The State of Clean Technology Manufacturing

An Energy Technology Perspectives Special Briefing

International Energy Agency

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Key findings

- Clean energy technology manufacturing is expanding rapidly, driven by supportive policies, ambitious corporate strategies and consumer demand. The global energy crisis has instilled further impetus to develop manufacturing capacity that can strengthen energy security and diversify the supply chain. This Energy Technology Perspectives (ETP) Special Briefing is designed to provide policy makers with strategic insights in this area, focusing on five critical technologies: solar photovoltaic (PV), wind, batteries, electrolysers and heat pumps.
- New manufacturing projects are being announced by the day. In the short time since the last IEA analysis of clean technology manufacturing in Energy Technology Perspectives 2023 (covering announcements through to late 2022), the projected output in 2030 from announced projects for solar PV has increased by 60%, for batteries it has increased by around one-quarter, and for electrolysers by around 20%.
- It is not just announcements that are posting strong growth rates. The latest data available for year-end 2022 show installed manufacturing capacity posted strong year-on-year growth for batteries (72%), solar PV (39%), electrolysers (26%) and heat pumps (13%). Wind manufacturing capacity grew much more modestly at around 2%.
- If all announced projects were to come to fruition, solar PV manufacturing capacity would comfortably exceed the deployment needs of the IEA's Net Zero Emissions by 2050 (NZE) Scenario in 2030. Even if only half of this new capacity were to be utilised – the global average utilisation rate of solar PV manufacturing capacity in 2022 was slightly over 40% – throughput would still be sufficient to reach demand levels in the NZE Scenario (around 650 GW per year in 2030).
- For the first time, announced projects for battery manufacturing capacity could cover virtually all of the 2030 global deployment needs of the NZE Scenario. Significant gaps remain for wind, where projected throughput from existing capacity and announced projects equates to just under 30% of NZE Scenario deployment levels, electrolysers (just over 60%) and heat pumps (just over 40%). But relatively short lead times – for both announcements and construction – for the factories that supply these technologies imply a more positive outlook than these gaps initially suggest.
- While the pipelines of announced projects for solar PV and batteries appear well-stocked, many of the projects they comprise have not yet started construction or reached a final investment decision. Globally, only around 25% of the announced projects for solar PV manufacturing capacity can be considered committed, with the equivalent figure for batteries being around 30%.
- Manufacturing operations are highly geographically concentrated: currently, four countries and the European Union account for around 80-90% of global manufacturing capacity for the five clean technologies examined in this briefing. China alone accounts for 40-80% across these technologies. If all announced projects were to be realised, these shares would shift to 70-95% and 30-80% respectively.
- Major policy announcements of the past year are already starting to diversify supply chains, as evidenced by the scale-up in planned battery manufacturing capacity in the United States following adoption of the Inflation Reduction Act. In the United States, just the announcements in the second half of 2022 and the first quarter of 2023 account for nearly

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half of the total project pipeline for battery manufacturing to 2030. The full impacts of the Net Zero Industry Act in the European Union are still too early to gauge.

- In monetary terms, the projected output of the announced manufacturing capacity for the five key clean technologies (USD 790 billion per year) now exceeds that of the market size for their demand (USD 640 billion) in 2030, in a scenario in which governments implement their announced climate pledges on time and in full – the Announced Pledges Scenario (APS). The aggregate supply surplus at the global level is mirrored for individual technologies (solar PV, batteries and electrolysers), but masks deficits for others (wind and heat pumps). In aggregate, this suggests that for several technologies, the deployment levels needed to meet governments' climate pledges in the APS are highly achievable.
- China appears well positioned to capture USD 500 billion, or around 65% of the projected output from global clean technology manufacturing capacity in 2030, including both existing and announced projects. Unless China's domestic deployment of key clean technologies exceeds the levels projected in the APS, more than two-thirds of this output would be surplus to domestic requirements and need to find export markets.
- If all announced projects are realised, the European Union now appears able to fulfil all of its domestic needs for batteries, electrolysers and heat pumps in the APS in 2030. The United States could also be virtually self-sufficient with respect to its battery needs by 2030 in the APS, based on these latest project announcements.
- This briefing concludes with a set of policy recommendations targeted at G7 members, but applicable to all interested governments. They reflect the fact that no country – nor any supply chain segment – can exist in a vacuum. From strategic supply chain assessments to strategic partnerships, governments will need to formulate industrial strategies that balance climate and energy security imperatives with economic opportunities.

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Part I: Introduction

Deploying clean energy technologies at the pace required to put the world on a trajectory consistent with net zero emissions by mid-century will demand rapid expansion in clean energy technology manufacturing[1] capacity, underpinned by robust supply chains for their components and materials. As such, technology manufacturing plays a pivotal role in the energy transition required to meet climate, energy security and economic development goals.

Change is already happening apace in sectors such as electric vehicles and solar PV, heralding a new era in manufacturing, with countries around the world introducing policies to shore up their position in the emerging clean energy economy. This fast-moving transition has been given added impetus by the current global energy crisis, which has increased energy security concerns and starkly illustrates the need for clean energy technologies with diversified supply chains.

The place of clean technology manufacturing in industrial strategy is today a critical consideration for governments, with policy makers committing to scale up investments and diversify supply chains. Strategic policy making in the area of clean technology manufacturing will require a clear understanding of the expected demand for clean energy technologies in different regional and policy contexts, and an assessment of bottlenecks that need to be addressed in order to fulfil climate ambitions.

This briefing provides an update on recent progress in clean technology manufacturing in key regions. It builds upon the latest edition of the IEA's flagship technology publication, Energy Technology Perspectives 2023 (ETP-2023), published in January 2023. The analysis in ETP-2023 has been updated to take into account recent announcements of expansions in manufacturing capacity, in order to inform considerations by decision makers seeking to tap into the opportunities offered by the emerging clean energy economy.

We begin with a review of recent developments, exploring how far the current project pipeline is consistent with the trajectory needed to reach net zero emissions by 2050. We consider where these developments are occurring by technology to assess levels of regional concentration in clean technology manufacturing. We go on to consider the global market for key clean energy technologies, and finally to explore how recent policy developments are shaping the landscape of clean technology manufacturing.

[1] Hereafter "clean technology manufacturing".

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Box 1 Scenarios used in this briefing

Analysis in this briefing is underpinned by global projections of clean energy technologies derived from the IEA's Global Energy and Climate (GEC) model, a detailed bottom-up modelling framework composed of several interlinked models covering energy supply and transformation, and energy use in the buildings, industry and transport sectors. The modelling framework includes 26 regions or countries covering the whole world.

The most recent year of complete historical data from the GEC model is 2021, to which year-end 2022 manufacturing capacity data have been added as part of the analysis for this briefing. Data for Q1 2023 are available for some technologies. For projected values – we focus on 2030 in forward-looking assessments – we make use of two IEA scenarios produced using the GEC model that describe possible energy system pathways:

The Net Zero Emissions by 2050 (NZE) Scenario is a normative scenario that sets out a pathway to stabilise global average temperatures at 1.5°C above pre-industrial levels. The NZE Scenario achieves global net zero energy sector CO_2 emissions by 2050 without relying on emissions reductions from outside the energy sector. In doing so, advanced economies reach net zero emissions before developing economies do. The NZE Scenario also meets the key energy-related UN Sustainable Development Goals, achieving universal access to energy by 2030 and securing major improvements in air quality.

The Announced Pledges Scenario (APS) assumes that governments will meet, in full and on time, all the climate-related commitments they have announced, including longer-term net zero emissions targets and Nationally Determined Contributions (NDCs), as well as commitments in related areas such as energy access. It does so irrespective of whether these commitments are underpinned by specific policies to secure their implementation. Pledges made in international fora and initiatives on the part of businesses and other non-governmental organisations are also taken into account wherever they add to the ambition of governments.

Neither scenario should be considered a prediction or forecast. Rather, they are intended to offer insights into the impacts and trade-offs of different technology choices and policy targets, and to provide a quantitative framework to support decision-making in the energy sector, and strategic guidance on technology choices for governments and other stakeholders. The scenarios and results are consistent with those presented in the World Energy Outlook 2022, and ETP-2023, with the exception of battery demand, which has been revised based on updates presented in the Global EV Outlook 2023.

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Part II: Analysis

An update on technologies that are advancing rapidly

The IEA report Energy Technology Perspectives 2023 (ETP-2023) analysed the risks and opportunities surrounding the development of clean energy technology supply chains, exploring all the major steps throughout the supply chain. This briefing examines the manufacturing steps in more detail, with a specific focus on five key technologies for the clean energy transition: solar PV modules,[2] wind turbines,[3] batteries,[4] electrolysers[5] and heat pumps.[6]

Manufacturing capacity expansions for these technologies tend to have shorter lead times than other steps in the supply chain, such as mining. This means that progress from announcement to operation can be especially dynamic in a supportive environment. These supply chain steps have also been strongly emphasised in recent policy announcements. The manufacturing data compiled for this briefing (see Box 2) aims to capture these latest developments and provide a snapshot of the current outlook for capacity additions through to 2030. Of particular interest is whether recent project announcements have changed the picture with respect to the significant degree of regional concentration in clean technology manufacturing revealed in ETP-2023, and which countries and regions appear best-positioned to capture shares of the markets for key clean technologies in the coming years.

Box 2 Manufacturing data compiled for this briefing

The manufacturing data compiled for this briefing, covering the five focus clean energy technologies – solar PV, wind, batteries, electrolysers and heat pumps – can be categorised as follows:

"Installed manufacturing capacity" refers to the maximum rated output of facilities for producing a given technology, as distinguished from the installed capacity of the technologies themselves once deployed. Capacity is stated on an annual basis for the final product (e.g. solar PV modules) and does not speak to

[2] Hereafter "solar PV", unless a particular component or intermediate step in production is specified.
[3] Hereafter "wind", with analysis based on aggregate or average quantities for nacelles, towers and blades as appropriate.
[4] Including both mobile and stationary applications and all battery chemistries.
[5] Including both alkaline and proton exchange membrane technologies.
[6] For residential applications only.

