there is around 1,300GW of storage for load shifting by 2050 (Figure 65 and Figure 66).

Figure 65: Global cumulative battery capacity installed, by region, BNEF’s 2020 New Energy Outlook Economic Transition Scenario

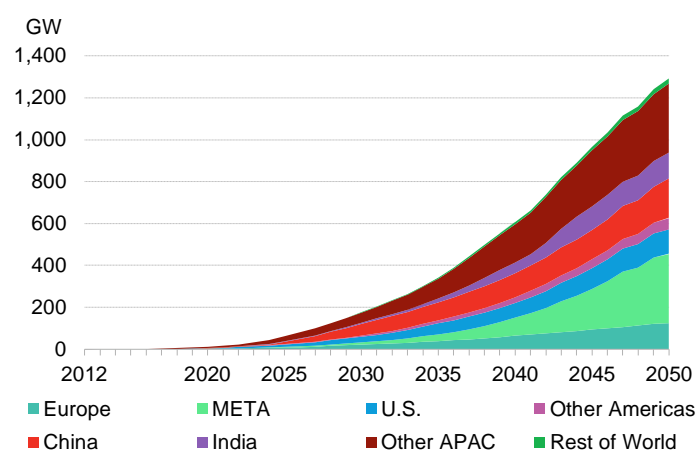
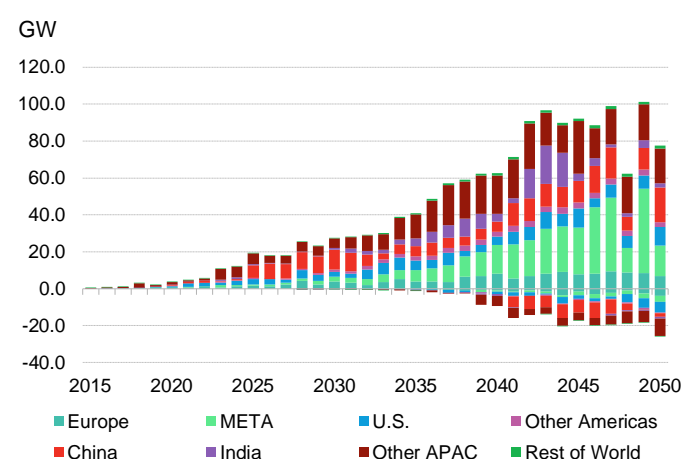


Figure 66: Global annual battery capacity additions, by region, BNEF’s 2020 New Energy Outlook Economic Transition Scenario



Source: 2020 BNEF New Energy Outlook Economic Transition Scenario. Note: META is the Middle-east Turkey and Africa region. APAC is Asia-Pacific.

Utility-scale batteries make up the majority of stationary battery capacity globally today and over the next 30 years, largely because BNEF’s ETS assumes small-scale batteries only get built in tandem with small-scale PV systems. New additions of small-scale batteries grow at a 10% year-over-year average over the next 30 years, BNEF projects. By 2050, about 444GW of total small-scale battery capacity is online globally (Figure 67 and Figure).



Figure 67: Global cumulative battery capacity installed, by market segment, BNEF's 2020 New Energy Outlook Economic Transition Scenario

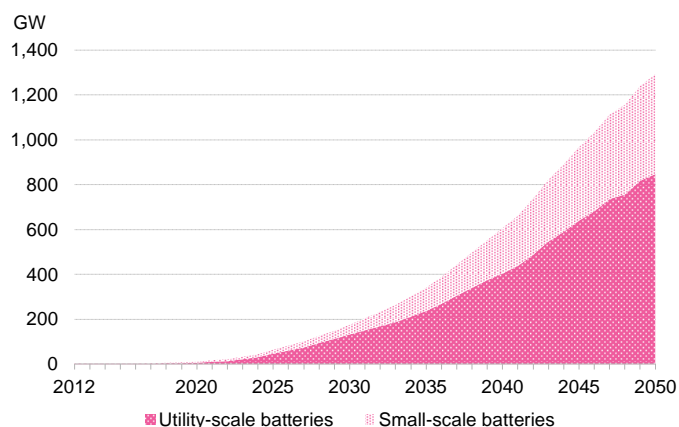
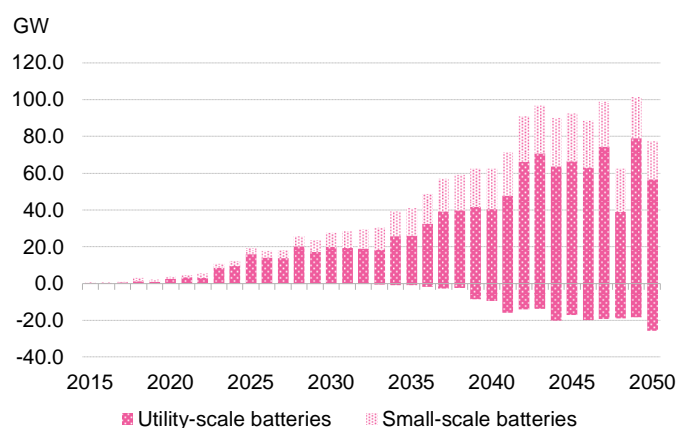


Figure 68: Global annual battery capacity additions, by market segment, BNEF's 2020 New Energy Outlook Economic Transition Scenario

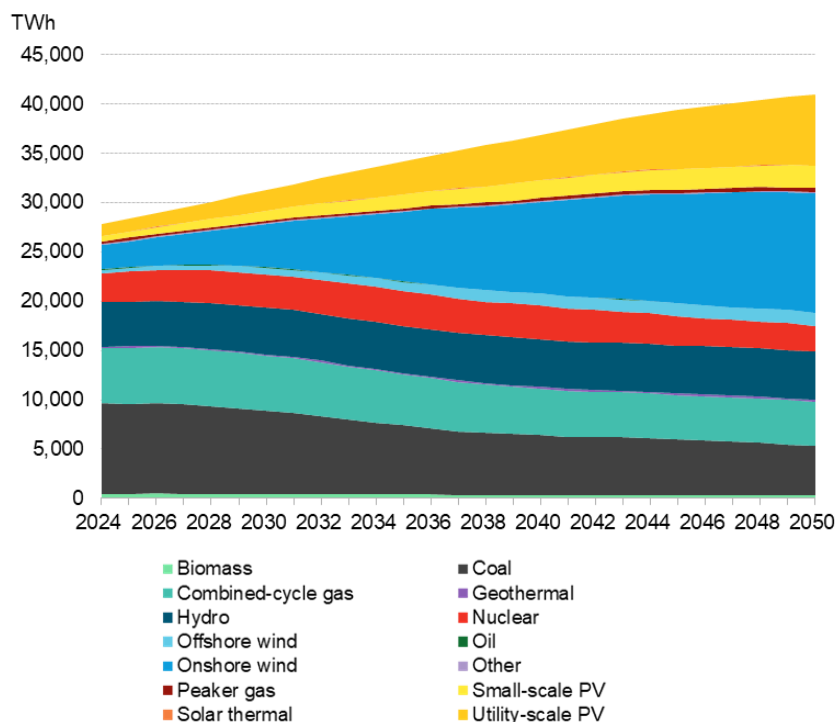


Source: 2020 BNEF New Energy Outlook Economic Transition Scenario

5.2. Generation

Generation from zero-carbon sources – solar, wind, geothermal, biomass, hydro, and nuclear – rises steadily over the next 30 years as clean capacity grows. In BNEF's Economic Transition Scenario, contributions from these clean sources grow 4.6% annually through 2050 (Figure 69). Nonetheless, fossil sources – coal, oil, and gas – still account for a significant portion of total generation by 2050. In 2021, fossil fuels are on track to meet 58% of electricity demand, with zero-carbon energy accounting for the balance. By 2050, this flips with fossils making up only 24% and clean electricity (including six percentage points from nuclear) 76%.

Figure 69: Global electricity generation, by technology, BNEF's 2020 New Energy Outlook Economic Transition Scenario

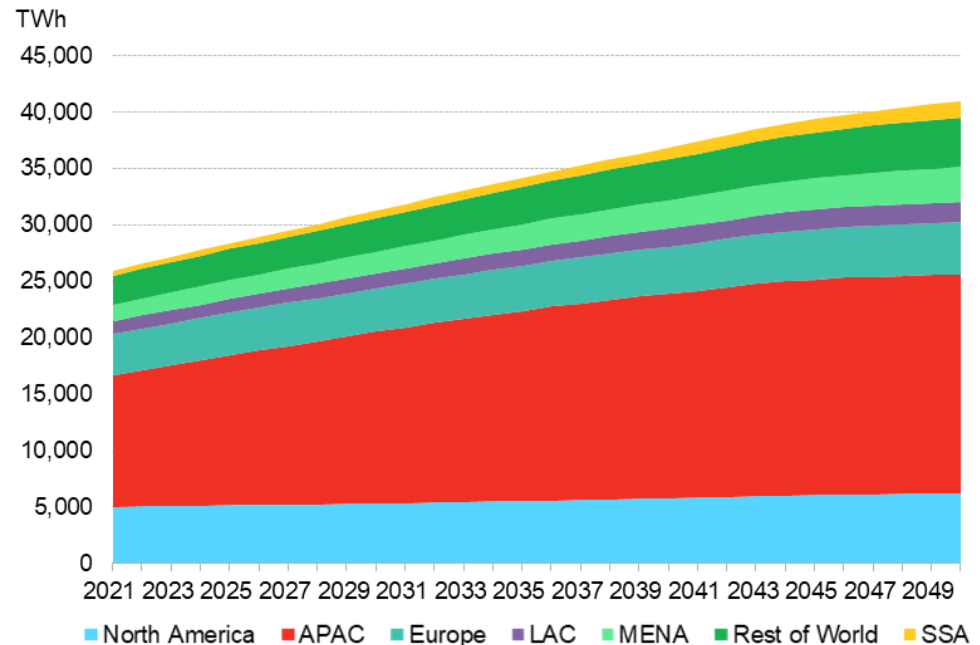


Source: BloombergNEF

Regionally, APAC today is the largest market with the majority of the generation coming from coal though contributions from renewables have grown in recent years. Over the next three decades, as renewables become lower cost and proliferate, fossil fuels will play a smaller role (Figure 70). In LATAM, hydro power today is the primary source of generation though its role is expected to be somewhat diminished over the next three decades as more solar comes online. In MENA, combined-cycle gas makes up the majority of generation but onshore wind and utility-scale PV become large sources.

