STRATEGIC PERSPECTIVES

Competing in the new zero-carbon industrial era

Assessing the performance of five major economies on key decarbonisation technologies

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Introduction

With a large share of countries looking into transforming their economies to reach net-zero emissions or sustainable development in line with the Paris Agreement, the global demand for zero-carbon technologies is rapidly growing. The UN's Intergovernmental Panel on Climate Change (IPCC) has been clear[1] on what it takes to limit the increase of average global temperature to 1.5°C. By 2030, the world must reduce its greenhouse gas emissions by 43%. Reaching that goal requires a significant increase in the speed and scale of deploying zero-carbon technologies across the globe. To give just one example, the International Energy Agency (IEA) suggests[2] tripling renewable energy deployment by 2030, a target recently supported[3] as a key outcome for the 28th UN climate summit (COP28) by the European Union (EU) and by the United Arab Emirates as the incoming COP presidency.

This report seeks to provide an overview on the global race to the top on renewable energy, electric vehicles and heat pumps to highlight the political motivations for an economic transition to net-zero emissions, and covers the feasibility of rapid technology deployment if finance and strong policy frameworks are available. It will shed light on the competition among a few selected economies based on existing data where comparable information is available for all economies. No new modelling was undertaken. The research is largely based on data from Bloomberg New Energy Finance (BloombergNEF) and the IEA.

While the transition to net-zero emission economies and societies is the main driver, we look into zero-carbon technologies in this report, acknowledging that electrified equipment is only 'zero-carbon' if used with zero-emission power. Subsequently, both "net-zero" and "zero-carbon" will be used frequently throughout.

Given the clear technology competition between China, the EU and the US, these economies were the obvious choice as a starting point. This year's G7 host Japan and G20 host India were added to provide more geographic balance and recognise their ambitions in the global technology race to the top. Together they are called "the five economies" in this report. It is clear that India cannot be compared on equal footing with the other economies given its different entry position on economic development. As India has strong ambitions to become an integral part of the global net-zero supply chain, the foundations are there for it to benefit from the transition in the near future – if additional investments can be secured.

Strategic Perspectives has worked with international researchers and national experts who provided invaluable input to this report and verified national dynamics outside Europe. This report tries to capture different national drivers and terms for the transition as much as possible.

Solar farm in China.
Photo by Young777 on iStock.

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Executive Summary

Net-zero transition plans are driving the emergence of a new industrial era based on zero-carbon technologies[4] manufacturing and deployment that create jobs, competitive advantages and emissions reductions in key sectors. Major economies like China, the EU, the US, Japan and India are competing to deploy renewable energy, electric vehicles and heat pumps, and to lead the global supply of these zero-carbon technologies.

National transition plans such as the European Green Deal, China's 14th Five-Year Plan, India's Energy Conservation Act, Japan's Green Growth Strategy and, more recently, the US Inflation Reduction Act are being turned into industrial strategies. They have the potential to create millions of quality jobs, with the International Renewable Energy Agency (IRENA)[5] assuming the renewable energy sector alone could employ 40 million people by 2050. The five economies of China, the EU, the US, Japan and India seek to position themselves as global leaders in the transition to net-zero, shaping markets and fostering innovation. **While the net-zero transition should reduce all greenhouse gas emissions along the value chain, it has fast turned into a strategic choice for strengthening countries' energy security, industrial competitiveness and future economic prosperity.** This transformation is happening now in many countries that have the fiscal space, with the potential to reshape the global economy. Net-zero investment is booming at unprecedented levels, driven by the shift to electric vehicles and renewables, and will overtake fossil fuel investment in 2023[6]. **Countries that miss this opportunity are unlikely to embark on this new industrial era and risk heavy dependence on gas, coal and oil** – an economically and politically costly option.

This report examines the dynamic landscape of key zero-carbon technologies in China, the EU, the US, Japan and India. **These five economies play a critical role in shaping the global energy landscape** and serve as frontrunners for potential global leadership in technology deployment. Investment, innovation, manufacturing and deployment of renewable energy technologies, electric vehicle batteries and heat pumps specifically serve as a barometer when tracking which economy is leading the race to the top, which are in close competition, and which is well-positioned to lead future developments.

The results of this analysis clearly show that the deployment of key zero-carbon technologies is rapidly scaling up in all five economies, driven by clear plans and national policy goals or laws. The growing share of renewable energy and electrified equipment using zero-carbon electricity will substitute the use of fossil fuels. The five economies are competing with each other, with leaders emerging in different categories. Having the fiscal space to invest in domestic innovation, manufacturing and deployment is key to success. Thus, international financial reforms are vital to ensure that all countries can accelerate their net-zero transition and development.

China is a clear leader in the zero-carbon technology race, investing heavily in the deployment of renewables and electric vehicles, and in the manufacturing of zero-carbon technologies. Alone, China's new renewables capacity accounts for 55% of the world's additional installed capacity[7] in 2023, while more than half of all fully electric cars[8] in the world

EV in San Francisco, US.
Photo by Sundry Photography on iStock.

run on Chinese roads (2022 data). More importantly, China covers 60% of the global zero-carbon technology manufacturing, creating millions of jobs and new economic activity in its territory. By doing so, **the country aims to capture a large part of the growing net-zero market as well as to have control of technology and component supply** chains for the rest of the world. The vast majority of solar as well as large parts of battery supply chains are managed by Chinese companies. They are also gaining market shares in the wind and heat pump industries, putting pressure on competitors in the EU and the US. The high dependence of other economies on China exposes them to major supply risks, bottlenecks or even disruptions in strategic technologies.

However, despite the advance of China, the other economies are quickly catching up and even directly competing. **The EU is decarbonising its economy fast with the largest share of wind and solar electricity generation**, accounting for 22% of the electricity mix in 2022 and overtaking[9] gas (20%) and coal (16%). The use of electric cars per capita in Europe is the highest of the economies covered by this report, and it has taken the lead in investment and deployment of heat pumps, which are rapidly replacing gas, coal and fuel boilers. **The European Green Deal was initiated at the right time to strengthen Europe's position in the race to net-zero in the new industrial era** and to reinforce the ongoing transformation of its economy. European laws are creating a favourable policy environment to attract investors in renewable energy, electric vehicles and heat pumps. The European Green Deal could turn into the best strategic response to the multiple crises Europe is facing, improving its energy security, restoring its competitiveness and protecting households from high energy bills. However, to continue competing in the new industrial era, Europe will need to scale up investments and bring fresh money to building new manufacturing capacities and consolidating its wind and heat pump industries.

Similarly, **the US is quickly catching up with China and the EU, largely thanks to the Inflation Reduction Act**, which aims to increase domestic net-zero manufacturing and to support consumers in buying zero-carbon technologies. In contrast to the EU's regulatory approach, the US is focusing on tax incentives, which will allow net-zero industries to ramp up quickly. The Inflation Reduction Act plans to increase the production of renewables and batteries tenfold[10] in the US by 2027. Zero-carbon technology manufacturers could replace fossil fuel companies as the strongest economic asset of the country, bringing high added-value and job creation. In just a year, 170,000 new green jobs[11] have been created in the old, declining industrial centre, the so-called 'Rust Belt', as well as in the South, showing the social and economic benefits of investment in the transition to net-zero. In addition, **the US is a fierce competitor of China and Japan regarding innovation** in the renewable energy sector. This is a strategic choice, as innovation leadership is as important as deployment leadership, given it will shape future markets and standards.

Despite the high potential of its economy, Japan seems to be missing out on the key economic and security opportunities of the new industrial era. Although Japan is extremely dependent on gas, oil and coal imports, it is the only developed country covered by the report where net-zero investments have declined in recent years. The lock-in in the hybrid vehicle segment undermines the ability of the country to benefit from the rapid development of battery electric vehicles and prevents its car manufacturers from competing in global electric vehicle sales. Its energy transition is hampered even though solar accounts for 10% of the country's power mix and the Japanese government has a strong plan to expand renewables, especially offshore wind. Japan is the only G7 country not currently engaged in a stringent coal phase-out process, and it continues to open new coal power plants. **This position makes the country less attractive for new investors and, crucially, more vulnerable to international energy price volatility.**

India faces different challenges in this new industrial era and provides an excellent example of an emerging economy with certain policy ambitions that could bring about the transition to a net-zero economy much faster if receiving financial support. With investment, the country's decarbonisation plans could be effectively implemented and **India could become a showcase of successful net-zero development. The electric vehicle industry is expected to grow at a compound annual growth rate of 49% between 2022 and 2030**, creating 50 million jobs by 2030.[12] This will allow the quick deployment of electric cars and two-wheelers. Similarly, India is making progress in incorporating solar and wind into its electricity generation, almost doubling its share from 2017 figures (5% to 9%). However, having less financial capacity to invest in research and development, India is still very dependent on technological transfer and relies on Chinese imports. Building its zero-carbon technology factories and investing in innovation will be crucial elements in securing its transition and positioning India in the global net-zero supply chain.

As this overview of the positions of the five different economies shows, the new industrial era is underway and is creating strong competition among them. Countries that succeed in leading the innovation, manufacturing and deployment of key strategic sectors will gain quality jobs and shape international standards. However, to ensure a well-distributed transition to net-zero globally, financial support needs to be more abundantly available for developing countries. In addition, a new paradigm of economic cooperation can create net-zero value chains in countries seeking to join the race on zero-carbon technologies. Through mutually beneficial partnerships, new actors enter the global net-zero supply chain and can benefit from the socio-economic opportunities of the net-zero transition.

Solar Panels in Karunagappalli, India.
Photo by Omkar Jadhav on Unsplash.

CHAPTER I

Decarbonisation in a global context: data availability and policy comparability

This report seeks to present a comparison of the technology deployment and related data of five major economies: China, the EU, the US, Japan and India. **To consider the scale of investment and the effectiveness of the energy and economic transitions in these major economies, the most recent data was used when available for all or most countries.** Occasionally, information was not available for all countries, or was difficult to compare, or was incomplete – thus, data availability created limitations, in particular for the analysis of the heat and transport sectors.

Given the substantial differences in size and economic development of the four countries and the EU, absolute levels of investment or deployment are used infrequently in this report. To enable a direct comparison between economies, we provide data as a function of population or Gross Domestic Product (GDP) instead. This approach allows for a more balanced view of the state of play. **In fact, the results show that the economies which are often perceived as runaway leaders in a sector may not be as far ahead.**

Policy frameworks are at the base of the new economic landscape for many of the geographies analysed. These include the greenhouse gas emissions targets stated in Nationally Determined Contributions (NDC) under the UN Framework Convention on Climate Change (UNFCCC). All five economies considered in this report have introduced legislation and enabling policies which are intended to drive decarbonisation directly or indirectly.

There is no uniform approach to achieving the net-zero transition across the different geographies compared. In particular, the goals of the US Inflation Reduction Act to encourage rapid deployment through massive investments is strikingly different from the emphasis on innovation through regulation and carbon pricing in the EU's European Green Deal, or the comprehensive economy-wide plans set out by China. While adopting an "industrial policy" approach to growing the decarbonisation sectors seems to be the preferred approach in general, India appears to favour developing individual sectors rather than a broader, economy-focused plan to expand its industrial base.

Wind turbines in Shizuoka Prefecture, Japan.
Photo by discoverjapan on Adobe Stock.

Despite these differences, legislation is the most powerful driver for change on the ground. All five economies analysed have targets for renewable electricity deployment, while types of incentives for the use of electric vehicles vary according to motivation (for example, air quality, technology leadership, greenhouse gas emissions reductions, etc.). The Annexe provides more details of recent policy and legislative action designed to enhance decarbonisation.

The rich variety of approaches across the five economies can provide inspiration and lessons learned for other countries to follow. **Taken all together, this analysis shows an energy and economy transition to net-zero in full swing, comparable in scale and scope to a new industrial era that can drive electrification globally.**

CHAPTER II

Global competition for net-zero investment, innovation and jobs

Wind turbine in Gänserndorf, Austria
Photo by Wolfgang on Adobe Stock.

The emergence of a new industrial era based on renewable energy and electrification of sectors is being driven by three critical enabling factors in which countries are competing: investment, research and development (R&D), and job creation. These enabling factors provide a solid indication of the rapidly evolving energy markets as well as how the five economies are seeking to perform on the net-zero transition both at the domestic and international level.

