

Global PV Market Outlook, 4Q 2023

**Growth, Hangovers and a
Game of Chicken**

November 22, 2023

BloombergNEF

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Section 1. Executive summary

413GW

BNEF's current 2023 new-build PV forecast in the mid scenario

12-12.5 US cents

BNEF's estimate of per watt price for typical monocrystalline silicon monofacial modules by the end of the year

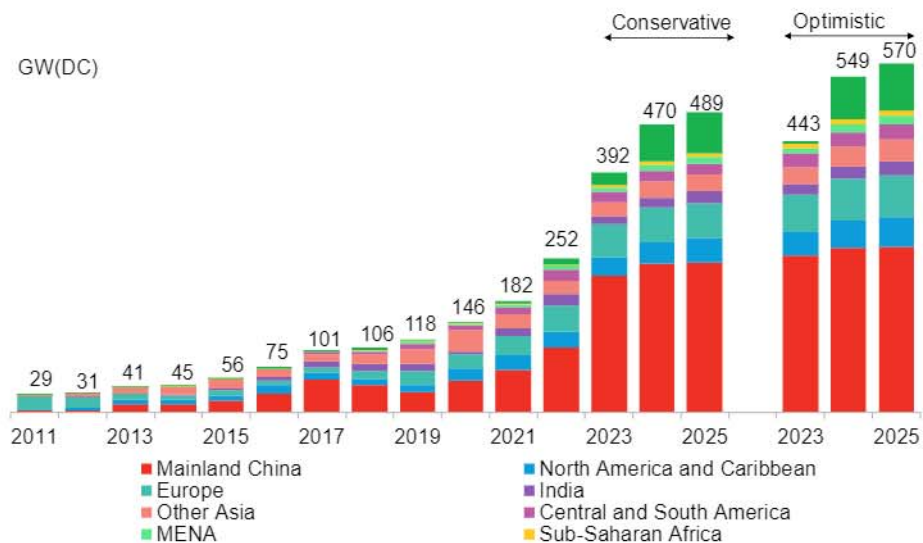
580GW

Estimated supply of polysilicon (in module equivalent) in 2023

As 2023 draws to a close, the solar industry is installing record volumes worldwide and selling at record-low prices. BloombergNEF has increased its build forecast yet again for this year to 413 gigawatts, largely due to mainland China, as there are some signs that build in a few other markets is weaker than expected. This could reflect a 'hangover' from demand pulled forward into 2022 by the energy crisis.

- Installed volumes in the solar market are up about 64% from 2022 to 2023, exceeding our previous estimates. The biggest upward revision was in mainland China, which looks set to build 240 gigawatts this year, but there are now 33 markets installing over 1GW each year.
- However, demand is dwarfed by the scale-up of manufacturing capacity across the value chain. Total module capacity of Tier 1 manufacturers is 839GW. Inventory buildup is severe in Europe, where some residential markets are weaker than in 2022 on lower power prices.
- Module prices are at their lowest level ever, reaching \$0.128 per watt in the third week of November. Nonetheless, most manufacturers plan to continue production, buoyed by strong cash positions, which allow them to play a game of chicken with their competitors over who will succumb to the pressure and exit the market first.
- BNEF expects module prices to drop to 1 yuan/W or even lower by the end of the year in mainland China and 12-12.5 US cents per watt¹ in other markets without trade barriers.
- (Runergy has been added to the Tier 1 list on page 15, and total Tier 1 module capacity on page 1 was corrected to 840GW on November 22, 2023.)

Figure 1: Historical and forecast annual PV new build



Source: BloombergNEF. Note: MENA is Middle East and North Africa. Details in BNEF's Capacity tool ([web](#) | [terminal](#)).

¹ The free-on-board value excluding the 13% VAT. \$1 = 7.1 yuan for December 2023.

Section 2. Demand

Table 1 shows changes to our forecasts in the world's leading 28 solar markets. Other forecasts can be found in the accompanying Excel and BNEF's Capacity tool ([web](#) | [terminal](#)).

Table 1: Changes to full-year PV new build forecast, by market, since BNEF's last quarterly Market Outlook, in megawatts

Market	2022	2023 mid, 3Q 2023	2023 mid, 4Q 2023	Movement from 2022 to 2023	Quarter-on-quarter movement in 2023 forecast
Mainland China	106,560	208,800	239,520	125%	15%
US	23,623	33,707	33,214	41%	-1%
Brazil	14,185	16,262	16,262	15%	0%
India	18,280	15,860	15,420	-16%	-3%
Germany	7,374	11,239	12,849	74%	14%
Spain	7,825	8,357	8,357	7%	0%
Japan	6,198	5,670	5,847	-6%	3%
Netherlands	4,350	5,466	5,489	26%	0%
Australia	4,338	5,050	5,050	16%	0%
Italy	2,483	4,425	4,425	78%	0%
South Africa	1,000	5,000	3,500	250%	-30%
Poland	4,508	3,371	3,371	-25%	0%
France	2,281	3,267	3,267	43%	0%
Pakistan	2,200	2,380	2,805	28%	18%
South Korea	1,000	2,763	3,500	250%	27%
Taiwan	2,024	3,100	2,600	28%	-16%
Chile	2,295	2,161	2,405	5%	11%
United Arab Emirates	2,105	2,315	2,315	10%	0%
Turkey	2,092	2,200	2,200	5%	0%
UK	1,210	2,050	2,050	69%	0%
Hungary	1,102	1,700	1,700	54%	0%
Switzerland	1,083	1,523	1,522	41%	0%
Saudi Arabia	811	1,472	1,472	82%	0%
Mexico	1,631	1,419	1,365	-16%	-4%
Denmark	1,230	1,315	1,315	7%	0%
Austria	1,009	1,396	1,299	29%	-7%
Greece	1,235	1,120	1,195	-3%	7%
Portugal	891	1,163	1,163	31%	0%
Other and unknown	27,077	37,321	27,773	3%	-26%
Total	252,000	391,871	413,250	64%	5%

Source: BloombergNEF. Note: All capacity in direct current (DC), which is module capacity. See Appendices for discussion.

Mainland China is yet again exceeding expectations

Mainland China installed 128.9GW(AC) of solar in the first three quarters of 2023, according to the [National Energy Administration](#). This is equivalent to about 158GW of modules and there is no reason to expect a slowdown in the fourth quarter. Indeed, the utility-scale sector will very likely speed up to meet end-of-year deadlines for the first round of auctioned solar 'megabases', and falling module prices will accelerate the strong rooftop segment.

BNEF raised its forecast for mainland China this year to 195GW(AC), or 240GW(DC), from just over 200GW(DC) in our previous outlook. The impact of this exceeds any adjustments we could have made to estimates for other markets, but we have trimmed the 'buffer/ unknown' allocation, which exists to account for any potential underestimate of regional booms.

Some markets, especially residential, have 'hangovers'

Last year's energy crisis caused a surge of interest in rooftop solar in Europe, and many orders were placed with installers. After the supply chain disruptions seen in 2020 and 2021, distributors and installers were also keen to stock up to avoid future delays. Although installation volumes across Europe (both in the European Union and non-EU markets) are up 35% in 2023 compared with 2022, this is less than some sources expected. Poland in particular seems to be building at a slower rate than in 2022, though Germany is bucking any negative trend.

BNEF estimates there is 60-80GW of inventory in the solar supply chain in Europe, and developers of large projects are mostly buying directly from manufacturers to get the latest products in bulk. This inventory may therefore take more than a year to work through. There are some reports of modules being reshipped from Europe back to mainland China or on to Africa.

South Africa also appears to have a slight hangover. Instead of rooftop build accelerating from the 1GW estimated by Eskom in the May to June period, it has slowed down. Anecdotally, this is because load shedding (in other words, blackouts) has eased as the hottest period ended and more solar was available, and residential and even business consumers responded very quickly to this signal. However, a bad few months of load shedding could cause demand to return, and the fundamentals are still there in the South Africa market. Even so, we have revised our 2023 installation estimate for the country down to 3.5GW, from 5GW.

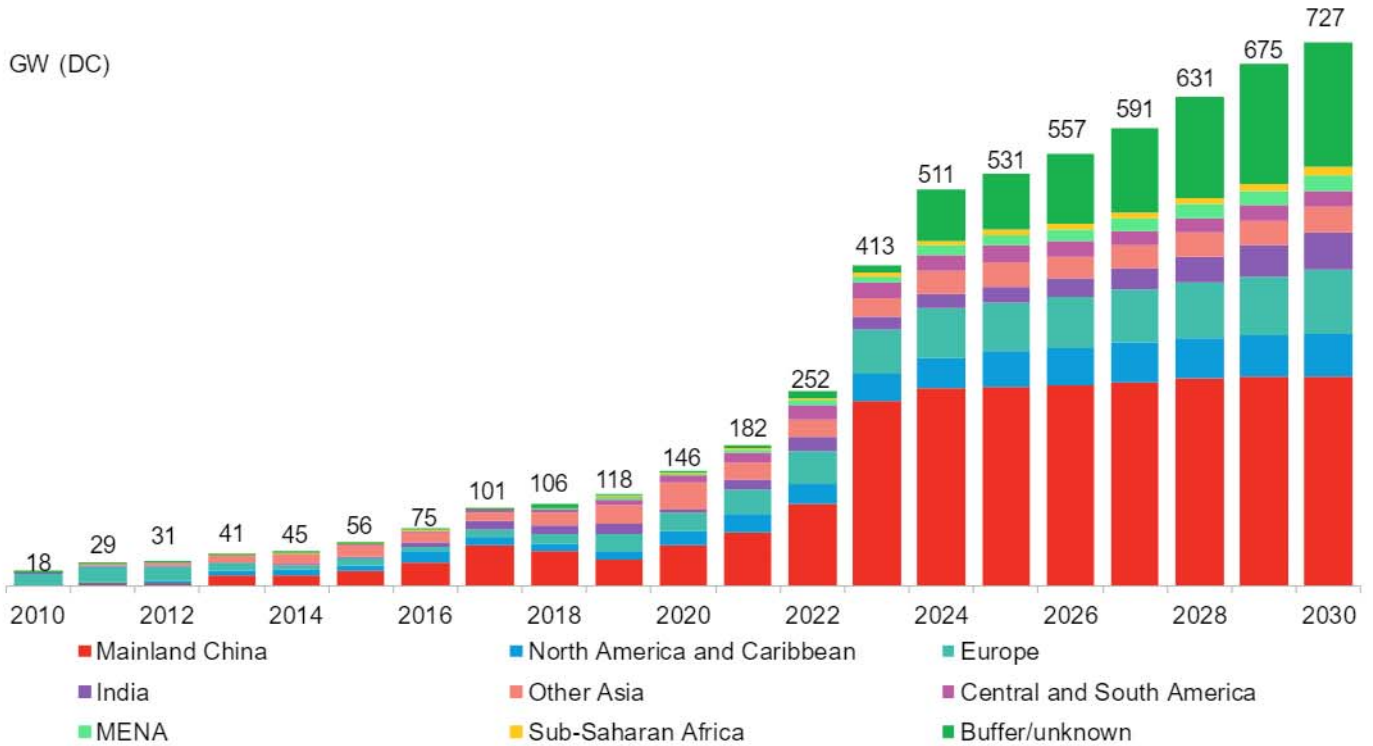
Global build is once again more than we anticipated, but not nearly as high as buyers apparently expected

Overall, we have raised our build forecast for 2023 by 5% from the estimate published last quarter, to 413GW (Table 1) and our 2024 projection is also about 5% higher. This should be good news for solar companies, but the stock prices of most solar companies have fallen over the last three months as the prices of solar modules and components have continued their inexorable decline. As predicted in each of our quarterly outlooks this year, the production of polysilicon and therefore modules is exceeding even the most optimistic demand forecast. We expect quarterly results for 4Q 2023 to show a substantial downward revaluation of inventory held across the supply chain, particularly for modules.

The challenge in forecasting solar is always that the market usually surpasses even the most conservative assumptions – but not homogeneously, and individual markets can fall as well as rise. There are negative feedback mechanisms in play, as well as huge economic tailwinds. For example, in Guangdong, mainland China, a study of local grids has resulted in the suspension of new solar build in 11 counties and restrictions in more, to prevent saturation. Solar is already driving down power prices in the middle of the day in an increasing number of merchant power

markets, reducing the economic attractiveness of further merchant solar. These factors interact in complex ways with the falling solar module prices.

Figure 2: Historical and mid-scenario forecast for global PV installations



Source: BloombergNEF. Note: MENA is Middle East and North Africa. Details in BNEF's Capacity tool ([web](#) | [terminal](#)). All capacity in direct current (DC), which is module capacity.