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the capacity for producing any intermediate products and components (e.g. polysilicon). Manufacturing throughput – also stated on an annual basis – is a fraction of the installed manufacturing capacity. It depends on the utilisation rate of production facilities, which are typically around 85% if operating normally, but are sometimes much lower. ETP-2023 covered data for installed manufacturing capacity to year-end 2021; in this update data for year-end 2022 are added.

“Announced projects” refers to the aggregate stated capacity – or estimated throughput of that capacity assuming a default utilisation rate of 85% – of potential future manufacturing facilities for which projects have been announced. Announcements include projects that are at different stages of development, with some already under construction and others not yet at the final investment decision stage. The quantities associated with these projects are not a forecast, nor are they directly associated with the projected quantities embodied by the scenarios described in Box 1. Actual manufacturing capacity additions could turn out to be higher than current public announcements at a given point in time, or lower, as not all announced projects will materialise. As such, they provide an indicator of where the industry is headed, but not an expectation on the eventual outcome. How these factors play out will vary by technology and by regional context. ETP-2023 provided a snapshot of announced projects as of end-November 2022 (hereafter “late 2022”); this briefing covers those project announcements and in addition any further announcements up to end-March 2023 (hereafter “end-Q1 2023”). Unless stated otherwise, forward-looking quantities associated with the capacity or throughput of announced projects include all projects in operation up to and including the year 2030.

Complete data on manufacturing capacity and throughput have been compiled for 2021 and 2022. Project announcements are compiled on an on-going basis for electrolysers, on a monthly basis for solar PV and batteries, and on an ad-hoc basis for wind and heat pumps. No new quantifiable data on project announcements were available for wind since the publication of ETP-2023, and thus there is no change in the quantification of announced projects for that technology in this briefing. External data providers include InfoLink, Thomson Reuters, Bloomberg New Energy Finance, Wood Mackenzie, and Benchmark Mineral Intelligence.

Recent developments in clean technology manufacturing

A review of the latest project announcements for clean technology manufacturing shows that some manufacturing sectors look set to meet – and even to exceed – the capacity required by 2030 to get on track with the deployment needs of the

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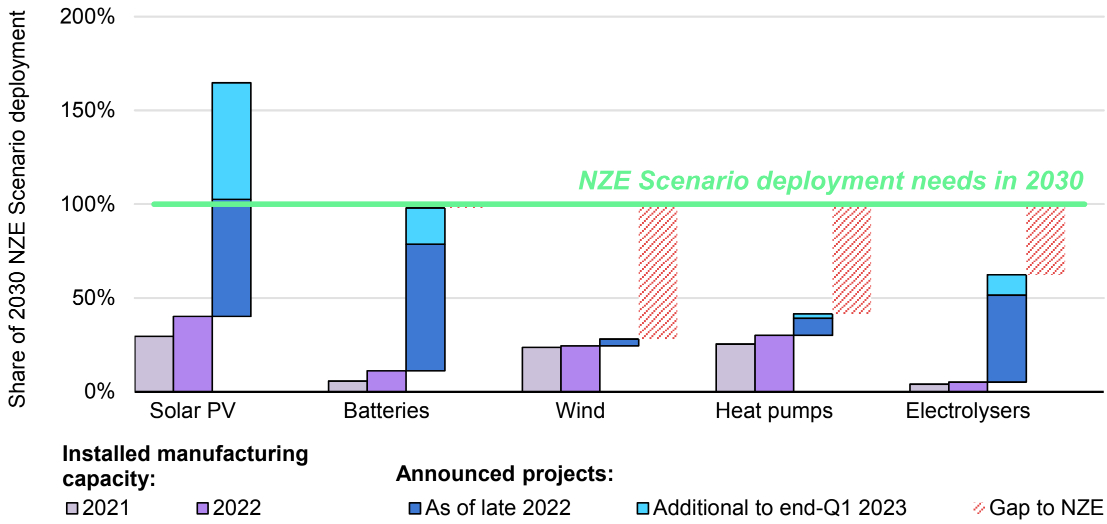
NZE Scenario. Others are lagging behind, with substantial increases in ambition required to meet emissions reduction goals, but progress has been made in the past few months. Given the short lead times required to bring manufacturing capacity online, reaching the 2030 deployment levels in the NZE Scenario, though a significant challenge, is not an insurmountable one for these technologies.

Figure 1 Announced project throughput and deployment for key clean energy technologies in 2030 in the Net Zero Emissions by 2050 Scenario



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Notes: PV = photovoltaic; NZE Scenario = Net Zero Emissions by 2050 Scenario. "Announced projects: late 2022" corresponds to the project pipeline assessed for ETP-2023, including project announcements through to the end of November 2022. "Announced projects: Additional to end-Q1 2023" corresponds to projects announced between the end of November 2022 and the end of March 2023. Deployment and throughput are expressed in physical units, normalised to 2030 NZE Scenario deployment needs.

For solar PV and batteries, announced projects today already meet and even exceed the deployment levels required in the NZE Scenario in 2030. Short lead times suggest the gaps remaining for wind, heat pumps and electrolysers, though significant, are not insurmountable.

Solar PV manufacturing continues to expand dramatically

Solar PV manufacturing – which increased at a compound annual growth rate of 25% during the period 2010-2021 – shows no sign of slowing down. In 2021, manufacturing throughput stood just over 190 GW globally, compared with around 160 GW of solar PV deployed in the same year. In 2022, global manufacturing capacity rose by nearly 40% to about 640 GW, with 90% of the growth relative to 2021 taking place in People's Republic of China (hereafter, "China"). Manufacturing throughput in 2022 was around 260 GW, significantly below the 640 GW of installed manufacturing capacity – indicating a global average utilisation rate of around 40%.

As of late 2022, our analysis of announced projects for solar PV suggested that manufacturers were already on track to meet projected demand in 2030 in the NZE Scenario, with about 670 GW of throughput by that year resulting from

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announcements for additional manufacturing capacity. As of end-Q1 2023, the project pipeline has expanded even further. Around 480 GW of additional module manufacturing capacity has been announced (570 GW of cells, 250 GW of wafers, 570 GW of polysilicon), increasing the total volume of planned capacity by 60%. The result is nearly 1.1 TW of projected throughput from this announced manufacturing capacity for modules, which, when combined with current installed capacity, is 65% higher than the level required to satisfy deployment needs under the NZE Scenario in 2030. When examining the projected output for other major PV components – albeit with a shorter time horizon for announced projects up to and including 2027 – the figures are 80%, 37% and 96% for cells, wafers and polysilicon respectively. However, only around 25% of the announced module manufacturing capacity is committed, i.e. under construction or having reached final investment decision. Even considering just these projects – alongside existing capacity of 640 GW – the project pipeline appears capable of accommodating the NZE Scenario deployment needs by 2030, if utilisation rates increase to 85% on average globally by then.

Major project[7] announcements made in Q1 2023 include new manufacturing facilities for the world's top three producers – LONGi, Jinko Solar and Trina – as well as for other larger (e.g. Tongwei, Suntech) and smaller or emerging players (e.g. Solar Grids, REC Group, Hoshine, Royal), mostly based in China. These major projects account for 45% of the total additional capacity announced as of Q1 2023.

Acceleration in battery manufacturing is closing the gap with net zero needs

Battery manufacturing capacity is also booming, owing to rapid increases in electric vehicle (EV) sales. In 2021, battery manufacturing throughput stood at 340 GWh, with this figure nearly doubling to reach 660 GWh in 2022. 580 GWh of manufacturing capacity was added in 2022, up 85% from the capacity added in 2021. About 80% of the 2022 manufacturing capacity additions were in China, just over 10% in Europe and just under 10% in the United States. Around 90% of these batteries are currently destined for automotive applications. Global electric car sales rose by 55% year-on-year in 2022, with the share of electric cars in total car sales reaching 14%, up from 9% in 2021. In major markets such as China and Europe this share reached 29% and 21%, respectively. Sales also rose to a nearly 8% share in the United States, representing 55% year-on-year growth.

Looking at the pipeline of announced projects, from late 2022 to end-Q1 2023, planned manufacturing capacity has risen from around 5.5 TWh to 6.8 TWh per

[7] "Major projects" refers to plants with stated production capacity greater than or equal to 20 GW per year for solar PV modules. To compare, the average manufacturing capacity of a solar PV module plant was around 2.8 GW per year in 2022.

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year – an increase of 25%. As of late 2022, the total potential output from these announced projects stood at around 80% of what was needed by 2030 to be on track with the NZE Scenario. The updated assessment performed for this briefing now puts the total projected output from these projects just below the levels required (5.9 TWh annually), demonstrating strong investment in – and strong policy support and demand for – battery manufacturing. We estimate that around 30% of these projects can be considered committed globally, with the proportion being slightly higher in the United States (just under 40%) but much lower in the European Union (around 10%). If only committed projects materialised, there would be a gap to global NZE Scenario deployment levels of around 50% in 2030.