Key takeaways:

I. Decarbonisation plans such as the European Green Deal, China's 14th Five-Year Plan, India's Energy Conservation Act and, more recently, the US Inflation Reduction Act have led to **unprecedented levels of investment in the transition to a net-zero economy**. More than reducing greenhouse gas emissions alone, these plans have emerged as strategic responses to multiple crises, including the COVID-19 pandemic, the energy crisis and inflation. **Only Japan has seen a significant decline in net-zero investment**, a sign that its performance and competitiveness in zero-carbon technologies are at risk.

II. **China clearly has taken the lead on both net-zero investments and innovation**, followed by the EU and the US. Leadership on innovation is as important as on technology deployment, as innovation can shape future markets, improve technologies, and set new quality standards. Both Japan and China are serious frontrunners on innovation, with the European Green Deal and the Inflation Reduction Act **likely to help keep the EU and US in the competition**. In the case of the EU, a new European financial architecture that encourages fresh investments in manufacturing and deployment is key to avoid it falling behind in the coming years.

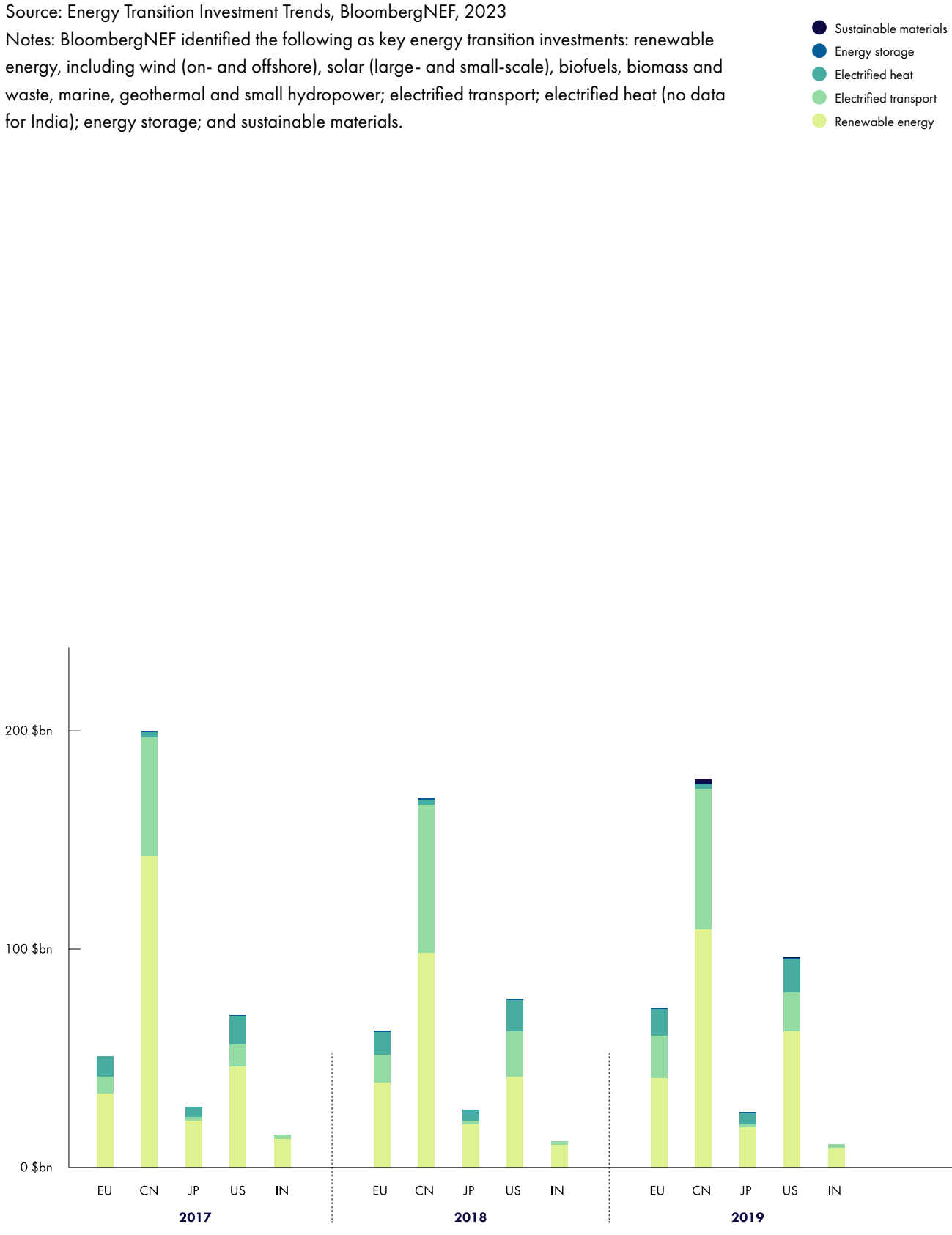
III. Among these major players, **India stands out as a fast-developing economy with ambitions to position itself in the new industrial era**. While its starting point is obviously different, its recent transition plans are producing investment effects that can help it quickly catch up in the global dynamic. Technology transfer, financial or other support structures to make India part of global value chains are key.

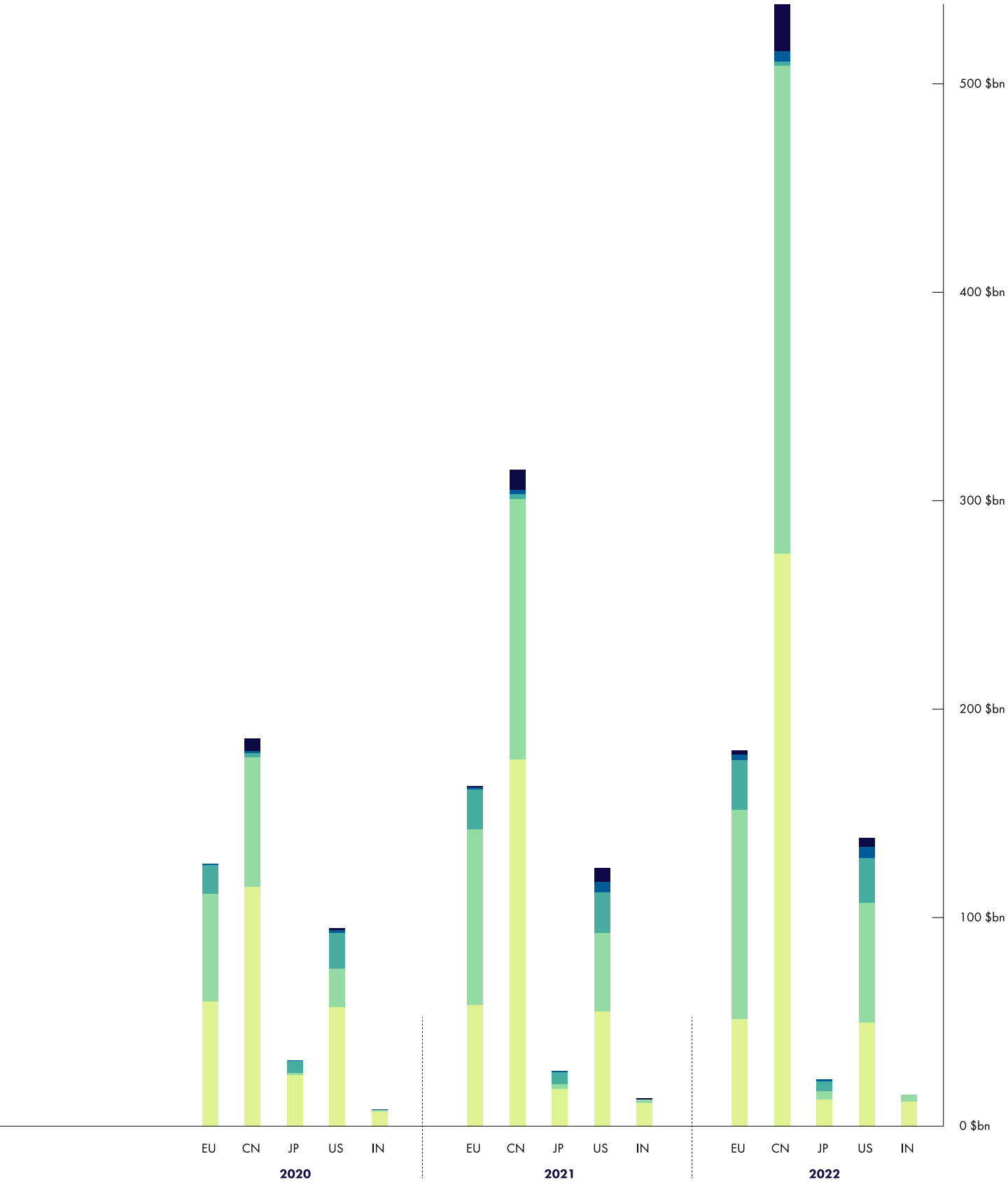
Figure 1.

Investments in zero-carbon technologies and sustainable materials

Source: Energy Transition Investment Trends, BloombergNEF, 2023

Notes: BloombergNEF identified the following as key energy transition investments: renewable energy, including wind (on- and offshore), solar (large- and small-scale), biofuels, biomass and waste, marine, geothermal and small hydropower; electrified transport; electrified heat (no data for India); energy storage; and sustainable materials.




500 $bn
400 $bn
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EU
CN
JP
US
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2020
2021
2022

Competing on net-zero investment

The Inflation Reduction Act has shown the serious intention of the US to modernise its economy based on zero-carbon technologies. The US entered, and thus exposed, the competition occurring between China and a range of G7 countries which have the necessary fiscal space despite inflation and the related cost of living crisis. The European Green Deal, China's 14th Five-Year Plan along with the US Inflation Reduction Act are major decarbonisation plans that have led to unprecedented levels of investment spurring the transition to a net-zero economy. Renewables and the development of electric vehicles are the most attractive sectors for investors. In the last two years, the development of electric vehicles has grown rapidly, with investments increasing by 59% year-on-year since 2021. ***See Figure 1.***

China is clearly leading the investment competition with a 71% increase in support for zero-carbon technologies between 2021 and 2022, up from 314.81 billion to 538 billion US Dollars (USD). This follows the announcement of its NDC update in 2021. China's investment is supporting the deployment of zero-carbon technologies domestically, meaning it is capturing an important international market share. For example, electric vehicle investments almost doubled in 2022 compared to 2021, reaching 234 billion USD – enabling the country to grow its role both in the supply chain and the electric vehicle sector.

While China is dominating net-zero investments so far, the EU and the US are increasingly competitive. **The EU** is the second-largest contributor to investment in zero-carbon technologies, with a total of 180.15 billion USD in 2022. Irrespective of the multiple crises it is facing, **the European Green Deal has sent a strong signal in favour of decarbonising the EU economy, giving clarity to investors.** The EU's climate laws and related investment appear to have formed a solid response to the economic turmoil caused by a combination of the COVID-19 pandemic, high energy dependence on Russia and inflation. For instance, the end date of 2035 for the sale of new diesel, petrol and hybrid cars is creating a major shift in the European car market. The clear and strong policy goal is attracting investor support for electric vehicles and new battery factories in the EU. Only renewable energy investment failed to bounce back to pre-pandemic growth rates,[13] despite record installations of solar[14] in 2022.

Similarly, **the US** has experienced a consistent upward trend in energy transition-related investment over the last six years. **In 2020, amid stagnation, the announcement of a plan to produce 100% carbon pollution-free electricity by 2035 has driven investors to support leaders in the US energy sectors.** The electrification of transport saw the most substantial increase in general investment, with a remarkable 207% surge from 2020 to 2022. While the US launched the Inflation Reduction Act to maintain this dynamic and catch up with China, especially in net-zero manufacturing, the EU and Japan risk lagging behind. The design of a new European financial architecture to support fresh investment will be critical to ensure public and private investment continue to support the net-zero transition of the EU's economy.