Section 3. Supply

Total established polysilicon capacity is now enough to support 1TW silicon PV production

There is little evidence that polysilicon, wafer, cell or module manufacturers are reducing production as yet. They are using their cash reserves to ‘play chicken’, hoping their rivals exit first and let prices rise. There is enough polysilicon factory capacity to make a terawatt (TW) of modules next year, and actual production in 2023 is expected to be enough for 580GW. Meanwhile, the capacity of Tier 1 module makers (Table 4) is 839GW.

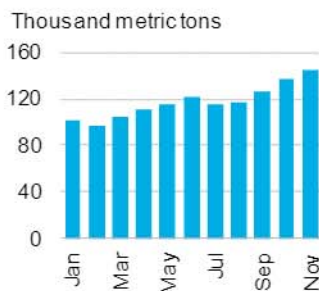
3.1. Polysilicon

Polysilicon production increased every month in the second half of 2023 as new capacity ramped up (Figure 3). BNEF has tracked factories with a total annual capacity of 625,000 metric tons commissioned in 2H 2023 (see the sheet for Figure 5 in the Excel accompanying this note). This brings total established solar-grade polysilicon capacity to 2.4 million tons globally, enough to support over 1TW of silicon PV production, although some of these facilities are still ramping up and may not contribute much to this year’s supply. Total polysilicon production this year is now estimated to be about 1,521,695 tons (Figure 4).

The excess supply further depressed market prices to \$8.3 per kilogram in the week of November 15, down from a previous rebound to \$10.5/kg in late September ([web](#) | [terminal](#)). Although wafer makers resuming purchases cleaned up inventory for some large polysilicon makers in the third quarter, severe oversupply across the value chain has caused new inventory buildup since October. As of mid-November, BNEF is not aware of any manufacturer plans to reduce production or exit. Polysilicon makers are well capitalized from a period of healthy profit, and new players are still trying to maintain production at brand-new factories. As a result, prices for polysilicon are likely to fall below \$8/kg by the end of the year, as many makers will be selling at cost or a loss (Figure 4).

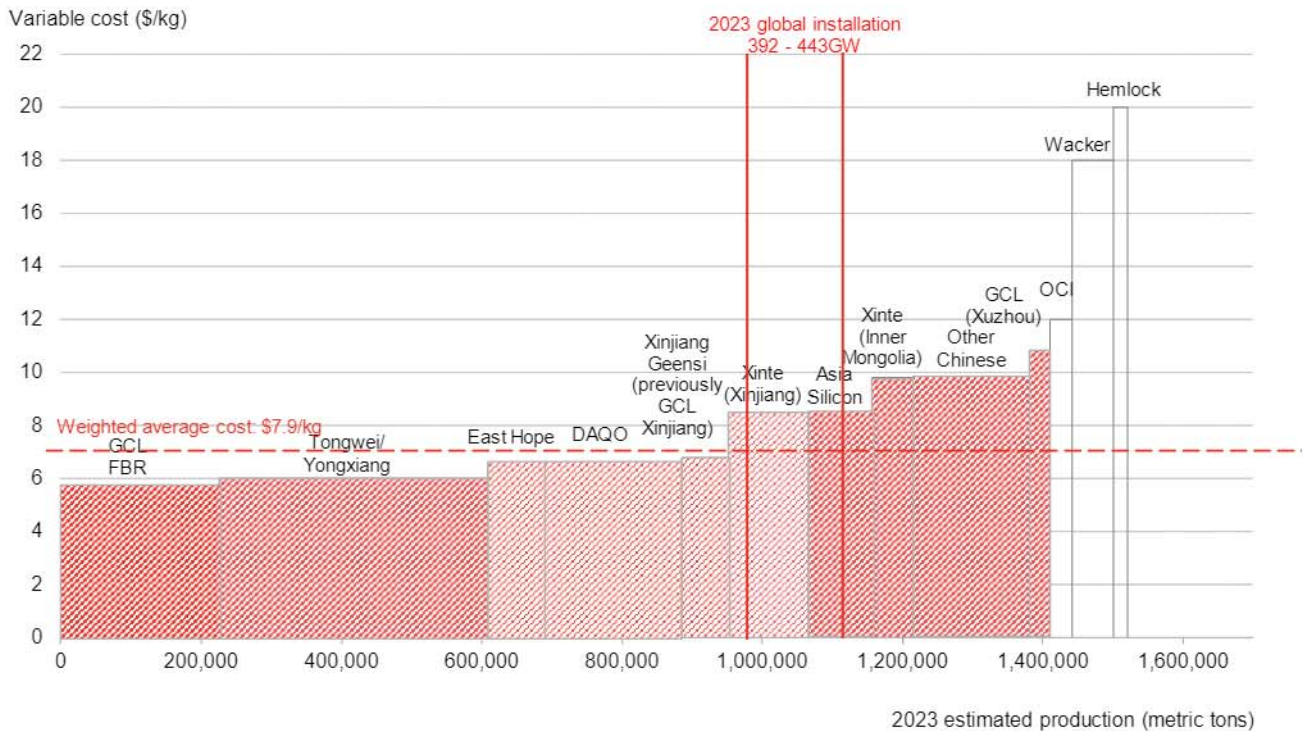
Shipments of high-purity polysilicon for negatively-doped (n-type) wafer production have increased, according to firms such as Daqo (New York: DQ) and Tongwei (Shanghai: 600438). The price premium, however, has been squeezed to 5 yuan (\$0.6) /kg, from over 10 yuan/kg in the first half of the year, as supply also increased.

Figure 3: Mainland China’s polysilicon production in 2023



Source: BloombergNEF, China Silicon Industry Association (CSIA).

Figure 4: Supply curve for solar-grade polysilicon in 2023



Source: BloombergNEF. Note: Each block is a factory or company capacity. Red blocks are factories in mainland China, with lighter red for Xinjiang production. Variable cost includes processing cost and selling, general and administrative (SG&A) expenses; depreciation excluded. Demand estimate for 2023 assumes 12GW of thin-film modules; 98% of silicon PV supply to mono, using 2.6 grams per watt (g/W) silicon, and 2% multi modules using 3.2g/W, so average polysilicon use is 2.6g/W. \$1 = 7.08 yuan for 2023.

Table 2 shows the details of polysilicon makers’ operations from company filings, industry news, and BNEF analyst estimates.

Table 2: Operational status of solar-grade polysilicon manufacturers in 2023

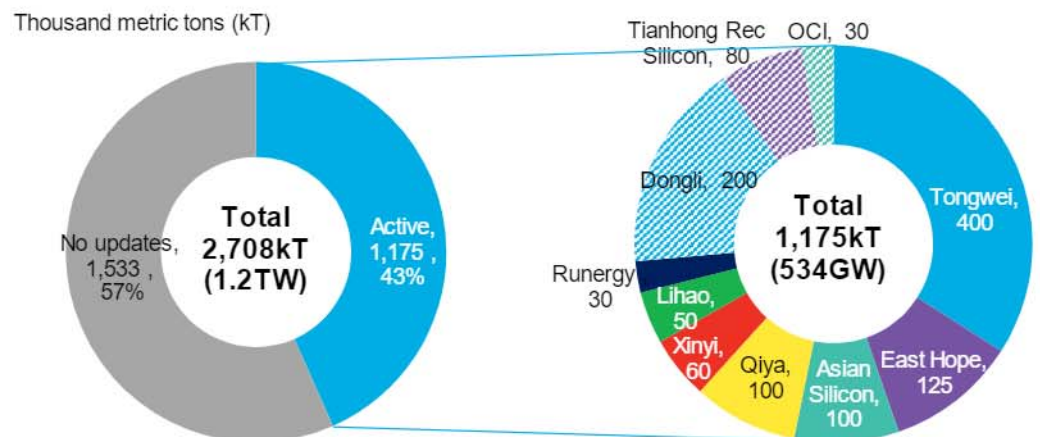
Company	Market	Estimated variable cost (\$/kg)	Potential production, kilotons (kt)	Notes (1 kiloton = 1,000 metric tons)
GCL’s fluidized bed reactor (FBR) plants	Mainland China	5.7	225	Total production was 136kT in the first three quarters of the year. The company’s total FBR capacity reached 400kT in September, when another 100kT/year factory <u>commissioned</u> in Inner Mongolia.
Yongxiang/Tongwei	Mainland China	6.0	385	Tongwei shipped 178kT of polysilicon in 1H 2023. A 120kT/year Sichuan factory was commissioned in August, from which we expect 30kT production assuming two to three months for ramping up to full production.
East Hope	Mainland China	6.6	80	As of November, the 125kT/year factory in Ningxia is still under construction, according to company news.
Daqo	Mainland China	6.6	196	Daqo produced 137kT across 1Q to 3Q 2023. The company expects 59-62kT production in 4Q, to reach full-year production of 196-199kT.
Xinjiang Geensi (previously GCL Xinjiang)	Mainland China	6.8	65	In September, TCL Zhonghuan (Shenzhen: 002129) exited the joint venture it formerly had with GCL, and fully <u>transferred</u> its 27% share to

			Guotong Trust, a banking group. The company name was changed to Xinjiang Geensi, from Xinjiang GCL New Materials in May.
Asia Silicon, Qinghai	Mainland 8.5 China	90	Asia Silicon commenced construction of a 100kT/year factory in Qinghai in August. This is scheduled to be completed in June 2024.
Xinte Energy - Xinjiang	Mainland 8.5 China	115	The company produced 76kT in total in 1H 2023. We estimate about 50kT was from its Xinjiang base.
Xinte Energy – Inner Mongolia	Mainland 10 China	60	We cut estimated full-year production from 80kT to 60kT, since production was lower in 1H 2023 than expected. The company’s blended production cost in its Xinjiang and Inner Mongolia bases was about 69 yuan/kg (\$9.9/kg) in 1H. We estimated a higher cost from the Inner Mongolia factory considering lower-than-expected utilization for technological upgrades.
Other Chinese	Mainland 10 China	165	There are currently 11 companies that are active in this group, including new players such as Jingnuo, Baofeng, Qiya and Hoshine. The total volume was cut from 180kT from the previous quarter due to a small factory accident and delayed commissioning of new factories.
GCL- Xuzhou Siemens factory	Mainland 11 China	29	Production was reported to be 28,695 tons in this factory, which was shut down in June, as GCL turned to FBR production at this base.
OCIMSB	Malaysia 12	32	Factory utilization rate was maintained at 90% in 3Q 2023.
Wacker (Xetra: WCH) - solar grade	Germany 18	60	Fully operational due to high demand for non-Chinese polysilicon for the US market.
Hemlock	US >20	20	The parent company Corning (New York: GLW) also reported reduced solar-grade polysilicon prices in 3Q 2023, but demand remained high with long-term contracts.
Total		1,522	Enough to make over 580GW of modules

Source: Company filings, estimates, enquiries, BloombergNEF. Note: Estimated variable cost includes cash cost in manufacturing and selling, general and administration (SG&A); depreciation excluded. Costs are annual averages (our best estimate) for those with cost-reduction plans. \$1 = 7.08 yuan for 2023. FBR is fluidized bed reactor, an alternative to Siemens production.

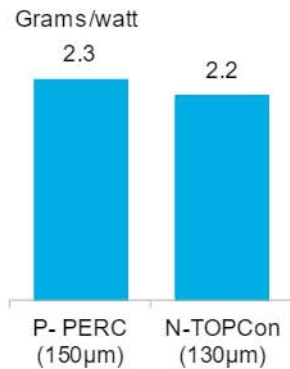
Given the large established capacity and slipping market prices, many capacity plans announced previously may just be canceled. But expansion has not stopped yet (Figure 5).

Figure 5: Status of announced and under-construction polysilicon plants, as of Nov 2023



Source: BloombergNEF, company filings. Note: ‘Active’ refers to capacity plans with progress since August 2023, otherwise ‘no updates’. Plans with solid colors in the right-hand side chart target commissioning either in 2023 or 2024. Those in pattern fill are scheduled to be completed after 2024.

Figure 6: Estimated polysilicon use by cell tech, at end of 2023



Source: BloombergNEF.
 Note: TOPCon uses thinner wafers with thickness of 130 microns (µm).