Table 1 Major project announcements for solar PV and battery manufacturing operations in Q1 2023

Company	Location	Country	Production capacity	Projected completion year/year reaching maximum throughput
Batteries				
Tesla	Austin	US	200 GWh	2024/2025-2030
CATL	Yibin	China	186 GWh	Operating/>2030
CATL	Fuding	China	120 GWh	Operating/2025-2030
LGES	Wroclaw	Poland	115 GWh	Operating/2025
CATL	Debrecen	Hungary	100 GWh	2025/2028
LGES	Nanjing 1	China	92 GWh	Operating/>2030
CALB	Changzhou	China	90 GWh	Operating/2025-2030
Tesla	Berlin	Germany	85 GWh	2024/>2030
CATL	Luoyang	China	80 GWh	2025/2025-2030
Solar PV				
Jinko Solar	Yuhuan	China	30 GW	2024/2025
Solar grids	Zhuhai	China	30 GW	2024/2024
Tongwei	Yancheng	China	25 GW	2023/2023
Tongwei	Nantong	China	25 GW	2023/2024
Jinko Solar	Shangrao	China	24 GW	2023/2025
LONGi	Taizhou	China	20 GW	Operating/Already at maximum
LONGi	Wuhu	China	20 GW	2023/2025
Trina	Yancheng Dafeng	China	20 GW	Operating/2024
Suntech	Chuzhou Fengyang	China	20 GW	2023/2024
REC Group	Jamnagar	India	20 GW	2023/2026
Solar grids	Yiwu	China	20 GW	2024/2024
Hoshine	Urumqi	China	20 GW	2023/2026
Royal	Fuyang	China	20 GW	2023/2025

Notes: PV = photovoltaic. "Major projects" refer to plants with stated production capacity by 2030 greater than or equal to 20 GW per year for solar PV modules and 80 GWh per year for electric vehicle batteries. Any anticipated expansions beyond 2030 have not been included. The battery manufacturing facilities include all kinds of chemistries, both for mobility as well as stationary applications.

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Announced projects for electrolysers increase after a slow start

Electrolyser manufacturing for use in the production of hydrogen is still a nascent industry and is the least mature technology examined in this briefing. In 2021, electrolyser manufacturing throughput stood at around 7 GW, increasing to 9 GW in 2022. Looking forward, announced projects as of end-Q1 2023 suggest nearly 115 GW of additional installed manufacturing capacity could be expected by 2030. The resulting throughput projected from these announced projects – together with that from existing installations – would achieve more than 60% of the levels needed in the NZE Scenario in 2030. Counting only the projects that are committed, that figure drops to under 10%. The project pipeline is expected to continue to grow in the coming years, but announced projects need early support to ensure that they reach final investment decisions. If all planned projects were realised, costs for electrolysers could fall by more than 60% by 2030.

Wind and heat pump manufacturing is seeing more gradual change

Data for manufacturing capacity of wind and heat pumps is more limited, and so it is too early to tell whether there have been significant changes in the first months of this year. We estimate that manufacturing throughput for wind was around 100 GW in 2022, and just under 120 GW for heat pumps. A large gap between expected output from announced projects and 2030 NZE Scenario needs exists for both technologies: a gap of over 70% for wind and nearly 60% for heat pumps. However, lead times for constructing these facilities can be relatively short in many cases, around 1-3 years.

Virtually all of the project announcements for heat pumps are situated in Europe, although this may be because capacity additions in other regions are often not as prominently or explicitly announced as for other technologies, partly because heat pumps often represent a small proportion of a manufacturer's total production. Heat pump manufacturing capacity expansions typically follow near-term demand trends without explicit announcements. As such, the gaps to the NZE Scenario deployment levels may appear larger than they really are. If we assume that a similar share of already installed capacity to that in Europe is forthcoming in other regions, the existing gap to the 2030 NZE Scenario deployment levels, which is currently at around 60% globally, would fall to around 20%.

A complete set of quantitative data on the most recent announcements for wind components – nacelles, towers and blades – is not available at the time of preparing this briefing. However, preliminary analysis of component-level project announcements suggests that for onshore wind components, manufacturing capacity could reach 100-110 GW by 2025, of which 60% would be located in China, 15% in Europe and about 10% in North America. For offshore installations,

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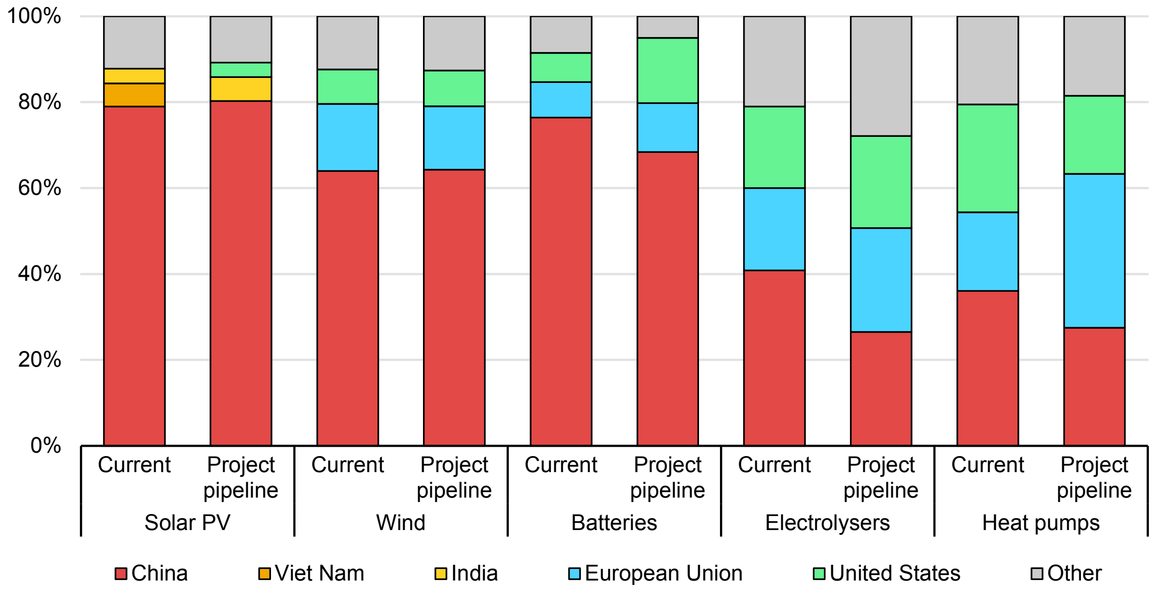
project announcements suggest a manufacturing capacity of around 30 GW, of which around 70-80% is in China and much of the rest in Europe.

Regional concentration in clean technology manufacturing

For the clean energy technologies considered in this briefing – solar PV, wind, batteries, electrolysers and heat pumps – four countries and the European Union account for 80-90% of manufacturing capacity, with China in the lead for all. For clean technology supply chains more broadly, there are important levels of concentration at each of the major steps, and not just in manufacturing. For example, the Democratic Republic of Congo alone produces 70% of the world's cobalt, and just three countries account for more than 90% of global lithium production. Concentration at any point along a supply chain makes the entire system vulnerable to unforeseen changes, such as an individual country's policy choices, natural hazards, technical failures or company decisions.

Figure 2 Current and projected geographic concentration for manufacturing operations for key clean technologies



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Notes: PV = photovoltaic. Wind refers to onshore wind nacelles in this analysis. For electrolysers, the analysis only includes projects for which location data was available. Shares are based on manufacturing capacity. 'Current' refers to installed capacity data for 2022 and Q1 2023 where available. "Project pipeline" refers to the sum of current installed capacity and all announced manufacturing capacity additions (as of end-Q1 2023) through to 2030. "Other" refers to the aggregate of all capacity besides that of the top three countries/regions for each technology and timeframe.

Announced projects – if all realised – will alter the global distribution of manufacturing capacity for batteries, electrolysers and heat pumps.

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China's prominent role in technology manufacturing is the result of a long-term industrial strategy, resulting in huge investment in clean energy supply chains, driven in part by consistent policy signals for domestic clean technology deployment in its successive Five-Year Plans. This investment has helped to reduce the costs of clean energy technologies in China, and in the rest of the world, while at the same time making China the leading exporter of several clean energy technologies.

In the following section, we examine how the outlook for geographical concentration of manufacturing operations may change based on the updated pipeline of announced projects developed for this briefing.

Solar PV

In 2022, three countries accounted for nearly 90% of installed capacity for manufacturing solar PV modules, with China alone accounting for 80%. Some individual plants in China are country-sized with respect to their rated production capacity. The largest operating plant in China – the LONGi plant in Taizhou (see Table 1) – iis large enough to supply half of the capacity additions of solar PV modules in the European Union in 2022, which totalled 38 GW. The next two largest countries with respect to installed manufacturing capacity are Viet Nam and India, accounting for 5% and 3% of all capacity, respectively. The largest plants in these countries tend to be much smaller than those in China, at around 7-8 GW of annual production capacity.

If all announced projects come to fruition, concentration among the top three producers would remain very similar to the current level (90%). The share of today's second largest country by installed capacity, Viet Nam, would give way to India, today's third largest, as well as to the United States, which would move to third, just ahead of Viet Nam. China's share would remain virtually unchanged at around 80%.

These high levels of concentration reflect, in part, the fact that solar PV is already a mature technology, with large-scale deployment taking place in nearly all regions of the world. Solar PV accounted for nearly 40% of global electricity generation capacity additions in 2022, and now accounts for 4% of global electricity generation. The concentration of capacity levels in mature industries is inherently more stable than in nascent industries, as annual capacity additions account for smaller shares of the cumulative capacity installed.

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Box 3 Concentration in solar PV component manufacturing

Manufacturing any clean technology is dependent on many different supply chains for components, and concentration at any level can create vulnerabilities with the potential to affect the entire supply chain for a given technology, just as it can for the wider system of clean technology supply chains. A closer look at the components that make up solar PV panels highlights even higher degrees of concentration than those of the finished modules alone.

Solar PV modules are assembled from cells, which in turn are made from wafers, which in turn are made from polysilicon. A solar PV manufacturing facility rarely comprises all of these steps, but each is necessary to the manufacture of the final module. China is the single largest producer for all three sub-components (cells, wafers, polysilicon) today, accounting for 85-97% of global installed capacity at each stage in the supply chain.