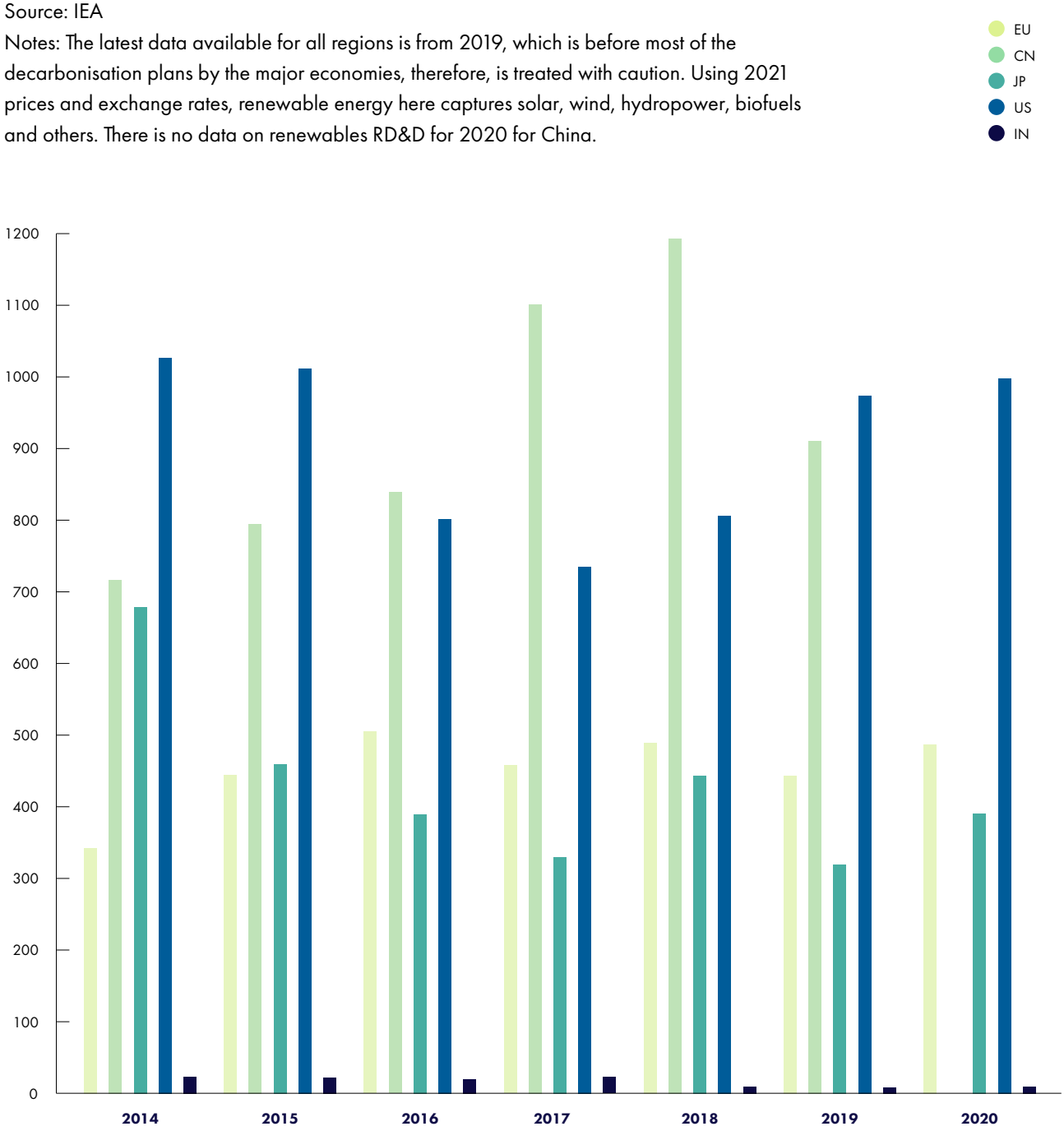
In 2021, **India** saw a turning point with increasing investment in zero-carbon technologies after a consistent decline over the preceding four years. During the 26th UN climate summit in Glasgow (COP26), India committed to significantly increase its renewable energy capacity to 600 GW by 2032 and to meet half of its energy needs from renewable sources by 2030, bringing new momentum to the country's transition. **In 2022, India witnessed record-breaking levels of financial flows to the transition**, driven by the doubling of investment in electrified transport. The increase in renewable energy finance is still relatively modest, but with the policy ambition now there, this can be scaled up significantly with more foreign capital.

Only **Japan has significantly decreased its net-zero investments in recent years**, despite its updated NDC and Green Growth Strategy launched in October 2020. Specifically, investment dropped from 24.32 billion USD in 2020 to 17.65 billion USD the following year. As the Japanese government seeks to deploy a broad range of technologies, not all of which are effectively decarbonising its energy sector, the net-zero transition of its economy is slowing down, with investment in zero-

carbon technologies dropping accordingly. Japan thus risks maintaining its dependence on fossil fuels and hampering its competitiveness as other economies move into a new industrial era.

Figure 2.
Renewables RD&D spending (million USD)

Source: IEA
Notes: The latest data available for all regions is from 2019, which is before most of the decarbonisation plans by the major economies, therefore, is treated with caution. Using 2021 prices and exchange rates, renewable energy here captures solar, wind, hydropower, biofuels and others. There is no data on renewables RD&D for 2020 for China.



Research and development spending as an indicator for innovation

Innovation is another fiercely competitive area among countries with commitments to transition to a net-zero economy. By investing in research, development and demonstration (RD&D), governments have a significant opportunity to shape future technologies and set global standards in terms of policy and product quality. **RD&D spending thus gives an indication of where leadership in innovation and growth markets will be in the coming years.** For example, RD&D investment will be crucial for technologies such as electrolysers, energy storage or more efficient renewables, and heat pumps. ***See Figure 2.***

In 2014, the US was leading the way in RD&D spending on renewables, followed by China and Japan. Given the change in administration, US spending subsequently dropped and did not reach 2014 levels again until 2020. Japan's spending also saw a decline, while China increased its spending consistently. The EU's R&D spending was somewhat stable until 2020, with the assumption that the new set of climate laws presented under the European Green Deal in 2021 might lead to a stronger upwards trend. The US is the only major economy to show year-on-year growth between 2018 and 2020 though. The decline in China's growth in 2019 might be due to the timing of the finalisation of its 14th Five-Year Plan in that period, or to the cyclical nature of R&D budgets.[15]

However, it is important to note that a completely different picture emerges when RD&D spending is compared to inhabitants (per capita). **From this perspective, Japan led renewables RD&D from 2014 to 2018, and has been competing with the US for the leading position since then.** Indeed, Japan has the potential to shape future innovations in the renewables sector if it manages to increase its political and policy targets once again and fully commits to the energy decarbonisation.

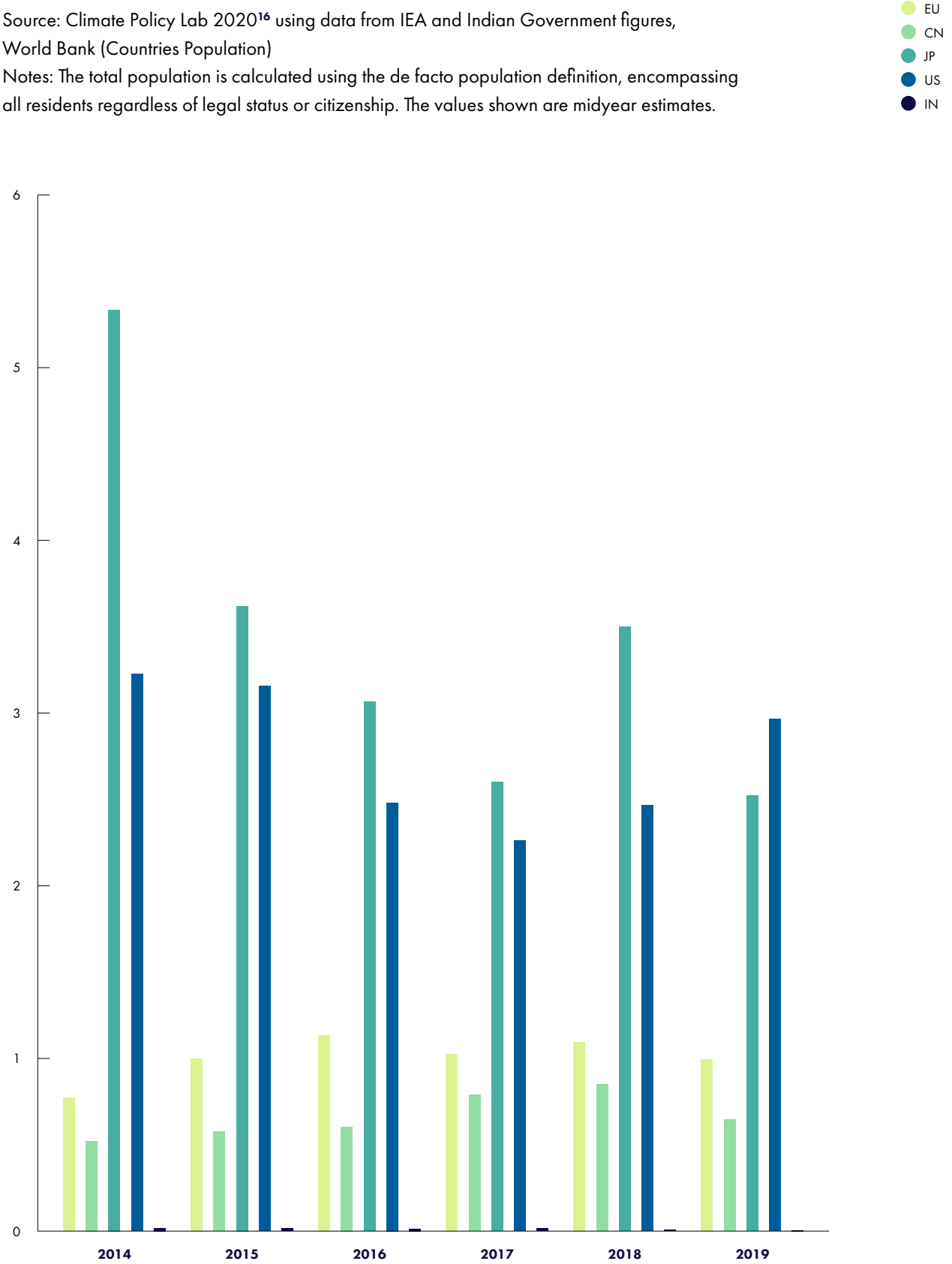
Given a starting point with lower financial means, India has much less capital to spend on RD&D in absolute and relative terms. The country's intent to scale up its patenting and technological innovation requires meaningful RD&D investment, or even technology transfers from international partners. India's cooperation with the US and some EU countries is pointing in that direction but is so far insufficient to notably position India in the global zero-carbon technology value chain. New forms of mutually beneficial economic cooperation – as set out in chapter 6 – can support India's RD&D and innovation capacity, and strengthen its future role in the net-zero economy. ***See Figure 3.***

Figure 3.

Renewables RD&D spending per capita (USD)

Source: Climate Policy Lab 2020[16] using data from IEA and Indian Government figures, World Bank (Countries Population)

Notes: The total population is calculated using the de facto population definition, encompassing all residents regardless of legal status or citizenship. The values shown are midyear estimates.



