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Disruptive Innovations for Net Zero

Global Renewables Sector

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Renewable energy innovations to pave the road beyond grid-parity

In the past decade, we have witnessed dramatic cost reductions in renewables driven by technology improvements, which helped most of the world achieve grid-parity. For the next decade, a new round of innovations already in progress will bring global renewables demand to a new level, by making renewables more economical, efficient and available. With those innovations, we expect solar/wind costs to fall by another 33%/25% by 2025, and global solar/wind annual installation to rise from 165/67GW in 2021 to 386/112GW in 2025.

Solar: Conversion efficiency to be the focus

Over the next few years, we believe a new round of solar technology innovations will not only drive the grid-parity to a new level ("solar + energy storage" grid-parity), but also deeply change the competition landscape across the entire solar supply chain. In the past, technology innovations were more in the upstream of the solar supply chain, to reduce production cost, but in the future we expect the innovations will focus more on improving conversion efficiency and power output, to keep breaking the limit. Driven by these technology innovations, we expect the solar power generation cost to be further reduced by 33% to US$0.04/kWh by 2025.

Wind: Larger turbines with lower Levelised Cost of Energy (LCOE)

We expect the application of larger turbines to continue to be the main theme. In Europe, machines with 14-15MW rated output and 220-236m rotors from all the major OEMs will be ready from 2024. In China, many of the new projects launched now require onshore wind turbine units of 4MW/5MW. The rapid pick-up in unit size could lead to disruption across the supply chain as well as new technologies. In addition, further expansion into offshore areas will also grow the market.

Existing leaders will be strengthened by the innovations

In contrast to some views, we believe disruptive innovations will not be a threat to existing renewables leaders, because: (1) The next innovation cycle should get prolonged; (2) Squeezed margins reduce the incentive and capability of existing capacities' replacement; (3) Capital and R&D strengths of existing leaders allow them to diversify their tech portfolios. We estimate the global capacity shares of the top 5 solar polysilicon/wafer/cell/module makers will be further increased from 66/85/40/53% in 2020 to 74/87/51/59% in 2023.

Global Renewables Sector

These disruptive innovations will extend our path beyond grid-parity, by making renewable energies even more economical, efficient and available.

While renewables are bringing about significant changes to the global energy mix, there are several disruptive innovations happening within the renewables space itself. In this global report, we focus on some such innovations which are likely to accelerate the global progress in achieving the sustainability goals in energy transition and carbon neutrality. We leverage efforts of multiple global teams and estimate the potential impact of 14 innovations across solar/wind supply chains and what we believe has not been priced in by the market.

Renewable energy innovations to pave the road beyond grid-parity

In the past decade, we have witnessed dramatic cost reductions in renewables driven by technology improvements, which helped most of the world achieve grid-parity. For the next decade, a new round of innovations already in progress will bring global renewables demand to a new level, by making renewables more economical, efficient and available. With those innovations, we expect solar/wind costs to fall by another 33%/25% by 2025, and global solar/wind annual installation to rise from 165/67GW in 2021 to 386/112GW in 2025.

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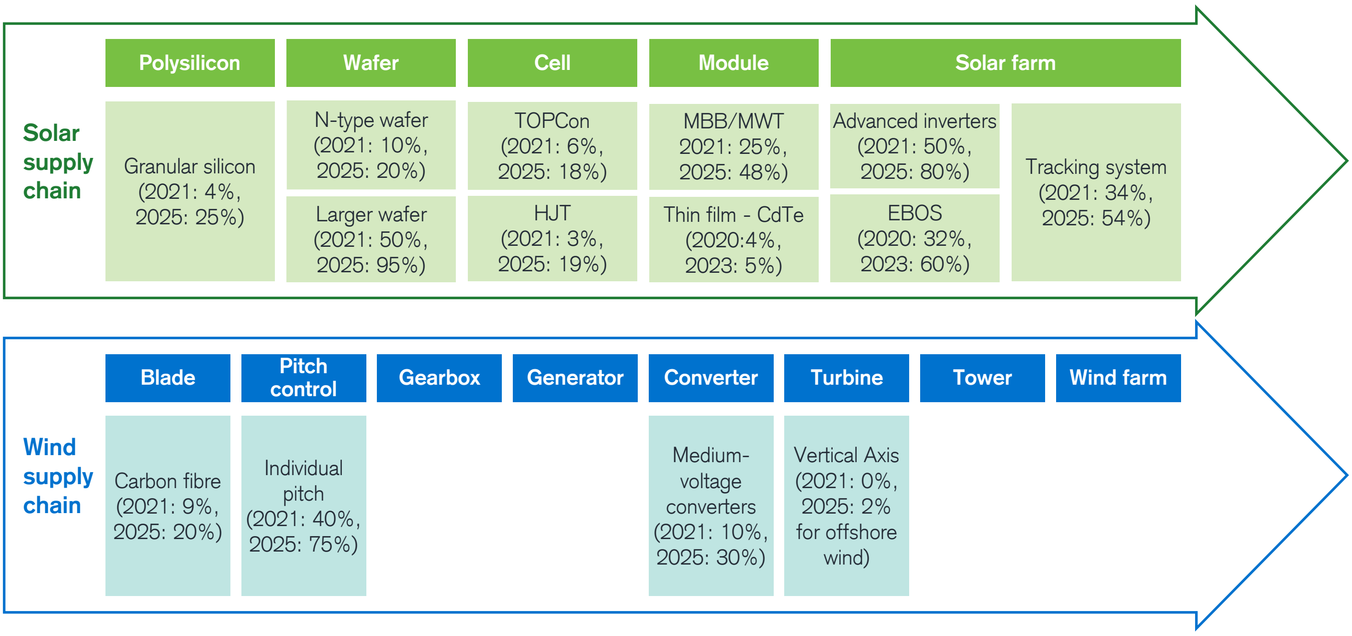
Demand upside and resilience of leaders not fully priced in

We expect the key component producers, equipment makers, materials providers and power project developers in the renewable supply chains to benefit most from the next round of tech innovations.

Figure 1: 14 disruptive innovations and our estimated market share changes



Note: TOPCon= Tunnel Oxide Passivated Contact; HJT= Heterojunction with Intrinsic Thin-layer; MBB= Multi-Busbars; MWT= Metal Wrap Through; CdTe= Cadmium Telluride; EBOS= electrical balance of systems.
Source: Credit Suisse

What to expect from new technologies in renewable energy

Another 33% and 25% cost reduction to be expected for solar and wind power, to be only US$0.04/kWh and US$0.03/kWh by 2025.

Innovations to pave the road beyond grid-parity

In the past decade, we have witnessed dramatic cost reductions in solar/wind power driven by continuous technology improvements across the supply chains, which helped most of the regions globally achieve renewables grid-parity. Based on our discussions, we believe the next round of innovations is happening now and will extend the path beyond grid-parity to bring the global demand for renewables to a new level, by making renewables more economical, efficient and available.

Next generation techs focussing on energy efficiency

There are two key directions in the technology innovation roadmap for renewable energy: (1) improving the energy conversion efficiency/power output; and (2) reducing direct costs in the production of the components. The ultimate goal is to lift the energy efficiency to a level as high as possible without significant incremental costs so that per Watt or per kWh renewable energy cost could be reduced. Unlike the last round of innovations, with exposures in both directions and focussing more on production cost reduction, we expect the next generation technology innovations to pay more attention to the energy efficiency improvement.

These include granular silicon for polysilicon, larger size/N-type for wafer, HJT/TOPCon for cell, MBB/MWT/thin film for module, and tracking system/EBOS/advanced inverters for power projects in solar; and carbon fibre for blade, individual pitch for pitch control, medium-voltage IGCT for converter, and vertical axis for turbine in wind. By adopting those innovations, we expect solar/wind power costs will reduce by another 33%/25% by 2025, and global solar/wind annual installation could be stimulated to 386GW/112GW in 2025.

Existing leaders to be strengthened by the innovations

Varying from some market views that consider the new round of technology innovations as a major threat to the existing leaders in the renewable supply chains, we believe the existing leaders' positions will be further strengthened, mainly because: (1) The next generation techs will focus more on energy efficiency improvement. This normally means the production cost may be increased first then can be reduced through mass production thereafter, which prolongs the whole tech replacement cycle and reduces the threat to existing players. (2) In the past year, the margins of key component makers across the renewable supply chains have been squeezed by both upstream material cost hikes and downstream end-user demand, e.g., we estimate the average gross margin of solar wafer/cell dropped from 30/15% in 2020 to 10/0% now. We expect the current deteriorated margins to reduce the incentive and capability of the renewable producers to aggressively replace existing capacities. Without massive production, the new technologies cannot be a threat to current capacities in terms of cost. (3) Thanks to the surging capital market in the renewables sector, the capital strengths and accumulated R&D of existing leaders now allow them to simultaneously develop in all the new major tech innovation directions, rather than focussing on just one technology in the early years. It also gives them the edge to add capacity more quickly if the visibility of a certain new technology becomes stronger. Therefore, we think the technology innovation and replacement will continue to happen, but the existing leaders will still be better positioned during that process. We estimate the global capacity share of the top 5 solar polysilicon/wafer/cell/module makers will be further increased, from 66/85/40/53% in 2020, to 74/87/51/59% in 2023.

Sector implications

We believe the market has priced in the stronger renewables demand stimulated by grid-party from the last round of tech innovations and global Net Zero efforts, and the potential threats to existing leaders from disruptive innovations, but has not yet fully priced in the resilience and strengths the existing leaders have over the next innovation cycle, and the demand and growth upside from the innovations to be further priced in. We expect the key related component producers, equipment makers, materials providers and power project developers in the renewable supply chains will benefit most from the next round of tech innovations.

Figure 2: Summary of the next-generation renewable technology innovations and the key beneficiaries

Sector	Segment	Key technology innovations	What is the purpose?	Our estimated market share of this tech
Solar	Polysilicon	Granular silicon	Reducing production cost and carbon emission during the production process	2020: 0%, 2021: 4%, 2025: 25%
	Wafer	Larger sized wafer	Improving power output and reducing unit power generation cost	2020: 5%, 2021: 50%, 2025: 95%
		N-type wafer	Improving a solar cell's conversion efficiency; better suitability to various environments	2020: 3%, 2021: 10%, 2025: 20%
	Cell	HJT	Improving conversion efficiency and power output; Reducing procedures in the production process	2020: 1%, 2021: 3%, 2025: 19%
		TOPCon	Improving conversion efficiency and power output; easier to upgrade existing PERC capacity	2020: 2%, 2021: 6%, 2025: 18%
	Module	MBB/MWT	Improving a solar module's conversion efficiency and power output	2020: 10%, 2021: 25%, 2025: 48%
		Thin film - CdTe	Reducing the dependence on crystalline silicon supply chain; Lower panel degradation	2020: 4%, 2023: 5%
	Solar power project	Tracking system	Improving energy efficiency and power output of the solar system and reducing unit power generation cost	2020: 29%, 2021: 34%, 2025: 54%
		Advanced inverter	Providing better feasibility of high voltage and energy storage	2020: 40%, 2021: 50%, 2025: 80%
		EBOS	Advanced wiring and connectors for faster project construction	2020: 32%, 2023: 60%
Wind	Blade	Carbon fibre	Can support longer blades as the material is stronger and lighter.	2020: 7%, 2021: 9%, 2025: 20%
	Pitch control	Individual pitch system	Adjusting the pitch of each rotor blade independently from other blades, thus reducing the loads on the wind turbine in blades, hub and tower.	2020: 30%, 2021: 40%, 2025: 70-80%
	Converter	Medium-voltage converter	As power ratings of wind turbines increase, medium-voltage converters become more competitive with low power loss, high efficiency, small size and ease of installation and maintenance.	2020: 8%, 2021: 10%, 2025: 30%
	Turbine	Vertical Axis	Low centre of gravity of VAWTs, which sit well with offshore floating platforms.	2020: 0%, 2021: 0%, 2025: 2% for offshore wind

Note: Using global annual solar/wind installation volume to estimate the market shares.