As the home to some of the least developed nations, SSA today has quite limited generation capacity. Coal meets the majority of demand with hydro being the second largest power-generating source. Solar is already cost-competitive in the region and should grow swiftly, eventually becoming a top technology in terms of meeting demand for the region. Still, BNEF expects coal generation to grow somewhat in SSA, posting a 0.4% annual growth rate 2021-2050. Utility-scale PV increases much more briskly at a projected annual growth rate of 16% over 30 years

Figure 70: Global generation, by region, BNEF's 2020 New Energy Outlook Economic Transition Scenario



Source: BloombergNEF

Utility-scale PV generation grows across all regions at an average pace of 8% per year through 2050, along with capacity although sunnier regions will generate more from the same capacity. MENA also has a very high projected growth rate at 13% while Other Americas (mainly Latin America) is only projected to grow an average of 9% annually (Figure 71). Small-scale PV generation is projected to grow in all regions at a year-over-year average of 7% (Figure 72).

Figure 71: Utility-scale solar generation by region, BNEF's 2020 New Energy Outlook Economic Transition Scenario

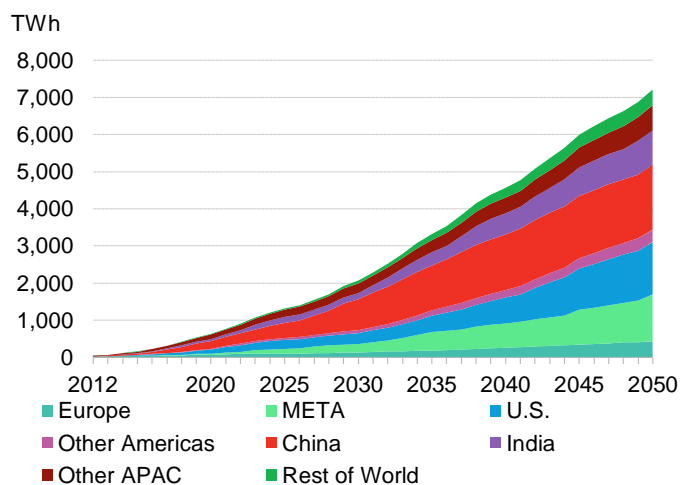
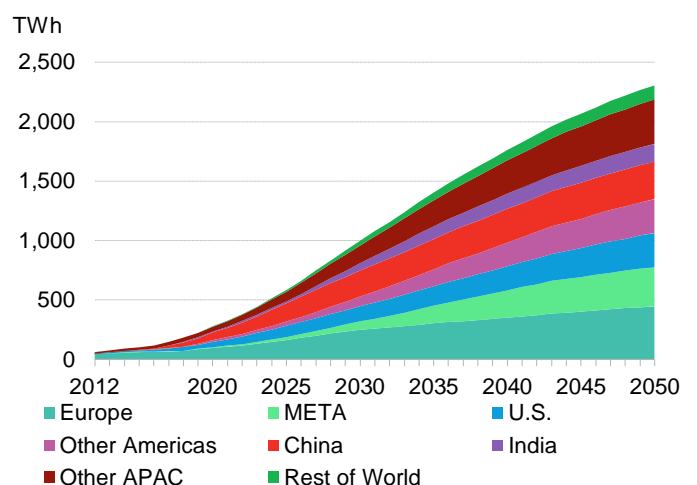


Figure 72: Small-scale solar generation by region, BNEF's 2020 New Energy Outlook Economic Transition Scenario

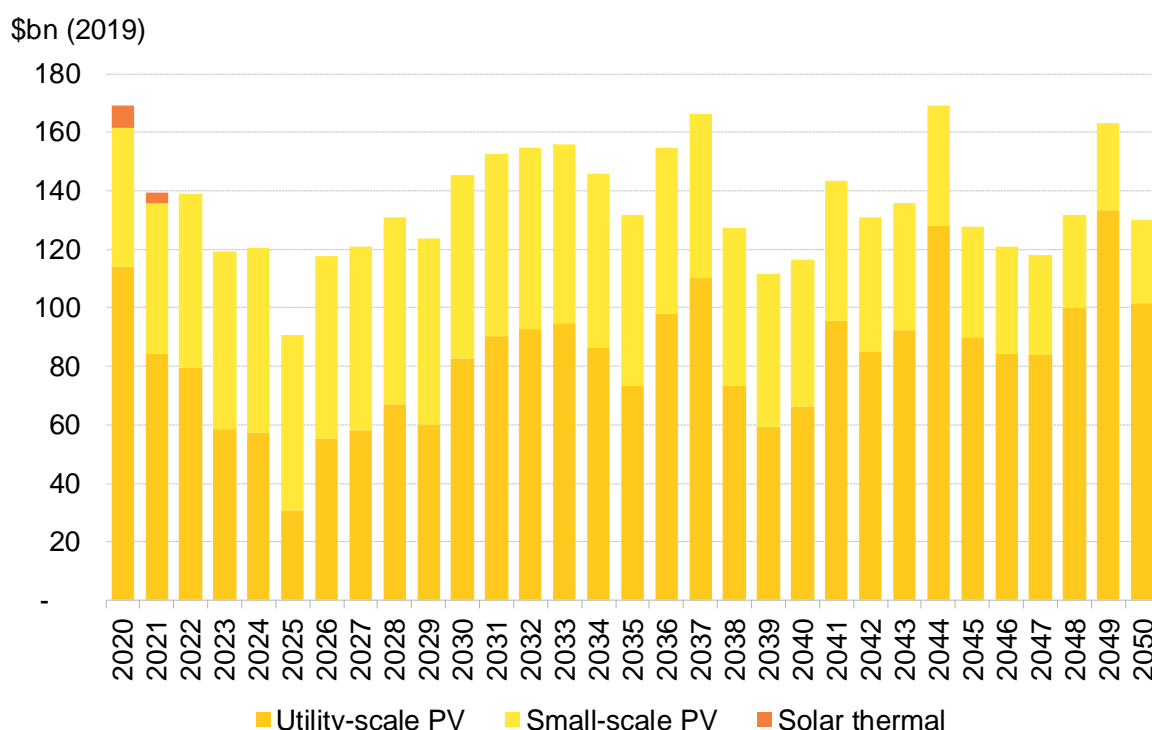


Source: 2020 BNEF New Energy Outlook Economic Transition Scenario

5.3. Investment

Taking global PV from 788GW to 2.4TW or 10% of world electricity generation by 2030 as projected under BNEF's ETS requires investment of approximately \$1.2 trillion from 2021 to 2030. In 2020, capital backing the build of new solar capacity totaled \$169 billion (an upwards revision from \$148.6 billion reported in February 2021). Under the fairly conservative ETS, annual investment is quite flat at \$120-150 billion nearly every year to 2050 (Figure 73). As total capacity installed rises, per-unit costs associated with PV projects (namely, the capital expenditures or "capex") declines. The result is investors get more capacity for their money. In addition, \$157 billion gets invested in batteries 2020-2030, and \$951 billion from 2020 to 2050.

Figure 73: Global solar investment, by segment, BNEF's 2020 New Energy Outlook Economic Transition Scenario

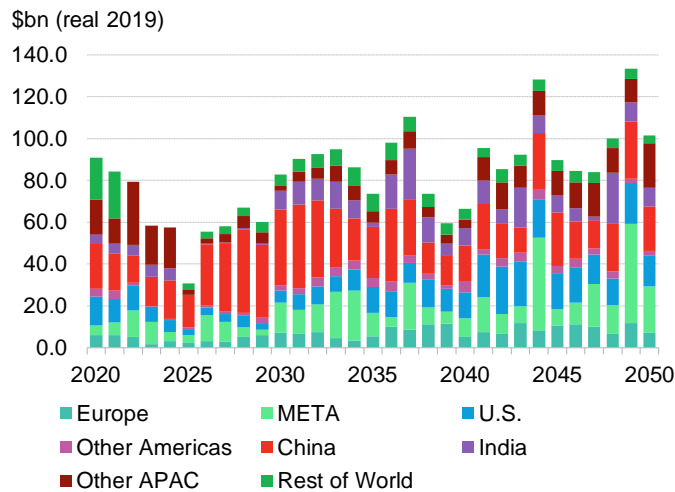


Source: BloombergNEF. Note: 2020 figure reflects actual investment tracked; all others are projections.