Employment opportunities of the new industrial era

Leading the way in any aspect of the net-zero transition brings domestic benefits, in particular new economic activity and employment. **A new industrial era underpinned by whole-economy modernisation or development plans creates high-quality jobs**, especially when governments make the choice not only to deploy zero-carbon technologies but also to invest in their manufacturing capacity. The reasons to be part of the new industrial era therefore go beyond technological or market leadership and energy security – the competition between China, the EU and the US to build zero-carbon technology factories can also be explained by the industrial prosperity and employment opportunities a net-zero transition entails. As global and domestic demand for zero-carbon technologies grow, associated jobs become future-proof jobs, and regions that transition away from fossil fuels can be reindustrialised. Although net-zero jobs are still a relatively small segment compared to total employment, they are growing significantly – as the case of the renewables industry in particular shows. ***See Figure 4.***

China employed 5.4 million people[17] in the renewable energy sector in 2021 according to calculations by the China Renewable Energy Society. This was driven by massive manufacturing in solar panels and wind turbines as well as strong domestic deployment, making it the world leader in renewable energy employment. **The EU is close behind China due to its targets and investment in renewable energy**, particularly solar and wind. In Germany, the wind energy sector alone employs over 130,000 individuals, while in Poland the creation of over 56,000 jobs was spurred entirely by the solar sector. In total, jobs in all net-zero sectors in the EU accounted for

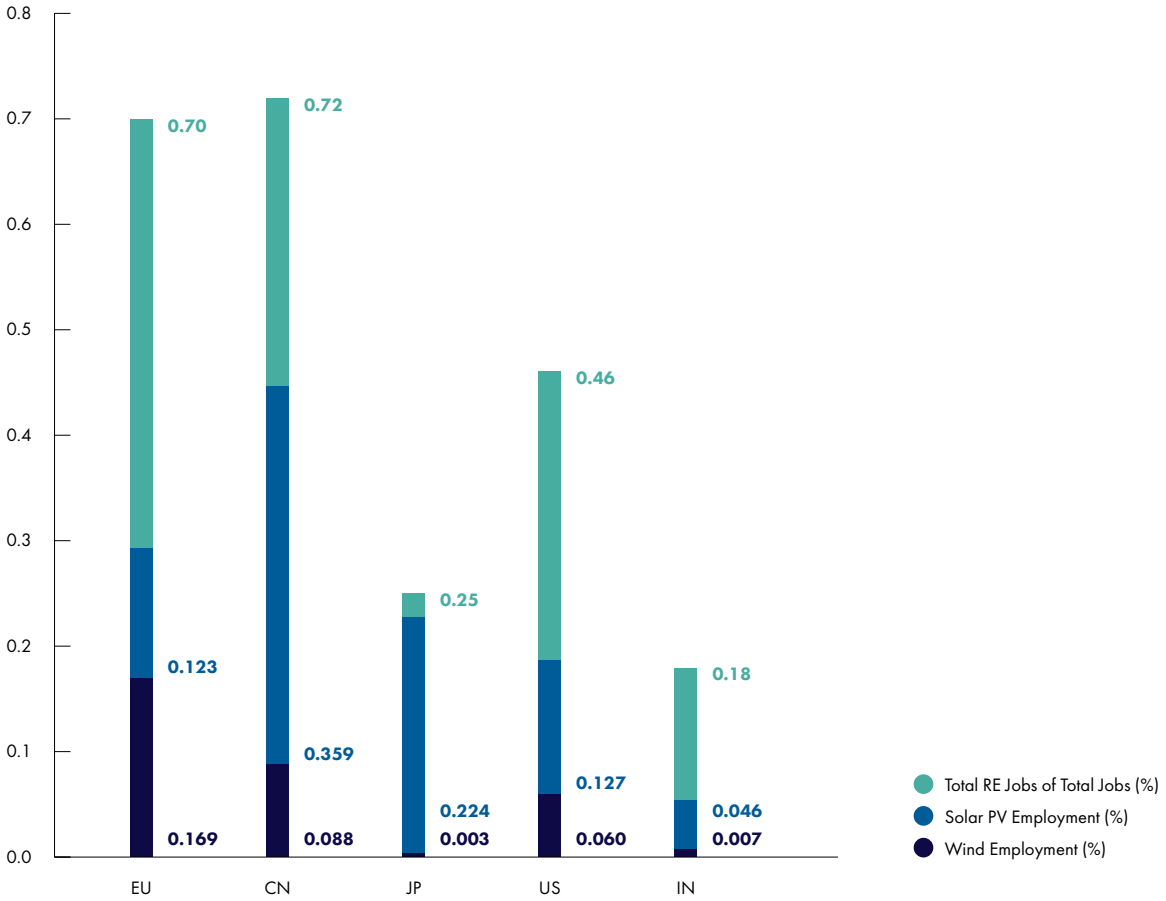
Solar Panels in New Delhi, India.
Photo by ertyo5 on iStock.

4.5 million full-time equivalent jobs in 2019, according to Eurostat. The political will to build new zero-carbon technologies manufacturing capacities in the EU could amplify related job development in the coming years.

India, Japan and the US may have smaller shares of renewable energy jobs in comparison to China and the EU, but these economies are also making significant progress, driven by government policies and technological advances. Solar photovoltaics (PV) alone accounts for around 217,000 jobs in India, 150,000 jobs in Japan and 255,000 jobs in the US. If governments seize the opportunity, the **net-zero manufacturing sector has the potential to provide many new, quality jobs while also offering new opportunities to fossil fuel industry workers**. For example, since the adoption of the US Inflation Reduction Act, 170,000 new green jobs[18] have been created in the old, declining industrial centre, the so-called 'Rust Belt', as well as in the South, showing both the social and economic interest of keeping pace with the net-zero transition.

Figure 4.
Renewables industry employment as a percentage of total jobs in 2021

Source: IRENA, European Union, Statista, US Rea Project
Notes: "Jobs in renewables" include biogas, concentrating solar power (CSP), geothermal, hydropower, biofuels, municipal and industrial waste, solar heating/cooling, biomass, and tide, wave and ocean energy.



CHAPTER III

Technology in focus: solar and wind power

Solar Panels near Mt. Fuji, Japan.
Photo by Paprikaworks on iStock.

The use of solar and wind power is a strategic choice to support the electrification of other sectors, while significantly reducing dependence on gas and coal for electricity generation. Russia's war in Ukraine and the subsequent rise in energy prices have highlighted the high cost of gas dependency for power generation, particularly in Europe and Japan. **Renewable power is not only the cheapest source of electricity, but also a quickly deployable energy security asset** for many major economies. In 2022, the world's solar and wind generation exceeded 10%[19] – a record that sets a new normal in the global energy landscape.

Key takeaways:

I. The five economies analysed have set strong targets and policies to boost solar and wind power which are driving rapid deployment. **Although China leads in terms of new installed capacity and investment in renewables, the EU has the largest share of renewable electricity generation.** Solar and wind alone accounted for more than 22% of the EU electricity mix in 2022, overtaking[20] coal and gas. **Japan follows with 10% of its electricity coming from solar alone, while India has almost doubled its solar and wind capacities since 2017.**

II. **China is the clear frontrunner in renewables manufacturing and supply chains**, especially solar, where Chinese factories produce 75% of the world's wafer-based solar cells. With the European Green Deal, the EU is well positioned to compete with China in wind manufacturing but falls behind in solar with related job losses, especially in Germany. Other economies are heavily dependent on technology imports, especially from China.

III. **Expanding solar and wind manufacturing supply chains will create new jobs and economic growth.** This was recognised by the EU and the US, which sought to build domestic factories for solar and wind technologies in 2022. Coupled with high levels of investment, the EU and the US may be able to compete with China in the industrial dimension of renewable energy development. Japan has the same potential if it corrects its policy ambitions, and so does India if it receives additional support.

Country targets to decarbonise power

Different policies and approaches are implemented among the five economies:

China: The 14th Five-Year Plan for the energy sector sets a target of 50% renewable energy in new power plants for 2021-2025.

EU: A new 42.5% renewable energy target by 2030 has been adopted under the European Green Deal laws, which will likely lead to a rapid ramp-up of solar and wind power. In addition, the European Commission's Net-Zero Industry Act proposal could help strengthen EU renewables industries.

Japan: The 6th Strategic Energy Plan,[21] approved by Japan's cabinet in 2022, aims to increase the share of renewables in power supplies to 36-38% in 2030,[22] double the 2019 level and well above its previous 2030 target of 22-24%.

India: The National Electricity Plan is set to approximately double India's renewables capacity by 2032 to almost 600 GW. The renewable energy[23] mix will be primarily solar and wind,[24] supported by hydropower, pumped storage plants, small hydropower, and biomass.

US: While not legally binding, the Biden administration announced an interim goal[25] to achieve an 80% reduction in US power sector emissions by 2030, with the further goal of fully decarbonising the sector by 2035, in line with the G7 commitment.

Solar and wind deployment

The **massive increase of renewables is becoming the new normal in a range of countries planning to transition to a net-zero economy**. This has clearly prompted a race to the top on solar and wind deployment. Many of the leaders in Latin America, Africa and Asia are outside the scope of the analysis of this report but, in brief; in 2019, Mauritania achieved a 29% share of solar and wind in its electricity supply, while in 2020 Uruguay reached over 40%.[26] Similarly, Chile and South Korea quadrupled electricity generation from solar and wind between 2015 and 2020, respectively.

Even though the 2023 cost of solar and onshore wind exceeds pre-COVID-19 levels[27], **they remain the cheapest and fastest option for new power generation in most countries**. Reforming the financial systems and support structures for developing countries is instrumental to guaranteeing faster deployment of renewables and thus access to energy in all countries seeking to deploy zero-carbon electricity technologies.

While China's new renewables capacity alone accounts for 55% of the world's additional installed capacity[28] in 2023, the country's power sector was still responsible for 51% of direct global CO2 emissions in 2021, making it the largest contributor to greenhouse gas emissions. As such, even though it is the frontrunner in solar and wind manufacturing, China lags behind the EU and US in terms of the share of its electricity generated by solar and wind. In this regard, **European countries clearly lead the way with solar and wind's share of their electricity mix reaching 22% in 2022**, overtaking coal and gas. The European Green Deal provides a strong framework for doubling the renewable generation share over just seven years[29] and for the continuing decarbonisation of the power sector. Renewable energy therefore is more than a powerful means of reducing emissions; it is also the smartest economic and strategic choice to strengthen the EU's energy security in the wake of Russia's war in Ukraine. ***See Figure 5.***

In 2022, **Japan was the country with the highest share of solar in electricity generation**, with solar PV providing more than 10% of supply. Japan's wind sector is relatively underdeveloped compared to the other four economies, but it has recently introduced plans for a rapid expansion of the sector, particularly offshore wind. Despite the opportunities offered by the renewables market, however, Japan is still opening new coal power plants.[30] It is the only G7 country not engaged in a structured coal phase-out process as part of a just energy transition.

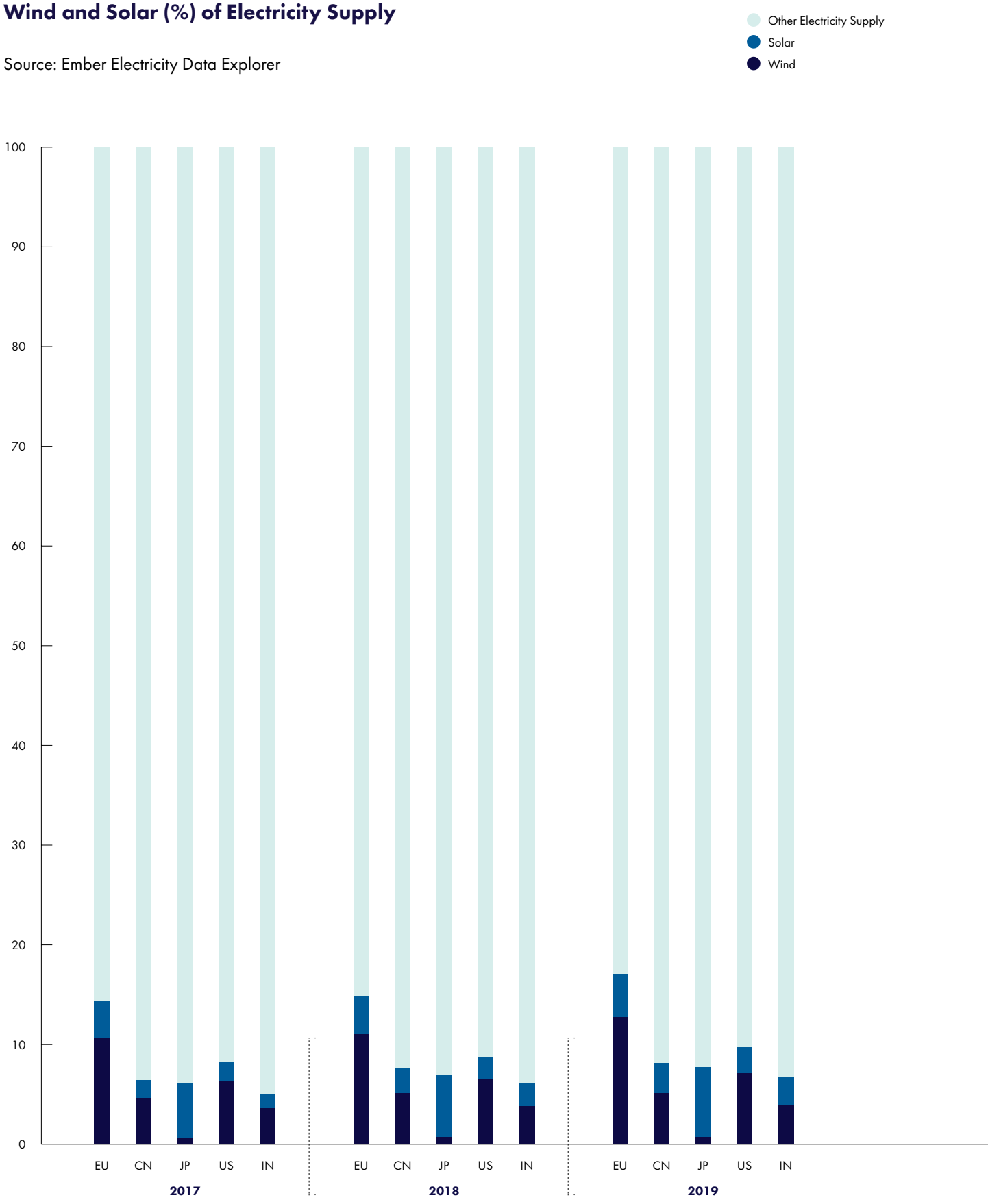
Among the five economies, **the EU leads in wind generation with a 15% share of electricity supply**. It is followed by **the US, which now has the second-largest share of wind generation (10%)** two years after committing to fully decarbonise its power sector by 2035. The US 2035 goal envisions solar and wind power comprising 60% to 80% of electricity generation.[31] However, when considering solar separately, the US has the smallest share, with generation only covering 4.75% of electricity supply in 2022, slightly behind China's 4.76%.