Source: Credit Suisse

“What will the next generation solar panels look like? Larger, thinner, trackable and more powerful.

Solar: Conversion efficiency to be the focus

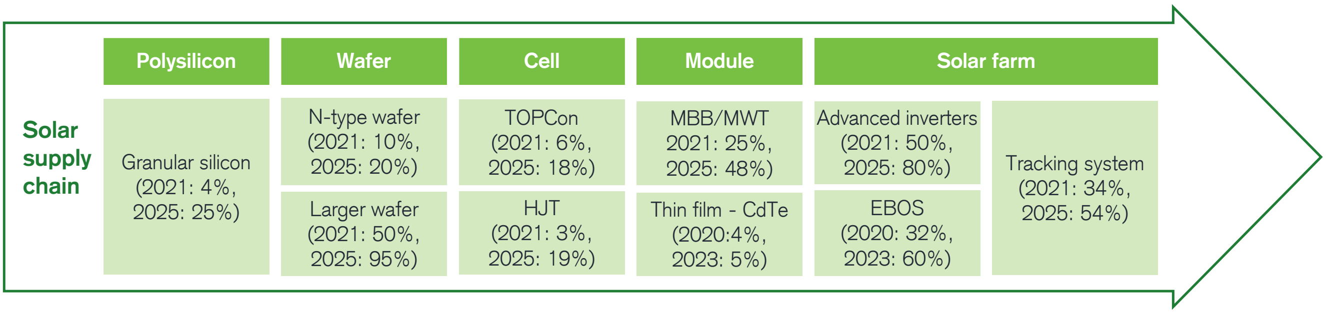
In the last round of innovations, solar technologies were focussing more on reducing the direct costs in component production. In the next round of innovations, the focus will be more on improving conversion efficiency and power output.

Solar technology innovations, whether in the past or the next decade, focus on two correlated directions: (1) improving the conversion efficiency (from insolation to electricity) and (2) reducing the production cost of the components. The ultimate goal is to lift conversion efficiency to a level as high as possible, but without significant incremental costs created, so that per Watt or per kWh solar power cost could be reduced.

In the past decade, we have witnessed the dramatic cost reduction in solar power from US$0.38/kWh in 2010 to US$0.06/kWh in 2020, helping most of the regions globally to achieve grid-parity (solar power cost lower than the power generation cost or price of other power sources). A series of key technology innovations across the board/globe played a major role during that process, including: (1) reducing the production cost: modified-Siemens method (hydro-chlorination) for polysilicon, mono-silicon wafer and diamond-wire cutting for wafer; (2) improving the conversion efficiency/unit power output: PERC (Passivated Emitter and Rear Contact) for cell and bi-facial and half-cut for module.

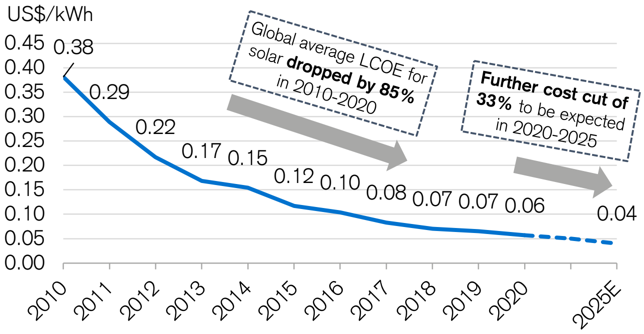
Over the next few years, we believe a new round of solar technology innovations will not only drive grid-parity to a new level ("solar + energy storage" grid-parity) through further cost reductions, but also deeply change the competitive landscape across the entire solar supply chain. In the past, technology innovations were more in the upstream of the solar supply chain, to reduce production cost, but in the future we expect innovations will focus more on improving conversion efficiency and power output, to keep breaking the limit. The technology innovations we think will be most relevant and impactful include: (1) reducing the production cost: granular silicon for polysilicon; (2) improving conversion efficiency/unit power output: larger size and N-type for

Figure 3: Major solar innovations and our estimated market share changes



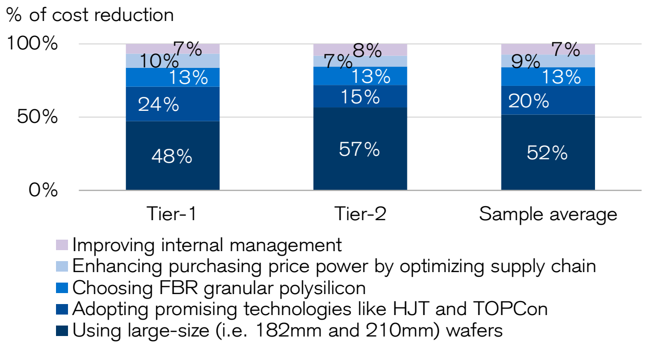
Source: Credit Suisse

Figure 4: Solar power generation cost reduction to continue



Source: Company data, IRENA, Credit Suisse

Figure 5: China Quantitative Insights (CQi) surveys to solar producers: What will be the main paths for you to cut production costs in 2022-25?



Note: The survey included 22 major solar producers. Source: CQi surveys.

wafer, HJT (Heterojunction with Intrinsic Thin-layer) and TOPCon (Tunnel Oxide Passivated Contact) for cell, MBB (Multi-Busbars)/MWT (Metal Wrap Through) and thin film for module, tracking system, EBOS (Electrical Balance of Systems) and advanced inverters for solar power project. Driven by these technology innovations, we expect the solar power generation cost to be further reduced by 33% to US$0.04/kWh by 2025.

Polysilicon: 20% more cost reduction can be expected

Granular silicon

Modified Siemens method and fluidised bed reactor (FBR) are the two major technologies in solar-grade polysilicon production. The first one (Siemens method) produces polysilicon in rods, and currently has a dominant market share (~96%) among existing capacities, helped by its mature technology and consistent product quality. In recent years, FBR technology (or its granular polysilicon product) is also starting to gain some market traction, especially after GCL Poly's granular polysilicon capacity expansion from 6kt in 2020, to 10kt in February 2021 and 30kt in November 2021, which has received decent feedback from its downstream wafer customers. Based on our estimates, the global market share of granular polysilicon may grow from 4% in 2021, to 11% and 18% in 2022E and 2023E respectively.

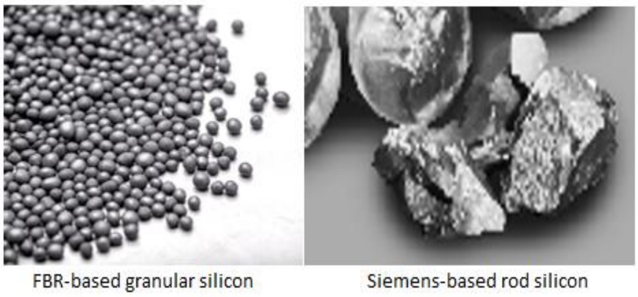
What is this technology innovation?

Compared with the mainstream modified Siemens method, the key advantage of granular polysilicon is its lower electricity consumption. For the Siemens method, the usual unit power consumption for every kilogram of polysilicon is close to 60 kWh. For FBR, however, it is much lower, at 15-20kWh. Assuming an electricity rate of Rmb0.25/kWh (or Rmb0.22/kWh ex. VAT), this 40-45kWh electricity consumption saving may help reduce unit production cost by around Rmb9-10/kg, per our calculation. We expect other costs to be largely similar between the two methods. As a result, we calculate granular may have 25%/23%/20% cost advantage at unit cash cost/production cost/all-in cost levels. Such cost advantage (around Rmb10/kg) may not make a big difference at the moment, as polysilicon is now selling at an extremely high price of >Rmb200/kg (incl. VAT) due to supply shortage. However, it could become a more important factor over the long run, when polysilicon price normalises (say at around Rmb80/kg).

What is our view?

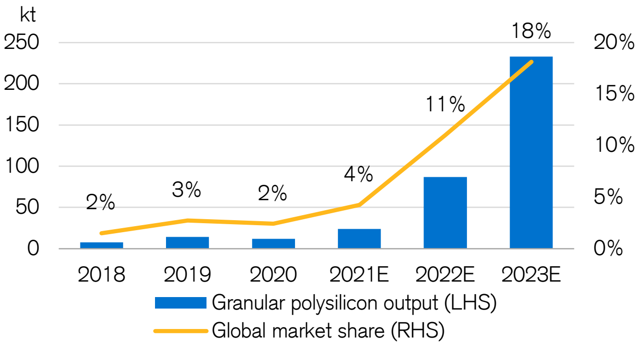
We expect there to be market demand for granular polysilicon going forward as a blending poly input. At the moment, most leading wafer companies we talked to believe that >20% blending ratio is achievable without causing wafer quality defects. Besides, they also believe that the ratio can be higher if further quality improvement on its granular polysilicon product is achieved. We estimate 25% market share for granular polysilicon by 2025 (vs 4% by 2021).

Figure 6: Granular silicon vs. rod silicon



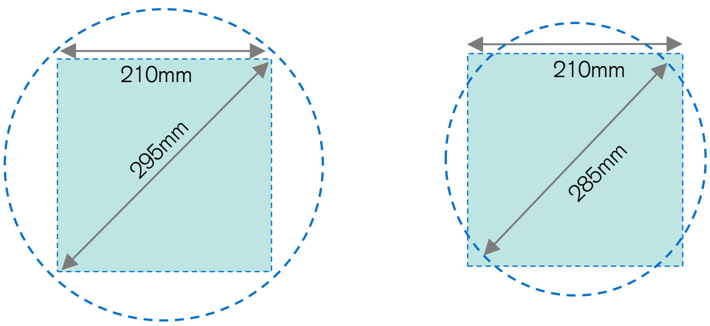
Source: Industry

Figure 7: Granular polysilicon—annual output and market share



Source: Industry, Credit Suisse

Figure 8: Current largest size of solar wafer—210x210mm



Source: Credit Suisse

Wafer: the larger (not necessarily) the better

Larger sized wafer

What is this technology innovation?