This supply chain concentration has increased over time, for some components more than others. China has long been a leader in silicon wafer production, accounting for around 80% of production in 2010, with this share rising to more than 95% in recent years. For cells and modules, a lower but still considerable share of 55-60% of manufacturing capacity in 2010 has risen over time to over 85% for cells and 80% for modules in 2022. For polysilicon, China accounted for less than 30% of the world's manufacturing capacity in 2010, with this share rising rapidly to over 85% in 2022.

China is a major exporter of solar PV panels, as domestic manufacturing capacity for solar PV modules has exceeded domestic demand since the 2000s. This has been achieved through clear and sustained policy signals and deployment targets in its Five-Year Plans. Since 2010, installed capacity of solar PV has grown at a compound annual growth rate of over 65%, reaching 427 GW in 2022. This compares to a compound annual growth rate (CAGR) over the same period of 40% and installed capacity in 2022 of 140 GW in the United States, and just under 20% and 200 GW in Europe.

Examining announced projects at each stage in the solar PV supply chain, we see that China's shares at each of these stages would remain flat for modules and cells, fall modestly for wafers and increase modestly for polysilicon through to 2027, if all projects were to come to fruition. These slight changes in China's shares when projecting forward are primarily due to project announcements in India, Thailand, the United States and Viet Nam. While capacity additions in these countries would be small relative to China's large existing stock, they would represent significant increases in domestic manufacturing capacity. For modules, announced projects would lead to a sixfold increase in manufacturing capacity in the United States, and a tripling in India. For cells, there would be a tenfold increase in India and a doubling in Viet Nam and Thailand. For wafers, India would

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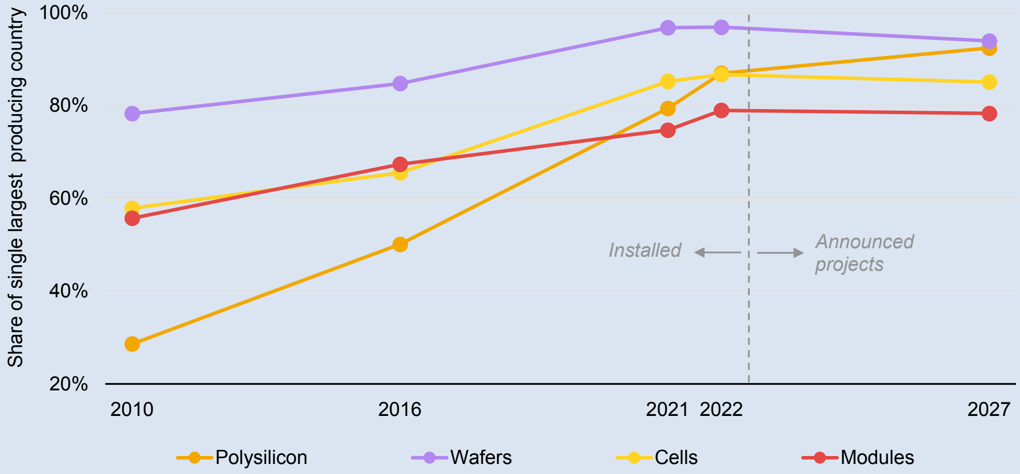
become second largest global manufacturer and the United States would rank third globally, starting from virtually zero production in 2022.

Figure 3 Current and projected geographic concentration of manufacturing operations for key solar photovoltaic (PV) components



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Notes: All values stipulated as a share of global production capacity. Values for 2027 correspond to existing capacity and announced projects (as of end-Q1 2023) combined.

Manufacturing of key solar PV components has become increasingly concentrated in China in recent years and looks to remain so in the short term.

Batteries

In 2022, China, the European Union and the United States accounted for over 90% of global installed manufacturing capacity. China alone accounted for 75%. The European Union accounted for 8% and the United States 7%. Beyond the top three, Korea also has a sizeable share of installed manufacturing capacity, at 5% of the global total.

If all announced manufacturing projects for batteries came to fruition, this level of supply concentration would remain relatively flat, with China, the United States and the European Union still accounting for around 95% combined. China's share would decrease moderately to around two-thirds of global manufacturing capacity, while that of the United States would jump to 15%, and the European Union's to 11%. This is because – unlike solar PV – the largest so-called "gigafactory" project announcements are not solely located in China. The largest project planned is part of a Tesla facility in the United States. At 200 GWh of annual production capacity, this project announcement is equivalent to around 13% of global battery manufacturing capacity installed today.

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Electric vehicle markets – the primary driver of battery manufacturing capacity additions – are maturing rapidly, but sales of EVs are still outweighed by sales of internal combustion engine vehicles globally. While solar PV has been the largest single source of capacity additions in the power sector since 2017, electric cars accounted for 14% of total car sales in 2022. However, sales are increasing rapidly: electric cars accounted for just 2.6% of car sales in 2019, and are projected to reach 18% in 2023. There have also been important battery technology developments and breakthroughs in recent years to cut costs and decrease critical mineral requirements. As EV penetration increases in more countries and innovative battery concepts mature, the landscape for global battery manufacturing and regional concentration could change.

Box 4 Diversification for enhanced security and resilience in clean energy technology supply chains

Adding manufacturing capacity is not the only way to secure supply for domestic demand in the long term. Where possible, pursuing diversification strategies can moderate supply chain risks and increase resilience. Measures to reduce overall demand and promote recycling and reuse can also help.

Diversifying the origin of supplies among several trade partners – for either finished goods, technology components, equipment or materials – can help increase resilience in the case of supply chain shocks.

Diversifying technology and material needs, such as through technology or material substitution, can help reduce structural reliance on foreign trade and increase security of supply, including in cases of high regional concentration for existing technologies and the materials they require. In the case of EV batteries, for example, developing innovative chemistries with lower critical mineral requirements, such as nickel-free lithium iron phosphate, or none, such as the emerging sodium-ion batteries, can significantly decrease exposure to regional concentration of critical minerals extraction and processing.

Wind, electrolysers and heat pumps

Manufacturing of onshore wind nacelles was also highly concentrated in 2022. China accounted for over 60% of global manufacturing capacity, followed by the European Union (just under 15%) and the United States (10%). If all announced projects for additional capacity were to come to fruition, these shares would not change significantly by 2030. Regional concentration also varies for different pieces of equipment such as towers and blades, and offshore-specific components. We estimate that for onshore equipment overall, announced projects

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would lead China to account for 55-65% of global manufacturing capacity by 2030, and up to 70-80% for offshore equipment.

For electrolysers and heat pumps, while the United States, China and the European Union combined accounted for nearly 80% of global manufacturing capacity in 2022, capacity is more evenly distributed between them. China accounted for about 40% of electrolyser manufacturing capacity, and the European Union and the United States 20% each. For heat pumps, about 35% of manufacturing capacity was located in China, 25% in the United States and a little under 20% in the European Union.

If all announced projects came to fruition, regional concentration for electrolyser manufacturing would decrease slightly by 2030 and the distribution among the top producers would further improve: China and the European Union would each account for a quarter of global manufacturing capacity, and the United States 20%. For heat pumps, the combined share of global capacity held by this group – the United States, the European Union and China – would remain at 80%, if no further capacity announcements were made. The European Union would hold the largest share (just around 35%), ahead of China (just under 30%) and the United States (just under 20%), but project announcements for this technology tend to be more frequent and prominent in Europe than in other regions.

The global market for key clean energy technologies

The combined global market for key clean technologies – solar PV, batteries, wind, electrolysers and heat pumps – reaches USD 640 billion per year by 2030 in the APS (see Box 1 for a description of this scenario). Domestic demand in China, the European Union, the United States and India combined accounts for nearly three-quarters of the global market for key clean technologies by 2030 in this scenario. The regions of Southeast Asia and Central and South America account for a further 10% and 3% respectively.

Since our last estimates in late 2022 – published in ETP-2023 – there have been numerous additional project announcements, thereby increasing the total market value of their combined projected outputs. As of end-Q1 2023, the projected output from existing and announced manufacturing capacity in 2030 would lead to a global market size on the supply side of nearly USD 790 billion, which is a

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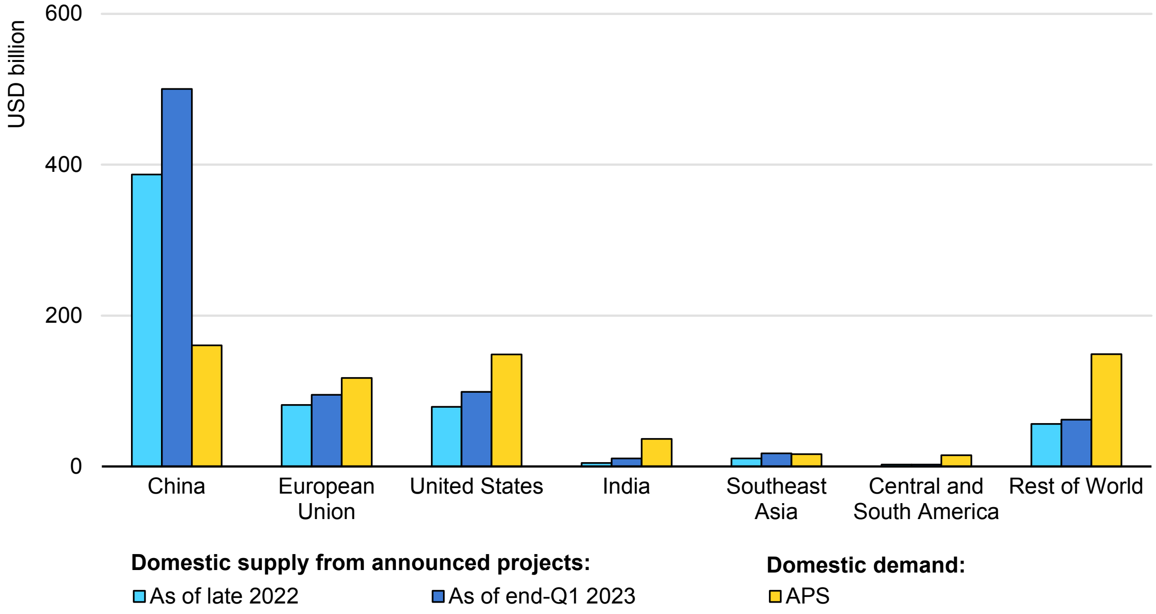
significant increase relative to our previous estimate of around USD 625 billion.[8] However, this overall figure hides significant disparities for individual technologies and regions.