Utility-scale solar is expected to represent a slightly larger investment opportunity than small-scale in most geographies up to 2050 (Figure 74 and Figure 75). APAC is the region that presents the most consistent investment opportunity. For small-scale solar, under the ETS, rooftop space starts to hit saturation constraints in many markets and shrinks to 2050 (although this may not actually be what transpires).

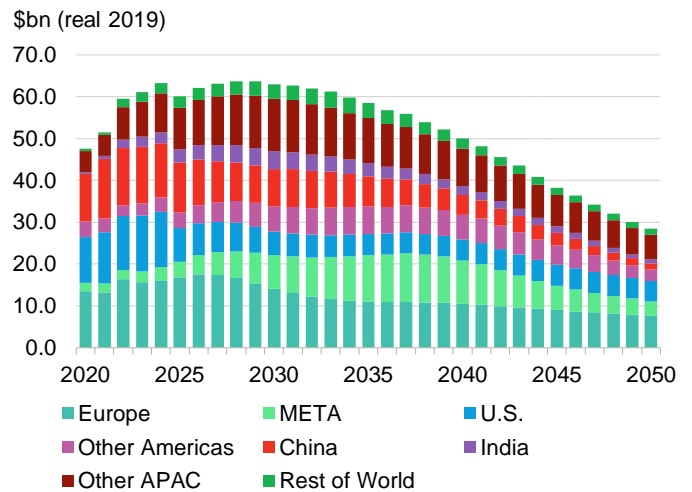


Figure 74: Utility-scale solar investment by region, 2020-2050, BNEF's 2020 NEO Economic Transition Scenario



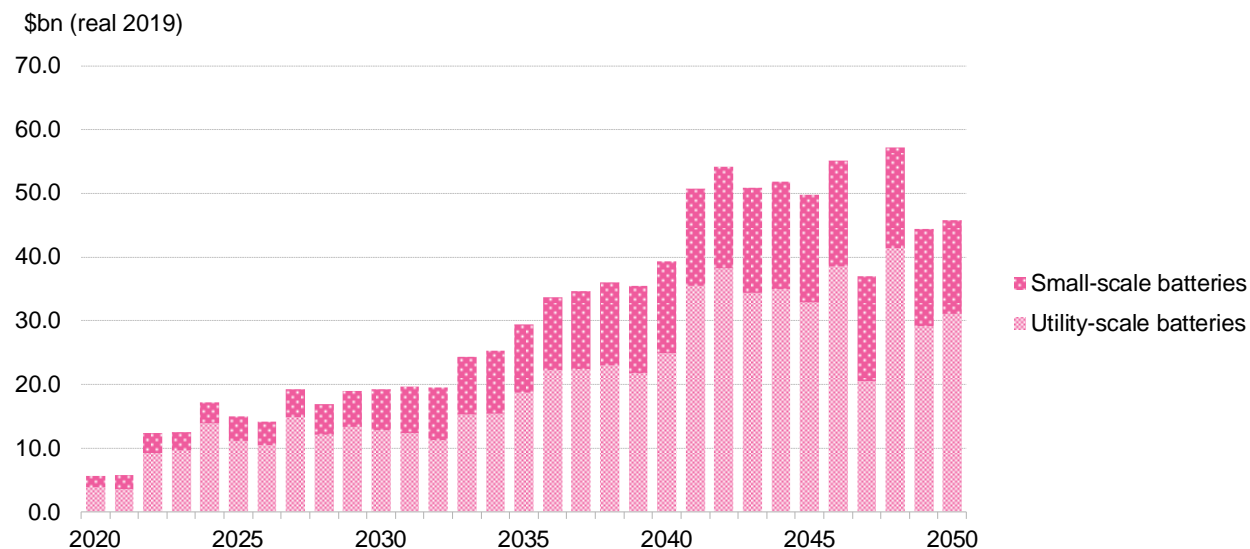
Source: BloombergNEF

Figure 75: Small-scale PV investment by region, 2020-2050, BNEF's 2020 NEO Economic Transition Scenario



The build-out of solar is accompanied by mass deployment of batteries and this energy storage equipment represents a \$951 billion investment opportunity over the next 30 years. In 2020, a total of \$4 billion went into new storage capacity. BNEF's ETS has that growing to approximately \$50 billion annually by 2041 before levelling off. The utility-scale segment of the market accounts for the large majority of the capital required, at \$638 billion between 2020 and 2050 (Figure 76).

Figure 76: Global battery investment, by market segment, BNEF's 2020 New Energy Outlook Economic Transition Scenario



Source: BloombergNEF

Utility-scale battery investment reaches about \$35 billion in 2041 and then largely levels off, with Asian countries leading investment into the 2040s and then other regions needing significant amounts of new capacity (Figure 78). Small-scale residential and commercial



battery investment is projected to grow until 2044 and then start to level off as the market saturates (Figure 78).

Figure 77: Utility-scale battery investment by region, BNEF's 2020 New Energy Outlook Economic Transition Scenario

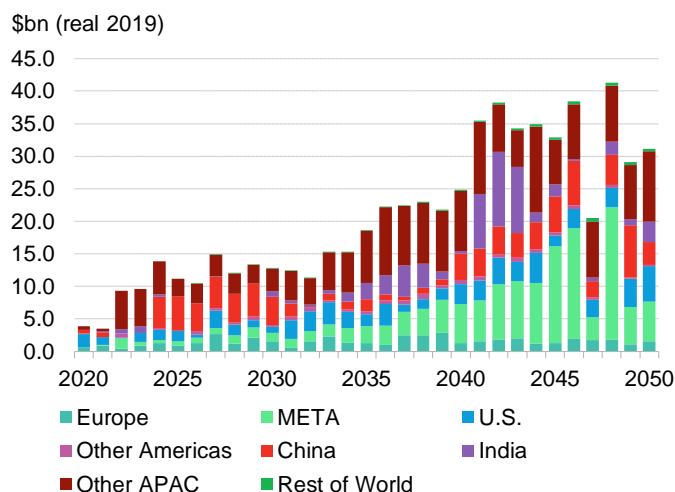
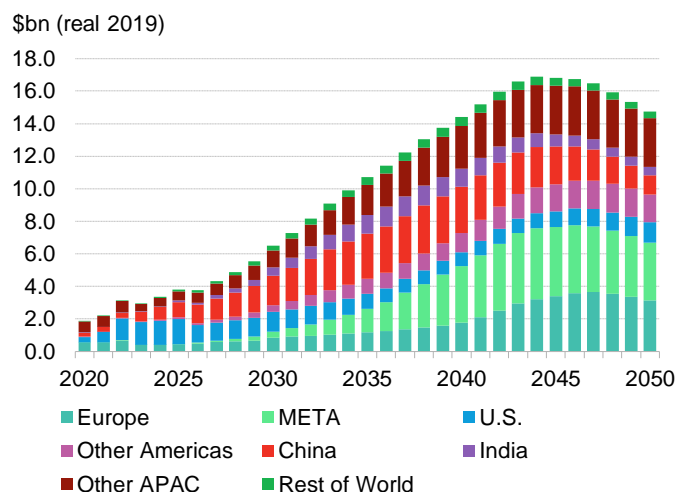


Figure 78: Small-scale battery investment by region, BNEF's 2020 New Energy Outlook Economic Transition Scenario



Source: BNEF

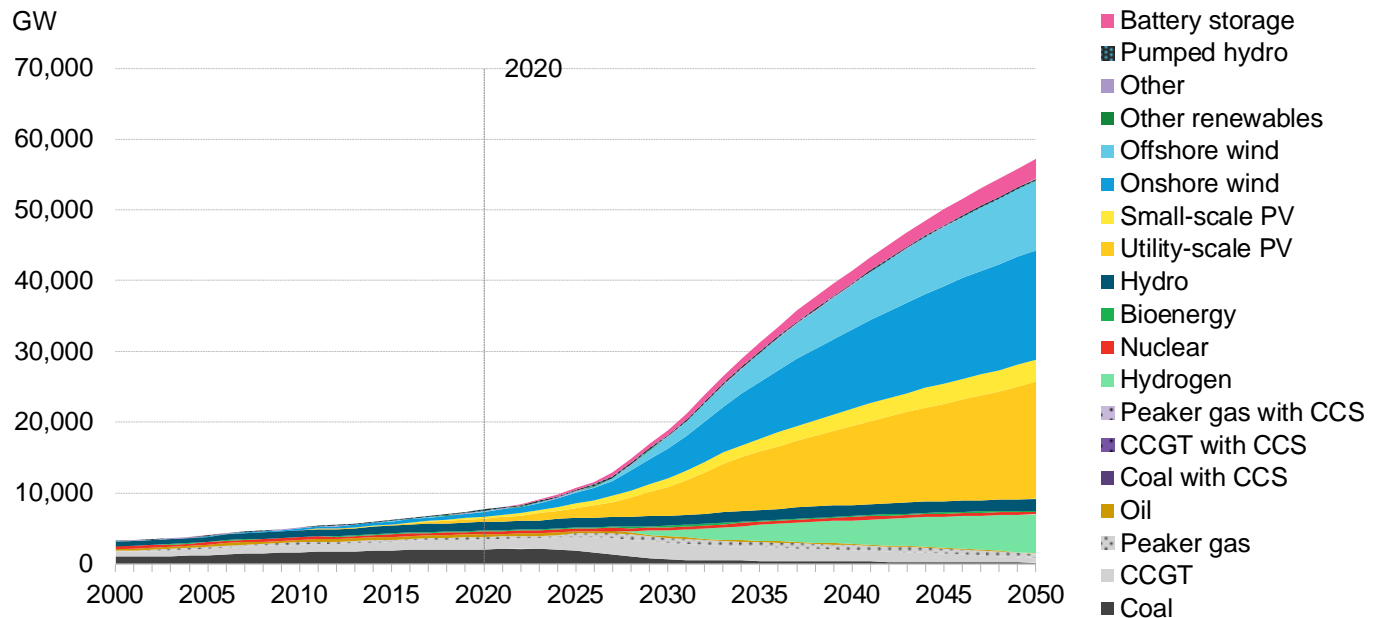
5.4. The Path to Deep Decarbonization

BNEF's ETS projects a world in which renewables grow, alongside batteries and potentially other low-carbon technologies. But the transition envisioned under the ETS is not nearly sufficient to address climate change. To keep global temperature increases in check will require much faster decarbonization of the global economy. To consider the potential pathways for achieving this broader goal, in 2021 BloombergNEF modelled new scenarios to 2050.