Solar wafer is the foundation of a solar cell/module, which not only decides the size of a solar cell but also has a major impact on its conversion efficiency. Wafer is normally in a square shape. In the past decade, its size has increased from125x125mm in 2010 to 210x210mm now. The major driver of this trend is to reduce per Watt cost of the solar system, by enlarging the total power output per solar module (normally consisting of 50 to 72 pieces of wafer) to dilute the fixed costs of the system.

Currently several sizes of wafer are under commercial production, including 158.75/166/182/210mm. The key questions and debates are still going on: Is 182mm or 210mm more suitable and economical for the solar installation in the next few years? Will 210mm be the cap size or will an even larger one emerge?

What is our view?

1. **Larger wafers will grab larger market share at a faster pace**

Driven by better per-Watt cost-efficiency, we believe the new capacity additions of larger-sized wafers (182/210mm) and the replacement of existing smaller-sized capacities will be accelerated in the next 1-2 years. We think this trend will be strengthened by the further cost reduction through mass production after more capacities ramp up.

Meanwhile, we expect this trend to be further stimulated by the development of utility-scale solar projects. Driven by the global efforts on carbon emission control and energy transition, utility-scale solar projects are becoming a major driver of renewable energy development, because per-project capacity is much larger than distributed projects, which will accelerate renewable capacity addition growth. For example, China recently announced its plan regarding the construction of large bases of solar/wind power projects. Large-sized solar modules are more suitable for utility-scale projects in terms of feasibility and economy, which will provide more opportunities for larger-sized wafer.

2. **182mm and 210mm sizes will co-exist, and the chance of an even larger size emerging is low**

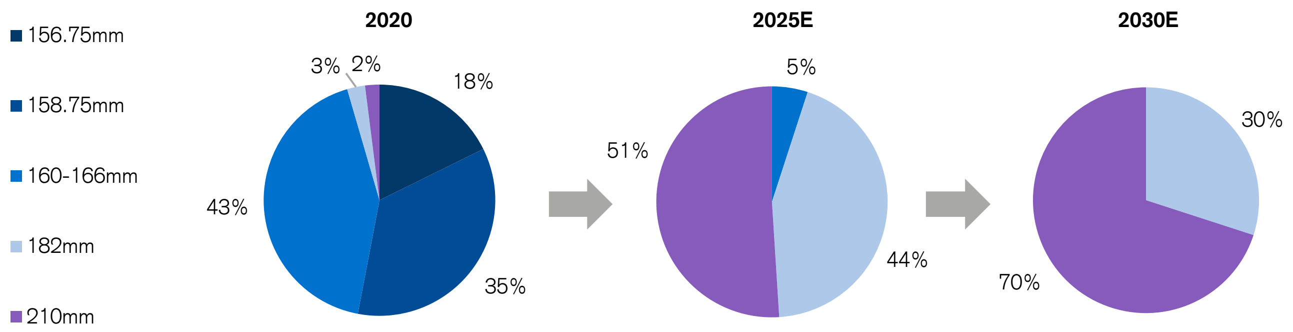
Considering that there is no absolute advantage yet for 182mm or 210mm wafer against each other – mostly no major per-Watt cost difference, we think both sizes will co-exist in the next few years, but as a whole, they will replace the smaller sizes promptly. However, we believe the chance of a larger-than-210mm sized wafer is low, because the already known issues like lower yield rate and higher breakage ratio in the production process will become even more serious when the wafer size goes larger, which will significantly reduce the cost-efficiency of the wafer. We think 210mm seems to be the cap of the economical solar wafer size. Overall, we estimate the penetration rate of 182mm and 210mm wafer will increase from less than 5% in 2020 to over 90% in 2025, and the sizes below 160mm may disappear in the next 2-3 years (Figure 9).

N-type wafer

What is this technology innovation?

There are two major types of solar wafer in terms of technologies: P-type and N-type. Currently P-type/N-type wafers account for 87%/3% of the global solar wafer capacity, while N-type wafer's market share is expected to pick up quickly. The two types differ from each other mainly because of the internal structural differences: To bring electro–conductibility to the silicon materials, certain elements need to be added during the wafer production process, which include the two most important elements—boron and phosphorus. The wafer with boron added is called P-type and the one with phosphorus added is N-type wafer. Generally, P-type wafer has a relatively simpler production process and is more mature, while N-type provides larger potential for solar cells with high conversion efficiency.

Figure 9: Solar wafer market shares breakdown by sizes



Source: Company data, Multiple solar wafer makers, China Photovoltaic Industry Association, Credit Suisse

What is our view?

1. **It will take time for N-type wafer to overcome the market share of P-type**

We think the reluctance of wafer makers to aggressively expand capacity in N-type or replace current P-type is still significant, mainly because: (1) Most of the existing P-type wafer capacities were added in the past two years, and are still in their payback periods. Investment in N-type wafer capacity is relatively capital intensive, and will require incremental capital right after the wafer makers' last round of major investments. (2) Due to the aggressive capacity expansions, the nameplate capacity of P-type wafer is still in serious oversupply, which we think will limit the upside in ASP/margin for either P-type or N-type wafer. (3) It also depends on the solar cell makers' adoption of, and capacity expansions for, N-type products, which were restrained by current low margins.

Therefore, we think the penetration of N-type wafer will be at a gradual pace until wafer supply-demand gets more balanced and the N-type capacity expansion in cell gets accelerated by improved margin outlook. Overall, we estimate the penetration rate of N-type wafer will increase, from 3% in 2020, to over 20% in 2025 and around 50% in 2030 (Figure 10).

2. **New entrants will not be a major threat to current existing wafer leaders**

Several new wafer players have announced their aggressive capacity expansion plans, and some of them claimed they have leading technology advantages in N-type wafer. Also, the existing wafer leaders haven't announced their significant moves into the N-type area. All this has made the market concerned about the threat from new N-type wafer makers to existing wafer leaders. However, we think the threat will be limited, because: (1) current wafer leaders not expanding aggressively in N-type does not mean that they do not own the edge in N-type; they may just be holding on, mainly due to economic considerations. The current leaders' continuous investments in R&D and capital strength will be their edge in N-type wafer. (2) The margin gaps in P-type wafer between the current wafer leaders and others showcase the cost leadership, which will likely be applicable to N-type wafer also. (3) As the fundamental component of solar cell/module, wafer decides the quality and output of downstream products. Therefore, the track record of wafer makers' product delivery and quality will be key for their clients, and current leaders have accumulated advantages from that perspective. (4) Some of the current leading wafer makers have developed vertically-integrated capacity from wafer to module, and they can guarantee a certain part of their wafer production will be consumed internally, which will be better-positioned compared with the pure wafer makers (100% dependence on external wafer customers).
(5) Current wafer leaders have already built long-term relationships with their upstream polysilicon makers and signed long-term supply contracts, which is crucial under the current tight supply of polysilicon.

Cell: HJT and TOPCon—a neck and neck race

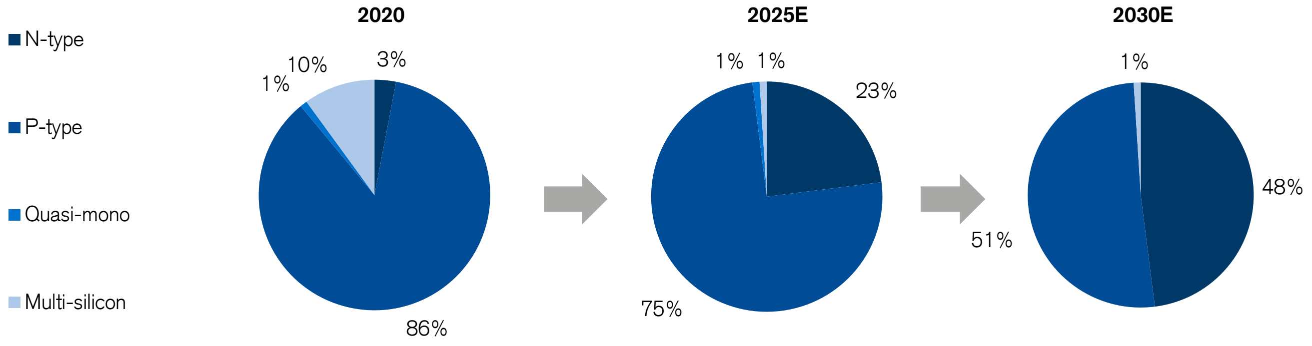
HJT

What is this technology innovation?

HJT or HIT (Heterojunction with Intrinsic Thin-layer) is a solar cell technology based on N-type silicon wafer substrate, using non-silicon thin film as the passivation layer, which is different from traditional cells using silicon materials for both substrate and passivation layer. Compared with traditional cells, HJT cell has higher conversion efficiency but with increased production cost. It is not a new technology, having been developed by a Japanese company in 1990, which registered the patent for "HIT" until the patent protection period ended in 2015, with the rest cells using heterojunction technology called "HJT", and that's the reason why both HIT and HJT refer to heterojunction technology.

Though HJT is not new, it had not been put into massive commercial production until recent years, mainly due to the relatively high cost and low economy compared with current generation of PERC cell. Thanks to the breakthroughs in HJT-related technologies, equipment and materials in recent years, HJT cell has been lifting its conversion efficiency premium and reducing the cost gap. As of end-2021, we estimate the global manufacturing capacity for HJT cell is 11GW, accounting for only 3% of global solar cell capacity, which we think has significant upside through HJT technology's continuous evolution.

Figure 10: Solar wafer market share breakdown by types



Source: Multiple solar wafer makers, CPIA, Credit Suisse

What is our view?

HJT will eventually replace PERC, but the progress could be delayed and prolonged. When some of the cell makers announced their capacity expansion plans in HJT from 2H19, the market previously expected the penetration of HJT in global solar demand would rise to over 20% as early as 2021, but it is only low single digit at end-2021. We expect the replacement by HJT to take longer, mainly because: (1) Margins are not favourable for HJT cell: The higher capex and materials cost increased the production cost of HJT cells, while the ASP premium of HJT cell vs PERC cell is still limited, which caused even lower margins for HJT cell. Based on our estimate, the production cost of HJT is US$0.17/W, 20% higher than US$0.14/W of PERC cell, but the ASP premium now is only around 10%; (2) Breakthroughs in PERC cell prolonged its shelf life: Thanks to the continuous innovations and modifications on current PERC cell capacities, the conversion efficiency of PERC and upgraded PERC+ cells have been improved from 20-22% in 2019 to 21-23% in 2021, bringing back more competitiveness vs HJT cell; (3) Cell makers not in an ideal position to aggressively invest in HJT capacity: Squeezed by both upstream polysilicon/wafer price hikes and downstream demand pressure, the gross margin of cell has been at a historical low level of 5-10% in the past one year, which we think significantly reduced the incentive of cell makers to aggressively add new capacity in HJT, especially considering current PERC cell capacity is still in the middle of its payback period and there is oversupply in the overall cell capacity. However, given the existing cap of PERC cell, we believe the replacement by HJT will eventually happen, and will be accelerated in the next 2-3 years when more Chinese equipment makers and material providers penetrate the supply chain to bring down the costs in both capex and materials for HJT. Overall, we estimate HJT cell capacity to account for 19% of global solar cell capacity in 2025, vs 3% in 2021.