Figure 4 Market sizes for key clean energy technologies in 2030



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Notes: APS = Announced Pledges Scenario. "Domestic supply from announced projects: As of late 2022" corresponds to the project pipeline assessed for ETP-2023, including project announcements through to the end of November 2022. "Domestic supply from announced projects: As of end-Q1 2023" corresponds to projects announced through to the end of March 2023. Key clean energy technologies include solar PV, wind, batteries, electrolysers and heat pumps. Market size is calculated based on the unit cost for each technology in the APS, excluding installation and construction costs. All market sizes and revenues are expressed in undiscounted 2021 US dollars.

In the APS, the combined global market for five key clean technologies reaches USD 630 billion per year by 2030.

Announced projects for solar PV modules – if all realised – could deliver USD 160 billion per year worth of output globally, relative to a market size of around USD 55 billion in 2030 in the APS. This would result in a more than USD 100 billion manufacturing surplus compared to deployment according to countries' net zero pledges. Manufacturers cannot operate continuously at maximum capacity, and so some extra capacity is necessary, but more climate ambition could be beneficial for the commercial viability of these projects.

Similarly, if all announced projects for batteries and electrolysers were to be realised, they would result in surpluses of around USD 170 billion and just under USD 10 billion respectively. However, manufacturing projects announced for wind and heat pumps fall short of the projected global market size in the APS by

[8] A figure of USD 650 billion was published in ETP-2023, but this included fuel cells, which are not included in this analysis.

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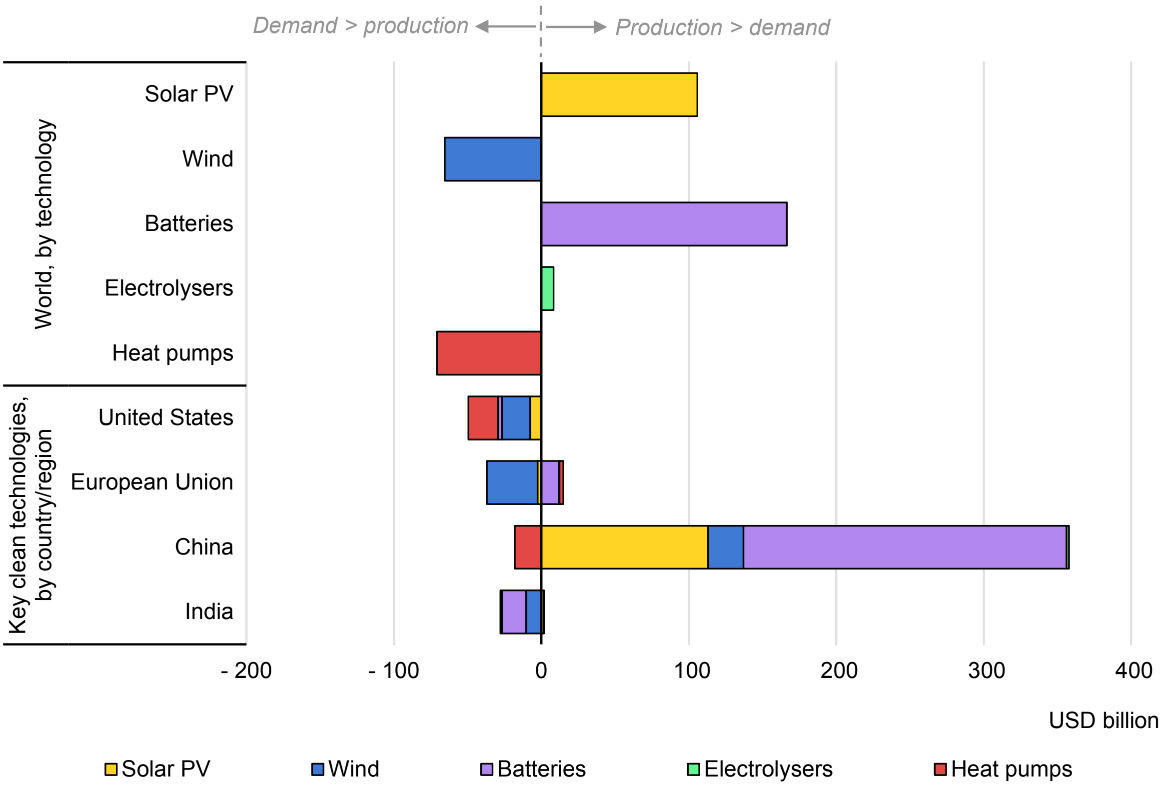
USD 140 billion combined. For these latter two technologies, there is a clear demand gap that could be filled by new manufacturing projects, and sizeable associated markets.

Similar imbalances between the market sizes associated with APS deployment levels (demand) and projected output from existing and announced manufacturing facilities (supply) exist within countries and regions. Assuming that domestic production is first used to meet domestic demand, and focusing on the final manufactured product as opposed to individual supply chain components, the resulting imbalance can provide some indication as to the direction and magnitude of future trade.

Figure 5 Market value of imbalances between supply from existing and announced projects and demand in the Announced Pledges Scenario in 2030 for key clean technologies



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Notes: PV = photovoltaic. Market imbalances are computed as the projected output from existing and announced projects (as of end-Q1 2023) less APS deployment needs for each country/region in 2030. Negative values indicate the potential value of net imports and positive values indicate the potential value of net exports. Figures are computed based on the value of the final manufactured technology (e.g. solar PV modules), with trade in intermediate components (e.g. cells) and materials (e.g. polysilicon) being outside the scope of the analysis. All domestic production is first used to meet domestic deployment needs, irrespective of existing trade patterns.

Around two-thirds of the projected output from existing and announced capacity in China would be surplus to domestic requirements in the APS and would need to find export markets. Global climate ambition would need to be raised in order for them to do so.

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China appears well positioned to capture USD 500 billion in 2030, or around 65% of the outputs of announced manufacturing capacity in monetary terms in the same year. Unless China's domestic deployment of key clean technologies exceeds the levels projected in the APS, around two-thirds of this output on a net basis (USD 340 billion per year) would be surplus to domestic requirements, and would need to find export markets. For solar PV, batteries and electrolysers, global climate ambition would need to be raised in order to do so, given that these technologies see projected manufacturing output in excess of global APS deployment requirements in 2030.

Announced projects in the United States put the country on a trajectory to capture USD 100 billion of the supply-side market in 2030, while the combined domestic market is projected to grow to nearly USD 150 billion in the APS. This implies potential net import needs of nearly USD 50 billion if no additional capacity is forthcoming. Heat pumps account for 40% of this market imbalance, with wind turbines and solar PV accounting for most of the rest. The European Union's domestic market imbalance balance looks set to reach USD 20 billion in imports for these technologies, if no more manufacturing capacity is forthcoming. However, the Net Zero Industry Act and Green Deal Industrial Plan can be expected to change projections. India's net trade balance is expected to reach USD 25 billion in imports for these technologies, with batteries accounting for around USD 15 billion of this, in the absence of additional manufacturing capacity.

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Part III: Recent policy developments

The age of clean technology manufacturing offers big opportunities for the countries that embrace it, including positive synergies with climate and energy security goals, as well as benefits for economic growth.

Countries will need to define industrial strategies fit for the clean technology manufacturing age in accordance with their national circumstances, considering potential strengths with regards to different technology areas, as well as priority needs for collaboration and strategic partnerships with third countries. Governments seeking to stimulate domestic manufacturing also have a unique possibility to influence local demand for clean energy technologies at the same time, such as by supporting incentives for purchasing EVs. For suppliers, local markets offer benefits such as lower transport and administrative costs for reaching potential buyers.

The majority of announced manufacturing projects across most key clean energy technologies do not have committed investments. In the United States, for example, almost 40% of the announced battery factories are under construction whereas the figure is just 2% for electrolysers. In Europe, the equivalent figures are around 10% and 15% respectively. However, such manufacturing facilities can be brought online with relatively short lead times – around 1-3 years on average – meaning that deployment can rapidly scale up if support is maintained. Likewise, manufacturing projects that have been announced but not firmly committed may end up moving to different countries in response to policy shifts and market developments.

In an era of great change, project developers and investors are on the lookout for supportive policies that could give them the edge in different markets, and since the beginning of the decade, several major economies have introduced new policies to boost domestic clean technology manufacturing. Examples from the past year alone include the Inflation Reduction Act in the United States, the Net Zero Industry Act in the European Union and various milestones in Japan’s Green Transformation programme. Together with China’s latest Five-Year-Plan (2021-2025) and India’s Production Linked Incentive scheme, these policies are transforming industrial policy relevant to clean energy technology and reshaping the balance of global trade.