Each new scenario involves far more solar and wind build than under the ETS. Even under BNEF's "Gray" scenario in which gas with carbon capture, utilization and storage plays a big role, renewables grow faster than under the ETS. Under the "Green" scenario where the world runs primarily on renewables to achieve net-zero annual emissions by 2050 (Figure 79), BNEF expects 4.3TW of cumulative solar by 2030 for power generation, supplying 16% of the world's directly used electricity, plus another 1TW for making hydrogen using electrolysis, for a total of 5.3TW in 2030.



Figure 79: Global installed electric power capacity in BloombergNEF's 2021 "Green scenario" for net zero by 2050



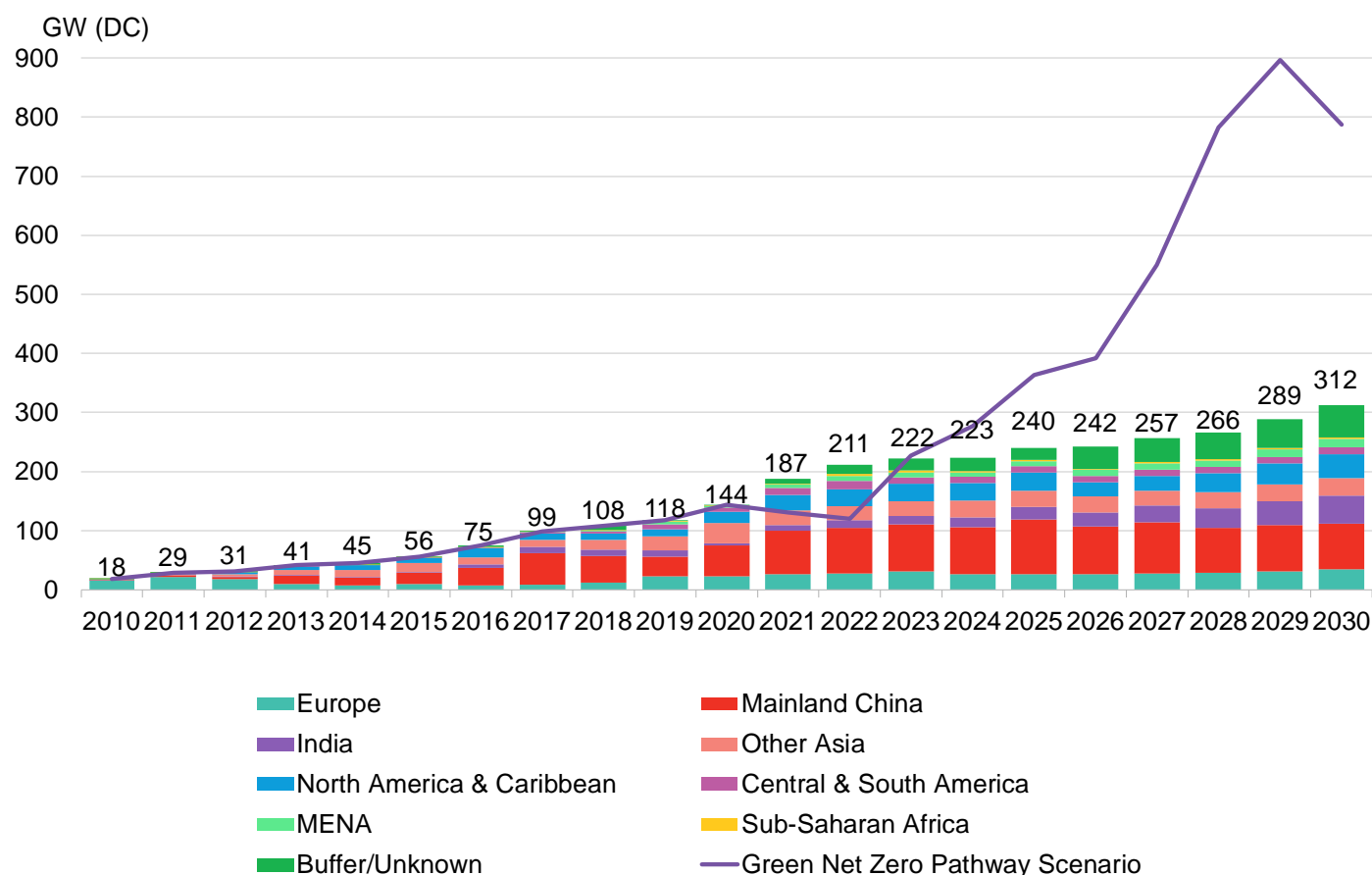
Source: BloombergNEF New Energy Outlook 2021

This scenario requires wind/solar build to ramp very sharply from about 250GW per year to no less than 1,760GW in calendar year 2030. To put that in context, BNEF's short-term forecast (based on actual market conditions and the pipeline of projects now under development) expects 79-129GW of wind to be built per year over this period with annual solar build only expected to reach 312GW in 2030 (Figure 80). While the Green scenario portrays build ramping very quickly in the latter half of this decade, finding sufficient land and grid connections will be challenging to achieve the higher rate of growth.

It would thus be easy to regard the Green scenario growth rate as entirely out of reach. However, the solar industry has a history of revolutionary growth. In 2000, just 0.29GW of solar was built worldwide. In 2004, Germany established the first major feed-in tariff and the global market reached 1.47GW in 2005. By 2010, it was 18GW, and in 2021 we expect new build to be over ten times that at about 190GW. It is difficult to look ahead and forecast revolution, but it is possible for revolution to happen, especially now that solar is now the cheapest source of bulk electricity in most sunbelt countries.



Figure 80: BloombergNEF's central forecast for global PV new build to 2030 as of September 2021 (bars), plus global solar build required to be on the path to net zero by 2050 under the "green" (high-renewables) modelled scenario



Source: BloombergNEF Note: Unlike the New Energy Outlook scenarios, this is a forecast based on country targets, policy and pipeline.

BNEF's Green scenario for net zero represents an investment opportunity in power generation assets of around \$64 trillion worldwide by 2050. In 2020, about \$333 billion was invested in renewable energy, of which \$169 billion was for solar. At the same time, more than 100GW of coal-fired capacity needs to retire on average each year so that by 2030 coal-fired power is 67-72% below 2019 levels. Capital flows need to accelerate markedly too. New investment in wind and solar capacity has been flat at around \$300 billion per year for several years. This figure needs to rise to between \$763 billion to \$1.8 trillion per year between 2021 and 2030 depending on scenario, to get on track for net zero.

ISA targets \$1 trillion of investment mobilized in solar in its countries by 2030, which would be significant in bringing the world closer to the net zero pathway. In practice, this may not need to be targeted solar investment, and could include enabling infrastructure such as transmission, batteries, micro and minigrids and even electrolyzer capacity to get the solar electricity delivered when and where it is needed.