TOPCon

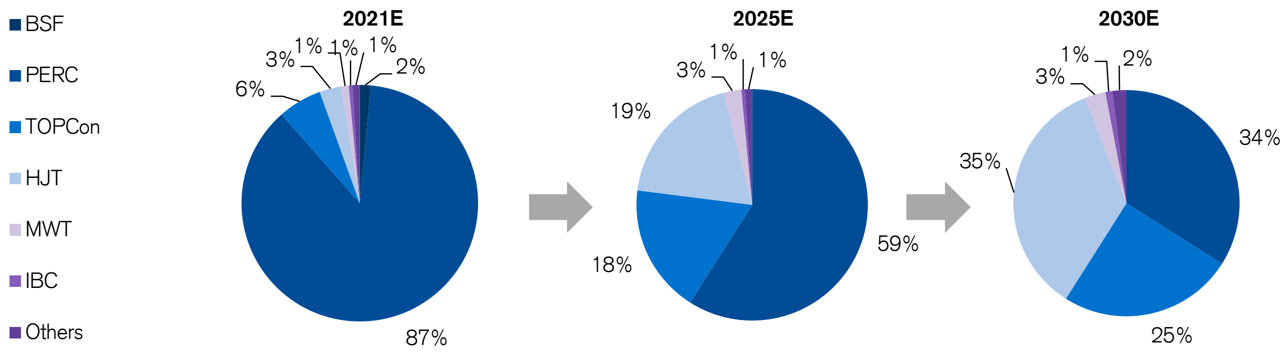
What is this technology innovation?

TOPCon (Tunnel Oxide Passivated Contact) is a solar cell technology providing higher conversion efficiency than traditional cells. Mostly based on N-type silicon wafer substrate, the key difference is the passivated backside the TOPCon cell has: with a thin layer of SiO_2 and the non-silicon mixture on the surface of the layer. Though having the leading conversion efficiency, its relatively higher cost and lower production yield rate have slowed down the penetration of TOPCon cell, which only accounts for 6% of global solar cell capacity in 2021 but with a series of announced capacity expansions in the pipeline.

What is our view?

Though the replacement of PERC may be delayed, we expect TOPCon and HJT to go fifty-fifty in new additional market shares. As we discussed earlier, the not yet favourable margins of new generation cells and the breakthroughs in current PERC cell have prolonged the shelf life of PERC, but the replacement will be accelerated once the cost of new-gen cells is brought down to a sweet spot.

Figure 11: Solar cell market share breakdown by technologies



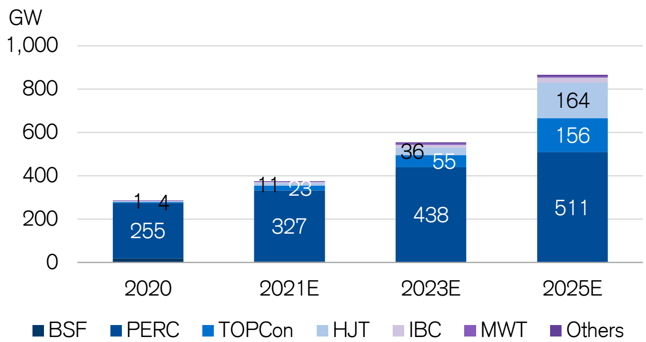
Source: Multiple solar cell makers, CPIA, Credit Suisse

Figure 12: Solar cell conversion efficiency comparison

Solar cell types		2020	2021	2025E	2030E
	BSF multi	19.4%	19.5%	-	-
P-type multi	PERC multi	20.8%	21.1%	21.7%	22.5%
	PERC quasi-mono	22.3%	22.6%	23.3%	23.7%
P-type mono	PERC mono	22.8%	23.1%	23.7%	24.1%
	TOPCon mono	23.5%	24.0%	25.0%	25.7%
N-type mono	HJT	23.8%	24.2%	25.2%	25.9%
	IBC	23.6%	24.0%	25.0%	25.8%

Source: CPIA, company data, Credit Suisse

Figure 13: Global solar cell manufacturing capacity forecasts



Source: Multiple solar cell makers, CPIA, Credit Suisse

We believe the replacement for PERC will definitely happen in the next few years, and TOPCon and HJT will equally enjoy the market shares of the new generation cells, mainly because TOPCon is mostly preferred by existing cell makers as they can upgrade their PERC lines, while new entrants would prefer HJT more as it has more compressed production procedures. There are over 300GW of PERC cell capacities globally under operation now, and most of them are still in the middle of their payback periods. In the meantime, a batch of new entrants in the cell segment are targeting HJT, which they believe can help them gain an edge over the non-upgraded PERC cell capacities. On the other hand, the differences in per Watt cost and conversion efficiency upside are not significant enough to let either of the two gain absolute advantage over the other.

We believe TOPCon and HJT will have market-leading shares among next-generation solar technologies, while other new techs like IBC (Interdigitated Back Contact) or PERT (Passivated Emitter and Rear Totally-diffused) will have relatively limited market shares due to the conversion efficiency or cost gaps. We expect TOPCon/HJT capacity to grow from 4GW/3GW in 2020 to 156GW/164GW in 2025, implying 18%/19% of global cell capacity in 2025.

Module: room still exists for power output accretion

MBB/MWT

What is this technology innovation?

MBB (Multi-Busbars) and MWT (Metal Wrap Through) are both cell/module packaging technologies, to improve power output of solar module through innovations on the busbars. MBB increases the amount of busbars on the surface of solar cell/module and reduces the width of the busbars. MWT removes the busbars on the surface by arranging them at the rear of a cell/module.

What is our view?

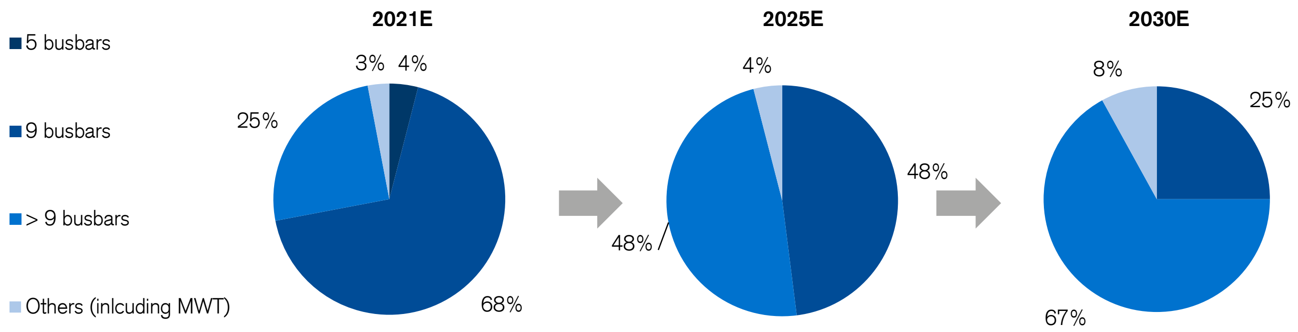
Thanks to their improvement of power output and reduction of silver paste usage, we expect the penetration of MBB and MWT modules to keep growing in the next few years, especially for the ones with over 9 busbars, and this trend to be strengthened by the newly added cell/module capacities. We estimate the market share of MBB modules with over 9 busbars to increase from 25% in 2021 to 48%/67% in 2025/2030.

Thin film module: Cadmium Telluride technology (CdTe)

What is this technology innovation?

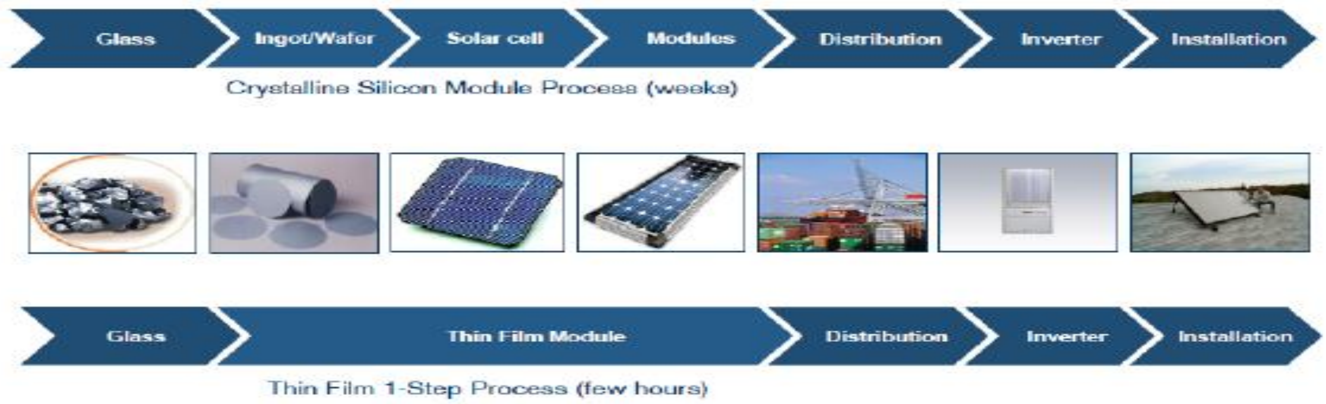
The thin-film CdTe technology is similar in function compared to c-Si modules and can be used interchangeably. The most common commercially available module technologies are on multi-crystalline (lower efficiency) and mono-crystalline silicon (higher efficiency).

Figure 14: Solar module market share breakdown by the number of busbars



Source: Multiple solar cell makers, CPIA, Credit Suisse

Figure 15: Thin Film—Simpler Production Process



Source: Leading industry player, Credit Suisse

The process is simpler, involves fewer steps, is fully integrated, not dependent on polysilicon as a raw material, and takes less time to produce. Compared to its crystalline silicon competitors, the production technology of CdTe uses different raw materials (cadmium telluride vs polysilicon for others), uses a simpler method that produces a solar module from raw materials within few hours (vs weeks for crystalline silicon).

The Copper Replacement module technology achieves greater efficiency and lower LCOE. It delivers the lowest warranted degradation rate and highest life-time energy for large-scale solar projects.

What is our view?

This technology is the biggest beneficiary of import tariffs in the US against c-Si module manufacturers. For thin film module, we estimate 5% market share by 2023 (vs 4% in 2020).

Solar power project: diluting the unit fixed costs

Tracking system

What is this technology innovation?

A tracking system is applied on solar power projects to improve the power generation volume, by making the solar panels track the movements of the sun. The types of solar structure include: single-pole or dual-pole fixed structures in horizontal or vertical direction, adjustable fixed structure and tracking system.

What is our view?

Global penetration of solar tracking system will continue to grow by stronger demand outlook in utility-scale solar projects.

We expect penetration of the tracking system to accelerate in the next few years, mainly driven by countries like China with stronger demand outlook in utility-scale solar projects. We also think the future cost reduction through potential price cuts in solar module and materials for tracking system will stimulate penetration. According to Wood Mackenzie, the market share of the solar tracking system in the global utility-scale solar installation will increase from 34% in 2021 to 54% in 2025; we estimate the total addressable market for solar tracking systems to grow to US$7 bn per year with a 13% CAGR through 2025.