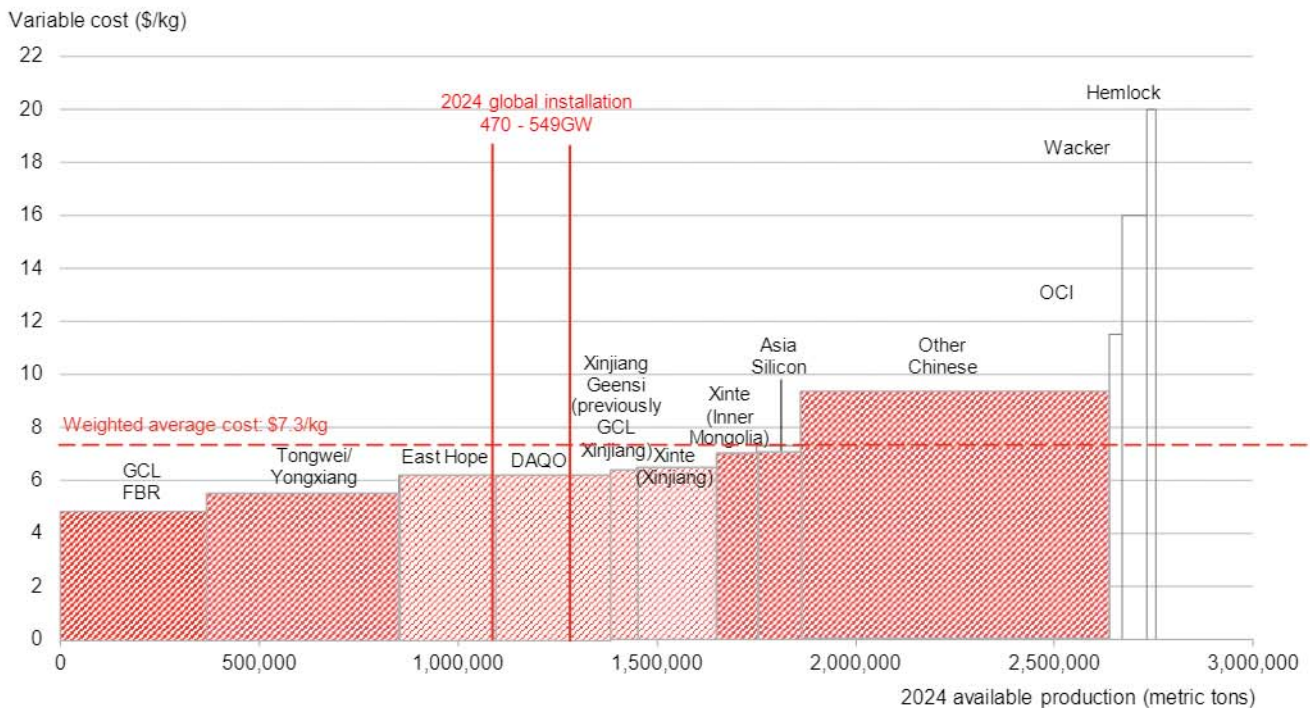
This will bring total available production in 2024 to 2,757,000 tons, enough to support 1.25TW of silicon PV production. That is significantly higher than our expected global installation of 550GW in the optimistic scenario (Figure 7). As a result, we expect the polysilicon price to fall to as low as \$6/kg in 2024, at which level even some big makers will be selling below cash cost. A lot more factories will shut down during the year.

Silicon PV wafer and cell makers are also using less polysilicon for each watt of production, thanks to continuous improvement in wafer production and the transition to more efficient cell technologies (Figure 6).

Polysilicon plans outside mainland China are being implemented only slowly. REC Silicon (Oslo: RECSI) has restarted its fluidized bed reactor production in the US and expects first delivery in 1Q 2024 to Hanwha Q-Cells under their offtake agreement. The company has announced plans to reach 50% of its capacity (16,000 tons) by 2Q 2024 and full capacity by 4Q 2024, according to its third-quarter earnings call. OCI (Seoul: 010060) is maintaining its plan to add another 30,000 tons of solar-grade production in Malaysia but expects to complete this only by 2027.

Another two possible plans are from GCL, which expects some site selection progress in Saudi Arabia at the end of 2023, according to a Bloomberg interview with Joint Chief Executive Officer Lan Tianshi, and Trina Solar, which announced a 50,000 ton (terminal) plan in the United Arab Emirates. Both are at an early stage.

Figure 7: Supply curve for solar-grade polysilicon in 2024

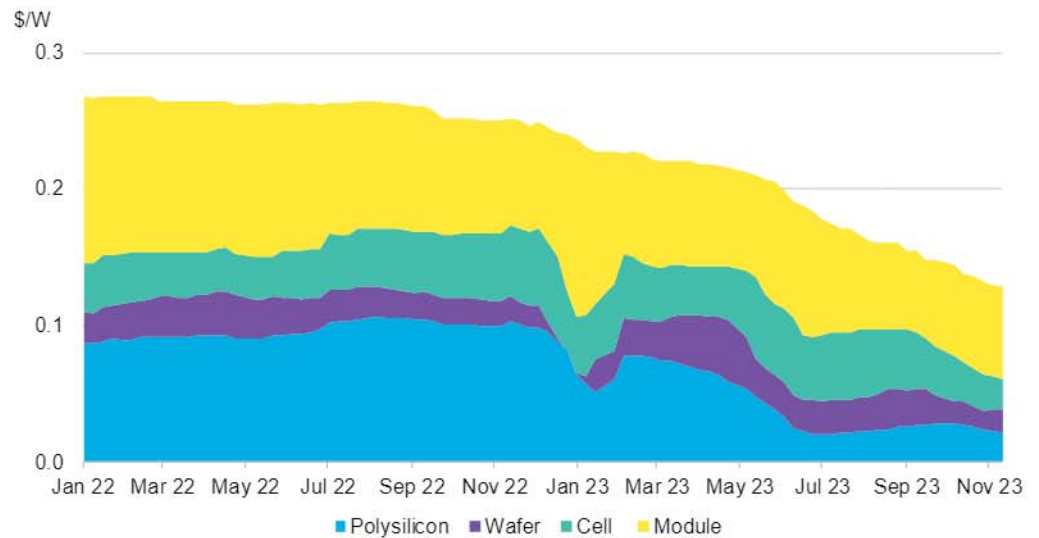


Source: BloombergNEF. Note: Each block is a factory or company capacity. Red blocks are factories in mainland China, with the lighter red for Xinjiang production. Colorless blocks are outside mainland China. Variable cost includes processing cost and selling, general and administrative (SG&A) expenses; depreciation is excluded. The demand estimate for 2024 is 470-549GW. Assumes 16 gigawatts (GW) supply of thin-film modules; 99.5% of silicon PV supply to mono, using 2.2 grams per watt (g/W) silicon, and 0.5% multi modules using 3.2g/W, so average polysilicon use is 2.2g/W. \$1 = 7 yuan for 2024.

3.2. Wafers and cells

Wafer prices have declined by 28% since September to \$0.294 per piece in the week of November 13 for standard products with a side length of 182 millimeters (Figure 8). The current market spot price for polysilicon, at \$8.3/kg, suggests a gross margin near zero or even negative for wafer makers if sourced from the spot market.

Figure 8: Solar component price movements since the beginning of 2022



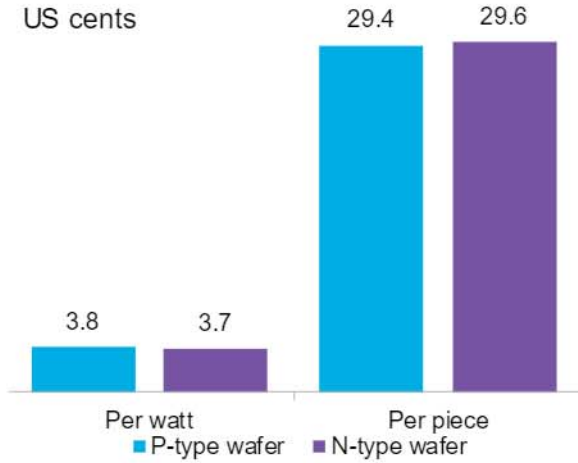
Source: BloombergNEF, PV InfoLink. Note: Assumes polysilicon consumption of 2.7 grams per Watt for mono wafer in 2022 and 2.6g/W in 2023.

Prices of N-type solar wafers have also dropped by 31% during the same period and sell at a premium of only 0.2 US cents per piece. This means that they now have a cost advantage per watt due to their ability to be made into higher-efficiency solar cells (Figure 9).

Solar cell prices have dropped 38% since September, reaching 6 US cents/W and 7.5 cents/W in the week starting November 13, for cells made from wafers with side lengths of 182mm and 210mm respectively. See our *Bimonthly PV Index, November 2023* ([web](#) | [terminal](#)) for more.

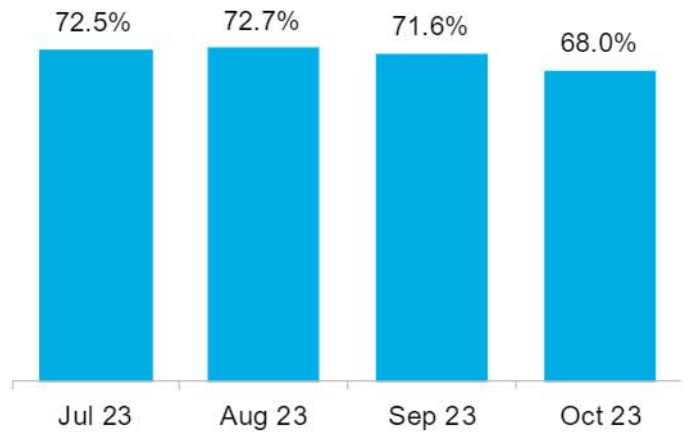
Cell production was the most profitable segment along the solar supply chain earlier this year but has been squeezed to single-digit profit margins at current prices. The utilization rate of solar cell factories fell in October (Figure 10) but according to silver paste maker Heraeus, the industry still produced more solar cells due to new capacity ramping up.

Figure 9: Spot prices for standard solar wafers in mid-November 2023



Source: BloombergNEF, PV InfoLink. Note: Assumes 7.72 watts per piece for passive emitter rear contact (PERC) cells based on P-type wafers and 8.02 watts per piece for tunnel oxidized passivated contact (TOPCon) cells based on N-type wafers.

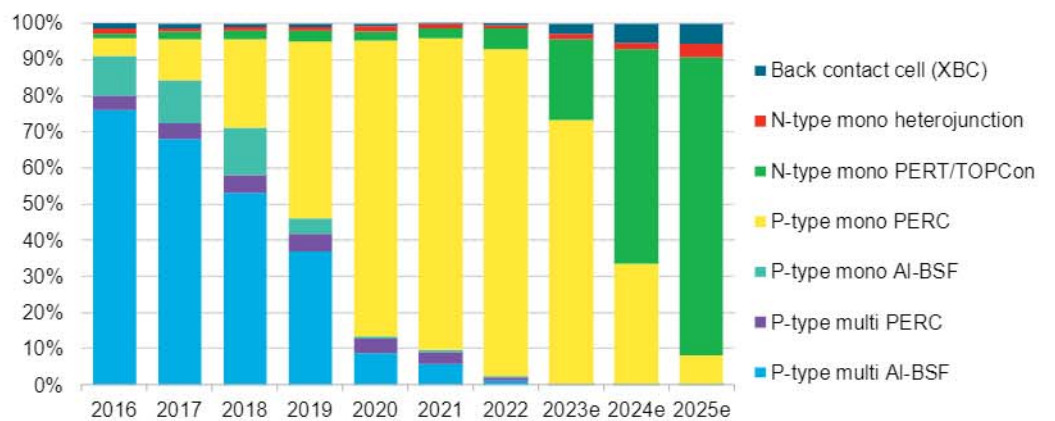
Figure 10: Major solar cell factory utilization rate



Source: Heraeus, BloombergNEF Note: Data collected by silver paste maker Heraeus for top-15 and some other cell makers.

Cells based on tunnel oxide passivated contact (TOPCon) technology have about a \$0.005 per watt price premium at the moment, but we expect that more TOPCon cell production coming online will lower the premium. Most cell production is expected to be TOPCon by the end of 2024, which will further squeeze out PERC production in the next two years (Figure 11).

Figure 11: Market share of different crystalline silicon solar cells



Source: BloombergNEF. Note: Back contact cell (XBC) is a collective term for different variations, such like Longi's hybrid passivated back contact (HPBC) production, which is based on p-type wafers. TOPCon is tunnel oxide passivated contact, PERT is passivated emitter and rear totally diffused, PERC is passivated emitter and rear contact, Al-BSF is aluminum back surface field.

3.3. Modules

BNEF expects module prices to drop below 1 yuan/W by the end of the year in the mainland China market and 12-12.5 US cents per watt in other markets without trade barriers

With solar module prices hitting record lows nearly every week, even leading integrated solar manufacturers are struggling to maintain profitability.

Pricing for PV modules recently dipped below 13 US cents/W and is expected to continue decreasing. Some inventory and redirected modules are for sale below \$0.10/W. Hence, the shift towards cent-based pricing for solar modules, and even to the smaller jiao denomination in the Chinese yuan, has come. BNEF estimates module prices will drop to 1 yuan/W or even lower by the end of the year in the mainland China market and 12-12.5 US cents/W² (free-on-board value excluding the 13% VAT) in other markets without trade barriers.