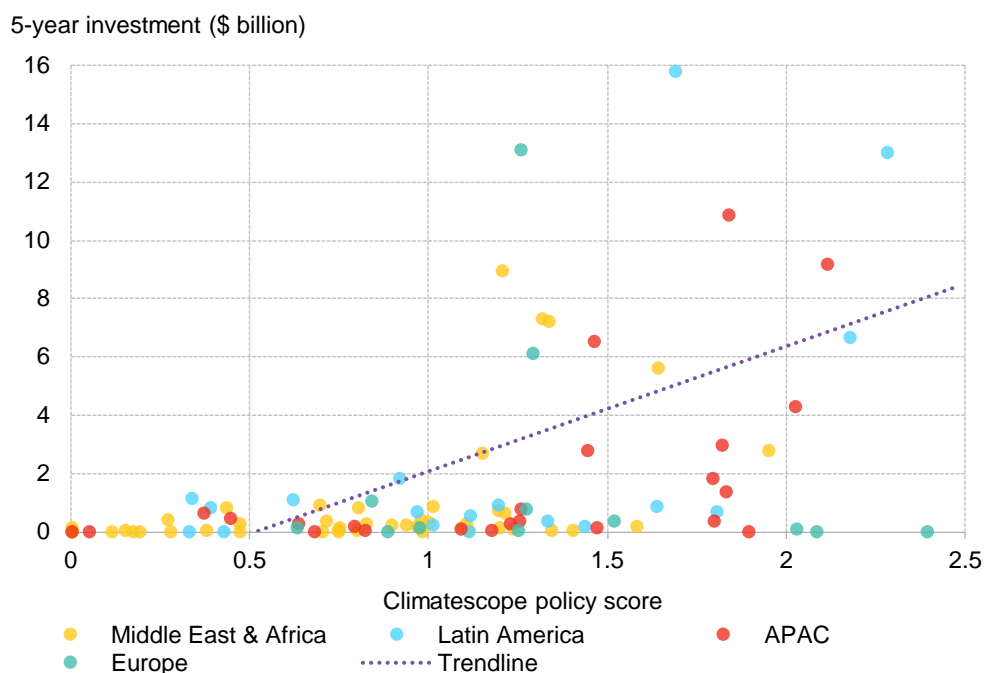
Section 6. Policy

Solar technology costs have never been lower and clean power has never been more cost competitive, even on an entirely unsubsidized basis. Still, stable, well-defined clean energy enabling environments remain critical to attracting investment, particularly private capital. This is especially true in emerging markets, where country risk tends to be higher for investors and project developers.

6.1. On-grid policies

When it comes to supporting development of utility-scale projects and rooftop systems connected to the grid, policy mechanisms such as targets, auctions, feed-in tariffs, tax incentives and net metering are critical. BNEF's annual survey Climatescope evaluates markets' renewable energy policy regimes by analyzing the ambition, access, stability and success of each type of policy they have implemented. Our research shows that none of the 60 markets at the bottom of our 2020 policy ranking received more than \$2 billion in clean energy investment 2015-2019 and just four received more than \$1 billion over the period. On average, these economies attracted \$275 million over the 5-year period, or \$55 million per year. In contrast, the remaining 47 markets surveyed (excluding mainland China), attracted on average \$4.6 billion over the period, or \$907 million per year (Figure 81).

Figure 81: Climatescope renewable energy policy score vs. 5-year clean energy asset finance in emerging markets

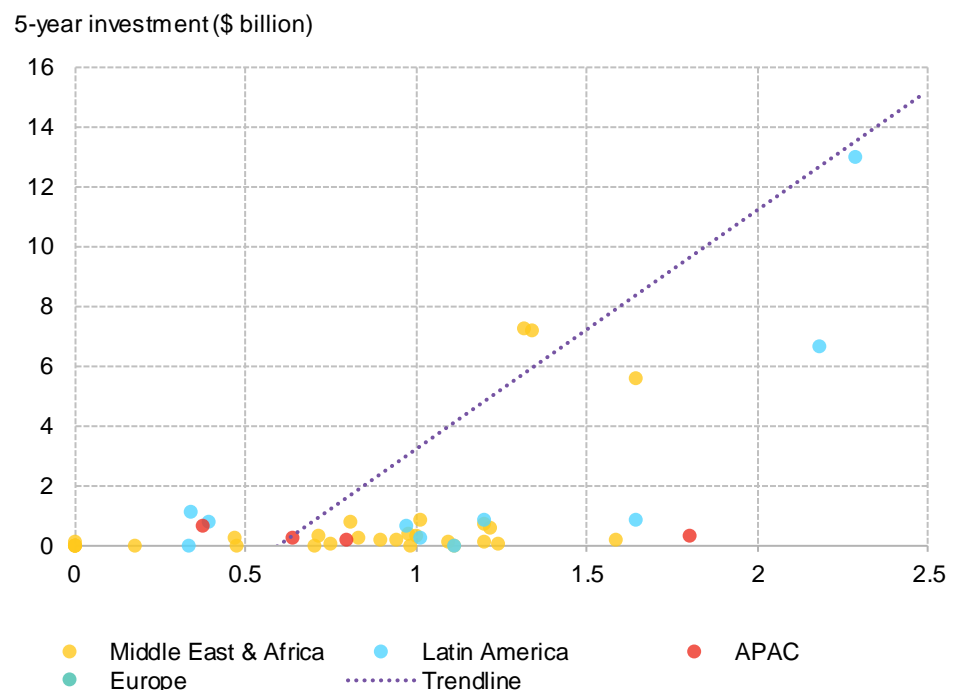


Source: BloombergNEF, Climatescope. Note: x axis refers to Climatescope renewable energy policy score.

In the ISA countries defined as emerging markets, the relationship between policy and clean energy investment is even stronger. While the top 20 ISA countries in the Climatescope 2020 policy ranking attracted on average \$1.2 billion per year in clean energy investment over 2015-2019, the bottom 25 received just \$55 million per year over the same period (Figure 82).

Excluding behemoths India and Brazil, only four emerging markets on the ISA country list received more than \$6 billion in clean energy investment 2015-2019: Chile, Morocco, U.A.E. and Argentina. These markets fell in the top 10 ISA countries in the Climatescope policy ranking⁷. This highlights that implementing appropriate policy frameworks should be one of the first steps to spur solar investment in these nations.

Figure 82: Climatescope renewable energy policy score vs. 5-year clean energy asset finance in ISA emerging markets



Source: BloombergNEF, Climatescope. Includes 45 ISA emerging markets that have been surveyed by Climatescope. Outliers India and Brazil do not appear on the chart for scale purposes. Brazil attracted \$25.6 billion 2015-2019 and India \$50.2 billion over the period. Note: See Appendix A for ISA country list. Note: x axis refers to Climatescope renewable energy policy score.

Development of new clean energy policy frameworks has varied by country, of course. However, there have been some notable trends in how these have emerged and ultimately succeeded:

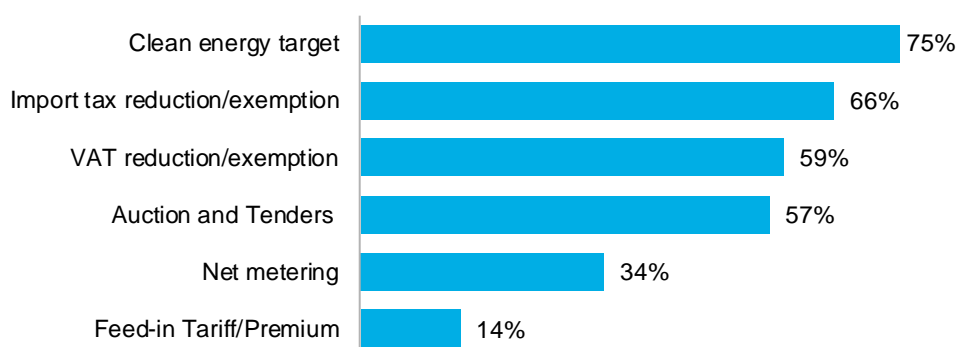
- With international support, typically from development finance institutions, governments or NGO's, governments implement new policies that aim to provide clarity to investors on their nation's vision for the power sector, reduce the bureaucracy around clean energy build-out and provide incentives for the construction of renewable energy plants. The package tends to include at least a clean energy target, as well as a renewable energy auction or feed-in tariff.

⁷. BNEF's annual survey Climatescope evaluates markets' renewable energy policy regimes by analyzing the ambition, access, stability and success of each type of policy they have implemented.

- Once the policy is rolled out, developers tend to count on the support of international development banks to finance the earliest projects. These institutions play a key role in supporting first-movers in these nations, as they are comfortable taking higher risks and can offer investment at lower cost.
- After the first projects are built and the country gains experience in a specific clean energy sector, overseas investors' perceptions of risk tend to diminish. Private capital starts to "crowd in"; the need for development finance fades.

To date, a limited number of ISA emerging markets have followed the basic steps outlined above to completion. Nearly three quarters of the ISA emerging markets surveyed for Climatescope 2020 have clean energy targets in force. However, implementation of other policies that are key to ensure deployment of clean energy projects has been limited. Only 57% of the 45 ISA markets surveyed by Climatescope have auctions in force, just 34% have net metering policies, and only 14% have implemented feed-in tariffs (Figure 83).

Figure 83: Share of Climatescope ISA emerging markets surveyed with specific renewable energy policies



Source: BloombergNEF, *Climatescope*. Note: includes 44 ISA emerging markets surveyed in *Climatescope 2020*. Note: See Appendix A for ISA country list.