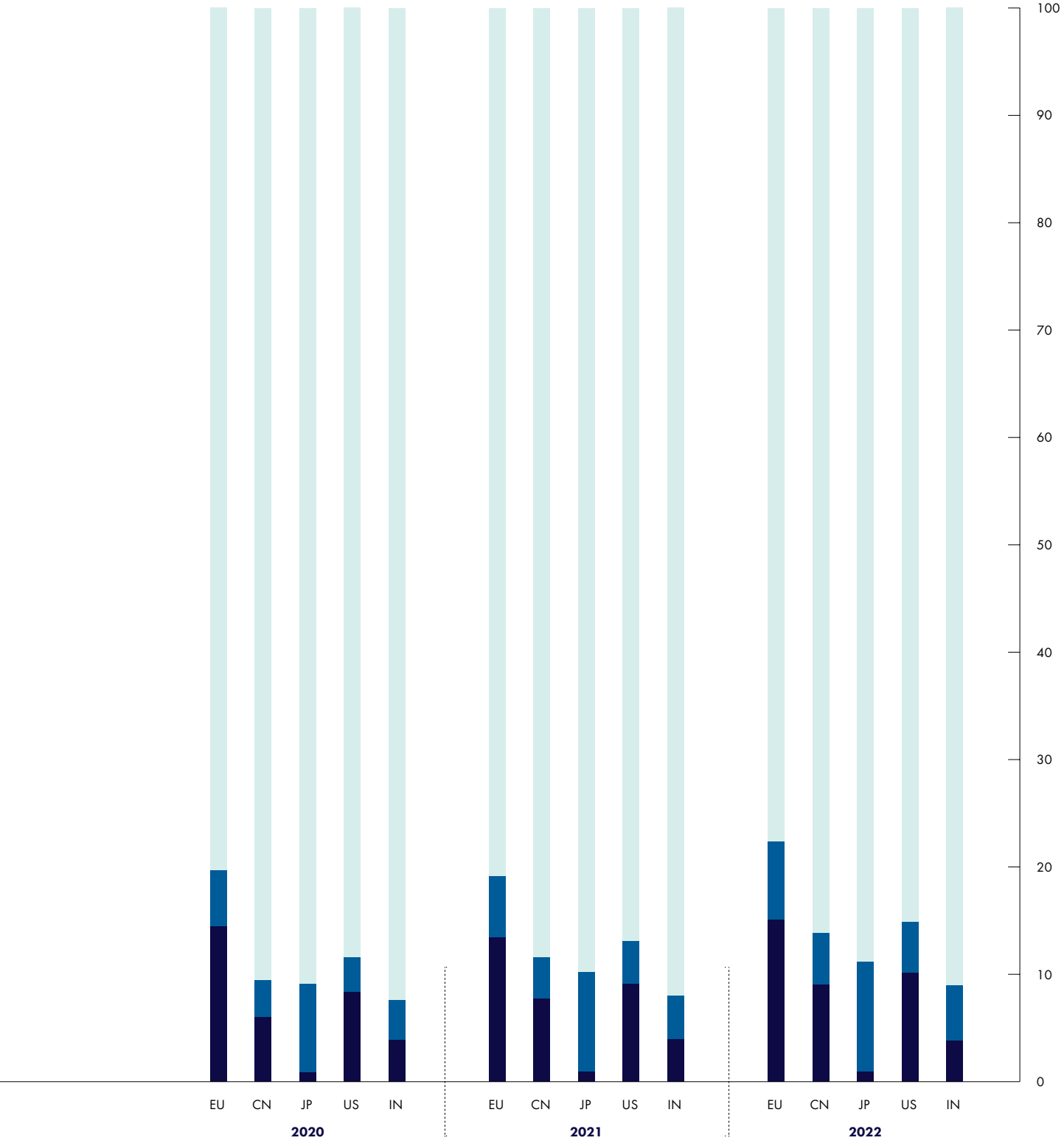
India is making progress in generating electricity from solar and wind, **almost doubling its share from 2017 figures** (5% to 9%). The country has the opportunity to be a showcase of an emerging economy decarbonising its power sector, with the further potential to leapfrog into the new industrial era if it successfully attracts foreign public and private finance for its renewable energy plans.

Figure 5.

Wind and Solar (%) of Electricity Supply

Source: Ember Electricity Data Explorer

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The impetus to develop solar and wind industries

Ensuring domestic climate targets can be met, maximising employment opportunities and de-risking dependence on the international value chain are the key challenges on the road to massive renewables uplift. **China's strong focus on renewable energy deployment and the manufacturing supply chain has proven successful in driving growth and job creation** in the country. The vast majority of solar manufacturing takes place in China, accounting for 2.7 million jobs, or 62% of the world's solar jobs.[32] The EU imported 84% of its installed solar modules between 2017 and 2021, the US 77% and India 75%.[33] This high dependence on China for the delivery of strategic technologies exposes other countries to major supply risks from delays, bottlenecks or even disruptions. ***See Figure 6.***

The US Inflation Reduction Act and the EU Net-Zero Industry Act share the goal of rebuilding solar industries, with the US presenting it as a strong geo-economic goal and the EU incorporating it as part of a 'de-risking' approach. India[34] also plans to diversify its solar supply to become less dependent on Chinese manufacturing. This could be challenging for many developed countries as it will require significant investment and a business model based on higher levels of innovation to compensate for the labour costs[35] that negatively impact the competitiveness of solar panel manufacturing. However, governments might deem the geopolitical, economic and security considerations to be worth this investment. The interest in diversifying solar supply in India could also turn into an opportunity for other developing countries if adequate support enables them to build solar industries for domestic use and exports. The development of solar manufacturing is a strategic choice – the global solar market[36] boomed between 2020 and 2022 from 155 billion USD to 235 billion USD and is expected to be worth 373 billion USD by 2029.

The picture is different for the wind sector. China has a growing market share with 45% of manufacturing capacities, but the EU is well-positioned[37] to compete, with 31% of industrial facilities – 83% of the EU's domestic markets were supplied[38] by European manufacturers. The European Green Deal's renewable energy goals can strengthen the competitiveness of the EU's wind industries. **The US and India are following each other closely** in terms of manufacturing capacities and could continue gaining market shares as their respective domestic policies are implemented. Only Japan seems to be missing out on the economic and competitive advantages that domestic manufacturing brings. ***See Figure 7.***

Figure 6.

Solar PV manufacturer shares as unit percentage

Source: IEA PVPS, RTS Corporation

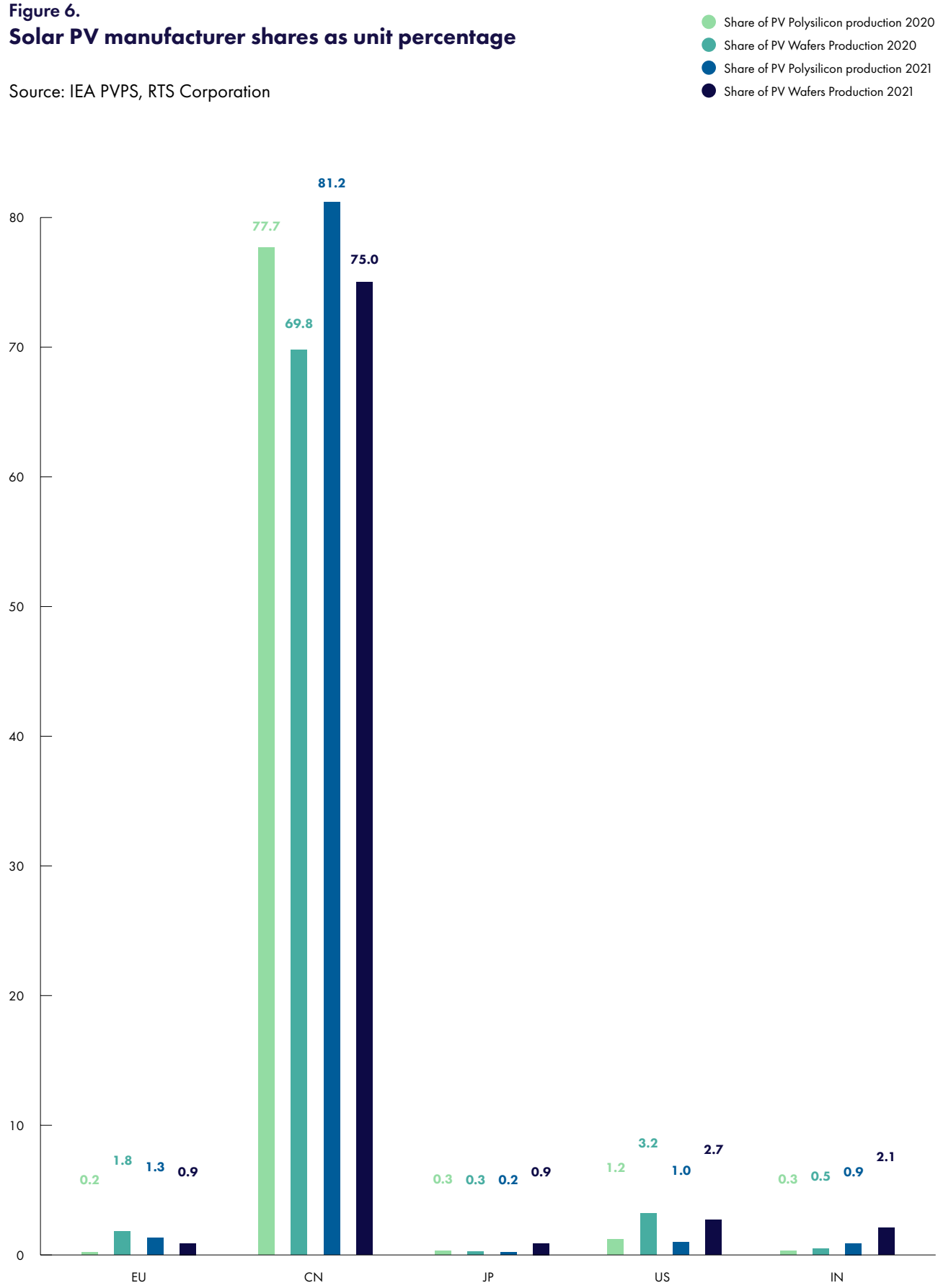
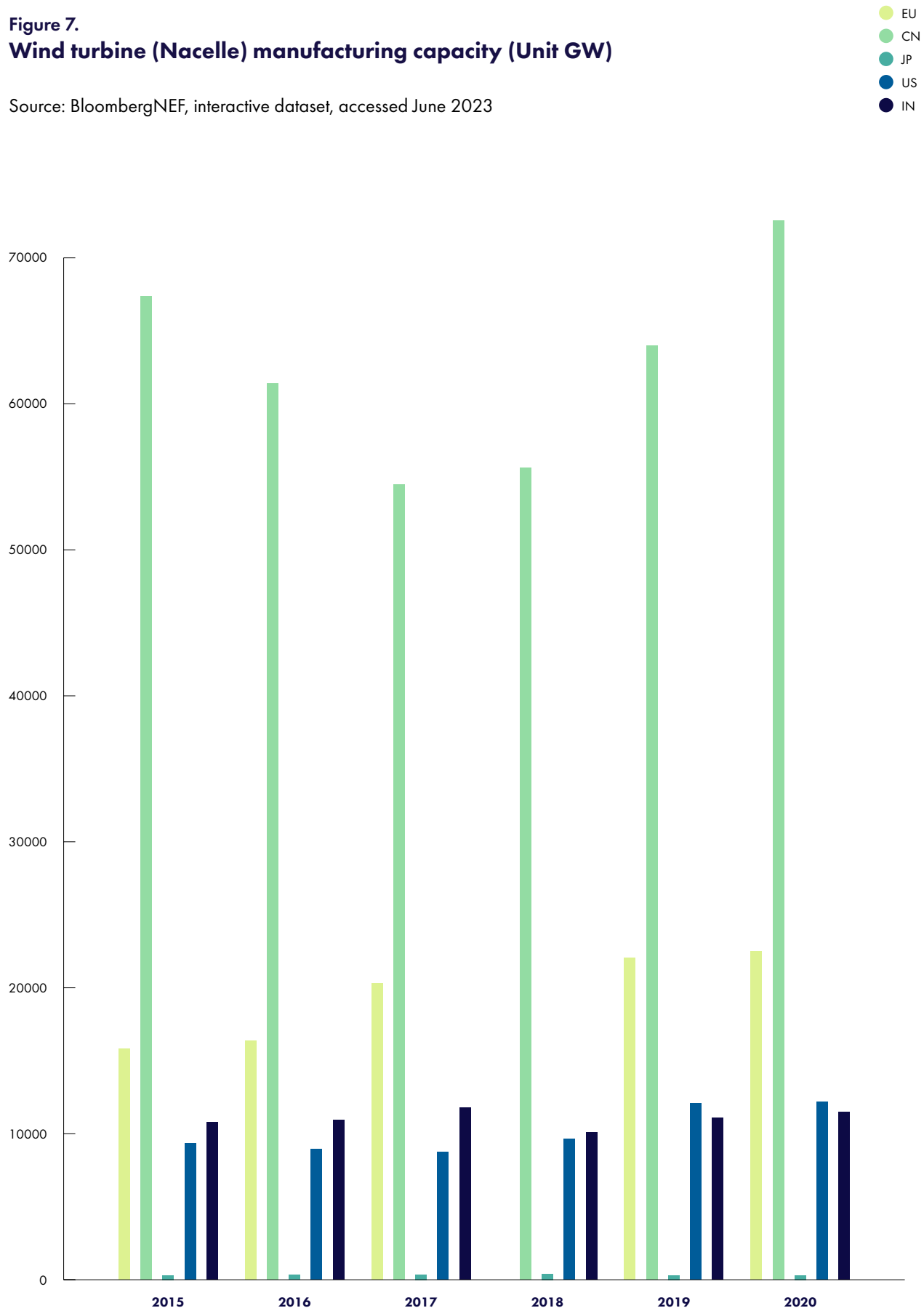