Module prices have declined 30% since July, to 12.8 US cents/W in the week of November 13. This means prices have almost halved since the beginning of this year. Higher-efficiency modules based on TOPCon cell technology now command a price premium of approximately 0.5 US cents/W in November, a significant reduction from the previous premium of 1.8 US cents/W in July, due to the rapid increase in production capacity. The price gap will narrow further until the current mainstream PERC products are replaced by the TOPCon modules in 2024. BNEF expects TOPCon modules to comprise up to 59% of the market in 2024. See *Solar Cell and Module Efficiency Improves Steadily* ([web](#) | [terminal](#)) for more.

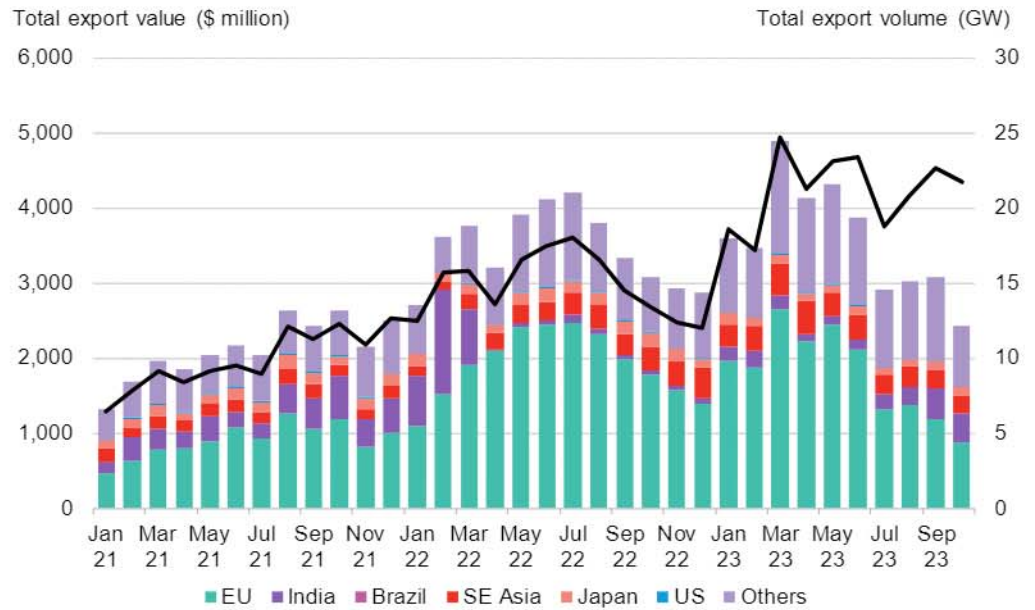
With solar module prices hitting record lows nearly every week, even leading integrated solar manufacturers are struggling to maintain profitability. Production cost is critical, as even a tenth of a cent advantage could determine solar manufacturers' survival chances.

Module makers have significantly lowered utilization rates since October. Large integrated manufacturers strive to maintain a certain utilization level to keep unit costs down by continuing the normal operation of the production line. Small factories reported average utilization rates below 50% due to very thin or negative margins if sourcing at current spot prices.

Mainland China exported 212GW of solar cells and modules in the first 10 months of 2023, some 19% more than the full-year exports seen in 2022. The value of mainland China's solar product exports was flat in 3Q, but volumes rose month-on-month thanks to lower module prices (Figure 12). The largest markets for Chinese solar products were still in Europe, but their share dropped to 32% in October.

² \$1 = 7.1 yuan for December 2023

Figure 12: Mainland China's PV cell and module exports, by month

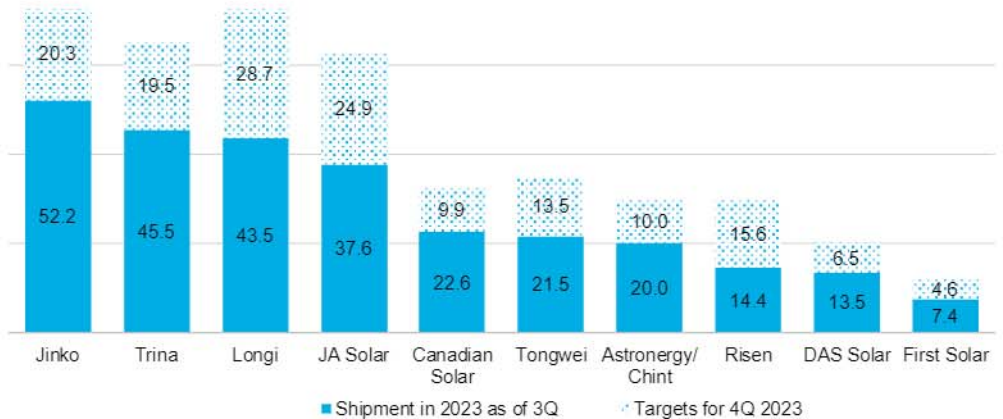


Source: BloombergNEF, Sinoimex. Note: SE Asia refers to Southeast Asia. To check more granular data regarding importing markets and exporters, see BNEF's online interactive data tool: [PV Exports and Imports \(web | terminal\)](#).

A sample of major module makers shipped 278GW of solar modules in the first three quarters of 2023, less than 65% of their annual target as of September

A sample of major module makers shipped 278GW of solar modules in the first three quarters of 2023, less than 65% of their annual target as of September (Figure 13). Some module makers, including Longi, have already lowered their full-year module shipment targets in their third-quarter earnings, while others have indicated that they are still trying to reach their annual targets by offering even more competitive prices as the year closes.

Figure 13: Estimated solar module shipments in first three quarters of 2023 and targets for the end of 2023, for a sample of major manufacturers



Source: BloombergNEF, company filings, industry sources. Note: Shipments in 3Q 2023 are estimated from company guidance, results estimates and industry sources.

Figure 14: Average module quotes for mainland China SOE centralized procurement tenders



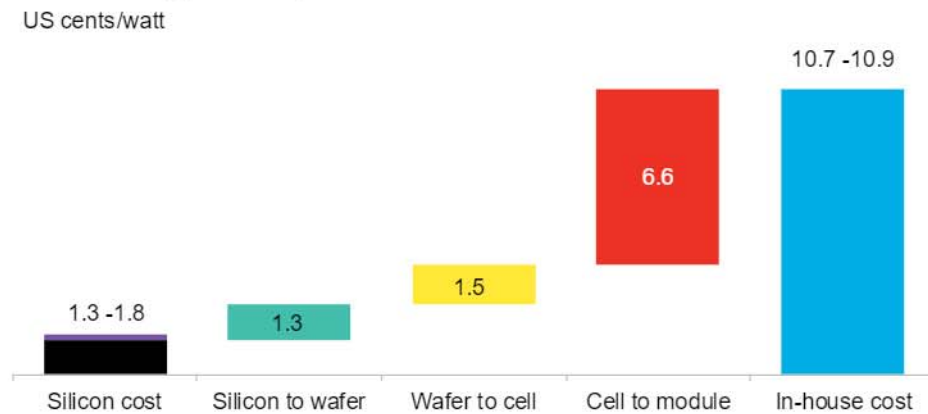
Source: BloombergNEF, PVmen. Note: SOE is state-owned enterprise. Delivery is mostly for 2024.

Quotes for mainland China’s recent gigawatt-scale module bids (usually for delivery within a year, with prices slightly lower than spot levels because of the volume) were 0.94-1.09 yuan/W, or 11.6-13.5 US cents/W, for standard p-type modules and 0.6 US cents/W more for n-type modules (Figure 14).

A \$6-7/kg polysilicon price by the end of 2024 suggests that the cash cost of best-in-class module production by integrated module makers could drop to below 11 US cents/W by the end of next year (Figure 15). The big integrated companies will exert pressure on smaller manufacturers that have less cost control across the supply chain, leveraging their cost advantages and cash holdings to maintain their market share. Retiring the less-competitive factories will likely be a long process, and accompanied by further expansion by leading manufacturers.

We therefore see a module price as low as 11.5 US cents/W by the end of 2024, assuming the mainstream products based on TOPCon cell technology make the average efficiency jump to 22.5%, and \$1 equals 7 yuan for 2024 from Bloomberg composite foreign exchange forecasts (Bloomberg Terminal FXFC <GO>).

Figure 15: Estimated best-in-class cash cost for each step of the solar module manufacturing process by the end of 2024



Source: BloombergNEF. Note: Cash cost assumes the in-house production from polysilicon to modules by integrated solar makers. Depreciation and selling, general and administrative expenses are excluded. Purple range based on a polysilicon price of \$6-7/kg. Assumes 2.14 grams/polysilicon in 2024. \$1=7 yuan when referring to cost level in mainland China factories.

3.4. Trade disputes and local manufacturing

Solar factory announcements shot up after the US Inflation Reduction Act (IRA) was announced and plateaued as companies work on implementation. More than 50GW per year of planned new US module factory capacity has been announced, which should increase cell imports to the US in 2024. However, just 3.7GW of cells were imported from January to October of this year, which suggests that few of these new factories have started production. See *Sizing Up the US Clean-Tech Manufacturing Boom, One Year In* ([web](#) | [terminal](#)) for more.

Pricing pressures are making solar makers in the US very nervous about new factory competitiveness. The IRA production tax credit for manufacturers is worth about \$0.17/W for a fully integrated PV module maker (only First Solar will definitely get all of this) and the local content bonus for project developers will probably result in them paying a 4-5 US cent/W premium for US-made modules. Most planned solar factories intend to make only modules and would earn

7 cents/W in IRA subsidies. However, given higher production costs in the US, this may not be sufficient to compete with modules from southeast Asia, for which prices may well soon fall below \$0.25/W in the US market.

Indian solar manufacturers have been taking advantage of protectionist measures imposed by the US on Chinese solar products, but they are also under pressure from low prices and being forced to lower utilization rates. Cheaper solar modules from mainland China and Southeast Asia have triggered Indian firms to idle some capacity, Bloomberg News [reports](#).

3.5. Tier 1 list – inverters

Table 3 shows the list of inverter brands meeting BNEF's Tier 1 criteria for inverters (currently four projects, with at least two commercial banks providing nonrecourse project financing, in the past two years). Compared with the 3Q 2023 list, Willings has been removed, as one of the projects that qualified it for the tiering was financed more than two years ago. There are no companies that only supply module-level power electronics like microinverters and optimizers on this list, as we do not track projects under 1.5MW of capacity. This is not a reflection of the quality of microinverters, merely that they are generally not used in large solar projects, so banks are unlikely to have conducted due diligence on them.

Table 3: PV inverter manufacturers meeting BNEF's Tier 1 criteria as of 4Q 2023

Firm/brand	2022 solar inverter production, MW/year
TMEIC	7,447
Sungrow	82,000
SMA Solar Technology	12,000
Sineng	13,719
Power Electronics	20,000
Ingeteam	4,229
Huawei	112,000
Ginlong / Solis	26,400
Chint / Astronergy	4,222

Source: BloombergNEF. Note: Methodology is [here](#). List is in reverse alphabetical order to avoid giving the impression that the order is relevant. Companies can download the dataset of financings [here](#).

3.6. Tier 1 list – modules

Table 4 shows the module makers which, as of 4Q 2023, meet our criteria of supplying projects with non-recourse financing from six different commercial banks in the last two years, as tracked by our database.

Waaree, VSUN and SEG Solar have been suspended from the Tier 1 list due to irregularities in the data submitted to BNEF's tiering team. The methodology for tiering is [here](#).