Clean energy targets

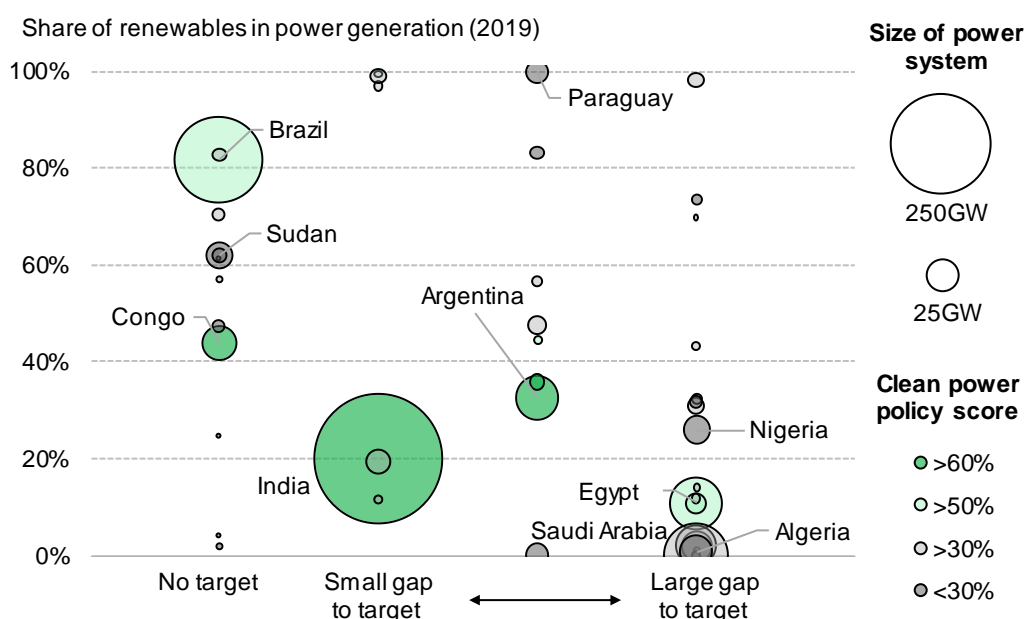
Setting targets typically is the starting point for building successful renewable energy policy frameworks, but an objective alone is not enough to create a vibrant local clean energy sector. Targets must be accompanied by more specific policies that ensure stakeholders have sufficient incentives to enter the market.

Setting a target is often the first major policy action a government takes to explicitly address climate change. Targets have the benefit of signalling to the market policy makers' future priorities while not requiring the spending of actual government funds. Targets can be high level, ambiguous and often have little value when set in isolation. Others are specific, ambitious and are coupled with policies that penalize those who fail to achieve them.

The ambition of clean energy targets among ISA member countries varies widely. Many have raised their expectations for deploying renewable energy considerably, including those with almost no installed wind or solar to date. Benin, Niger, Bangladesh, Botswana and Algeria all now have large gaps to reach renewable energy targets their governments have set and are starting from close to zero. Solar stands to play a key role in helping these nations reach their goals (Figure 84).

On the other hand, other ISA nations have made few declarations about their clean energy ambitions and implemented few policies. The list includes El Salvador, Rwanda, Zambia, Peru and Cambodia.

Figure 84: Status of clean power targets in ISA emerging markets and policy supports vs. share of renewables in generation



Source: BloombergNEF, *Climatescope*. Note: includes 44 ISA emerging markets surveyed in *Climatescope 2020*. Gap to target was collected as part *Climatescope 2020* qualitative research. See Appendix A for ISA country list.

The evolution of clean energy targets

Broad targets to install clean energy have long been useful in setting the overall policy direction a government hopes to follow. In recent years, however, these goals have become a bit more nuanced. Some countries today, especially developed nations, are phasing out technology-specific capacity targets in favor of generation-based or technology-neutral targets. The EU, for instance, has a target framework for member states to achieve certain shares of renewables in gross final energy consumption, with sub-targets for electricity demand, to meet the bloc's 2020 and 2030 goals.

Despite this overarching trend, there are two particular cases where a government may prefer more specific targets. The first is where it is eager to expand a particular sector, potentially as part of a plan to become a regional hub for a given technology. The U.K. for instance wants to further develop the offshore wind sector as part of its industrial strategy and therefore has implemented a target for 40GW of installed capacity by 2030.

A specific target may also be applied to encourage adoption of newer technologies, such as energy storage, especially in the U.S. In the case of California, a target was imposed in 2013 on the three investor-owned utilities – San Diego Gas & Electric (SDG&E), Pacific Gas & Electric (PG&E) and Southern California Edison (SCE) – to procure a total of 1.3GW of storage capacity by 2020. State regulators added a goal of 500MW of distribution-connected or behind-the-meter

storage, and utilities were required to analyze the potential for long-duration storage. This helped take the total mandated capacity to just over 1.8GW.

Clean energy target in Saudi Arabia

Saudi Arabia has a target of 42.7GW of solar by 2030 (of which 2.7GW is theoretically earmarked for solar thermal), and 16GW of wind. BNEF does not expect the country to meet its wind targets, while actual build of solar has been slow to date.

Saudi Arabia has so far run three rounds of auctions for solar. The first, in 2017, awarded 300MW of solar capacity to be built by Saudi power and infrastructure firm ACWA Power at a reported price of \$24/MWh. This Sakaka project was built on schedule in 2019.

The second round was held in 2019 and awarded 2.97GW in April 2021, including what Saudi Arabia claims is the world's lowest bid of \$10.4/MWh, to a consortium including ACWA Power, Gulf Investment Corporation and a local holding company. BloombergNEF suspects there are undisclosed terms complicating this headline figure. Little progress was reported on these projects through the pandemic, and Chinese export data from Sinoimex shows \$113.8 million of solar exports to Saudi Arabia in 2019 (presumably mostly for the Sakaka project) but only \$23.8 million in 2020 and \$11.3 million in 1H 2021. We therefore believe build on further projects has barely started.

Saudi Arabia first published regulations for net metering in August 2017, but the framework was not robust enough to spur meaningful uptake.

We expect Saudi Arabia's hiatus on solar build to end, probably after the current boom in module and commodity prices fades and low auction bids are possible again, and we expect the country to meet at least the solar target by 2030. Saudi giant ACWA Power has been very active in winning auctions and building solar in other countries, so has the experience when the environment at home is right.

Clean energy auctions

Scaling grid-connected renewable energy capacity relies on clear investment signals as most of the capital is deployed in the project development phase. Auctions are often the policy mechanism of choice for emerging markets to procure new renewable energy capacity for their grids and attract private investment. Auctions for long-term price contracts can provide revenue certainty, drive investment into clean energy, and attract a low cost of capital to new renewables projects.

Climatescope research shows that auctions are not only a critical contributor to the growth of renewables globally, but also the most successful clean energy policy to boost investment in developing countries. The 48 emerging markets, surveyed under Climatescope, with auctions in force combined (excluding China) attracted \$42 billion in clean energy asset finance in 2019, or an average of \$873 million per country. This is almost five times the average investment that nations with no auctions attracted in 2019. Countries with auctions also received on average over four times more foreign capital than countries that do not have this mechanism in place (Figure 86).



Figure 85: 2019 new-build clean energy asset finance committed under due to auction/tender status (excluding China)

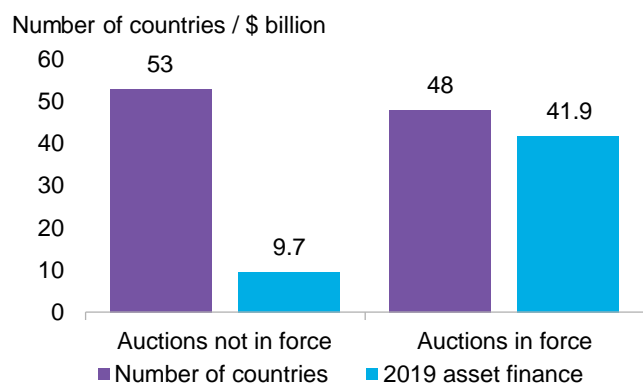
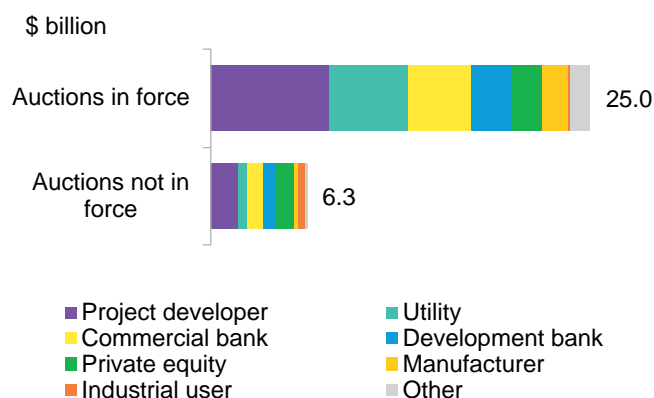