Solar EBOS

What is this technology innovation?

Solar EBOS comprises all of the components that work together to transmit the electric current produced by solar panels to an inverter and ultimately to the power grid. EBOS components typically include cable assemblies, inline fuses, combiners, disconnects, recombiners, wireless monitoring systems, junction boxes, transition enclosures and splice boxes. EBOS wiring architecture is primarily of two types: homerun and combine-as-you-go. In conventional homerun architecture, each string of solar panels in the project is individually connected to a combiner box using separate wires. The combiner box ties the individual wire runs into a single feeder wire that transmits the electric current to the inverter, where it is converted from DC to AC so that it can be ultimately fed into the power grid. On the other hand, the combine-as-you-go architecture connects all strings in a project to “trunk” wires that feed directly into disconnect boxes, which are connected to the inverter. Due to the high installation-to-component cost ratio, many EPCs prefer combine-as-you-go EBOS products due to the simple plug-n-play architecture, which makes installation faster using inexpensive general labour, over homerun EBOS, which are time consuming to install and require licensed electricians.

What is our view?

The leading player stands to benefit from the accelerated demand growth in the US due to renewable tax credit extension and incentives (for solar, storage, EV chargers).

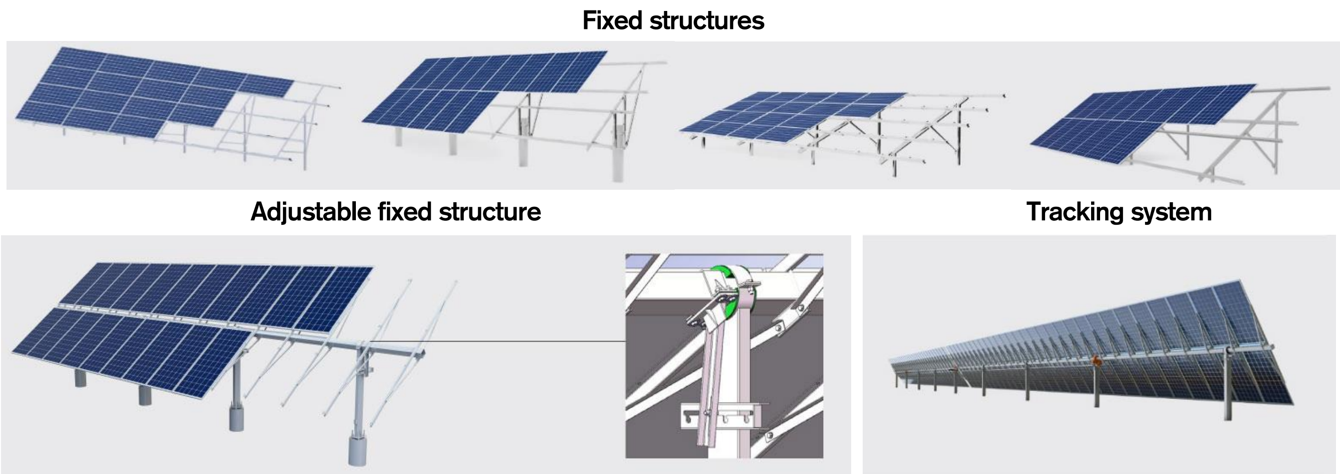
Advanced inverters

What is this technology innovation?

Inverters are used to convert Direct Current generated by modules to Alternating Current for connection to the grid system, and can affect the power generation efficiency as well as stability. There are four major categories of inverters: central inverters, string inverters, modular inverters and micro-inverters, with applications listed as below.

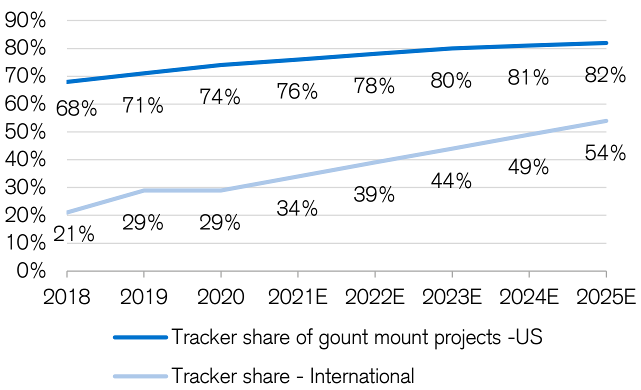
The key competitive edge comes from circuit and algorithm design capability, supply chain management and quality control, as well as marketing channels. Through lower cost driven by large-scale production and domestic substitution, top players in China grew rapidly in recent years and now account for a majority of the total market share of inverters in terms of shipment volume. Currently, IGBT is the only core device that hasn’t realised domestic substitution.

Figure 16: Different types of solar structures



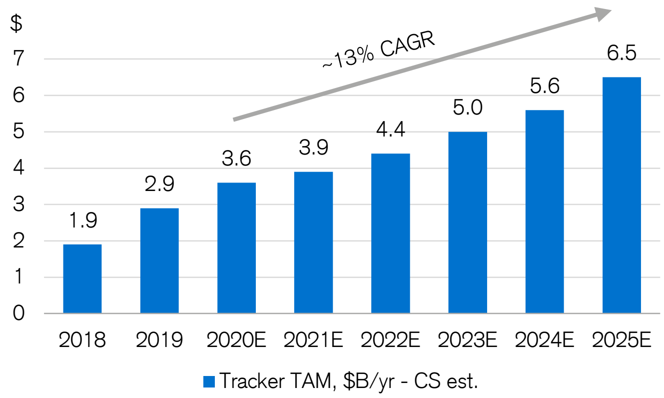
Source: Industry

Figure 17: Share of solar trackers to grow in the US and global market



Source: Wood Mackenzie, Credit Suisse

Figure 18: CS expects the total addressable market for solar tracker to see 13% CAGR through 2025 to US$7 bn/yr



Source: Credit Suisse

Higher voltage inverters for utility-scale solar farms: As China continues to build utility-scale solar farms, we expect higher penetration of inverters with higher voltage ~1,500V. Compared to 1,000V inverters which are currently widely adopted, 1,500V inverters can reduce line loss and improve generating efficiency. In the meantime, higher voltage would require fewer PV strings and arrays, thus bringing down total construction cost in the system. Increased voltage also demands enhanced system security and more reliable equipment parts.

Hybrid inverters integrating energy storage: The future trend is to integrate solar and energy storage inverters, which could effectively increase the utilisation for power generation. During peak usage hours in the daytime, direct current generated by modules can be converted to alternating current and get connected to the power grid. In the evening during valley hours, energy storage batteries can be charged by the grid through inverters. When the sunlight is insufficient, or during peak usage hours, power stored in batteries can be released through inverters to alternating current.

Application in data collection: Inverters not only carry the responsibility of converting direct current to alternate current, but also perform the function of collecting data and monitoring the system. It can also transfer instant data to cloud for easier review and management.

What is our view?

Following the launch of utility-scale solar farms in large energy bases in China, we see the wider application of higher voltage inverters. Hybrid inverters, which perform the functions of energy storage and data application and are also gaining traction though cost, are still a concern for solar farms equipped with energy storage facilities. We expect significant improvements in costs and advanced inverters to gain 80% market share by the end of 2025.

Figure 19: Comparison on the four types of inverters

	Central inverters	String inverters	Modular inverter	Micro-inverters
Power rating	>500kW	3-220kW	50-1000kW	0.25-2kW
Maximum input voltage	1,000V	600-1,000V	600-1,000V	60V
Number of modules for max output	~3,000 pieces	10-1,000 pieces	150-3,000 pieces	Single piece module
Applicable to distributed rooftop solar?	No	Yes	Yes	Yes
Voltage of Direct Current	1,000V	1,000V	1,000V	60V
Unit price per watt	Low	Medium	Medium	High
Major applications	Utility-scale solar farms	Utility-scale solar farms, distributed solar (commercial & industrial, residential)	Utility-scale solar farms, distributed solar (mainly commercial & industrial)	Distributed solar (mainly residential)

Source: Industry sources, Credit Suisse

“Larger wind turbines, lower unit capex, higher utilisation hours and lower Levelised Cost of Energy (LCOE).

Wind: Larger turbines with lower LCOE

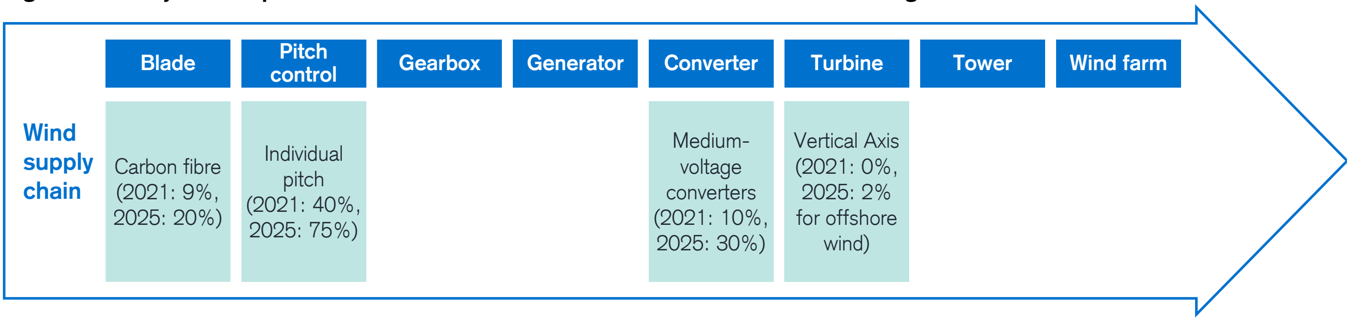
We expect the application of larger turbines will continue to be the main theme, which could lead to disruption across the supply chain as well as new technologies. In the meantime, further expansion into offshore areas will also lead to other developments.

Wind technology has been consistently following the trend of adopting larger turbines. In Europe, the move from c3.6MW rated output with 112m diameter rotors up to 10MW with 174m diameter rotors has been the main improvement. In China, mainstream unit turbine capacity reached 2.0-2.9MW in 2020 (maximum capacity at 5MW), and average unit capacity reached 2.6MW, 76% increase compared to 2010. For offshore wind, mainstream unit turbine capacity reached 5.0MW and above (maximum capacity at 10MW), and average unit capacity reached 4.9MW, 85% increase compared to 2010. The application of larger turbines led to lower unit CapEx, higher utilisation hours and lower LCOE. In the meantime, the OEMs have worked to reduce cost through modularisation and standardisation during production. Technology improvement also led to reduced downtime and higher load factors.

According to International Renewable Energy Agency (IRENA), LCOE for onshore and offshore wind declined by 39% and 29% respectively globally between 2010 and 2019. Such a trend is more obvious in Europe, as the LCOE for offshore wind fell from c.€160/MWh in 2013, to €52/MWh for projects completing today, a 67% drop. The decline in LCOE in China was relatively smaller though.