Figure 7.
Wind turbine (Nacelle) manufacturing capacity (Unit GW)

Source: BloombergNEF, interactive dataset, accessed June 2023



Windmills in China.
Photo by Ke Zhuang on iStock.

CHAPTER IV

Technology in focus: heat pumps

Heat pumpl in Görisried, Germany.
Photo by Andie Alpion on Adobe Stock.

Decarbonising the building sector has been challenging across most countries due to the high upfront costs of insulating or renovating buildings and the relatively cheap cost of fossil fuel heating in the past. In Europe,[39] Russia's war in Ukraine has exposed high household dependence on gas heating, leading to a significant increase in energy bills. **Replacing gas, coal and other fuel heating systems with electric heat pumps reduces reliance on imported fossil fuels, can lower bills for householders and helps decarbonise the building sector.** Coupled with renewable electricity such as solar and wind power, installing heat pumps in residential and commercial buildings both can be a promising decarbonisation option for countries[40] and can strengthen energy security.

Key takeaways:

I. In the context of volatile energy prices, **European countries took the lead in heat pump investment and deployment**, replacing gas, coal and fuel boilers. The US are following the EU by investing massively in electric heat pump manufacturing. In both cases, clear policy incentives, additional investment and regulation are driving the shift.

II. **The Japanese case[41] is interesting, as over 90% of households use reversible air-conditioning (heat-pump air conditioners) for cooling, with two out of three households using fuel or electric heaters in addition.** This is quite inefficient, especially as major heat pump companies like Daikin, Mitsubishi and Panasonic are Japanese and could cater for the domestic market.

III. **The global heat pump market is growing very fast and is forecast to double its share of heating in buildings by 2030** according to the IEA.[42] In this context, many countries are in a newly fierce competition for the lead in heat pump manufacturing.

Heat pump.
Photo by Napa 74 on Adobe Stock.

Country policies and targets for decarbonising heat

Heating decarbonisation pathways differ in the five economies analysed:

China has no specific targets for heat pumps. However, in 2017, the Chinese central government issued its Clean Winter Heating Plan for Northern China,[43] which aimed to increase the region's share of cleaner heating[44] (including heat pumps, but still also some gas) to 50% by 2019 and 70% by 2021 compared to the 2016 base scenario.

The **EU** has set a plan ('RePowerEU'[45]) to achieve faster deployment of heat pumps in buildings and district heating networks. Its objective is to install 10 million additional heat pumps by 2027. A phase-out of stand-alone boilers by 2029, if it gets adopted, could result in the additional deployment of over 30 million heat pumps by 2030 (compared to 2020 figures).

India has no specific targets for heat pumps – India's naturally hotter climate means heating concerns are not a prominent policy focus.

Japan released a decarbonisation roadmap for buildings in 2021, setting the aim to improve energy efficiency and implement more clean energy. By 2023, Japan aims to achieve average net-zero energy consumption for newly constructed buildings and houses, as well as all buildings[46] and houses by 2050.

The **US** has no policy in force to set targets for buildings or heat pump deployment. However, in 2023 the US Department of Energy (DOE), announced[47] a 250 million USD funding opportunity to accelerate electric heat pump manufacturing, underscoring the US' aim to create a domestic supply chain for clean tech manufacturing.

Heat pump investment and deployment

In 2022, global investment in heat pumps increased by 10% year-on-year to more than 64 billion USD,[48] driven mainly by the EU and the US. However, it is still far from matching investment levels in renewables and electric vehicles, representing only 0.1% of total investment in energy transition technologies. ***See Figure 8.***

Under the pressure of high and volatile energy prices, the EU has taken the lead in heat pump investment and deployment. The European Green Deal laws, strengthened by the REPowerEU plan, have created a supportive policy environment and boosted heat pump sales in 2022.[49] **A record 3 million heat pumps were installed in the EU in 2022**, 38% more than in 2021,[51] which was already considered a record year with 2 million heat pumps sold. In Italy, more than 500,000 heat pumps were installed in 2022, while in Poland and Belgium, the heat pump market doubled in a single year. The IEA estimates[52] that heat pumps can reduce gas demand by nearly 7 billion cubic metres (bcm), which is equivalent to the gas supply in the Trans Adriatic Pipeline in 2021.

The US follows the EU with steady year-on-year growth of absolute electrified heat investment. Government-backed tax credits like the Inflation Reduction Act's Energy Efficient Home Improvement Credit[53] as well as state-mandated energy performance standards for buildings[54] are driving the transition to lower emission buildings. Japan has the largest heat pump market in the Asia-Pacific region, driven largely by low upfront costs. In 2021, Japan was one of the only two countries where heat pumps were cheaper than oil-fired boilers (excluding subsidies), and the only country in which heat pumps were cheaper than gas-fired boilers.[55]

By comparison, **China has low rates of heat pump investment**. In some countries, the strong dependence on gas, coal and oil heating could be a strong incentive for decarbonising the heating sector, limiting air pollution and reducing fossil fuel imports.

Heat pump industry growth

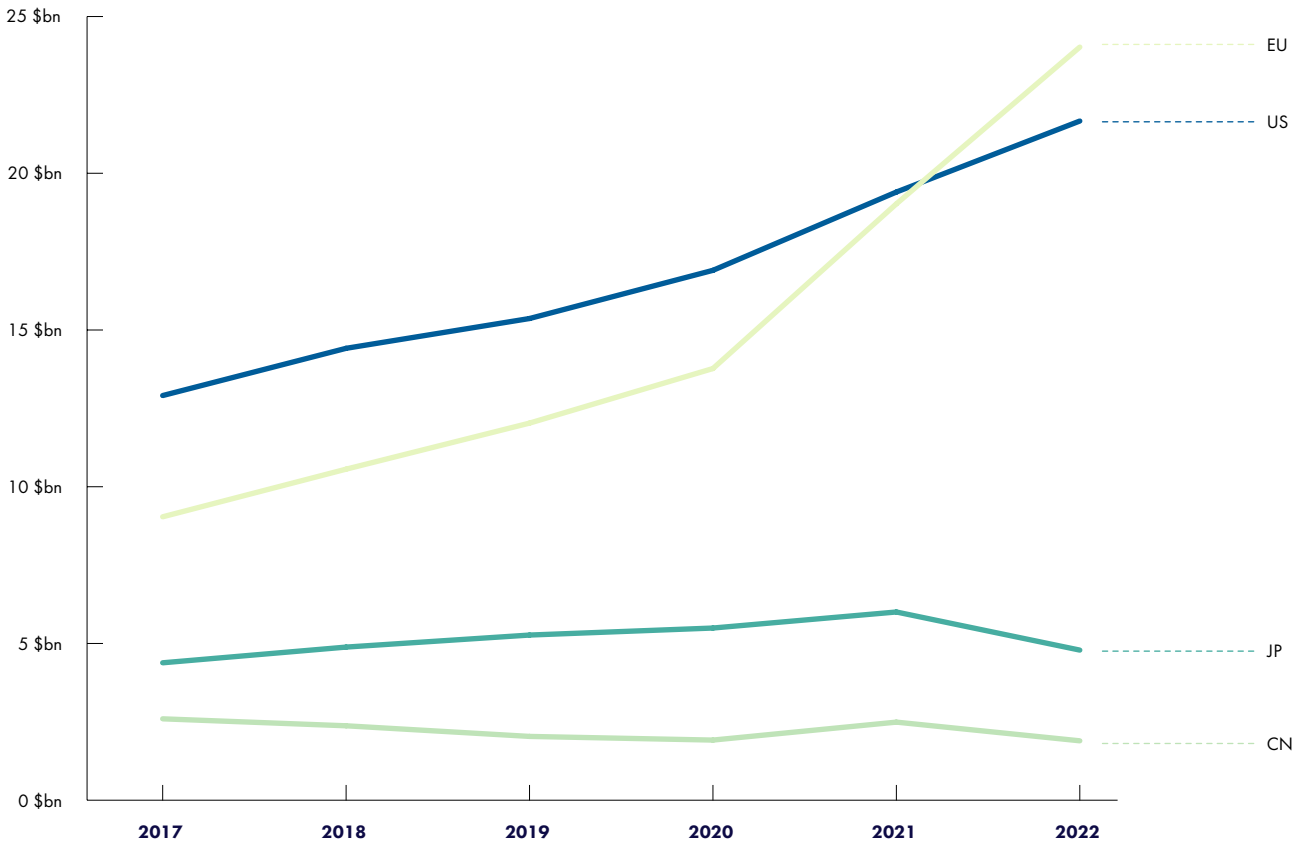
The global market for heat pumps increased by 11% between 2021 and 2022 and will likely double by 2030, according to the IEA,[56] offering economic and trade opportunities for many countries. The EU and the US are net importers[57] of heat pumps, while China and Japan are net exporters. Despite the fact that 73% of European domestic demand for heat pumps is met by its own production, growing demand in the EU is leading to increasing imports.[58]

China, the EU and the US are planning to expand heat pump manufacturing capacities in the coming years to supply a growing global market and to secure their domestic needs. The policy environment in the EU is attracting many investors. For instance, Japanese companies[59] are planning to extend their European production sites in response to the policy support for domestic heat pump deployment. Similarly, the Inflation Reduction Act aims to maintain the US' position in heat pump manufacturing.

The development of industrial heat pumps is expected to turn into the next race to the top, with major economies competing to manufacture and deploy heat pumps to support the decarbonisation of industries, particularly the most energy-intensive ones.

Figure 8.
Investment in the electrification of heat (bn USD)

Source: Energy Transition Investment Trends, BloombergNEF 2023
Notes: GDP data adjusted to current US$, World Bank, 2023. Also, no data was found on heat pump investment for India.



CHAPTER V

Technology in focus: electric vehicles

EV in Spain.
Photo by Basilico Studio on Adobe Stock

Electric vehicles (EVs) comprise one of the fastest-growing sectors of the net-zero transition globally, attracting investment and innovation, but also high competition in manufacturing. **There has been significant growth in EV sales and production across all the economies analysed in this report except Japan**, with each aiming to grow their global market share. The electrification of transport will play a crucial role in efforts to reduce greenhouse gas emissions and dependence on petroleum. Oil products still account for 91%[60] of the total final energy use of the transport sector.