Table 4: PV module manufacturers meeting BNEF's Tier 1 criteria as of 4Q 2023

Firm/brand	Annual module capacity, MW/year	Firm/brand	Annual module capacity, MW/year
ZNShine*	10,000	Jetion	2,500
Yingli*†	15,000	JA Solar*†	85,000
Ulica Solar	3,000	HT-SAAE*	5,000
Trina*†	95,000	Heliene*†	950
Tongwei*	55,000	Hanwha Q-Cells*†	12,400
Suntech*	16,500	Hansol Technics	600
Sunpro Power / YH Sunpro	2,000	Hanersun	1,000
Sunova Solar/ Thornova*	4,200	Haitai Solar	10,000
Sumec/ Phono Solar*	4,000	GCL Solar	25,000
Solarspace*†	6,000	First Solar*†	12,300
Sharp	210	Exiom Group	2,000
Seraphim†	12,000	ET Solar Inc / Elite Solar*	3,500
Runergy/ Hyperion	21,000	Eging*	10,000
Risen Energy*	25,000	DMEGC*	12,000
Renesola	5,000	DAS Solar*	20,000
Recom	1,200	Chint/ Astronergy*†	55,000
Neo Solar Power/ URE	1,800	Canadian Solar	51,000
Maxeon*	10,100	Boviet Solar*	3,000
Luxen Solar	3,000	Anhui Huasun*	20,000
Longi Green*†	95,000	Anhui Daheng (DAH Solar)	2,000
Leapton Energy*	3,000	Akcome*	12,600
Jinneng/ Jinergy*	4,000	AE Solar*	2,000
Jinko*†	95,000	Adani / Mundra*	4,000
		Total	838,860

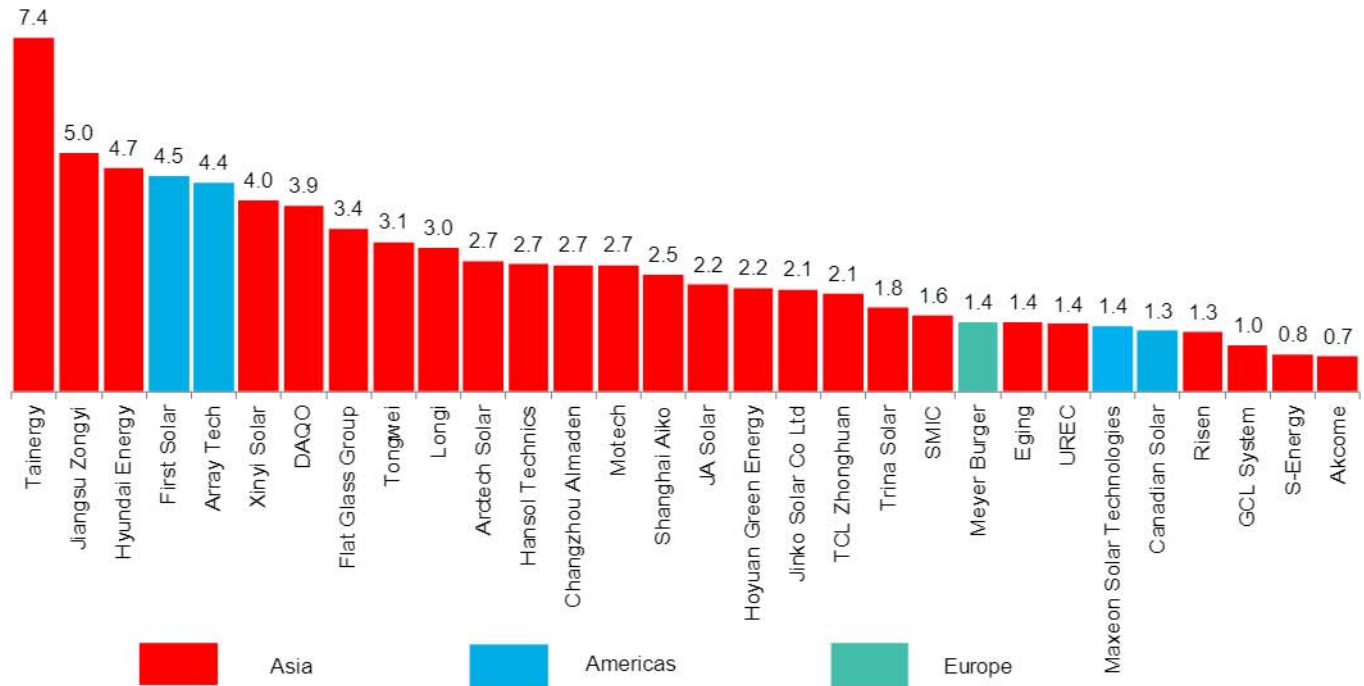
Source: BloombergNEF Note: Methodology [here](#). * Denotes a company for which technical due diligence reports are available from PV Evolution Labs, PVEL. Contact Tristan.erion-lorico@pvel.com. † Denotes manufacturers upon which RETC has recently conducted or is conducting technical due diligence. Contact info@retc-ca.com for details. Brands are shown in reverse alphabetical order to avoid giving the impression that position in the list is significant. Companies can download the dataset of financings [here](#).

3.7. Altman-Z score

The Altman Z-score is a combination of financial metrics that has been found to correlate with a publicly traded manufacturing company's likelihood of bankruptcy. It uses profitability, leverage, liquidity, solvency and activity to predict whether a company has a high probability of becoming insolvent. A score below 1.8 means a company may be headed for bankruptcy, while companies with scores above 3 are not likely to go bust. Figure 16 shows the latest Altman-Z scores for key solar manufacturers.

After several years of strong prices across the value chain, most major solar firms are well above the 1.8 considered to indicate a risk of bankruptcy, suggesting that they have resources to survive a period of much lower prices and margins.

Figure 16: Altman-Z scores of quoted pureplay solar manufacturing companies, 2Q or 3Q 2023



Source: BloombergNEF

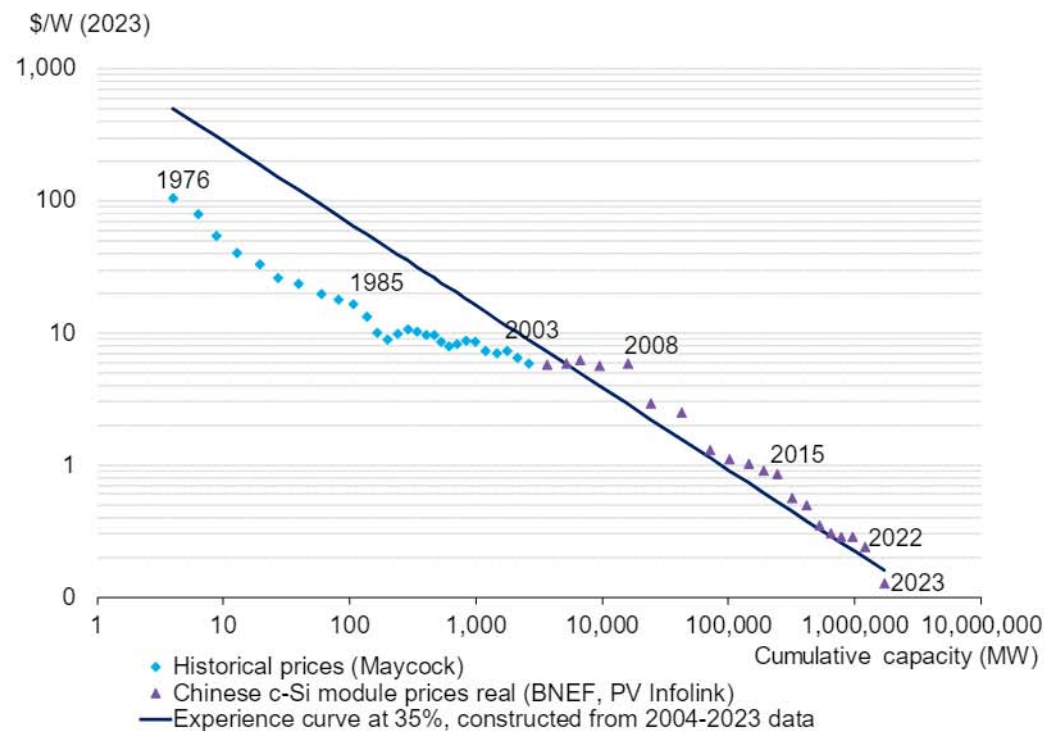
Section 4. Price

The current low prices break the construction of the crystalline silicon PV experience curve; module makers have been cutting costs faster than ever

The module spot price dropped to 12.8 US cents/W in November 2023. This is the lowest level ever, even in nominal terms, and is significantly below where the crystalline silicon PV experience curve suggests it should be (Figure 17).

The construction of the experience curve involves many estimates, assumptions and choices of inflation index. It is not unusual for prices to diverge from the curve for years at a time, but this deviation is dramatic, and the experience curve is therefore not currently very useful as a guide for future prices. For example, constructing the curve based on the 2004-2022 prices in Figure 17 suggests that the current cost should be 20.3 US cents per W, which is nearly double the actual spot price. Constructing the gradient based only on 2004-2023 prices (without the slightest theoretical justification) suggests that the learning rate for this period is 35% – every doubling of capacity manufactured has brought the cost down by 35%. This would be one of the highest rates ever observed in an industry.

Figure 17: Crystalline silicon PV experience curve

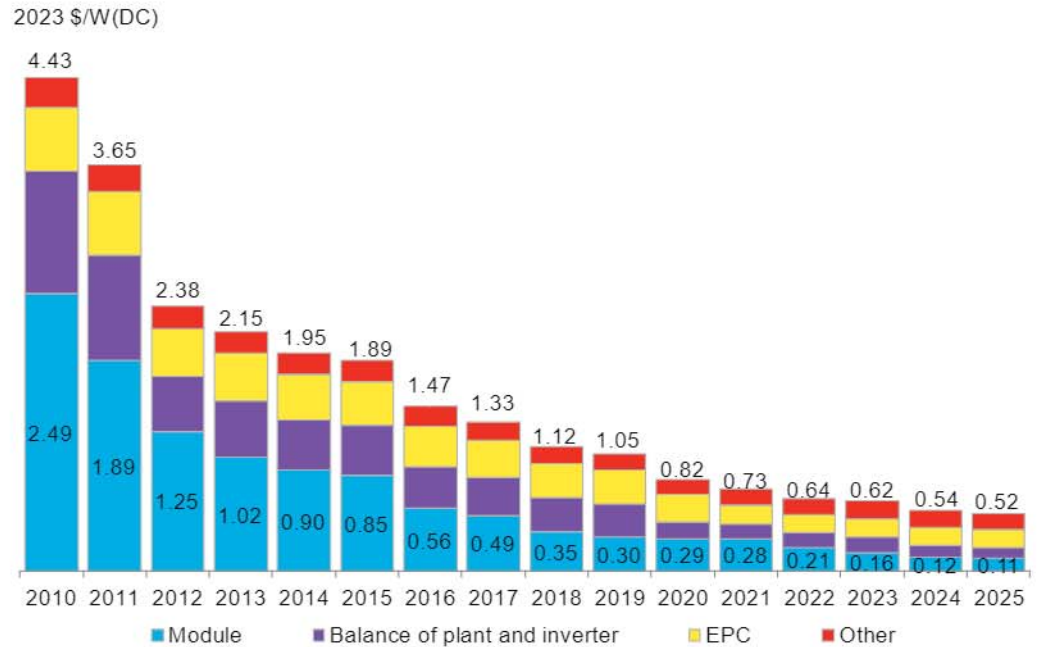


Source: BloombergNEF, PV InfoLink, Maycock. Note: Inflation indexed by US PPI Processed Goods for Intermediate Demand inflation index from the US Bureau of Labor Statistics (PPIITOTL Index). c-Si is crystalline silicon.

From Figure 17, we have attempted to make some sensible assumptions about the intercept of the curve, and a bottom-up estimate of costs, to revise our capital expenditure (capex) forecast (Figure 18). The assumption is that prices do eventually return to the experience curve, and modules cost around 7.4 cents/W (in real 2023 dollar terms) by 2030. For developers, the 'other' costs – namely the outlay of finding grid and land suitable to build on, which vary wildly between

projects and depending on the difficulties developers encounter in doing so – are now more significant than the price of solar modules.

Figure 18: Fixed-axis PV capex benchmark, historical and forecast



Source: BloombergNEF. Note: Values shown for a market without major trade barriers, such as Europe, mainland China and Latin America. EPC is engineering, procurement and construction.

The price of modules from mainland China is a good benchmark for markets such as Europe, Africa and Latin America that have free trade. There are two major exceptions: the US and India, both of which have trade barriers.

In the US, there is a complicated system of tariffs and restrictions on solar imports, but in 3Q 2023 module prices have fallen to as low as 20 cents/W, down from an average 40 cents/W last year. Suppliers are rushing to sell to the US before a new tariff takes effect in June 2024. A total of 35GW of modules have been imported in the US in January-August 2023 (data), a 144% increase compared with the same period last year. To avoid the tariffs, modules shipped before June 2024 must be installed by December 2024.