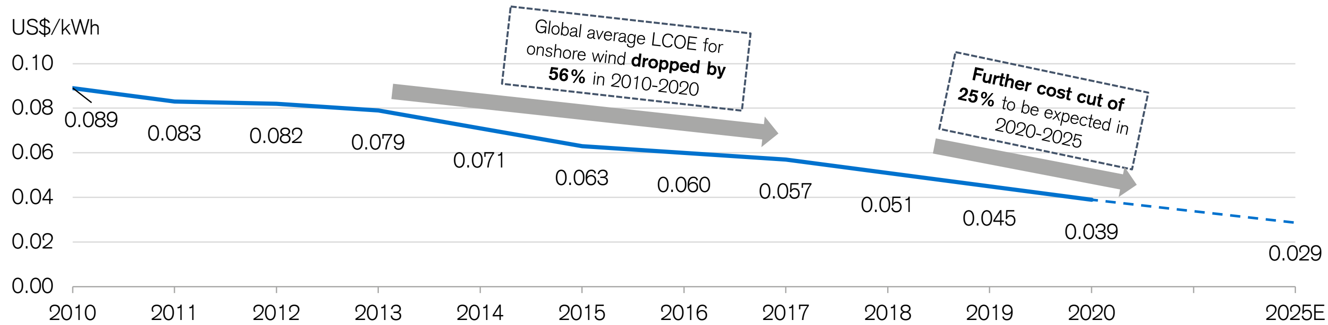
We expect the application of larger turbines to continue to be the main theme. In Europe, machines with 14-15MW rated output and 220-236m rotors from all the major OEMs will be ready from 2024. In China, many of the new projects launched now require onshore wind turbine units of 4MW/5MW. The rapid pick up in unit size could lead to disruption across the supply chain as well as new technologies. In the meantime, further expansion into offshore areas also lead to other developments. We identify four technologies in our report: (1) carbon fibre for longer turbine blades which enjoys distinct advantages over glass fibre as the material is stronger and lighter. (2) Individual pitch system which adjust the pitch of each rotor blade individually and lead to load reduction. (3) Medium-voltage IGCT converters which are more competitive in higher power

Figure 20: Major wind power innovations and our estimated market share changes



Source: Credit Suisse

Figure 21: Wind power generation cost reduction to be continued



Source: IRENA, Credit Suisse

wind turbines. (4) Renewed interest in Vertical Axis Wind Turbines (VAWT) with low centre of gravity and can fit well with floating offshore wind platforms.

Europe: 14-15MW rated output will be ready from 2024

The Levelised Cost of Electricity for offshore wind in Europe has fallen from c.€160/MWh in 2013, to €52/MWh for projects completing today. For projects reaching final investment decision (FID) today, and coming online in 2025, there is an LCOE of €45/MWh. There are several items that have driven this:

1. **Larger turbines:** The move from c.3.6MW rated output with 112m diameter rotors up to 10MW with 174m diameter rotors has been the main improvement. Machines with 14-15MW rated output and 220-236m rotors from all the major OEMs will be ready from 2024. As the turbine size has quadrupled, the balance of plant has not. If anything, items such as inter-array cables became cheaper as there are fewer absolute turbines to link up;
2. **Efficiencies in production:** The OEMs have worked to reduce cost through modularisation and standardisation. They have also found more efficient ways to transport the turbines, such as using purpose built Ro-Ro vessels. Installers of turbines have found ways to use dynamic positioning barges, rather than jack and lift, which take longer to do an individual install;
3. **Reduced downtime:** The machines are c.98-99% available. This is because of higher quality, predictive maintenance and fewer moving parts. Further, turbines are able to quickly commission, with much of the process work done on the quayside where cost is lower, rather than at sea where costs are higher;
4. **Higher load factors:** Turbines are able to get c55%, driven by better blades and positioning further out to sea. The wind speed-power output curve has been shifted to the left; and
5. **Lower WACC:** Projects have become more financeable. Debt finance and insurance is easier to get. For example, debt at rates of SONIA + 125bp is possible. We estimate that hurdle rates have fallen from c.9-10% post tax nominal down to c.5-6% post-tax nominal.

There is ever-increasing requirement for local content, which can increase cost. However, the above items have prevailed.

We would expect the current generation of turbines under development to be upgraded to blades with diameters of up to 250m and 17-18MW rated output.

Turbine suppliers: only space for 2 or 3 companies

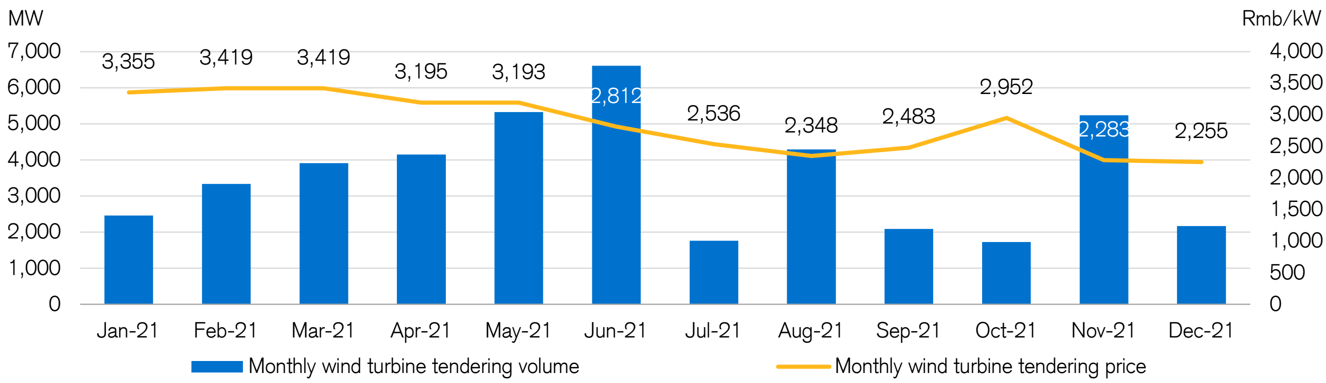
Only one profitable offshore turbine OEM across 2020-25E: At present, only one turbine OEM makes a materially positive EBIT margin in offshore. The company has c.65% market share in offshore and enough business to produce c.2GW even in a trough year such as 2020. Indeed, volumes are running at c.3GW p.a., ex China.

Breakeven for offshore wind turbine production at the EBIT level is around c1.5GW. That is to say, at least 3 turbines per week. This is because there are high Research and Development costs associated with having a product and nacelle assembly facilities. Blades are usually produced in-house, which further increases the fixed cost in the business and makes for a high entry hurdle.

China: application of large wind turbines to accelerate post grid-parity

Post grid-parity in China, pricing has been on a downward trend, driven by the pressure on post reduction and product upgrades. According to industry data consolidated by one of the leading companies, average tendering price for 3MW and 4MW turbines declined by 22-23% since the beginning of 2021 to Rmb2,410 and Rmb2,326 per kW in September 2021 respectively. Per latest bidding results, average bidding price for wind turbines decreased further to ~Rmb2,255 per kW in December 2021, which was a 33% drop from the price in January 2021. As the tendering price approaches the break-even point for wind turbine makers, we see a few areas which could help mitigate the impacts from the decline in tendering price.

Figure 22: Wind tendering volume and price by quarter



Source: Bid Centre, Credit Suisse

1. Wider application of larger-scale units

According to Chinese Wind Energy Association, mainstream unit turbine capacity reached 2.0-2.9MW in 2020 (maximum capacity at 5MW), and average unit capacity reached 2.6MW, 76% increase compared to 2010. For offshore wind, mainstream unit turbine capacity reached 5.0MW and above (maximum capacity at 10MW), and average unit capacity reached 4.9MW, 85% increase compared to 2010. Post grid-parity, wider application of larger-scale turbine units have become more common and we see significant increase in average unit capacity. According to bidding documents from Bid Centre, many of the new projects launched now require onshore wind turbine units of 4MW/5MW, and we expect this trend to continue. The application of big-scale wind turbines would have the following benefits.

a. **Reduction in unit weight and cost**
Raw materials accounted for 90-95% of the total cost of wind turbines, with blades, gearbox and generators being the heaviest parts. Reduction in unit weight per MW could help lower cost significantly. According to another industry player, unit weight per MW declines by 26% as the offshore wind turbine model moves from 5.5MW to 8.3MW.

b. **Reduction in construction and land cost**
As large-size wind turbines are adopted, it requires fewer wind turbine generator sites and less land. This could help lower equipment, transportation as well as construction costs. As local governments become increasingly strict on the approval of land for developing wind farms, more efficient use of land has become increasingly important.

2. Cost pass-through to upstream components

Upstream parts suppliers enjoy a price premium during rush installation in 2020. Following the rush installation, we see wind turbines passing on some of the costs to upstream parts suppliers, which led to a margin squeeze in 2021. Take castings as an example, quarterly margin dropped from the peak at ~30% to 15-17% in 3Q21, due to price hike in raw materials and lower selling price for castings for smaller turbines post rush installation. On the other hand, leading wind turbine makers continued to maintain its gross margin at above 20%. Moving into 2022, we expect wind turbine makers will continue to pass on price hike to the parts suppliers amid price decrease amid significant price decrease in tendering wind turbine price.

3. Domestic substitution

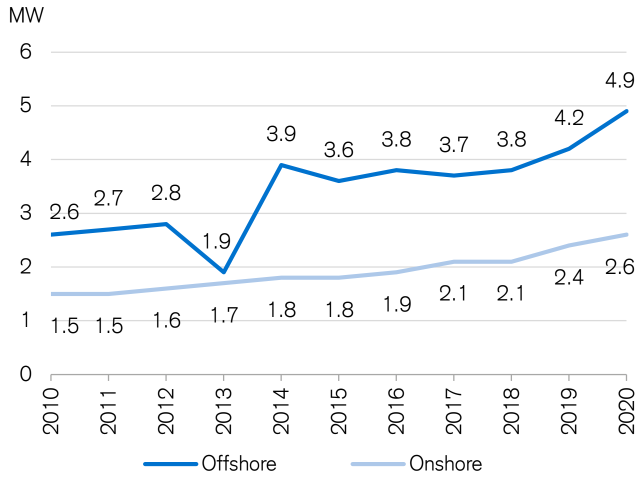
As China develops its own supply chain in wind, we see turbine makers substituting components produced by domestic players in recent years. Compared to foreign brands, domestic brands provide a price discount. According to industry sources, the price of main shaft bearings provided by domestic brands is around 35-37% lower than those provided by foreign players. Due to considerations on cost cutting pressure as well as ensuring security of supply chain, we expect the trend of domestic substitution to continue in upstream components.

Carbon fibre: Use case for longer turbine blades

What is this technology innovation?