Due to BNEF's region classification, data for "Europe" in one graph of this chapter includes the EU, the UK, and European Free Trade Association (EFTA) countries. The analysis will however focus on EU policies.

Key takeaways:

I. **All five economies are implementing laws and financial instruments to support the development of EVs.** The EU has set a clear end date of 2035 for the sale of new diesel, petrol and hybrid vehicles. Similarly, Japan has also set a target to phase out internal combustion engine (ICE) vehicles in 2035, while still allowing hybrids beside EVs.[61] On the other hand, China, India and the US have introduced strong financial and policy incentives to support the uptake of EVs.

II. Europe and China are ahead in absolute EV deployment, but **Europe and the US have a higher percentage of EV use relative to population**. With 85% of global electric truck sales and 80% of global bus sales, **China is clearly leading in the deployment of electric trucks and buses**, positioning itself as a strong global player. Only Japan appears to be missing the opportunity of EVs so far by being locked into the hybrid vehicle segment.

III. **74% of battery manufacturing capacity is located in China, resulting in strong market power and industrial leadership.** However, the EU, the US and Japan have firm plans to further develop battery and EV factories in their territories to maximise job creation and meet domestic demand. **India is electrifying its transport through the development of EVs and electric two-wheelers**, which could lead to the creation of more than 50 million jobs in the sector by 2030.

Country policies and targets for decarbonising road transport

National targets[62] to phase out internal combustion engine (ICE) vehicle sales:

- Norway (2025) as well as Israel, Iceland, the UK and Singapore (2030) have set the earliest dates to stop new sales of petrol and diesel cars.
- Among the economies analysed in this report, just the EU and Japan have set 2035 goals, alongside Canada and Chile.
- The US has not set an ICE phase-out target.[63] However, it aims to have electric as 50% of all new vehicle sales by 2030.
- The approaches of China and India also focus on setting targets for EV deployment. China, for instance, has set a goal of 40% of "new energy and clean energy-powered" passenger cars and commercial vehicles by 2030. Some sub-national governments have become pioneers, with regions such as Hainan[64] in China and Assam State[65] in India considering a ban on sales of ICE vehicles ahead of their respective national governments.

Electrification of road freight and buses targets:

- China is leading the global market on the deployment of electric trucks and buses with 85% of global electric truck sales and 80% of global bus sales.[66]
- The EU aims to achieve 90% emissions reductions from road freight by 2040 and 100% electric city bus sales by 2030 through the European Green Deal.
- The US plans to increase sales of zero-emissions vehicles in the long-haul tractor and short- to medium-haul tractor markets to 25% and 34% respectively by 2032.[67]

Electric bus in Shenzhen, China.
Photo by Nikada on iStock.

Deployment of electric vehicles

All economies analysed in this report have a strong policy and financial framework supporting the quick deployment of EVs, with Japan and China[68] still including hybrid vehicles in their policies. The EU end dates for the sale of new diesel, petrol and hybrid vehicles as well as the Chinese and US deployment goals for electric vehicles are all setting a clear direction toward the electrification of vehicles. This creates a race to the top between these economies on both the deployment and the manufacturing of electric vehicles and their components. **The most common measures to encourage EV sales are tax incentives and direct subsidies, which are applied by these four.** Even though plug-in hybrid (PHEVs) and hybrid cars are still very present in new vehicle sales, this is expected to change – certainly in the EU. Fuel cell vehicles have no significant share in the new vehicle markets of any of the five economies. Nevertheless, it is important to note that ICE cars are still dominant in the fleets compared to battery electric vehicles (BEV) given the average lifetime of cars. ***See Figure 9.***

At this stage, **China is clearly leading on the total electric vehicle production with 4.35 million BEVs sold** (reaching almost **6 million NEVs sold in 2022**). Its subsidy programme even manages to achieve price parity between ICE vehicles and EVs in its domestic market. In 2022, more than half of all electric cars[69] on the road globally were in China. Tax incentives, which will continue until the end of 2027,[70] are likely to reinforce this trend in the coming years. In addition, China owns two of the world's largest EV companies, SAIC Motor and BYD, which are gaining ground in international markets, particularly in the EU and the US.

Europe is catching up fast with 1.6 Million BEV share. Norway and the UK set targets for electric vehicles sales for 2025 and 2030. **The European Union's law setting an end date of 2035 for the sale of new ICE vehicles has led to a major shift in the car market**, with the first effects of the legislation already being seen – more than one in ten[71] new cars sold in 2022 was fully electric. On a per capita basis, the EU has far more EVs than China, showing the strong electrification process of its car fleet. EU policymakers have set the pace of change, encouraging traditional carmakers to develop new models that embrace this industrial transformation. Six major car manufacturers[72] (Renault, Mercedes-Benz, Stellantis, Volvo, Jaguar and Ford) are even outpacing governmental ambitions by committing to sell only electric cars by 2030, five years ahead of the legal deadline. This is a clear sign that car manufacturers see the competitive advantage in leading the global competition on electrifying passenger cars.

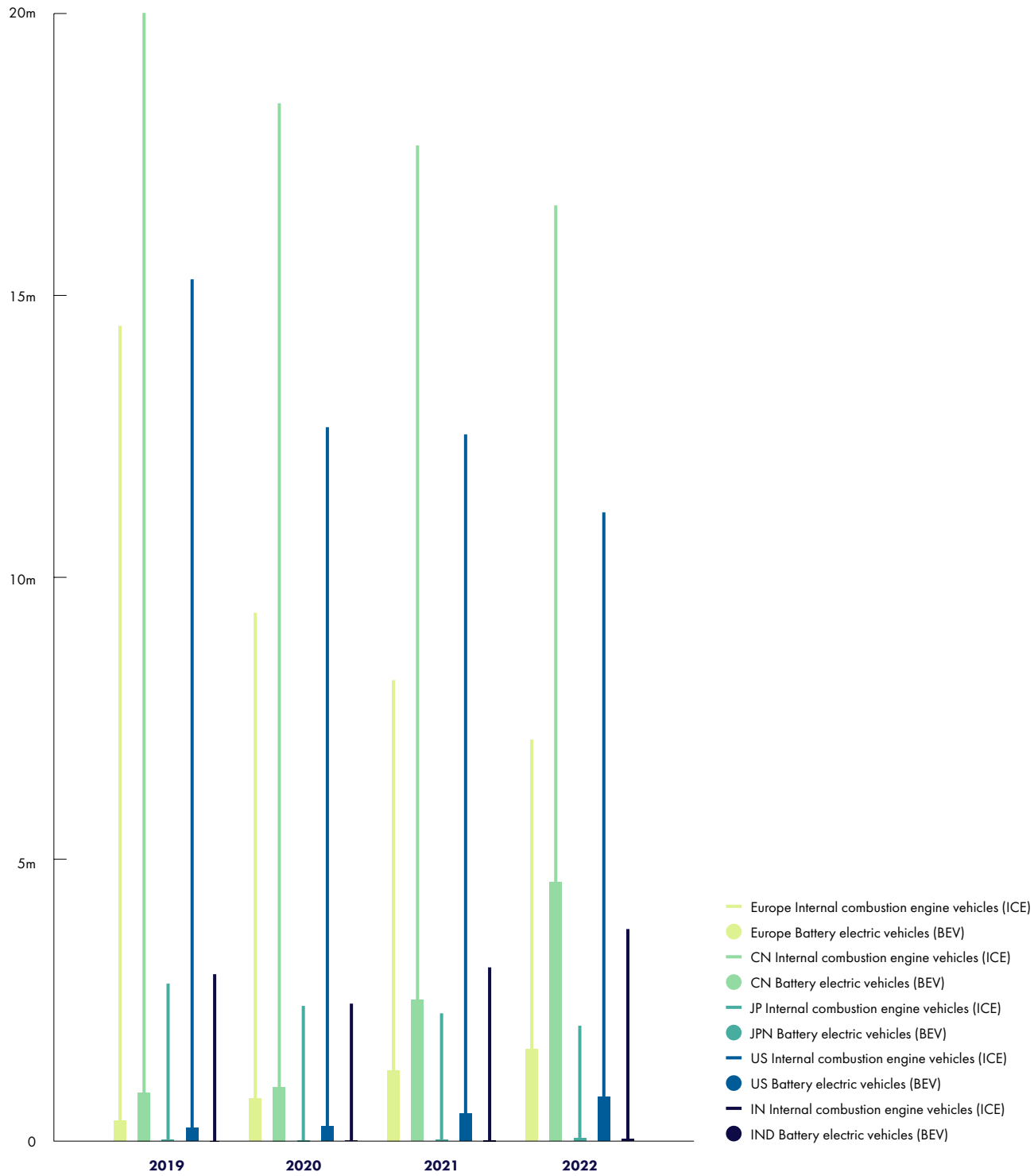
The US is the third-largest market[73] for electric cars, reaching 8% of the total sale of new cars. **The Inflation Reduction Act provides strong incentives for both the production and the sale of domestically produced EVs**, which soon could lead to an increase in EV sales in the US. The target of 50% EVs in new vehicles sales by 2030 also sends a clear signal in favour of this trend. With Tesla, the US is already well-positioned to export and capture global market shares.

Figure 9.

Annual passenger BEV sales versus ICE sales (number of units)

Source: Long-Term Electric Vehicle Outlook, BloombergNEF 2023

Notes: Includes BEVs. Europe includes the EU, the UK and European Free Trade Association (EFTA) countries.



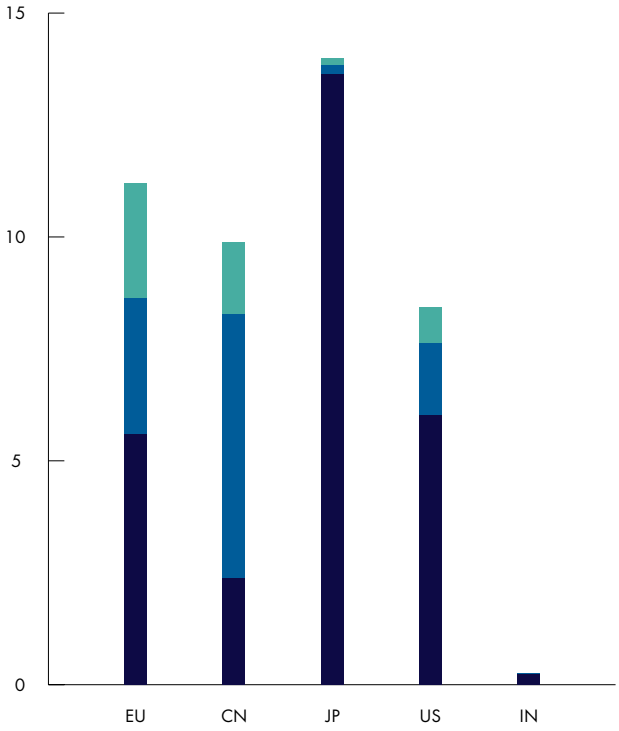


Figure 10.
BEVs and alternative drives fleet 2021 in millions

Source: Long-Term Electric Vehicle Outlook, BloombergNEF, 2023.