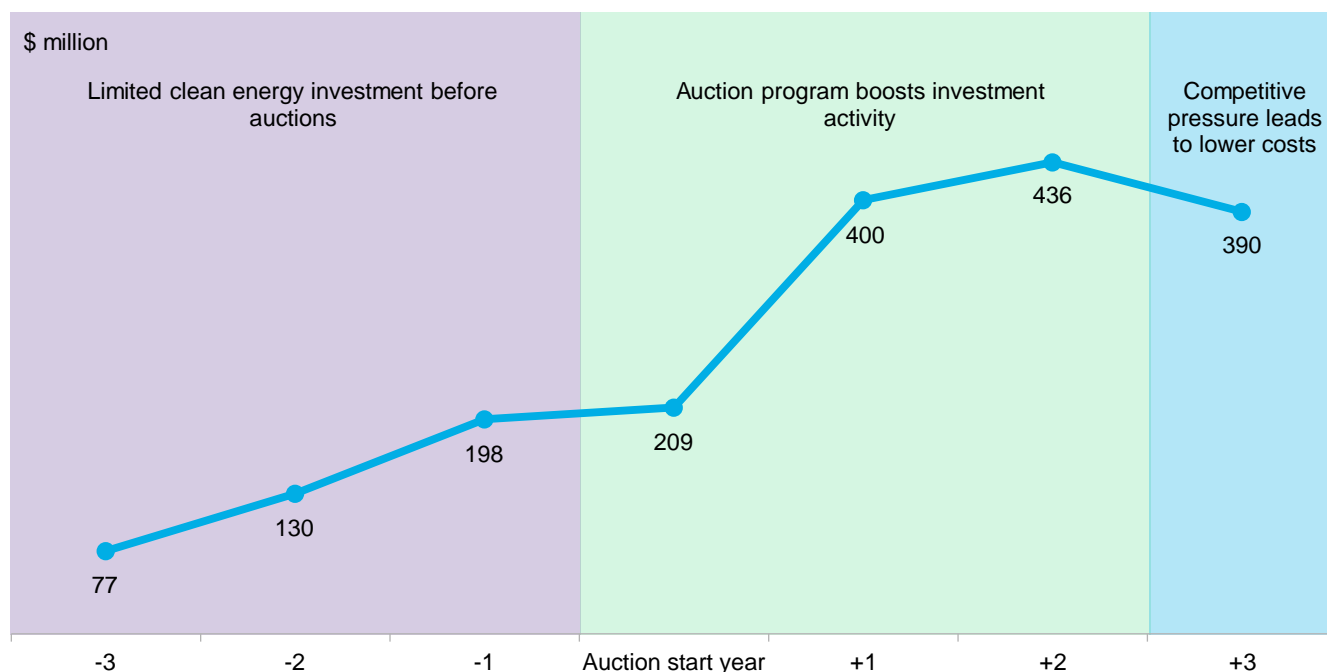
Figure 86: 2019 disclosed foreign investment by investor type under auction/tender status (excluding China)



Source: BloombergNEF, Climatescope.

It also drives a nearly immediate clean energy investment response. A total of 31 emerging markets started auctions between 2012 and 2018. On average, these countries received less than \$200 million per year before auctions were enforced, but they saw their renewable energy investments double in the two years following the establishment of the mechanism (Figure 87).

Figure 87: Average clean energy asset financing received by countries in years preceding and following reverse auctions for clean power delivery contracts

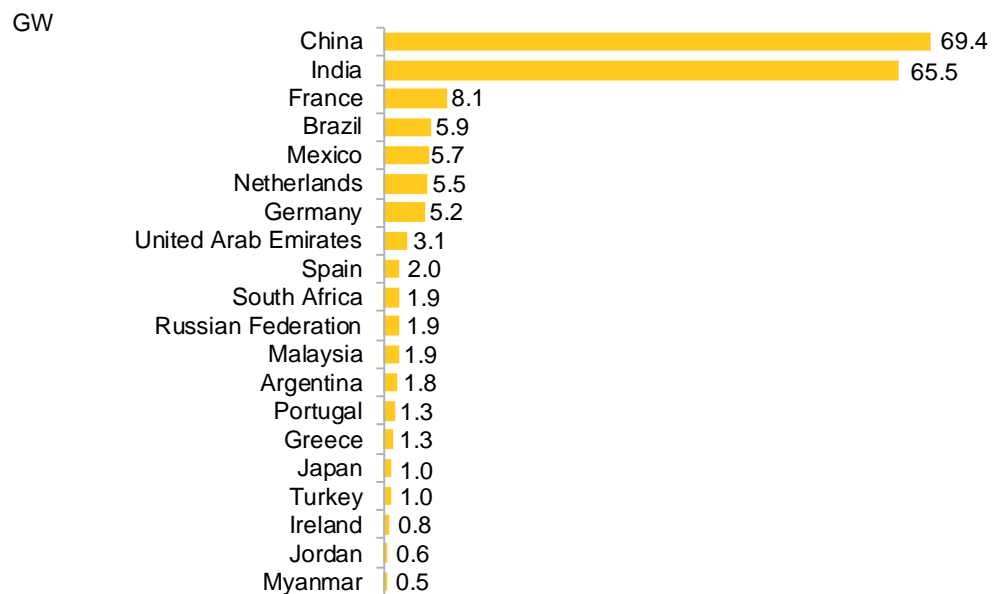


Source: BloombergNEF, Climatescope. Note: Includes 31 markets that started auctions between in 2012-2018.

Auctions also lead to a boost in competition, resulting in significant drops in clean energy tariffs and project costs. As consequence, the average investment secured for projects in developing nations actually drops three years after auctions occur.

From 2003 through the first half of 2021, countries have awarded contracts associated with the build of 190GW of PV through auctions. However, just 20 countries account for nearly 98% of this activity (Figure 88). Eight ISA member countries are among this 20: India, France, Brazil, Netherlands, U.A.E., Argentina, Japan, Myanmar.

Figure 88: Total PV capacity contracted under auctions for clean power delivery contracts, 2013 to 1H 2021



Source: BloombergNEF, *Climatescope*. Note: includes 44 ISA emerging markets surveyed in *Climatescope* 2020.

Auctions in the United Arab Emirates

Two of the United Arab Emirates, Dubai and Abu Dhabi, are engaged in a reputational competition with one another and with Saudi Arabia to report the lowest prices in a solar auction. This means that the headline prices often do not reflect the full prices paid by solar, and the projects are usually often substantially owned by the state-owned utilities, Dubai Electricity and Water Authority (DEWA) and Abu Dhabi Water & Electricity Company (ADWEA).

For example, in May 2016 DEWA announced a low winning bid in a first 800MW PV tender of \$29.90/MWh, submitted by Spanish developer Fotowatio Renewable Ventures, and the United Arab Emirates state-owned development and investment project Masdar. The next lowest bid was \$36.50/MWh, submitted by Chinese manufacturer/ developer Jinko Solar (NYSE: JKS). The terms were unclear.

In September 2016, Abu Dhabi reported a \$24.2/MWh winning bid to build solar on a site suitable for at least 350MW(AC). In this case the terms were clearer; the comparable price paid is likely to be closer to \$29/MWh, because power delivered between June and September (when Abu Dhabi's power demand peaks) is counted as 1.6 times that delivered at other times.

This is clever from a power planning standpoint, but the base rate was widely reported in a probable attempt to one-up Dubai.

Since then, the total solar capacity awarded under auctions in the U.A.E. has reached 5.8GW, including some solar thermal capacity (see Section 3.4). The emirates have slowed down on offering new auctions in 2020 and 2021, probably due to the pandemic and then rising solar equipment prices which rule out reporting a new record. However, they are expected to resume activity, and the country targets a 50% share of renewables and nuclear in energy generation by 2050.

Feed-in tariffs

Feed-in tariffs (FiTs) offer clean power generators, including owners of solar projects, fixed and guaranteed prices for the electricity they produce. FiTs, along with other types of premiums, underpinned renewables growth in China and the early years of many European markets, offering a stable (and sometimes generous) source of revenue to spur deployment and cost reduction. However, policy makers have begun to allocate power contracts via market-based mechanisms like auctions (rather than via an administrative application process). One reason has been to reduce government expenditure and promote competition in the market (and thus further cost reduction). The move to alternative mechanisms is well underway for larger projects but FiTs are likely to remain in use for consumer-facing or newer technologies.

Small-scale renewables are popular with voters and therefore policymakers, and FiTs effectively drive this segment, although often much more solar is built than expected. Program costs often spiralled out of control, and the local industry almost never adapted to the subsequent program suspensions or alterations.

Boom-and-bust cycles are likely to be repeated elsewhere. China's residential solar boom, with annual installations expected to exceed 17GW, will likely come to an end when current subsidies expire, as has occurred for utility- and commercial-scale projects. There is a broader shift in the country away from direct subsidies and it is not yet clear whether policy makers will make an exception for residential solar. Without any financial support, the segment will probably contract.

In Japan meanwhile, half a million households came off the generous export subsidy scheme in 2019. Started in November 2009, the program obliged Japan's 10 incumbent electric utilities to buy excess power from PV systems installed by retail customers in their regions at tariff rates set by the Ministry of Economy, Trade and Industry (METI). PV system owners on the program received the tariff for 10 years, which means that the first households lost their tariff in November 2019. The phasing out of the subsidy scheme is creating a new opportunity for other technologies in the country, such as energy storage, even though economics alone do not justify this switch.

These blunt and expensive instruments continue to have a role in less established renewables markets that are eager to encourage small-scale solar uptake.

Feed-in Tariff in Namibia

Namibia established a Feed-in Tariff (FiT) policy in 2015 for solar, biomass, and wind projects between 500kW and 5MW. That year, Namibia established 12MW of solar capacity on a grid that previously did not have any renewable capacity. In 2016, the country more than doubled its annual added capacity with 30MW.

FiT schemes are generally the first policy that countries put in place when their renewable energy market is developing. After which most countries establish auction schemes in order to increase capacity. Namibia established an auction scheme in 2016 and had their first tender in

2017. While the FiT scheme still exists, no new capacity has been added as a result of the country replacing the FiT scheme with auctions.

In just a few years, the nation, which has an area bigger than Texas but with only around 2.5 million people, installed almost 55MW of on-grid generation from renewables and has projects under construction for another 121MW, according to NamPower, the state-owned utility. The total installed capacity combined with committed renewable generation “is reaching the threshold the grid can accommodate,” the utility said in an emailed reply to questions.

Namibia has not been deterred from adopting more renewables in the future as it aims to reduce power imports. The National Integrated Resource Plan includes an allocation for biomass power plants with capacity of as much as 200MW. The plan also calls for solar thermal electricity generation, but we expect this to be dropped in favour of PV.