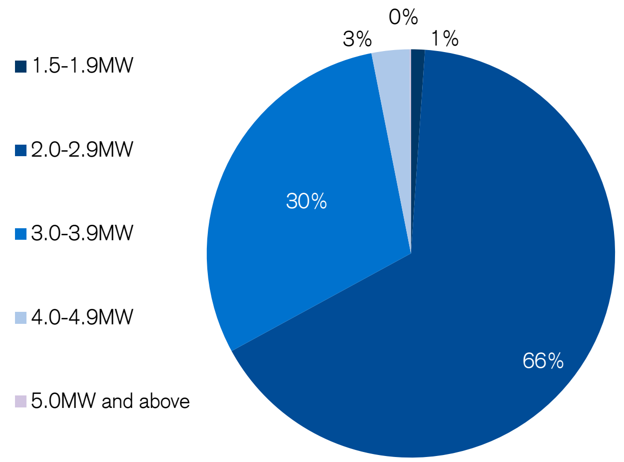
Many other composites are cheaper. But use of carbon fibre becomes increasingly necessary as blades become much longer, while needing to keep their weight down. Within the turbines, composites are mostly used to construct blades, as composite materials make the blade lighter so that it will spin at lower wind speeds, and stronger so it will manage 25 years in a harsh environment, and be transported to site. There is potential to construct a higher portion of a turbine blade using carbon fibre, which will make the blade lighter but at a much higher cost. Spar caps on wind blades were historically made using reinforced glass fibre (accounting for ~75-80% of spar cap installations) or carbon fibre (~20-25% of spar cap installations).

Figure 23: Average unit capacity of wind turbines installed in 2010-2020



Source: Chinese Wind Energy Association

Figure 24: Product mix for newly installed wind turbines in 2020



Source: Chinese Wind Energy Association

What is our view?

We expect the application of carbon fibre to continue in the turbine industry, expanding from its current scenario of use in making the spar cap of the turbine to making more parts of the blade and potentially other parts of the turbine. Further cost reductions are likely to help more carbon fibre adoption. We estimate the current market share at around 9%, increasing to 20% by 2025.

Individual pitch system: effective way for load reduction

What is this technology innovation?

A pitch control system controls turbine speed and power output, and also acts as a brake which can stop the rotor by turning the blades. Compared to collective pitch control which is set by a central controller in order to adjust the pitch of all blades to the same angle at the same time, IPC adjusts the pitch of each rotor blade individually.

What is our view?

Due to the benefits in load reduction and cost savings overall, we expect the penetration of individual pitch control system to continue to rise. We estimate the current market share at ~40%, increasing to 70-80% by 2025.

Medium-voltage converters: support higher power ratings

What is this technology innovation?

As more wind turbine with higher power ratings are applied, there is increasing demand for larger transformers, generators and gearboxes. Challenges include connecting wind farms to the power grid. Low-voltage is most cost-efficient at low power levels, while medium-voltage performs better at higher power levels. As power ratings increase, medium-voltage converters become more competitive which have low power loss, high efficiency, and are small in size and ease of installation & maintenance.

What is our view?

The application of higher power wind turbines could lead to a change in the supply chain. As offshore wind installation volume picks up which requirea even higher power rating turbines, we expect the penetration of medium-voltage converters to continue to increase. We estimate the current market share at around 10%, increasing to 30% by 2025.

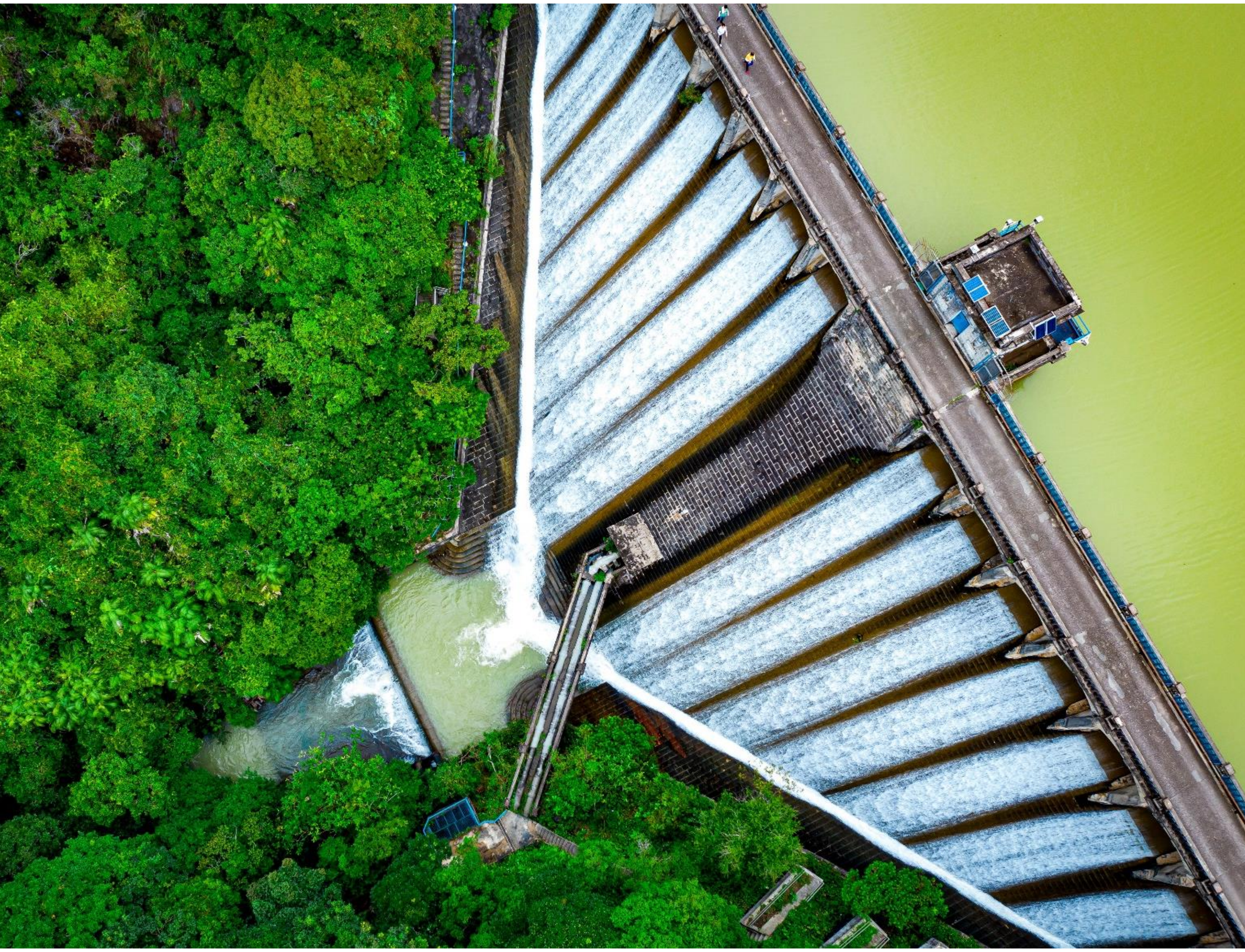
Vertical Axis Wind Turbines (VAWT): potential use in floating offshore wind

What is this technology innovation?

Most of the development has gone into horizontal wind turbines. However, there is a resurgence with SeaTwirl planning prototypes, especially in floating offshore. Currently there are limited uses for vertical turbines. While they perform better in urban areas with their omnidirectional blades suitable for areas with inconsistent wind and their quieter operations, concerns over efficiency have limited their applications. There is renewed interest in VAWT in recent years primarily around their use in floating offshore market, and industry analysis points to this being mainly due to the fact that the low centre of gravity of VAWTs often sits well with floating platforms.

What is our view?

Though VAWTs enjoy the benefits of being more applicable to inconsistent wind conditions, better addressing wake effect, as well as ease of maintenance and quieter operation, we expect HAWT to continue to be the mainstream due to higher efficiency. The application of VAWTs in floating offshore markets could come at a later stage.



“How large can the renewables market be? Likely to more than double in the next five years.

Implications for renewables/utilities sectors

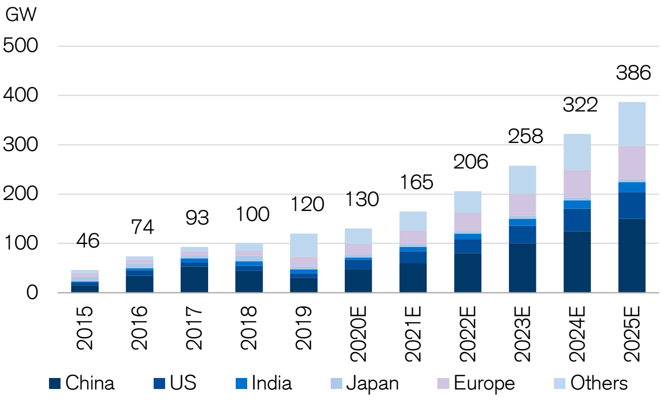
Driven by disruptive innovations, we expect solar/wind power's annual installation demand to grow from 165/67GW in 2021 to 386/112GW in 2025.

Through the new round of tech innovations, we believe renewable energy will gain larger competitiveness over traditional energies in terms of power generation cost and energy efficiency, which will further stimulate global renewables demand and accelerate the installation growth. In the past decade, along with the process of achieving renewable grid parity, global solar/wind power annual installation surged from 16/36GW in 2010 to 130GW/109GW in 2020 (incl. the impact of rush installation for wind power in China in 2020). In the new era post grid parity, we estimate global solar/wind power annual installation to further step up to 386GW/112GW in 2025.

Globally, the focus on expansion of renewables capacity has been one of the most disruptive factors to utilities. With the increased penetration of renewables generation, the sector saw its role transformed from the traditional, regulated role of network operators to spearheading decarbonisation efforts via renewables deployment.

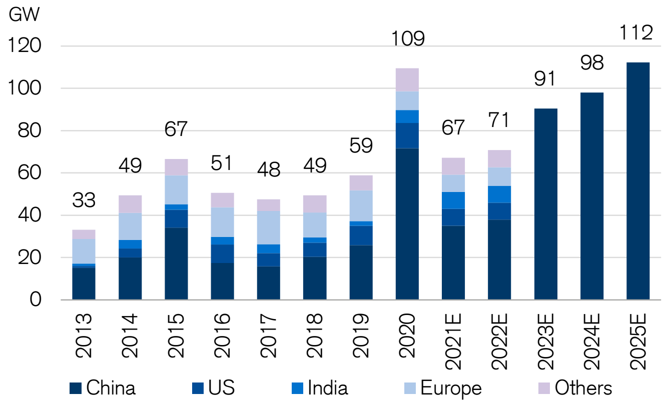
Over the past seven years, the annual renewable capacity additions exceeded the combined fossil fuels and nuclear capacity additions. Last year, 260GW of renewable capacity was added globally, which was more than 4 times the non-renewable capacity added, based on IRENA estimates. The share of the renewable capacity in total capacity additions globally increased from c.40% in 2010 to over 80% in 2020, on IRENA's estimates.