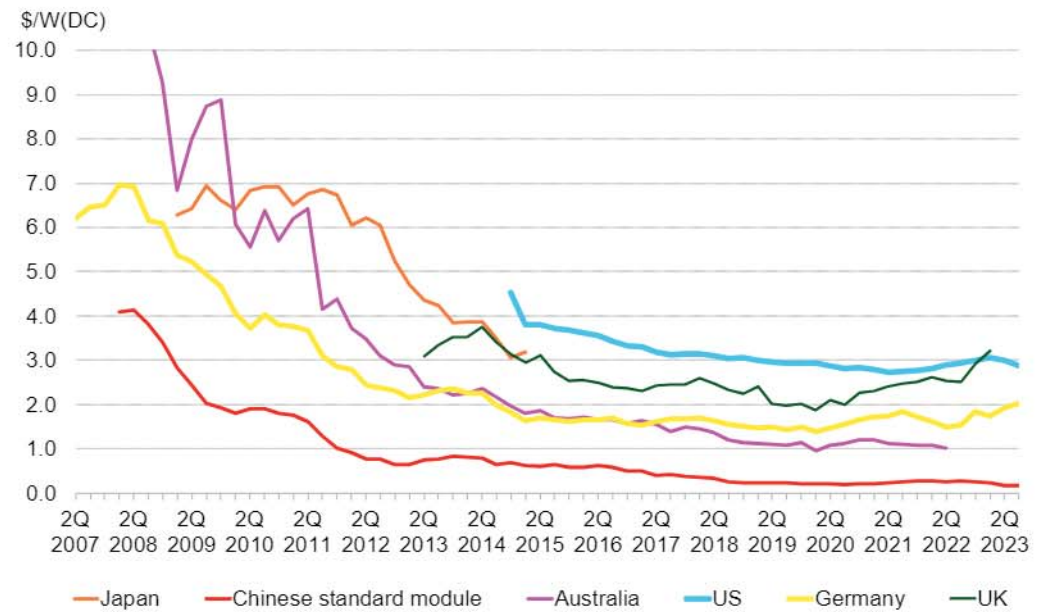
US suppliers are desperate to get rid of their modules as inventories grow rapidly, and some will have to pay the tariffs as they lack a project by the end of next year. We expect most US projects will pay between 25 to 30 cents/W for modules in 2024. Module quotes for utility-scale projects will range from 30-35 cents/W for 2024 delivery, and are not falling as fast because of long-term supply deals that big developers sign only with a handful of integrated suppliers.

The price of modules made in India is about \$0.23/W, though this may come down. It is higher than the price of those made in China, because there is a 40% import tariff on modules and 25% on cells coming into India, and because Indian brands can more easily be sold into the US than Chinese ones. The government may re-instate the Approved List of Module Makers (ALMM) requirement for modules used in state tenders from April 1, 2024, and since only Indian manufacturers are on this list, this would support demand. Most Indian module manufacturers

import cells from China, so falling cell costs reduces their manufacturing costs as well, but they will be under pressure in markets where modules from Southeast Asia and China can compete.

Despite the continued fall in module prices, capex for residential systems from 4-10kW in Germany and below 4kW in the UK has trended up in 2023 to date (Figure 19). This is probably the result of installers putting up prices due to strong demand in these two markets in 2022, when consumer energy prices rose sharply and there were fears of them going even higher.

Figure 19: Residential solar capex in different markets



Source: BSW-Solar, Eurostat, Solarchoice.au, Energysage, Ofgem, BloombergNEF

In 2023, European electricity prices have eased, and while people and businesses are still buying solar and build overall has almost certainly risen, there is no longer the urgency faced in 2022. The high demand in 2022 has caused a “hangover” of weaker new sales in European solar markets, according to Andreas Thorsheim, CEO of European solar marketplace Otovo Solar, in the firm’s 3Q results call. “In 2021 and 2022, that trend line got lifted upwards by an energy crisis that put a lot more urgency into consumers’ minds about making the shift to clean and affordable energy. But that led to a certain overheating that sucked demand out of 2023 and into 2022, and that means we are having a bit of a hangover this year that we are aching to end,” added Thorsheim.

In the US, average system costs ticked down slightly. Residential solar installers in the US hope to offset higher financing costs by cutting costs. A sharp decline in module prices since 1Q 2023 has also helped lower overall system costs.

Some European rooftop solar markets are experiencing a ‘hangover’ after the excitement of 2022

Appendices

Appendix A. Demand – Asia Pacific

Mainland China is expected to install 240GW of PV modules in 2023, which is more than double the size of its market last year

Mainland China installed 128.9GW(AC) of PV in the first three quarters of 2023, 145% higher than a year ago, according to the [National Energy Administration](#). The PV addition in the third quarter was reported at 50.5GW(AC), including 24.3GW of utility-scale projects and 26.2GW of small-scale. BNEF raised its China forecast for this year to 195GW(AC) or 240GW(DC) from just over 200GW in our previous market outlook.

The utility-scale sector has shown robust growth, mainly driven by renewable megabase projects, huge areas of land where state-owned developers have won the right to build multi-gigawatt complexes. Most of the new additions in 3Q were in Xinjiang, Gansu, Qinghai, Shanxi and Inner Mongolia. Developers are rushing to get the first batch of megabase projects commissioned by a deadline at the end of this year. BNEF tracked 16GW(AC) of such PV projects commissioned by October, and another 36GW(AC) is expected to come online in the fourth quarter. The second and third batch of megabase auctions will amount to another 55GW before 2025.

The small-scale market maintained steady growth, especially in the commercial and industrial (C&I) segment, which added 15GW(AC) in 3Q. Falling module prices and high power tariffs have been accelerating the installation rates. Large markets for small-scale solar, such as Zhejiang, Jiangsu and Guangdong, recorded growth and other emerging regions such as Hunan, Hubei and Henan, also grew to add nearly 1GW(AC) every quarter.

A few residential markets have slowed down, for example Hebei and Shandong. Local governments are tightening regulations and evaluating available grid connection capacity. There are 11 counties in Guangdong where rooftop solar has used up all the free regional grid capacity and further build is suspended, while the evaluation for other regions is still in progress. Some local officials have required PV developers to pair utility and commercial solar with energy storage and connect the generation at higher voltage level. As a result, investors have been exploring other provinces, like Shanxi and Jiangsu, which saw solid growth through the first three quarters.

India added 8GW(AC) of solar in the first nine months of 2023

India added 8GW(AC) of grid-connected solar capacity in the first nine months of 2023, according to [official](#) data. Commissioning has been faster than expected in the rooftop segment but there has been a slowdown in the build-out of utility-scale projects. As a result, we have raised our forecast for rooftop and reduced it for ground-mount projects. We still expect total commissioning for the year to be 11.2GW(AC) but total module demand will be 15.4GW or 440MW less than the previous forecast. This is because rooftop projects typically have a lower inverter loading, or DC:AC, ratio.

India has two major protectionist policies to promote domestic manufacturing. Module imports are taxed at 40%, but shipments from Southeast Asia are currently exempt under an India-Association of Southeast Asian Nations (ASEAN) free trade agreement (FTA). This has led to an increasing share of modules from Vietnam, as Chinese shipments are costlier after factoring in the 40% tax. India also has a non-tariff barrier in the form of a quality certification initiative (ALMM or Approved List of Models and Manufacturers) that excludes all foreign manufacturers.

However, the requirement that only modules on the ALMM be installed in India has been suspended until the end of March 2024 as the government is balancing the needs of domestic manufacturers and project developers. If ALMM is re-introduced, developers end up paying higher prices for made-in-India modules, which could slow down the volume of capacity commissioned in 2024. If no new announcement is made, projects commissioned after April 1, 2024 can only use modules on the ALMM. This means module imports will drop sharply from February 2024 and commissioning activity will be high in 1Q 2024.

Demand for green electricity from Japanese companies is on the rise, helping solar build

Japan's 2023 build of solar capacity is estimated at 4.9-6.0GW, 3-5% higher than our previous estimates. This is mainly due to an increase in the number of Japanese companies pledging to source 100% clean electricity for their operations. However, we reduced our forecast for 2024-2030 as the declining volume of solar projects in the pipeline should outweigh the growing interest in clean power procurement from the private sector. The cumulative installed solar capacity is 134GW by 2030 in our benchmark scenario – 3% lower than our previous forecast. This year auctions have been smaller than previously, bringing the volume of winning capacity in the latest three rounds to only 206M (AC), a 54% decrease year-on-year. The volume of 10-250kW solar projects approved by a feed-in tariff scheme in Japan's fiscal year 2022 was 272MW(AC), 43% lower than last year.

Curtailment is widespread in Japan

Renewable electricity curtailment has expanded to all regions of Japan apart from the Tokyo area this year, and in Tokyo, the Tepco Power Grid expects its first curtailment starting next year, according to a governmental committee [meeting](#) in September. Given the increasing frequency of renewable electricity curtailment, the government committee is set to compile mitigation measures by the end of this year. As short-term measures, the [government](#) is keen to lower the minimum output of existing and new thermal power plants to 30% from the previous 50%, and deploy more demand-side flexibility such as grid-connected batteries, heat pumps, and time-of-use electricity tariffs.

Projects in Malaysia can now sign PPAs under the government's Corporate Green Power Programme

For **Malaysia**, we increased our forecast from the previous quarter, with 6.3GW of additional capacity addition from 2024-30 under the mid scenario, up from 5.7GW previously. The expected commissioning of some solar projects awarded under Malaysia's large-scale solar auctions was delayed from 2023 to 2024. Malaysia's Energy Commission reported that as of 3Q 2023, only 131.7MW of new large-scale solar projects had come online.

We also raised our forecast slightly for 2025 driven by the country's Corporate Green Power Programme (CGPP). The scheme has awarded 800MW of solar capacity to 32 projects. These projects can sign deals directly with private offtakers in the manufacturing or service industry via virtual power purchase agreements (PPAs). Previously, power projects in Malaysia could only contract with the state utilities, which acted as the single buyer. Projects awarded under the CGPP will need to come online by 2025. The launch of the CGPP could be a prelude to market reforms and liberalization plans, which were previously discussed in 2018.

Pakistan imported at least 4GW of modules from January to September 2023

Pakistan imported \$1.11 billion worth of solar products from January to September 2023, or at least 4GW of modules. A net metering scheme that has been in place since 2015 has resulted in cumulative capacity of 1,055MW to June 2023, according to the [Ministry of Energy's Power Division](#), and was not subject to proposed amendments in 2023. Some modules may be re-exported to Afghanistan for irrigation purposes, and significant amounts of commercial solar may be installed without licensing. National Electric Power Regulatory Authority's (NEPRA) [website on licensing](#), which lists licenses awarded to commercial enterprises – usually for PV systems of 50kW to 500kW – suggests an acceleration in 2023 in most regions.

The country's Alternative Energy Development Board merged with the Private Power and Infrastructure Board (PPIB) in June 2023, and this may be the beginning of reforms. In September 2023, the PPIB released [framework guidelines](#) for fast-tracking power purchase agreements for solar projects and for adding solar to the roofs of public buildings. We estimate installation of 2.8-3.0GW of solar in Pakistan in 2023, but with considerable uncertainty even about what has already been built.

South Korea's 2023 mid-case solar installation forecast remains at 2.76GW. As of November 6, South Korea has deployed 2.5GW of solar capacity in 2023. The current Yoon Suk-yeol administration's unfavorable stance on renewables, which includes stricter financial requirements for developers and a narrower window to retain permits, continues to hinder new project development. For more on the Korean government's renewable policy, please read *Yoon's 'Cartel' War Tightens Screws on Korea's Renewables* ([web](#) | [terminal](#)).

South Korea will auction 1GW of capacity with a ceiling price of \$117/MWh

In October 2023, the Korea Energy Agency [announced a 2H 2023 fixed-price solar auction](#). The agency will tender 1GW of solar capacity with a ceiling price of 155,597 won (\$117) per MWh. The previous auction, in 1H 2023 with 1GW capacity, was undersubscribed with only 285MW awarded from 298MW of submitted bids. The 2H 2023 auction is also likely to remain unpopular, as the Renewable Energy Certificate (REC) spot price is attractive and can be combined with selling electricity at the spot market. See Renewable Energy Certificate market section of *1H 2023 South Korea Market Outlook* ([web](#) | [terminal](#)).

South Korea's corporate energy market is also growing. This year, Lotte Global Logis and OB Beer installed 2.6MW and 7.6MW rooftop solar respectively to use clean power onsite. [BASF Korea closed an 80MW solar offsite direct power purchase agreement](#), by far the largest such contract in the market. See *Korea Clean Power Procurement 101* ([web](#) | [terminal](#)).

Taiwan aims for cumulative installed solar capacity of 20GW(DC) by 2025. However, only 11.4GW has been installed as of August 2023, with 1.7GW added in the first eight months of this year. The industry expects a slower deployment of solar, especially for utility-scale projects, due to an election next year, which has led local authorities to put large-scale solar projects on hold to avoid stirring controversy over land use and voter discontent. The rooftop solar segment is on track to build 1GW this year. In light of this, we lowered our forecast to 2.5GW for this year from over 3GW(DC) and expect an even lower build rate of 2.3GW in 2024.