In this part of the briefing, we examine the impact of recent policy developments on progress towards domestic deployment targets in selected regions and

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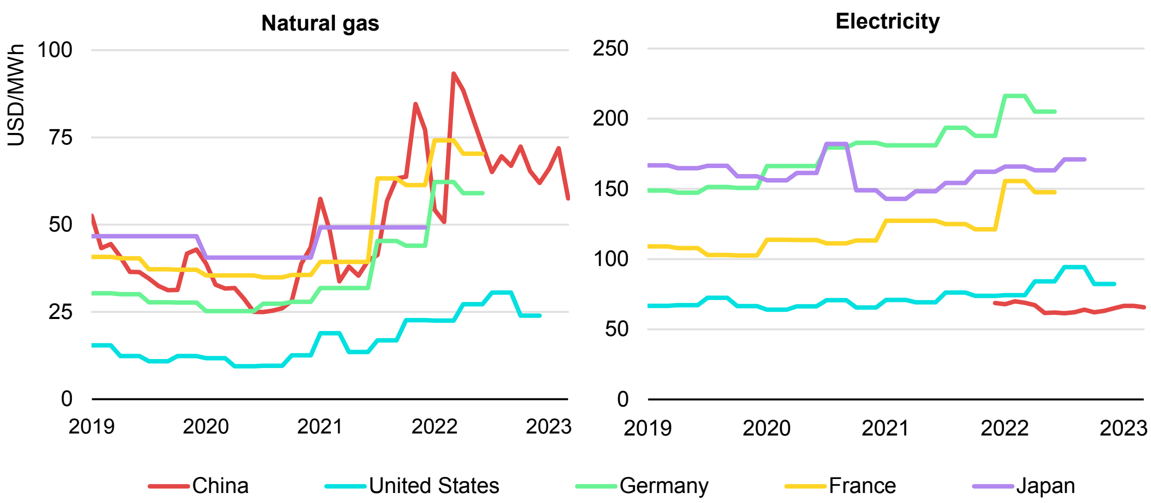
countries. We consider the potential role of these policies in shaping the expansion of clean technology manufacturing in the future, as a starting point for decision-making.

Policy frameworks are not the only factor influencing change in technology manufacturing. Each country will need to carefully consider their own individual circumstances to assess where in the supply chain to specialise domestically, and where it might be more effective to establish strategic partnerships or to make direct investments in other countries. One of the major differentiators in the competitiveness of energy-intensive industry sectors in different countries, and thus their attractiveness for manufacturers, is the cost of energy. This is especially true for natural gas and electricity, the prices of which vary significantly between countries.

Figure 6 Industry end-user prices for natural gas and electricity in selected countries



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Notes: Data for gas are from the China LNG Factory Price National Index. Electricity data are calculated from the “grid proxy electricity tariff for 30 provinces and cities in China”. Electricity data for China not available prior to reforms to liberalise markets at the province level in October 2021. Prices include taxes and are shown in 2021 US dollars using market exchange rates.

Sources: IEA (2023), OECD Energy Prices and Taxes quarterly; Shanghai Petroleum and Gas Exchange; State Grid Corporation of China; China Southern Power Grid.

Industry end-user prices for natural gas and electricity vary greatly between regions, with implications for industrial competitiveness.

Industrial competitiveness is also influenced by other contextual factors besides energy costs. Access to local customers and the size of the domestic market can be an important pull-factor for new manufacturing development, as can opportunities to exploit synergies with existing industries or to leverage the skills of an existing workforce. A favourable regulatory context, such as with regards to permitting times; competitive labour and capital costs; enabling infrastructure; and prospects for future development can also help encourage investment.

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United States

The Inflation Reduction Act (IRA), adopted in August 2022, set a new course for clean energy industrial strategy in the United States to support the achievement of decarbonisation ambitions, with around USD 370 billion allocated to energy and climate investments. It is already starting to have an impact on the pipeline of domestic manufacturing capacity. The IRA aims to provide more than USD 60 billion to scale up domestic clean energy manufacturing through production tax credits for manufacturers and consumer incentives to help drive demand. Specifically, the IRA provides USD 30 billion in production tax credits to accelerate domestic production of solar PV, wind turbines and batteries, as well as critical minerals processing. The IRA was also accompanied by new authority to use USD 500 million in Defense Production Act funds to increase production of five key clean energy technologies, including solar PV, heat pumps and electrolysers, as well as platinum group metals used in clean energy supply chains.

The effect of incentives and new requirements under the IRA to date has been particularly pronounced for battery manufacturing. Between August 2022 and March 2023, major EV and battery makers announced cumulative post-IRA investments of USD 52 billion in North American EV supply chains, of which 50% is for battery manufacturing, and about 20% each for battery components and EV manufacturing.

Total installed capacity for battery manufacturing rose 85% in 2022 relative to 2021, to 105 GWh per year. The pipeline of announced projects suggests huge growth over the next years – 30% CAGR through to 2030 and an additional 925 GWh of annual production capacity. If all these projects are realised, the manufacturing throughput for batteries made in the United States will be just shy of the domestic needs in the APS in 2030 – and over 60% of the levels needed in the NZE Scenario. As imports may still be needed for individual battery components, the minerals they use, and for specific battery types, the IRA includes provisions for collaborating with countries that have a trade agreement with the United States. This could slow down production in the near term, given the relatively limited possibilities to rapidly boost domestic production of some components. However, further provisions aim to strengthen the US domestic industrial base for large-capacity batteries and their component minerals, using loans and purchase commitments to incentivise expansion of domestic mining.

Solar PV module manufacturing capacity grew more slowly in 2022, albeit from a larger base, increasing by just 4% relative to 2021 to 7 GW. A sizeable amount of investment is expected to reach the solar PV industry, and announced projects suggest a further 35 GW of capacity could come online by 2030. Together with

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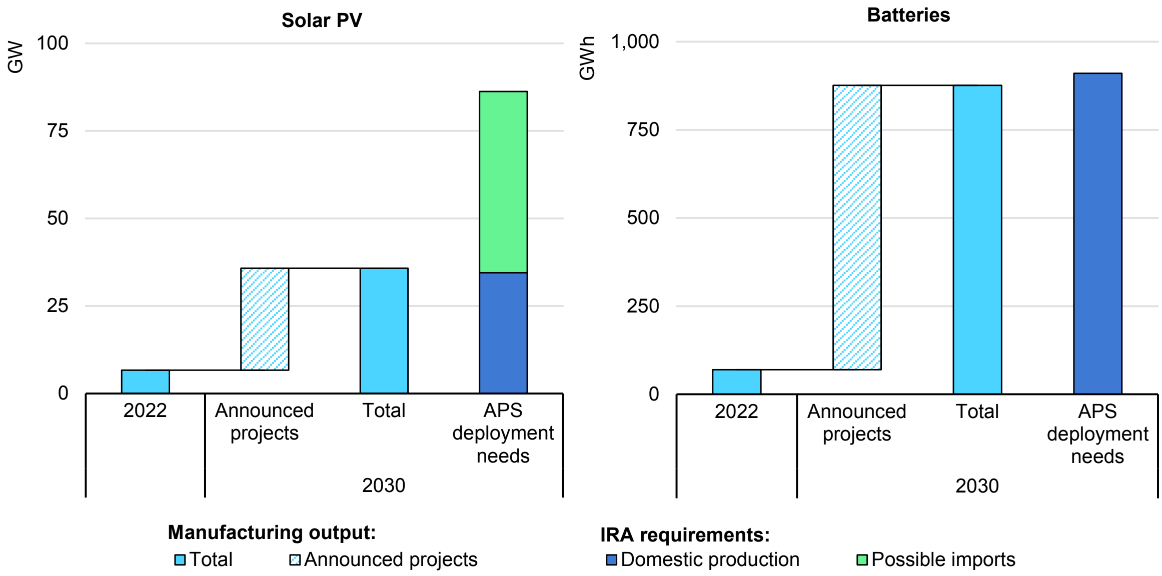
capacity already installed, if they were all realised, these announced projects could help deliver 40% of the domestic deployment needs in the APS in 2030.

Figure 7 Announced manufacturing projects and domestic production requirements in the Inflation Reduction Act for batteries and solar PV in the United States



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Notes: APS = Announced Pledges Scenario; PV = photovoltaic.

Increases in announced capacity expansions for battery manufacturing could meet deployment needs in the APS in 2030, but imports will be needed to meet requirements for solar PV.

Capacity additions for other technologies may be slower to get started. Electrolyser manufacturing installations registered no growth in 2022, relative to 2021, with installed capacity remaining flat at around 2 GW per year. However, the pipeline of announced projects for electrolysers implies substantial growth – a compound annual growth rate of over 30% – through to 2030, by which point domestic installed capacity would be able to satisfy 90% of domestic demand. Manufacturing output for heat pumps needs to more than double, and for wind power components to more than triple by 2030 in order to catch up with deployment needs in the APS.

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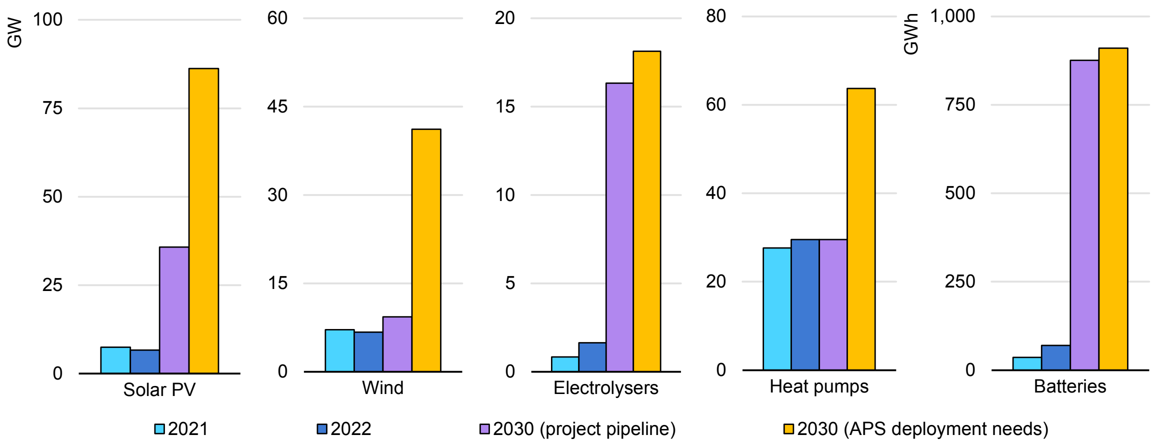
Figure 8 Current and projected manufacturing output for key clean technologies and domestic deployment in the Announced Pledges Scenario in the United States



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Notes: APS = Announced Pledges Scenario; PV = photovoltaic. “Project pipeline” refers to the sum of current installed capacity and all announced manufacturing capacity additions (as of end-Q1 2023) through to 2030. An average utilisation rate of 85% is applied to all existing and announced capacity in 2030.