Figure 25: Global solar power installation forecasts by regions



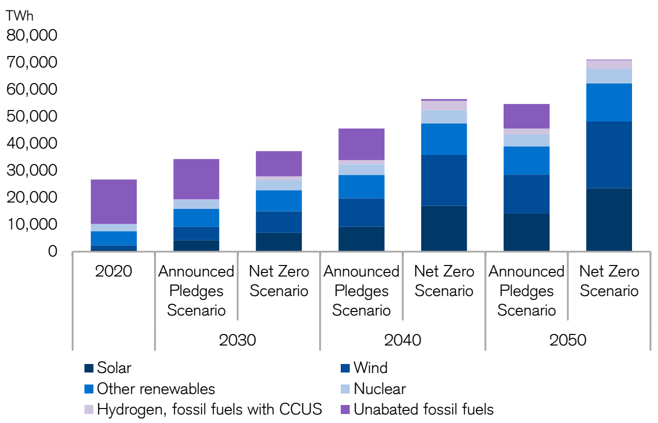
Source: National Energy Administration (NEA), WIND, Credit Suisse

Figure 26: Global wind power installation forecasts by regions



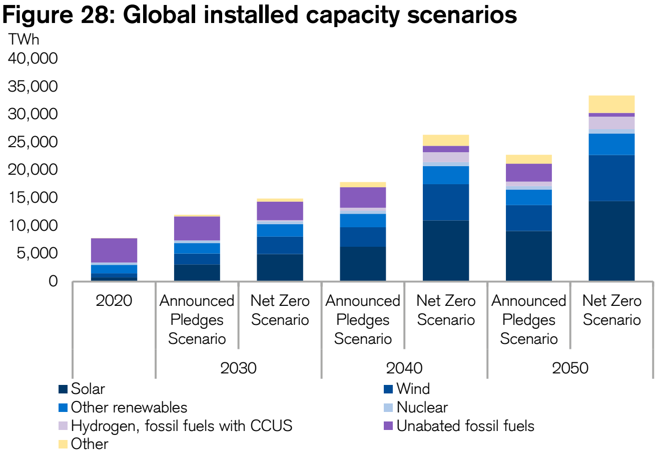
Source: NEA, Global Wind Energy Council, Credit Suisse

Figure 27: Global electricity mix scenarios



Source: IEA (2021) World Energy Outlook, Credit Suisse research

Figure 28: Global installed capacity scenarios



Source: IEA (2021) World Energy Outlook, Credit Suisse research

Industry is forecasting a steep trajectory of growth ahead in the next decade. The IEA estimates that under the Net Zero Scenario, global electricity generation needs to increase almost three-fold by 2050 to c.71 PWh (vs 2020) as shown in Figure 27. Given the fossil-fuel phase-out, renewable generation would need to increase more than eight-fold to meet increasing demand. As a result, under the scenario, renewable sources would account for a c.90% share of the mix (vs 25% in 2018). Renewable installed capacity would need to increase to c.27PW by 2050 vs 3PW in 2020, on the IEA's estimates, as shown in Figure 28. We expect the disruptive innovations in renewables will significantly accelerate the shift from traditional energies to renewables, not only due to the requirements of carbon emission control, but also because renewables will become even more economical and convenient than traditional energies (especially coal-fired power).

Against this backdrop of global renewables development, we highlight three key impacts on European utilities below, namely:

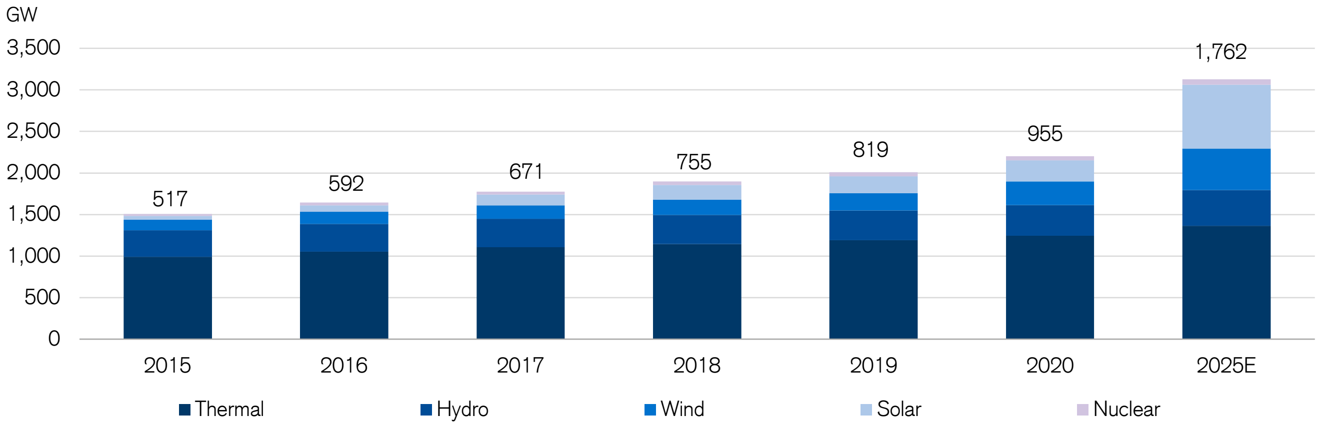
- Greater focus than ever on renewables development among utilities companies in Europe;
- More investment into networks; and
- Diminishing role of thermal capacities (particularly coal) in Europe.

Chinese IPPs expanding their renewables exposures

In late 2021, the power crunch in China came as a major surprise to the market, which we believe underscores China's dilemma between energy consumption control/ carbon emission reductions vs economy/power demand growth. As of 2020, thermal power still accounted for 57% of China's total installed power capacity and 70% of total output. Renewables, on the other hand, were only 10% (solar and wind combined) of China's power output. China's current energy consumption control policy includes restrictions on both total energy consumption level and energy consumption intensity (i.e. per GDP energy consumption). Renewable power consumption is encouraged, with additional renewables consumption above annual provincial targets exempted from total energy consumption limits calculation.

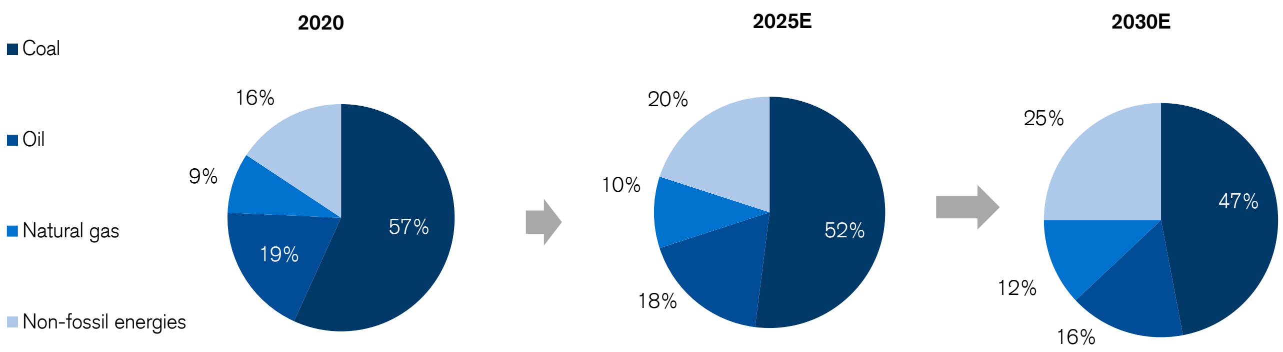
Most of the large SOE power companies in China have the majority of their current capacities in thermal power, but renewables is the area which is likely to see increasing investment. Going forward, almost all SOE power capacities have set up 14th Five-year Plans (2021-25) for their renewable power expansions.

Figure 29: Installed power capacity in China



Source: NEA, Credit Suisse

Figure 30: Primary energy consumption mix in China



Source: NEA, Credit Suisse

Besides, over the long run, we believe the increasing carbon cost could also push on power generation costs for traditional fossil fuels, and make renewables more cost competitive. China officially launched its national carbon trading market in July 2021. At the initial stage, we believe there is still limited financial impact on both coal-fired IPPs, as they are given enough free carbon credits. However, we believe it is likely that the annual emission allowance for coal-fired IPPs would be reduced over the long run, and more and more renewable power projects should be allowed to participate/selling carbon credits in the national market.

US Infrastructure Bill

Bottom line: The House passed the reconciliation bill which includes ten-year investment tax credit and production tax credit for solar, wind, energy storage, fuel cells, and other technologies. Importantly, the bill includes a premium for domestic content and direct cash pay (in lieu of tax credits). We believe the provision is most beneficial for US residential solar developers, and a direct check from the IRS will help avoid the use of tax equity which could increase advance rate from ABS investors (no TE senior) and reduce the asset cost of capital implying higher NPV per customer. We now await the US Senate's approval of the bill. We assign a 50% probability of approval.

Key highlights:

- 10-12 year tax credit extension proposed at full high levels (30% ITC for solar and 100% PTC for wind), instead of the latest tax credits (26/22% for solar or 80/60% for wind). Domestic content increases ITC and PTC by 10% points (i.e. 33% more ITC $ for solar, offshore wind, energy storage, fuel cells and 10% more PTC $ for onshore wind). Separate PTC for nuclear facilities ($15/MWh) available from 2022 to 2026. New tax credits for clean hydrogen ($3/kg for 100% zero-carbon facilities).
- The proposal initiates standalone investment tax credit for energy storage technologies (including batteries). Direct pay or tax credit refundability has been proposed as expected, though favours domestic content projects after 2023.
- Offshore wind, fuel cell, electricity transmission, geothermal, combined heat and power, biogas technologies also receive 30% ITC through 2035. CCUS PTC also extended by ten years (carbon capture receives $50/MT for geological storage, $35/MT for capture and use, $180/MT for geological air capture.
- EV charging stations receive 30% investment tax credit for every $100k investment and 20% thereafter. The charging tax credit is available for public and fleet chargers through 2031. The bill proposes refundable income tax credit $7,500/vehicle for electric vehicles. Increases by $4,500 to $12k for manufacturers with union employees, and additional $500 for >50% domestic content. Beginning 2027 the tax credit is available for vehicles assembled in the US. The regressive tax credit reduces for higher income households.
- We assume 50% probability for tax credit extensions across our coverage, as a clear majority in Senate seems less likely after Sen Manchin's comments. Though we believe that the various renewable and clean energy tax credit extensions still have a chance next year in the Build Back Better Act (BBB) or as part of other bills. Any tax credit extensions will likely have to come in by end of 1Q22, ahead of the mid-term elections.

US: long-term solar and wind needs to meet net zero goals: Biden's pre-election plan proposed to accelerate renewable energy deployment and achieve net-zero emissions by 2035, which will be positive for all renewables and utilities. But the devil will be in the details as a "net-zero" carbon is different from an "absolute zero carbon" which is different from a "100% renewable target". A net-zero status will require a carbon tax/fee or renewable fossil fuels (biogas, renewable natural gas, etc.) to offset emissions from natural gas consumption. Zero-carbon will use nuclear and hydroelectric, in addition to renewables, but not fuels that emit carbon.

We estimate US can achieve 60% zero-carbon mix by 2035 assuming annual utility scale solar and wind demand runrate of 25/11 GW/yr through the next 15 years. However, a net zero by 2035, or 100% renewables by 2035 requires a doubling of the runrates to 52/26 GW/yr. We estimate battery storage demand of 13-39 GW/yr. And total annual capex $31-69 bn/yr. We become less constructive on any additional policies under the Biden administration to help achieve net-zero by 2035 (which could result in 2x demand growth), and assume a 0% probability.

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