Net metering and export tariffs

Net metering policies offer owners of residential or commercial systems remuneration for excess power their systems generate. Such policies can vary widely by jurisdiction. Some allow consumers to sell their excess back at the prevailing retail or commercial rate they themselves would pay for power produced on the grid (classic net metering). Others allow system owners to sell back only at the wholesale power price or another, lower rate (export tariffs). Still others cap the volumes system owners can sell at fixed amounts. BNEF has tracked more than 60 such policies currently in force in jurisdictions around the world.

Net metering and export tariff policies have proven relatively uncontroversial in areas that have seen limited penetration of distributed solar. As penetration rates rise, however, so too can the costs for utilities that find themselves compelled to buy power back at the same rates they use to generate profits through sales to consumers.

Net metering policy in Brazil

A net metering policy has been driving a boom in Brazil’s small-scale PV market over the past seven years. In 2020, the country reached over 6GW of cumulative capacity, half of this built in 2020 despite the pandemic economic slowdown.

Since 2012, with the approval of resolution 482/2012, retail electricity customers may deliver surplus power from self-generation to the grid and obtain compensation in the form of a billing credit. The billing credit may be used by the self-generation consumer in the location where the power is generated (“local” net metering) or by another consumer unit at a different location from where it is produced (“remote” net metering). Projects as large as 5MW qualify for net metering and there are four types of consumption/consumers:

- **Local self-consumption** (autoconsumo local). A traditional net metering scheme, where consumers receive billing credits for power generated from a distributed generation system installed in the same place as the power is consumed. It applies to local net metering only.
- **Remote self-consumption** (autoconsumo remoto). Consumers may use their credit surplus to offset consumption in other locations, as long as it is served by the same distribution company and the bill is under the same customer name.
- **Shared generation** (geração compartilhada). Consumers can form a consortium or cooperative that brings together individuals or entities to share energy generated by distributed generation systems. The system may be installed in a different location from consumption, but must be in a unit under the ownership of the consortium or cooperative

and all consumers must be served by the same distribution company. The credits generated can be used by the cooperative/consortium members in their consumer units, in percentages previously defined by them.

- **Multiple consumer units** (múltiplas unidades consumidoras). Applicable to both residential and commercial buildings and housing complexes. All energy generated and injected into the network can be prorated among the participants. The system must be installed in the building or complex.

However, the distributed generation growth has prompted the government to rethink the country's net metering policy and Brazil is currently reforming its distributed generation regulations. The latest version of the law (Projeto de Lei nº 5.829) passed the lower house of Brazil's national congress in mid-August and is currently with the Senate, with strong chances of being taken up in the third quarter. If approved and passed into law, the current text would leave Brazil's generous net metering rules in place through 2045 for already existing solar systems, and those built within 12 months of the law being enacted. These users would continue to receive full compensation for surplus energy delivered to the grid. Households cannot offset their entire bill, however. Under the current scheme, a minimum bill is calculated based on the type of utility connection. The average residential power price in Brazil in 2020 was 0.534 reais (\$0.10)/kWh. New systems installed after the deadline will have a six-year transition period to a new tariff schedule that will gradually pare down compensation until consumers eventually bear all tariff costs not associated with the cost of electricity. Brazil's worsening hydro power crisis has been credited with easing the passage of the new rules, which are considered broadly favorable to solar.



Appendix A. ISA member countries

For the purposes of this report, we have divided ISA members into three groups.

Table 9: ISA member countries

	Beneficiaries	Pivotal partners	Facilitator partners
	Countries in need of direct assistance	Countries that are well positioned to facilitate learning and partner with ISA's effort to support other members through experience-sharing	Countries positioned to assist Beneficiary countries, and facilitate cooperation between Pivotal and Beneficiary countries, with the support via financing or technical contributions, e.g. through bilateral development co-operation assistance
Properties	Solar market <100MW/year in 2020	Low or middle income, solar market >100MW/year	High income, solar market >100MW/year
Countries – Asia-Pacific	Cambodia, Fiji*, Kiribati*, Maldives*, Marshall Islands*, Myanmar, Nauru*, Palau*, Papua New Guinea*, Samoa, Sri Lanka, Tonga*, Tuvalu*, Vanuatu*	Bangladesh, India	Australia, Japan
Countries – Europe, the Middle East and Africa	Botswana, Benin, Burkina Faso, Burundi, Cameroon, Cape Verde*, Chad, Comoros*, Congo, Djibouti*, Equatorial Guinea*, Ethiopia, Eritrea, Gabonese Republic*, Gambia, Ghana, Guinea, Guinea-Bissau*, Ivory Coast, Liberia, Madagascar, Malawi, Mali, Mauritius*, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe*, Senegal, Seychelles*, Somalia, Sudan, South Sudan, Tanzania, Togolese Republic, Uganda, Yemen*, Zambia, Zimbabwe,	Algeria, Egypt, Morocco, Oman	France, Saudi Arabia, The Netherlands, United Arab Emirates, United Kingdom, Denmark, Luxembourg*, Italy
Countries – the Americas	Barbados, Belize, Bolivia, Costa Rica, Cuba*, Dominica*, Dominican Republic, El Salvador, Grenada*, Guyana*, Haiti, Jamaica, Nicaragua, Paraguay, Saint Lucia, St Vincent and Grenadines*, St Kitts and Nevis*, Suriname, Trinidad and Tobago, Venezuela*	Brazil, Argentina, Peru	Chile

Source: ISA, BloombergNEF. Note: * indicates countries not covered in Climatescope, where BNEF might have limited data.

**Luxembourg is not a 100MW/year solar market, but it fits best into the third category.



Table 10: Cumulative solar capacity in ISA countries, MW at end of year

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Algeria	0	0	0	0	0	268	318	334	344	394	416
Argentina	0	1	11	13	19	19	19	19	216	496	843
Australia	582	1456	2506	3302	4134	5026	5931	7224	11236	14775	18485
Bangladesh	1	50	77	111	146	200	236	297	339	454	562
Benin	0	0	0	0	0	0	2	2	2	2	2
Bolivia	0	0	0	0	0	5	5	5	70	120	120
Brazil	0	1	3	8	19	43	109	1471	2924	5905	9878
Burkina Faso	0	0	0	0	0	2	6	12	21	32	44
Burundi	10	10	10	10	10	10	10	18	18	18	18
Cambodia	0	0	0	0	1	3	6	17	27	90	237
Cameroon	0	0	0	0	2	3	6	6	6	6	6
Cape Verde	0	8	8	8	8	8	8	8	8	8	8
Chile	0	0	2	10	450	727	1618	2211	2663	3157	3841
Costa Rica	0	0	1	1	1	1	14	31	45	64	80
Dominican Republic	0	0	1	8	15	24	70	95	189	277	330
Egypt	0	0	0	0	0	6	11	21	95	1531	1661
El Salvador	0	0	0	0	0	3	4	104	139	298	460
Ethiopia	0	0	0	0	0	0	0	0	0	3	3
France	1168	3029	4160	4818	5774	6673	7264	8140	9002	9966	10939
Ghana	0	0	2	4	6	34	42	52	87	126	179
India	66	375	1327	2365	3303	5369	10649	20911	32018	43578	47808
Japan	3268	4414	6446	13091	22756	33936	41962	49358	56081	62829	71493
Liberia	0	0	0	0	0	0	0	0	0	0	0
Madagascar	0	0	0	0	0	0	0	0	0	0	0
Malawi	0	0	0	0	0	0	0	0	0	0	0
Mali	0	0	0	0	0	0	0	0	0	0	0
Mauritius	0	0	0	0	0	0	0	0	0	0	0
Mozambique	0	0	0	0	0	0	0	0	0	0	0
Myanmar	0	0	0	0	0	0	3	6	9	64	84
Namibia	0	0	0	0	0	12	30	59	114	173	233
Netherlands	88	148	365	739	1014	1481	2015	2790	4400	6969	10469
Niger	0	0	0	0	0	0	0	0	0	0	0
Nigeria	0	0	0	8	20	39	69	108	162	242	464
Peru	0	0	64	84	100	100	100	100	320	320	320
Rwanda	0	0	0	0	9	9	10	11	13	15	18
Saudi Arabia	0	0	0	0	0	0	0	0	80	435	535



Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Senegal	0	0	0	0	2	17	76	126	218	279	377
Somalia	0	0	0	0	1	1	1	1	1	1	1
South Sudan	0	0	0	0	0	0	0	15	15	15	15
Sri Lanka	0	1	3	3	3	3	50	101	204	306	306
Sudan	0	0	0	0	0	0	0	0	0	0	0
Suriname	0	0	0	0	5	5	5	5	10	10	10
Tanzania	0	0	0	0	1	2	4	6	9	13	17
Uganda	0	0	0	0	0	2	13	15	18	22	26
United Arab Emirates	0	0	0	0	0	1	24	239	513	2092	2459
United Kingdom	108	1018	1792	2894	5465	9747	11900	12845	13141	13415	13694
Venezuela	0	0	0	0	0	1	1	1	1	1	1
Yemen	0	0	0	0	2	2	2	2	2	2	2
Zambia	0	0	0	0	0	0	3	9	103	260	269
Total	5291	10511	16778	27476	43265	63782	82596	106775	134863	168762	196710

Source: BloombergNEF

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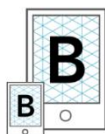
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