Demand is likely to pick up once elections are over, but developing a project takes an average of 15 months for land acquisition and getting local and state permit approvals, according to industry sources. We expect strong growth and the market to exceed 3GW in 2025, driven by the expanding backlog of projects. A mandate for new buildings to have solar on their rooftop will start next year under the Renewable Energy Development Act, updated in May 2023.

Uzbekistan may become a 4GW market next year

Uzbekistan may install up to 4GW in 2024. Part of this capacity already broke ground in 2H 2023, and the country imported modules worth a total of \$375 million from mainland China by the end of September (\$306 million in 3Q 2023 alone), equivalent to 1.9GW. The government is keen to replace part of its coal- and gas-fired power plant fleet, which in 2022 represented [90% of the total generation mix](#). While Uzbekistan has a target of 10GW of solar (and 5GW of wind) by 2030, this will likely be exceeded, as we expect new bilateral deals to drive the market beyond 2025.

Projects which are under construction include a 897MW portfolio by Masdar, a [400MW project by ACWA Power](#) in the Tashkent region, and two [500MW projects by Energy China Group Corporation](#) (CEEC) supplied by Longi. Uzbekistan's government officials have been active in a series of high level bilateral agreements over the past year, sealing deals with developers from

Vietnam's solar market is still slow after its 2020 boom; the draft power development plan targets 4.1GW of solar additions by 2030

the Middle East ([ACWA Power](#) and [Masdar](#)), Europe ([Votalia](#)) and China ([CEEC](#), [Huaneng Renewables](#) and Poly Technologies).

Uzbekistan has also held a series of PV auctions, the first of which supported the construction of Masdar's [100MW Nur Navoi Solar Project](#), back in 2021. In December 2022 the 500MW(AC) International Finance Corp. Scaling Solar round awarded 250MW to Masdar, 150MW to GD Power-Powerchina and 100MW to Votalia. In June 2023 the [Ministry of Energy](#) held a [300MW round](#) – which Masdar won – for the construction of a 300MW PV project in Guzar.

Vietnam's solar market remains slow after the 2020 boom, due to a lack of policy support and an absence of route to market for new projects. We have retained our 2024-30 forecast from previous quarter with the expectation that several discussed policies will enable new build. However, we do not expect solar capacity addition to hit the levels observed in 2019 and 2020, which was an unsustainable increase.

Vietnam implemented a transitional tariff scheme allowing eligible solar projects that missed the feed-in tariff deadline previously to negotiate a PPA price with the state utility, Vietnam Electricity Group. Through the program, 162.7MW of solar capacity achieved commissioned status as of November 10.

The country's draft power development plan VIII, released in August 2023, outlines a target of 4.1GW of solar capacity additions by 2030, 1.5GW of which would be utility-scale solar projects. Concerns over further grid congestion and high curtailment levels has led to limited ambitions for further solar capacity additions in the country.

However, Vietnam has many factories, which may represent significant corporate demand for clean energy. A direct PPA pilot of 1GW(AC) is under discussion, although the timeline for implementation is not yet announced. Vietnam also has plans to liberalize its electricity retail market. If this materializes, together with potential demand from corporates, solar developments in Vietnam could grow beyond the planned capacity under its most recent power development plan.

Appendix B. Demand – Europe, the Middle East and Africa

The EBRD is supporting Albanian authorities with a 300MW PV auction

Albania connected the [140MW Karavasta](#) PV project to the grid at the start of October. This is the country's first utility-scale solar project. Votalia, which is the developer and equity sponsor, obtained a syndicated loan from a group led by the International Finance Corp. (IFC), the [European Bank for Reconstruction and Development](#) (EBRD), Intesa Sanpaolo Bank Albania, and Privredna Banka Zagreb. The project costs €135 million (\$ 147 million), €99 million of which was financed with debt.

Votalia is also developing the 100MW Spitalla project, near Durrës. Votalia was awarded the right to build the projects after winning two tenders held by the Ministry of Infrastructure and Energy and sponsored by EBRD in 2020 and 2021.

The EBRD has also helped the Albanian authorities with a 150MW onshore wind auction, the [results](#) of which were recently announced in July. The EBRD is now working with Albanian authorities on supporting an upcoming 300MW PV auction originally expected to take place in June.

In **Austria**, four rounds of offers for rooftop or commercial PV funding in 2023 have offered support for 2,060MW of PV and 646MWh of battery storage. This is up from 1,400MW of solar support issued in 2022. While it is not clear how many of these systems have been built, it seems likely that the country is at least on track to build the estimated 1.3GW in 2023. This is a slight adjustment from the previous quarter as the 2022 total was also finally reported slightly below estimate.

The solar market in the **Czech Republic** accelerated again, with the industry association estimating that 487MW of projects were built in 1H 2023. These had an average size of 10.7kW, and 95% were added with storage. The main support mechanism is the New Green Savings Programme, which refunds up to 50% of capex for many different home energy efficiency measures. From September 2023, this fund was expanded to become eligible to apartment buildings and extended-family houses. In June 2023, the program received €1 billion from the EU Modernization Fund, and is expected to be funded until 2025. We have revised our estimates for the Czech market up from almost nothing to a 1GW/year market.

Finland will be hosting the projects from the EU's first cross-border renewables tender, with a target capacity of 400MW

Finland was the host country of EU's first cross-border renewables tender under the renewable energy financing mechanism framework (RENEWFM). According to an announcement at the beginning of October, the tender was oversubscribed and saw 516MW of solar projects apply compared with its target capacity of 400MW. The scheme aims to link countries that pay into the mechanism (the 'contributing country') with those that will host the projects in their region. The financial contributor and the host of the projects then share the contribution to national energy targets.

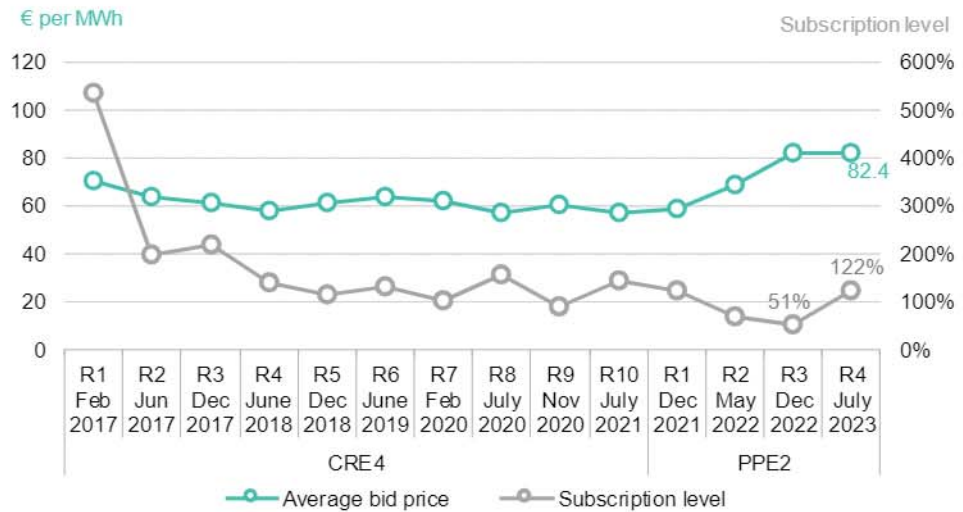
This round had Luxembourg contributing €40 million, and the selected projects will need to come online in 24 months after the grant agreement is signed. The targeted capacity is 400MW, with project sizes ranging between 5MW and 100MW. If all this capacity is allocated, Luxembourg's contribution would cover about 16% of total capex.

France installed 2.2GW during the first three quarters of 2023. Energy authority CRE announced the winners of its fourth auction round for ground mounted PV projects, which awarded 1.5GW to 129 ground-mounted PV projects at the average price of €82.42/MWh (Figure 20), the highest since March 2014. The largest winners were Photosol, Neoen and EDF.

France awarded 1.5GW of capacity in its fourth round of auction for ground-mounted PV projects, with the average winning price the highest since March 2014

Various factors have contributed to the high price. The exceptionally low subscription levels in round 3 resulted in an average price of €82.2/MWh, revealing a high price cap; unlike German auctions, French authorities do not disclose the price cap in each bidding round, to foster competitive bidding. This factor, combined with bidders' expectation that this fourth round would be undersubscribed due to the exceptionally large capacity volume on auction (1.5GW), may explain the high average price. Ultimately, the fourth round ended being oversubscribed, as CRE received bids totaling 1.8GW for 1.5GW available.

Figure 20: Average successful bid prices in ground-mounted PV auctions in France



Source: BloombergNEF. Note: Subscription level is the ratio between awarded (successful) capacity and overall targeted volume in each round. The CRE4 auction rounds ran from February 2017 to July 2021. The first round of the PPE2 series took place in December 2021.

Most of the capacity awarded is in the north of the country, specifically in Hauts-de-France (next to the border with Belgium) and Centre-Val de Loire (just south of Paris). This geographic shift from the south to the north has also contributed to an increase in the bid prices. According to our modeling, a drop in the assumed capacity factor of a benchmark French PV project from 14% (next to Bordeaux) to 12% (close to the Belgian border) results in an increase of the levelized cost of electricity generation (LCOE) from €40.7/MWh to €48.6/MWh.

The fifth auction round for PV on rooftops and agricultural structures assigned 342MW out of 800MW available at an average price of €101.2/MWh. CRE received bids for a total 682MW, but excluded 340MW for either not complying with the auction rules, exceeding the price cap, or for having already won in previous rounds. The fifth round awarded 83MW to agrivoltaic greenhouses across 22 projects, and 37MW open-air agrivoltaic systems across three projects.

France now mandates new parking lots larger than 500 square meters to have solar

The government has issued further guidance on the obligation to build solar carports on commercial car parking areas via Law No. 2023-175, which came into force on July 1, 2023. The law mandates new parking lots larger than 500 square meters to have at least 50% of their surface area covered by PV carports. For existing parking lots built prior to July 1, 2023, the minimum size threshold for PV carports increases to 1,500 square meters. Existing parking lots must be equipped with solar by July 1, 2026 if larger than 10,000 square meters, or by July 1, 2028 if between 1,500 and 10,000 square meters. The government allows exemptions to retrofitting PV carports if there are trees which provide shading on over 50% of the surface area of the parking lot, and estimates its measure could drive 11GW of solar build in total, equal to the country's existing utility-scale capacity. This is one of the 10 unorthodox measures identified by BNEF that governments around the world have implemented to accelerate renewables deployment. See *Ten Ways to Unstick Renewables Deployment* ([web](#) | [terminal](#)).

In **Germany**, the Bundesnetzagentur tracks 10,173MW of solar added from January to September 2023. The monthly build may well slow down in the fourth quarter due to limits on installation work that can be done with less daylight. However, there is also some solar unreported to the Bundesnetzagentur, either as 'balcony solar' or as utility-scale projects with

Greece's new draft National Energy and Climate Plan aims to have wind and solar make up 69% of electricity generation by 2030

direct power purchase agreements. BNEF has increased its 2023 build estimate for the country to 12.8GW, and adjusted the trajectory to 2030 so that the country meets its 215GW cumulative target at a moderate growth rate.

Greece installed 874MW of PV in 1H 2023, according to [data](#) from renewable energy operator Dapeep. The country unveiled its new draft National Energy and Climate Plan (NECP) on August 21, and this calls for wind and solar to make up 69% of electricity generation by 2030. While the vision for energy storage and offshore wind looks overdone, the goals for solar are conservative. The August draft NECP 2030 solar target is up 70% (corresponding to 13.1GW cumulative by 2030) relative to the current target, but still short of 3.2GW compared with BNEF's forecast. See [Greece's Climate Plan Overplays Batteries, Lowballs Solar \(web | terminal\)](#). We maintain our central forecast of a cumulative 16.7GW by 2030.

Hungary added 1,390MW in the first three quarters of 2023, according to data from grid operator Mavir. The residential and commercial (sub-50kW) segment accounted for 639MW (45%), while systems over 50kW added up to 751MW (55%).

In October, Minister of Energy Csaba Lantos announced that the government will lift restrictions it imposed on residential systems which filed grid connection requests after October 31, 2022, preventing them from receiving any compensation for excess electricity fed into the grid. These restrictions will be lifted as of January 1, 2024. The minister also indicated that the government is actively working to increase the cumulative installed PV capacity in Hungary from the current 5.2GW to 10-12 gigawatts by 2030, and that storage and highly flexible gas peakers are needed to deal with the saturation and variability related to an increase in PV generation. For this reason, the government will hold a HUF 75 billion (\$216 million) battery storage tender in 2024, covering 65% of the project capex. The maximum size allowed will be 4kW for PV and 8kWh for storage systems. The reason for relatively small PV system size threshold is to prevent more excess PV electricity feeding into the electricity grid. The current average size of residential systems in Hungary is 7kW.