A leap in announced projects for battery and electrolyser manufacturing implies strong growth to 2030.

European Union

The Net Zero Industry Act (NZIA), announced in March 2023, proposes measures to strengthen clean technology manufacturing in the European Union towards the overall aim of domestically manufacturing at least 40% of the technology required to achieve the Union’s 2030 climate and energy goals. While it is too early to assess the full impact of the NZIA, analysis of existing and announced projects shows significant progress towards the policy’s goals for some technologies.

The NZIA focuses on streamlining the regulatory environment and developing new avenues for internal co-ordination on manufacturing eight priority net zero technologies, including solar PV, onshore wind, batteries, heat pumps and electrolysers.[9] These technologies have been selected for their potential contribution to decarbonisation and competitiveness, as well as their relative maturity. A key aim is to improve diversification in supply chains: all the technologies selected have a component or part of the value chain for which the EU is currently heavily import-reliant, and tender opportunities will take into account the proportion of products or components originating from a single supply source. The NZIA also includes measures to create a skilled labour force, to test innovative technologies, and to establish a framework to monitor supply chains and track progress.

[9] The Act applies to the final technology product and its components, but not to associated upstream raw material supplies (which are covered in a separate regulation).

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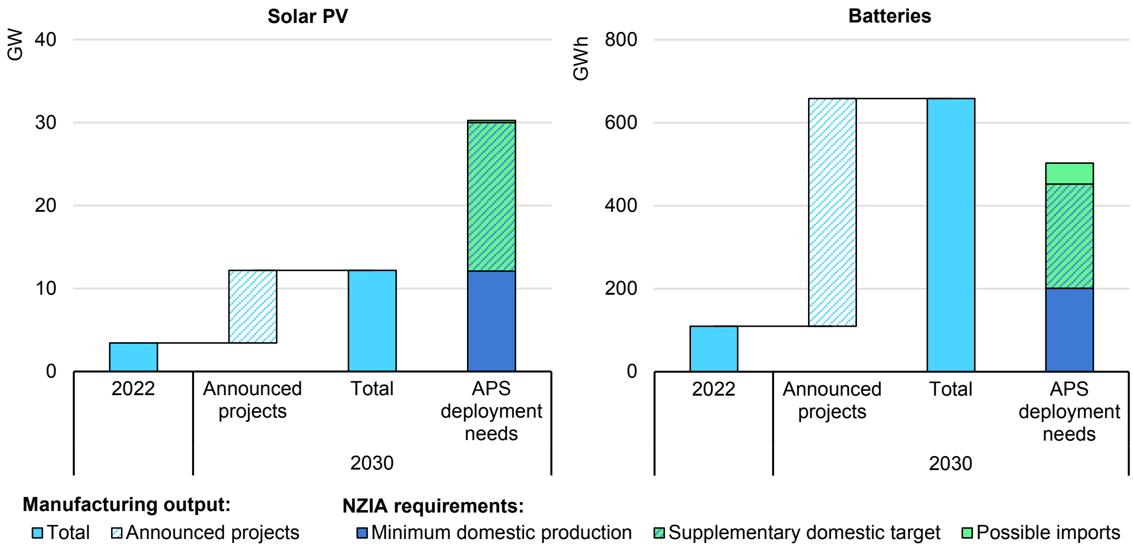
The NZIA does not emphasise financing schemes or trade policy, which are covered under other pillars of Europe's Green Deal Industrial Plan. The proposed European Sovereignty Fund is expected to provide more detail on investments for critical and emerging technologies.

There was strong growth in EU battery manufacturing in 2022 (110 GWh of output) relative to 2021 (70 GWh), driven by the increase in sales of EVs. Manufacturing capacity in the European Union increased 90% year-on-year to 130 GWh per year in 2022. Capacity is expected to increase at a compound annual growth rate of 25% per year through to 2030 if all announced projects are realised, with about 650 GWh per year added relative to 2022 levels.

The projected output of existing and announced projects combined looks set to comfortably achieve the cross-cutting 40% minimum level for domestic clean technology production specified in the NZIA. The supplementary targets stipulated for battery manufacturing include a further demand-dependent target of 90% of annual demand, and a 550 GWh absolute target, which also both appear achievable with the combined output from existing and announced projects (660 GWh). However, fewer than 10% of announced projects for battery manufacturing in the EU can be considered "committed" (i.e. have begun construction or reached final investment decision). If the NZIA domestic production targets are to remain within reach, a supportive policy environment is required to increase the likelihood that the remaining 90% of preliminary project announcements actually materialise.

Figure 9 Announced manufacturing projects and domestic production requirements in the Net Zero Industry Act for batteries and solar PV in the European Union



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Notes: APS = Announced Pledges Scenario; NZIA = Net Zero Industry Act; PV = photovoltaic. "Minimum" refers to the cross-cutting technology target in the NZIA, with "Supplementary" referring to the additional technology-specific targets.

While output from existing and announced EU battery manufacturing capacity is expected to fulfil the supplementary target of the NZIA, projected solar PV manufacturing output would only just fulfil the minimum target.

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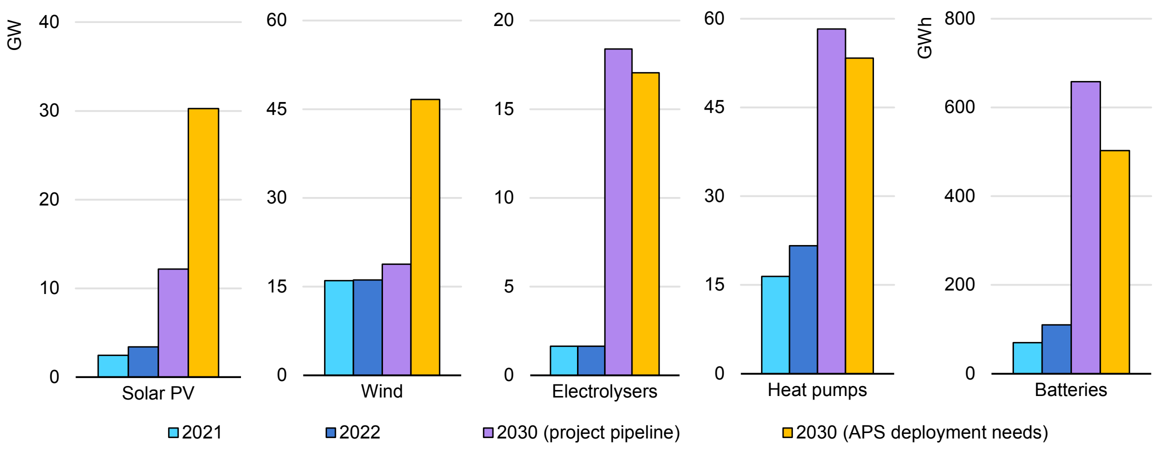
The global energy crisis sparked by Russian Federation's invasion of Ukraine and subsequent high gas prices have given additional impetus to the deployment of solar PV in the EU, which reached a record level of 38 GW in 2022. Despite this, domestic manufacturing capacity remained virtually flat, and domestic production was just 7.5 GW. Existing manufacturing capacity together with announced projects look set to fall well short of the 30 GW deployment needs of the APS in 2030, meaning the EU looks set to remain an importer of PV modules for the foreseeable future. While the overarching domestic manufacturing target in the NZIA of 40% of domestic needs looks achievable based on existing and announced capacity, there remains a large gap between the current project pipeline and the supplementary absolute target of 30 GW per year for solar PV.

Figure 10 Current and projected manufacturing output for key clean technologies and domestic deployment in the Announced Pledges Scenario in the European Union



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Notes: APS = Announced Pledges Scenario; PV = photovoltaic. "Project pipeline" refers to the sum of current installed capacity and all announced manufacturing capacity additions (as of end-Q1 2023) through to 2030. An average utilisation rate of 85% is applied to all existing and announced capacity in 2030.

Output from existing and announced manufacturing capacity in the European Union looks set to satisfy domestic demand in the APS for batteries, electrolysers and heat pumps.

Installed electrolyser manufacturing capacity remained flat over 2021 and 2022, but if all announced projects are realised, the projected CAGR of 34% over the next seven years looks set to deliver in excess of the level required in the APS by 2030 to meet domestic demand. The NZIA sets a target of 31 GW of annual manufacturing capacity by 2030 for heat pumps. The current pipeline of announced projects, together with existing capacity, look set to deliver in excess of this target, and moreover, in excess of the 53 GW annual deployment needs of the APS in 2030. Further project announcements could move the EU into a net export position for these two technologies.

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Given the European Union's dependence on imports for inputs to the manufacturing processes for clean technologies, the NZIA is expected to work in tandem with the 2023 EU Critical Raw Materials Act (CRMA), also announced in March 2023. The Act's overarching goal is to ensure the European Union's access to a secure and sustainable supply of critical raw materials for domestic manufacturing by: a) strengthening EU capacities along the different stages of the value chain, b) diversifying the European Union's imports of raw materials, c) improving monitoring and risk mitigation capacities, and d) improving the sustainability and circularity of critical raw materials. The impact of the NZIA on manufacturing capacity expansions is still too early to gauge.

China

China's 14th Five-Year Plan, launched in 2021, continued its support for clean technology manufacturing, contributing to the overarching aim of achieving a peak in CO_2 emissions before 2030. More than a decade of policy support has established China as the largest manufacturer for clean energy technologies and their components globally, and it looks set to maintain – and even extend – this position in the coming years.

For solar PV and wind, China already had enough manufacturing output in 2021 to satisfy its projected domestic demand under the APS in 2030. In 2022, manufacturing output was still growing, with solar PV reaching 190 GW and wind reaching 62 GW. These manufacturing operations are still seeing strong growth, driven in part by growing export markets. Manufacturing capacity is growing more quickly than domestic demand, and so if all announced projects are realised, exports of these technologies will also need to grow continually over the coming seven years. The combined output of existing and announced projects is estimated to reach nearly 860 GW for solar PV and around 70 GW for wind by 2030, relative to deployment needs in the APS of 108 GW and 41 GW per year for solar PV and wind respectively.

Manufacturing facilities for several technologies in China typically operate at lower utilisation rates than in other major economies. For solar PV manufacturing for example, current utilisation rate is estimated at 38% compared to an average of 65% for the next 5 largest producers.

For batteries, while existing manufacturing output would not be sufficient to satisfy domestic demand under the APS in 2030, the pipeline of announced projects would lead to around four times the volume of its domestic demand being produced by then. These projects – or the car manufacturing industries they supply – would need to find export markets if they are to operate at the utilisation rates modelled in this analysis (tending to 85% in 2030). Even if utilisation rates

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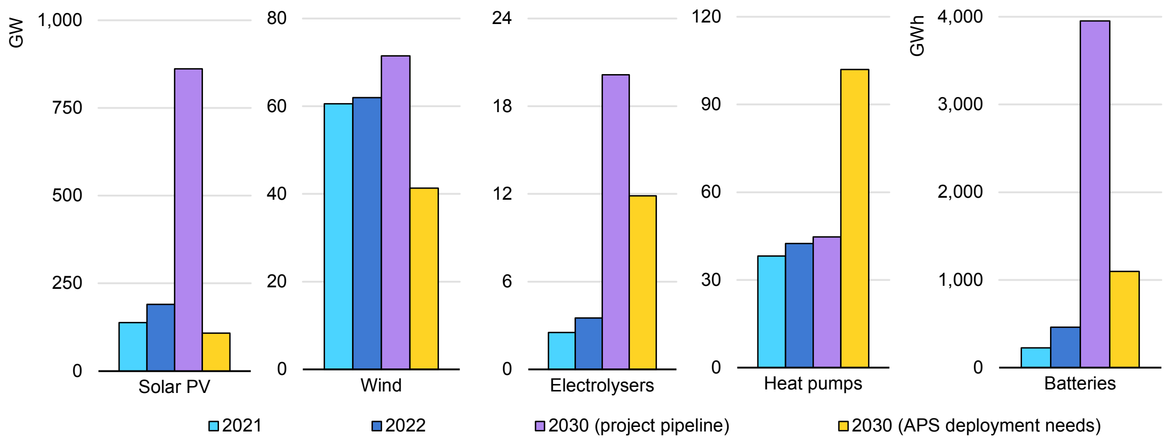
were to remain near today's levels in China, the country would still be able to service around twice its domestic demand for batteries in the APS.

For electrolysers, the project pipeline also constitutes huge growth, exceeding the level of installations in the APS in 2030 (12 GW per year). Installed and announced manufacturing capacity for heat pumps has also continued to grow steadily over the past few years, but it is the one technology among the five examined where sufficient output to satisfy 2030 APS needs is not currently forthcoming. However, the same caveat for heat pump manufacturing capacity applies in China as it does elsewhere: installations are not typically announced as prominently or as far in advance as for the other technologies assessed in this briefing.

Figure 11 Current and projected manufacturing output for key clean technologies and domestic deployment in the Announced Pledges Scenario in China



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Note: APS = Announced Pledges Scenario; PV = photovoltaic. "Project pipeline" refers to the sum of current installed capacity and all announced manufacturing capacity additions (as of end-Q1 2023) through to 2030. An average utilisation rate of 85% is applied to all existing and announced capacity in 2030.

Output from installed and announced projects in China looks set to significantly outstrip domestic demand in 2030 for most technologies, even if utilisation rates for manufacturing plants remain significantly lower than in some other major economies.

Other economies

In October 2022, India's Production Linked Incentive (PLI) scheme for High Efficiency Solar PV Modules entered its second phase, with incentives of nearly USD 2.4 billion – up from around 600 million in its first phase – to encourage integrated domestic manufacturing facilities for polysilicon, ingots, wafers, cells and modules. In this phase of the scheme the government awarded around 40 GW of additional manufacturing capacity, in addition to the nearly 9 GW contracted during the first phase. Eleven companies were awarded a total of USD 1.7 billion in March 2023 for a cumulative total of 39.6 GW of capacity

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additions. Import duties on PV modules and cells have also been increased to give Indian manufacturers a competitive edge.

The PLI on Advanced Chemistry Cell Battery Storage, announced in late 2021, is also ramping up. The scheme has allocated USD 2.2 billion to boost domestic battery manufacturing, with the aim of reaching 50 GWh in domestic manufacturing capacity. In March 2022, funding was awarded to projects collectively providing at least 50 GWh of annual capacity, with facilities to be set up within two years. An additional 95 GWh is expected to be established by other private companies. This is an ambitious target, as there is currently no significant domestic battery cell manufacturing in India, but considerable growth is expected in the domestic market if the country keeps on track with fulfilling its climate pledges.

Many other countries around the world are seeking to secure their place in the clean energy technology economy. Canada's 2023 Budget proposes a refundable tax credit equal to 30% of the cost of investments in new manufacturing equipment for key clean technologies, including batteries. In April 2023, Korea announced a number of initiatives to support battery manufacturing, including USD 5 billion worth of loans and guarantees from the Export-Import Bank of Korea and state-owned Korea Trade Insurance to advance the domestic industry. Japan's Green Transformation (GX) initiative includes measures to boost battery manufacturing with up to USD 1.8 billion in subsidies. Full details of how the initiative will be implemented are still emerging, but manufacturers have already announced new projects. The Australian federal government's USD 10 billion National Reconstruction Fund (NRF), passed in March 2023, also aims to boost domestic manufacturing, with up to USD 2 billion for clean technologies including solar PV, batteries, wind components and electrolysers.

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Part IV: Recommendations for the G7

The manufacturing facilities for the key clean energy technologies examined in this briefing can be developed relatively quickly, which – combined with recent policies to boost manufacturing – has created great dynamism in these sectors. For countries looking to establish a competitive position in the new clean energy economy, the industrial strategy decisions taken today will shape deployment and trade of clean technologies through to 2030 and beyond.

G7 members have already recognised the importance of building resilient, secure and sustainable supply chains to accelerate the clean energy transition and reduce vulnerabilities associated with undue dependencies. There is much countries can do domestically to proactively address the risks posed to supply chains – including developing industrial strategies that leverage their competitive advantages – but international co-operation will be crucial to ease, hasten and extend any progress that is to be made. The IEA stands ready to support G7 members and other governments in this endeavour.

With this in mind, this briefing concludes with recommendations for G7 members (also applicable to other interested countries), focussed on actions that require international co-operation:

1. **Co-ordinate efforts across supply chains** to determine risks posed to different elements that could delay or disrupt deployment and resilience in the face of potential market shocks. Much attention is now paid – quite rightly – to the security of supply of critical minerals, but supply chains are only as strong as their weakest link. G7 members should co-ordinate the work they are doing at each stage in the supply chain, examining remaining gaps that may lead to bottlenecks.
2. **Identify and build strategic partnerships**, both within the G7 and beyond. For most countries, it is not realistic to effectively compete in all supply chain steps, nor in all supply chains. Understanding relative strengths and competitiveness, and the potential to build complementary strategic partnerships, should be key considerations of industrial strategies, particularly for clean technology manufacturing.
3. **Facilitate investment in emerging market and developing economies** with pooled investments, knowledge-sharing and other strategies to reduce risks – and consequently, the costs of financing – for capital-intensive components of supply chains. Foreign direct investment should find an appropriate balance between export opportunities and support for in-country clean energy transitions and socio-economic development.

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4. **Develop a platform to inform the process of identifying strategic partnerships** for manufacturing. Such a platform could provide analytical information on current and projected future market sizes, production costs for different countries and regions and future expansion plans – among other insights – helping to reveal mutually beneficial relationships between countries.
5. **Share best practice and domestic experience** on measures relevant to accelerating progress in clean technology manufacturing, such as creating favourable investment conditions, accelerating permitting and stockpiling of input materials and components. “How-to-guides” for developing industrial strategies could be a vehicle for disseminating such efforts among countries.
6. **Promote manufacturing technologies and strategies to enhance resource efficiency**, thereby increasing the resilience of clean technology supply chains. Manufacturing processes that minimise material use, and technology designs that incorporate substitute materials when the security of supply of a given input is in question, should be incentivised through innovation policy, along with product designs that facilitate re-use, repairability and recyclability. Designing and adopting standards for clean technologies, such as common taxonomies and definitions for low- and zero emission products and materials, can support traceability of products and components and facilitate trade of components/scrap. Standards that determine which materials and practices are acceptable in clean technology supply chains can also promote transparency.

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