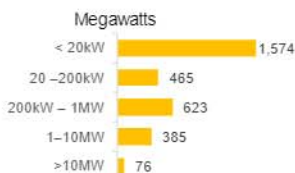
Italy has installed 3.1GW in 2023 as of the end of August, of which 1.2GW took place in July and August, the busiest months of the year so far. The residential segment accounted for half (1,379MW) of the capacity additions, driven by the 'Superbonus' tax break, which will phase out on December 31, 2023. We expect the residential segment to cool down once the Superbonus subsidy expires, while the commercial segment will be unaffected. Last year only 1% of the 1.3GW commercial-scale additions received the Superbonus backing, compared with 62% of the 1.2GW residential capacity, according to clean energy operator GSE. We maintain our 4.4GW full-year forecast for 2023 and 4.2GW for 2024.

The government plans to phase out the [net-billing scheme 'scambio sul posto'](#), from January 1, 2024, leaving room for other forms of incentives for new and existing PV systems under 500kW. This move will affect the attractiveness of building a commercial and residential solar system, and favor the installation of battery storage systems paired with new and existing PV systems.

The current 'scambio sul posto' scheme credits small-scale systems for the power they feed into the grid at a wholesale price, exempt from the transmission and system costs on the component of electricity exchanged. The framework is seen by policymakers as too generous, as [power prices averaged](#) €304/MWh in 2022 and €128/MWh in 2023 (as of November 7, 2023).

Instead, PV system owners will receive €44/MWh (€0.04/kWh) via the replacement ['ritiro dedicato'](#), a regulated compensation, already in place for older small-scale renewable energy sources. The price level for 2024 is yet to be set, but we do not expect much variation: between 2019 and 2022 the compensation ranged between €40/MWh and €41/MWh. According to the

Figure 21: PV additions by segment in Italy in 2023



Source: BloombergNEF, Note: Data as of August 31, 2023.

Italy aims to hire 298 public officials to speed up the permitting process of renewables

government's plan, new PV systems installed after January 1, 2024 will directly access the 'ritiro dedicato' scheme, while existing projects need to transition to the new framework starting from January 1, 2025. Chances that the phase-out of the 'scambio sul posto' will actually happen at the start of 2024 are getting slimmer, as the legal framework and practicalities were yet to be defined at the end of October 2023.

Permitting for utility-scale projects is notoriously slow and painful in Italy. For this reason the Ministry of the Environment and Energy Security in October published a [public call](#) to hire 298 public officials with the task of speeding up the permitting process. In Sardinia alone 30 to 40 requests for site permits are filed every week, according to a public official [interviewed](#) in mid-2023.

In **Poland**, data from the [Energy Market Agency, ARE](#), suggests additions of only 1,262MW from January to August 2023, a significant slowdown from 4.5GW installed in 2022. This is further confirmation of the 'hangover effect', where lower power prices and a relatively minor change to net metering have hit the sector harder than anticipated. We cut the forecast last quarter due to 1H data, and have kept it at 3,370MW as lower prices may accelerate large projects toward the end of the year.

Netherlands will add 5.5GW this year, mostly in its rooftop segment, which benefits from a net metering scheme. We expect a significant and sudden contraction in this market in 2025 as net metering starts being phased out. Our forecast for 2024 is 2.6GW for the residential segment, which then drops off to 900MW in 2025 and then gradually declines until 2030.

According to the government plans, the percentage of electricity that is subject to net metering will drop to 64% in 2025, and then gradually reduce until it is completely phased out in 2030. Instead of being compensated at the retail electricity rates for exported energy, households will instead receive a minimum price, which will be considerably lower but has yet to be decided. The law now has to pass the senate to be implemented.

Romania's solar sector is growing, with both utility and small-scale segments picking up pace

Romania's solar sector is growing. BNEF tracked 196MW of utility-scale projects commissioned in 2023 and another 551MW that is financed, some of which is already under construction. Earlier in the year it also announced an auction that will support 1GW of projects, described in the *3Q 2023 Global PV Market Outlook* ([web](#) | [terminal](#)). Small-scale solar, supported by net metering and a grant scheme, is also picking up pace. In 2023 by the end of September, Romania imported \$160 million of solar equipment, equivalent to 842MW of modules. We have therefore increased our mid-case forecast from 445MW to 700MW.

Spain imported \$1.8 billion worth of solar modules during the first three quarters of 2023, an estimated 9.1GW. The country is set to import 11GW by the end of the year, as much as it imported in 2022. BNEF's project database tracked 1.8GW of utility-scale additions as of the end of October, and we expect 3.4GW of small-scale additions to come online by the end of the year. We expect the market to add 8.4GW this year, 14% more than in 2022 (7.8GW).

Turkey added 1,477MW(AC) of solar in 2023 by the end of September, according to the Turkish Electricity Transmission Corporation (TEIAS). The commercial rooftop segment is the main driver of installations, due to a net metering scheme and abundance of large industrial and commercial rooftops in the region. We maintain our 2023 build forecast of 2.2GW(DC) for our mid-case scenario.

In its [12th Development Plan](#) prepared by the Ministry of Treasury and Finance, Turkey targets 30GW(AC) of solar capacity by 2028, which would mean build of about 4GW(AC) annually between 2024 and then. BNEF expects this target to be met.

Algeria's utility, Sonelgaz is yet to disclose the winners of a 2GW PV tender it launched in February 2023. The export data for solar products from China indicates only \$2 million worth of trade in the first three quarters of 2023, so we have lowered our expectation for the market to 15MW, all in the residential segment.

Saudi Arabia's Power Procurement Company (SPPC) has kicked off the fifth round of the government's renewable energy tender program. It announced a request for qualifications process for 3.7GW(AC) of capacity from five projects. Projects will be overseen by SPPC, which will also act as the offtaker of power from these projects. Saudi Arabia has a target of reaching 40GW of solar by 2030, and at the end of 2023 has only about 3GW. This requires it to add around 5GW of capacity annually between 2024 and 2030. With its potential for the rooftop segment and the government's ability to drive these large-scale tenders, BNEF maintains that reaching these targets could be feasible.

Israel has released installation data for 2022 (see page 30 of the official document), showing 820MW of new ground-mounted and 210MW of 'dual use' PV built in 2022. Renewable electricity supplied 10.4% of Israel's electricity in 2022. The market has likely slowed at least slightly in 2023.

In **South Africa**, the rooftop market has slowed down from the 1.8GW installed in 1H 2023, according to estimates by state utility Eskom, with only 472MW installed from July to September. Industry players active in the local market confirmed that residential solar sales have fallen in the third quarter, mainly because the load shedding situation has improved. From June to August, only six days had Stage 6 load shedding (where consumers can expect to lose power up to 12 times over a four-day period, six times for two hours and six times for four hours), compared with 14 days in April and 19 days in May (source). This has had a surprisingly rapid impact on residential solar orders, although we expect the commercial market to have a longer planning cycle.

We have cut our central build forecast for South Africa from 5GW in 2023 to 3.5GW in 2023, as a result of the residential slowdown. Further load shedding events caused by coal plant outages are likely to cause renewed uptake, but this is unpredictable, and already the amount of solar in the grid is making load shedding less likely in sunny hours. However, an industry source estimated that battery attachment rates are already over 80% for residential in South Africa.

Tunisia's solar uptake to date has been slow, and the country of 12 million people suffers load shedding when peak demand exceeds 4.5GW. According to local press, internal power plays have inhibited the wind and solar sectors for years now.

Official PV build data does not exist, but according to BNEF's project database, Tunisia had 37MW of utility-scale PV projects operating as of October 2023. We estimate that Tunisia imported 135MW worth of modules in 2022 and 190MW in the first three quarters of 2023, based on export data for solar products from China, which were \$35 million in 2022 and \$37 million from January to September 2023. We allocated this imported capacity (net of the 37MW utility-scale projects tracked in our database) to the residential and commercial segment. Satellite data from Google Earth indicates that rooftop systems are getting installed, especially in the wealthy urban areas of the country.

Tunisia's largest solar project to date – the 120MW Metbassta PV project – is now under construction. AMEA Power, the equity investor headquartered in Dubai, received debt financing from the International Finance Corp. and the African Development Bank. The project is expected to commission in mid-2025. This project was part of a large international tender held in 2018, awarding 500MW(AC) (about 600MW(DC)) across five projects. Once operational, these will

Table 5: Tunisia's PV tender results from 2019

Project	Size, MW (DC)	Status
<u>Tataouine</u>	240	Permitted
<u>Kairouan</u>	120	Financed
<u>Gafsa</u>	120	Permitted
<u>Sidi Bouzid</u>	60	Financed
<u>Tozeur</u>	60	Financed
Total	600	

Source: BloombergNEF

supply electricity to state-owned utility Société Tunisienne de l'Electricité et du Gaz (STEG) via 20-year PPAs. Norwegian Scatec was the major winner, as it had secured three solar projects totalling 360MW(DC). Despite having secured debt financing for the two smaller projects (60MW each), Scatec reported in its [3Q 2023 filing](#) that it is renegotiating the power price contract with Tunisian authorities, and trying to reduce its ownership in the projects by inviting new equity partners.

Results of the [new round of auctions](#) that the government held in June 2023 are not out yet.

Appendix C. Demand – Americas

The US will see 33GW of new solar come online this year, a big jump from last year's 24GW. We expect the market to add 38GW in 2024 and a total of 299GW between 2025 and 2030. See *2H 2023 US Clean Energy Market Outlook* ([web](#) | [terminal](#)). Our forecasts have gone up by 12GW for the 2023-2030 period compared with our previous outlook. Most of the increase will be in home solar, which will overcome financing constraints thanks to long-term cost declines.

Argentina market is bouncing back and is expected to install 256MW this year

In **Argentina**, after a slow 2022 which saw only 30MW of solar come online, the market is bouncing back this year and we expect it to add 256MW of capacity. The country commissioned 239MW of PV projects as of early November, including the [100MW YPF Parque Solar Zonda PV Plant Phase I](#). Argentina also awarded 43 small projects in its latest RenMDI auction in July, totaling 450MW, which should be commissioned from 2026 onward according to auction rules.

However, most projects added to Argentina's pipeline this year are tied to the corporate market. In the September round of the Mercado a Termino (MATER) scheme, which allows renewable projects with corporate power purchase agreements to have priority dispatch, 23 renewable projects secured a contract. In total, 11 PV projects totaling 875MW were awarded in the scheme, most of which plan to start operations in 2025. We expect Argentina to commission another 1.4GW of PV between 2024 and 2027, a 42% increase from our previous forecast. This is more than double the cumulative PV capacity as of today.

Brazil is on track to install 16.3GW this year, an all-time high thanks to its sub-5MW segment that is eligible for net metering

Brazil's capacity additions in the sub-5MW segment, which is eligible for the net metering scheme, remain strong and the country is on track for a record-high 16.3GW of installations in 2023. However, as the sector continues its aggressive growth, the cost of the subsidies that feed through to electricity tariffs has ballooned, prompting calls for government intervention. See *Brazil Clean Power Conundrum: Solar Blooms, Subsidies Boom* ([web](#) | [terminal](#)). This creates some risk of regulatory changes.

Starting in 2024, high-voltage consumers will be able to buy energy in the wholesale market (currently only customers above 0.5MW demand can participate), and regulators are discussing opening the market to all consumers, including residential, by 2026. This could allow consumers to access renewable energy without the need to bear the upfront costs of installing panels, which can be particularly challenging due to the country's high interest rates.

Accordingly, we have maintained our near-term outlook of sustained growth, while trimming cumulative total installed capacity of the sub-5MW segment by 15% by 2030, with slow down weighted toward the final years of the decade.

Chile will install 2.3GW in 2023, a new record

Chile is on track to hit an all-time high for annual solar installations. The country has already commissioned 2.2GW of PV this year as of November, including Enel's 510MW Campos del Sol and 517MW Guanchoi PV Plants. BNEF expects Chile to bring a total of 2.3GW of solar online by the end of the year, a 12% increase from our previous forecast. This is equivalent to more than 30% of total PV capacity installed in the Andean country today.

In October, the government published an update on its next power auction. The country will auction 5,000GWh/year to be supplied from 2027 and 2028 onwards, which is less power than previously announced. The government will receive bids on December 13 and award contracts to companies on January 12, 2024.

Chile's president also announced plans to hold a 2GW energy storage tender in 2024, aiming for projects to be operational in 2026. The Ministry of Energy introduced the Energy Transition bill to congress in July, which incorporates the storage tender proposal. According to the plan, the 2GW of capacity, planned for the north of the country, would be used mainly for energy shifting and would support a 40% reduction in energy curtailment by 2030. Congress has yet to vote on the bill.

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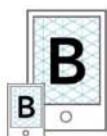
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