Japan is lagging behind in terms of plans to fully decarbonise road transport with EVs, **having relied mainly on the hybrid segment of its vehicles market**. This creates a significant lock-in effect for Japan and its main car manufacturer Toyota, which plans to sell only 50% EVs by 2030. Unlike[74] the other economies, Japanese policy favours incentives for hybrids and fuel cell vehicles (FCVs). This could cause the country to miss the industrial and decarbonisation opportunities of EVs, potentially relying heavily on imports in the coming years. ***See Figure 10.***

India cannot be compared directly as it still has far fewer individual cars per capita than the other countries covered in this report. Car sales and manufacturing are major contributors to the Indian economy, however. The Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) Scheme[75] positively supports EV development, which is a major opportunity and could enable India to advance on the decarbonisation of road transport. **The EV industry is expected to grow at a compound annual growth rate of 49% between 2022 and 2030, creating 50 million jobs by 2030.[76]**

Last, but not least, **two-wheelers will play a big part in the global EV market**, as both India and China are dominant in the market for both conventional and electric two-wheelers:

- India already had a fleet of 4 million EV two-wheelers in 2022, which is projected to rise to 6 million by 2024. The new FAME scheme could amplify this development for 2024.
- Within the same time frame, China will increase its fleet of EV two-wheelers by 27 million units, from about 280 million to 307 million.[77]

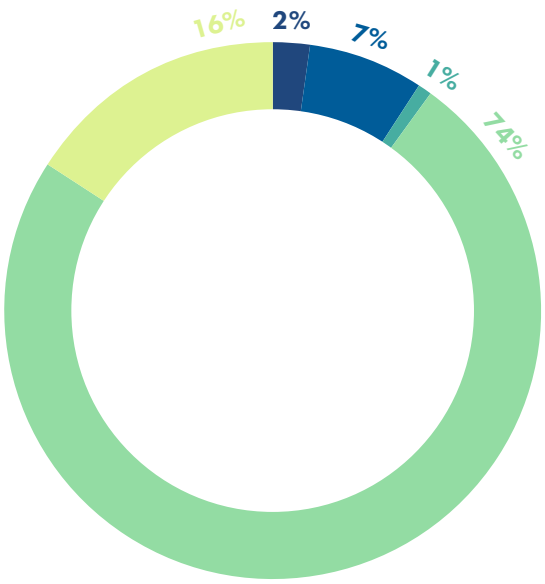


Figure 11.
Lithium-cell manufacturing capacity by region of plant location 2022 in %

Source: BloombergNEF, 2023
Notes: India does not currently have large lithium battery production yet, only battery assembly. However, it has plans to build around 12 gigafactories by 2030, boosting domestic production and also targeting the export market. The graph shows the total lithium cell manufacturing capacity in the world.

Battery manufacturing competition

The control of battery-related manufacturing and supply chains means China has a strong advantage in the EV and battery industries. **Six of the top 10 battery[78] manufacturing companies are in China**, and it oversees much of the battery production supply chain: the country produces 92% of battery anodes and 77% of cathodes.[79] 66% of battery assembly also happens in China, meaning it stands far in advance of other countries. **Figure 11.**

The US and the EU are doubling down on production by developing their respective EV supply chains. The US' push for locally sourced components and manufacturing through the Inflation Reduction Act is generating a massive ramp up of domestic EV and battery production, with plans for this to increase tenfold[80] by 2027. The European Commission also plans to scale up battery production by setting an indicative target of 90% of batteries made in the EU by 2030, with France and Germany among the countries planning to build new gigafactories. Some studies[81] show that with additional investment, the EU could even produce 100% of Li-ion batteries by 2027 while improving environmental standards. It is important to note that non-domestic companies play a huge role in the manufacturing capacities of both the US and the EU. This is the case for Chinese and Korean companies, such as CATL, CALB and LG.

At this stage, Japan risks losing out in the competition to manufacture batteries, but India has the potential to develop its own manufacturing further, creating millions of jobs in the new industrial era.

CHAPTER VI

A new paradigm for economic cooperation

As the analysis of this report shows, China, the EU and the US have entered a race to rapidly scale up manufacturing and deployment of zero-carbon technologies. The reasons are manifold and different policy approaches are taken. For the US, the competition with China is a clear driver to inject financial resources into manufacturing and deployment. European countries seek a competitive advantage in supplying the EU's growing markets, as well as increased energy security and the opportunity to create new jobs and prosperity for regions in transition.

In fact, **the analysis of this report shows that the mix of political will, financial incentive schemes based on adequate fiscal space, and accompanying policies is providing an ideal enabling environment** in China, the EU and the US. Japan often lags behind due to its low policy ambition (i.e. on coal phase-out) or support for a broad range of technologies that are not enabling full decarbonisation (i.e. hybrid cars). The majority of other countries lack the financial means to enter the global race on zero-carbon technologies. The analysis showed that India starts from a position that is not fully comparable to the other economies covered in this report. However, its political goals on renewable energy deployment and related policies are good indications of how the country plans to design its energy transition. **If India's domestic investment were matched by larger international and private capital influxes, zero-carbon technologies could be produced and deployed much faster.**

This situation is applicable to many developing countries that are seeking support to transform their entire economies, develop sustainably and enhance resilience to climate impacts. So far, traditional Official Development Assistance (ODA) and climate finance (including the 100 billion USD pledged[82] by developed countries) have fallen short of providing an adequate support scheme. Many approaches to reform Multilateral Development Banks (MDBs), International Financial Institutions (IFIs) and debt schemes, as well as creating innovative ways of finance, are under way, some of which made progress at the Summit for a New Global Financial Pact[83] in Paris. **It is the responsibility of the international community, and developed countries in particular, to create a financial system that allows for the rapid scaling up of financial resources for the mitigation and adaptation efforts in developing countries.** This is vital not only to meet the temperature goals agreed in the Paris Agreement, but also to restore trust in multilateralism and global solidarity.

Complementary to the progress on financial reforms, concrete cooperation and partnerships between developing and developed countries allow for effective climate action. **A new and more targeted approach has been explored with 'Just Energy Transition Partnerships' (JETPs)**,[84] which set up a financing cooperation mechanism between a developing country seeking to accelerate its coal phase-out and a set of developed countries supporting that effort. The Global South country in the partnership clearly defines its energy transition pathway away from coal to zero-carbon technologies with a just transition. The countries of the Global North pledge public finance support and seek to expand the donor pool to include development finance institutions or even private finance actors. The political commitment, policy development and financial support get enshrined into a Memorandum of Understanding to conclude the partnership. The JETP concept has received significant international attention given its potentially effective way to support the energy transition in developing countries heavily dependent on coal. As this report shows, there is a necessity to accelerate the decarbonisation of all sectors, providing an additional opportunity to increase jobs and prosperity. **Thus, a new paradigm for economic cooperation can be established for countries that have intentions to reach renewable energy goals or to enhance the electrification of their transport, heating or industrial sectors.**

In this context, the frontrunners in zero-carbon technology deployment as set out in this report can lead by example and create new economic cooperation with developing countries. **Supporting the manufacturing and deployment of zero-carbon technologies in the Global South can bring down global prices and allow for sustainable development pathways in these countries.** Creating new powerful actors in the value chain could also offer new export capacity that allows developed countries to diversify their supplies. In some cases, these new economic partnerships could be integrated into cooperation on resources or raw materials to enhance the benefits for developing countries.

These partnerships can foster implementation or increasing ambition as the next round of pledges under the Paris Agreement (Nationally Determined Contributions (NDCs)) is expected to be submitted well ahead of COP30 in 2025. Concrete technology cooperation can increase confidence that the goals set out in the NDCs can be met and facilitate finance flows.

Ideally, these new economic partnerships meet the following three criteria:

I. Policy certainty

As set out in this report, political will and policies provide the right predictability for business, the communities involved and investors alike. As governments might change, the commitment to zero-carbon technology deployment is best expressed when enshrined in domestic laws. This provides reassurance for all sides and can be matched with a lasting financial structure between the countries involved and other financial actors. Through policies, a broad participation of actors, transparency and attention to environmental and human rights can be established.

II. Financial structure

Targeted financial support as well as a financial environment that attracts additional resources are vital for success. Public finance by developed countries can be best used to de-risk an investment, provide guarantees, or bring in private finance sources to scale up the overall finance. Suggestions on cooperation from think tanks in interested countries, such as Power Shift Africa,[85] include not only focusing on building large-scale infrastructure but also small-scale projects that benefit communities directly. Public-private partnerships or equivalents of power purchase agreements could be explored to involve big industrial players as well as local businesses. De-centralised renewable energy can support access to energy, cleaner cooking facilities, cooling, and heating. As industrial heat pump production advances, a larger variety of industrial processes can be decarbonised or established as low-carbon facilities.

III. Local ownership and benefits

The new economic partnerships have a higher chance of success if they are development-centred, rights-based and involve local communities from the beginning. The benefits for the developed country should be clearly prioritised – especially in projects that also include resource cooperation or exports. For example, recent green hydrogen projects were criticised if they purely focused on the export quantities and infrastructure without guaranteeing renewable energy deployment, improving local infrastructure, and enabling local value chains to be created. Occasionally, technology transfer might be required to match capacity building and training.

The global stocktake and the 'ambition cycle' under the Paris Agreement provide the right framework and timeline to create this new economic cooperation. **With more countries manufacturing and deploying zero-carbon technologies, a global race to the top will emerge. At the same time, future-proof jobs and prosperity can be created while reducing greenhouse gas emissions.**

Solar panels in Asia.
Photo by Winsu on Adobe Stock.

ANNEXE

Annexe 1.
Overview of national climate targets – greenhouse gas (GHG) emissions

	GHG emissions (NDC)	GHG emissions (domestic)	Baseline
China	CO2 emissions peak before 2030 Carbon neutrality by 2060 -65% CO2 emissions per unit of GDP	-18% CO2 emissions per GDP by 2025	2005
Japan	-46% GHG emissions by 2030, with a goal of achieving -50% Net- zero GHG emissions by 2050	Same as NDC	2013
India	-45% GHG emissions intensity of GDP by 2030 Net- zero by 2070	500 GW of renewables by 2030 50% of energy mix to be non-fossil fuel by 2030	2005
EU	At least 55% reduction in GHG emissions by 2030 Net-zero GHG emissions by 2050	Same as NDC	1990
US	-50% to -52% GHG emissions by 2030 Net-zero emissions by 2050	Same as NDC[86]	2005

Annex 2.

Overview of key national targets for decarbonised electricity (renewable energy), electric vehicles and heat pumps

	Renewable energy	Electric vehicles	Heat pumps
China	25% non-fossil fuels in energy by 2030 1200 GW wind solar and solar wind by 2030 Renewables to make up 50% of installed electricity capacity Renewables to generate 39% of electricity by 2025	20% NEV by 2025 and 40% by 2030[87]	
Japan	36-38% by 2030 10 GW of Offshore Wind and 104-118 GW of Solar Power by 2030	All new private car sales to be EVs and HEVs by 2035 20-30% EVs in commercial vehicle sales by 2030 150,000 EV chargers by 2030	
India	311 GW of Solar and 82 GW of Wind energy by 2031-2032, with the total non- fossil fuel capacity share to be 68.4%	30% private cars, 70% commercial cars, 40% buses, 80% two and three wheelers to be EVs by 2030	
EU	42.5% by 2030 (aiming for 45%)	100% emission reduction target by 2035 for all new cars and vans 29% of final energy consumption in the transport sector to be renewable by 2030 (provisional)	10 million units by 2027
US	100% carbon pollution-free electricity by 2035	50% new light vehicles to be electric by 2030 New medium and heavy duty vehicles zero emission by 2040	

Annex 3.

Overview of domestic policies

China

The key driver in China for economic and social development, including decarbonisation and energy strategy, is its Five Year Plan. The 14th Five-Year Plan covers the years 2021-2025 and contains two elements that are specifically focused on modernising and decarbonising the energy system. The first of these – the **14th Five-Year Plan** for a Modern Energy System[88] – was issued in March 2022 and sets out a plan to link decarbonisation with the accelerated development of a **modern energy system**. It has a target for 20% of energy consumption and 39% of electricity consumption to be non-fossil fuel sourced by 2025.

The 14th Five-Year Plan[89] for Renewables was released in June 2022. While there is no specific capacity target for renewables, the plan sets the intention of increasing renewables generation by 50%[90] to deliver 33% of China's electricity demand. It also states that half of the increases in electricity and energy consumption will be delivered by renewables over the 2021–2025 period. In light of the rapid growth in solar module and wind turbine demand, it seems likely that these targets will be exceeded.[91]

There are a number of other policy measures in place in addition to the 14th Five-Year Plan. These include:

- The Energy Supply and Consumption Revolution Strategy (2016-2030)[92] – this is an important long-term strategy that guides the International Energy Agency's (IEA) Energy Sector Roadmap to Carbon Neutrality in China,[93] which was requested by China. It stresses the importance of making **energy consumption cleaner** and more efficient, as well as encouraging technological innovation. Action plans focus on specific aspects of energy, environment or climate change, such as air quality.

- Renewable Energy Law[94] – this 2005 law was the first major legislation to encourage "modern" renewables (wind, solar, hydro, biomass, geothermal and marine energy, but not low-efficiency burning of biomass). It requires power grid operators to purchase output from registered renewable energy producers and offers financial incentives, including preferential electricity tariffs for renewable power and discounted lending and tax preferences. The law established a national fund to foster renewable energy development.

- The emphasis on economic development through technical innovation[95] for renewables is also apparent in 2020's White Paper on Energy in China's New Era.[96]

China has no policy yet for the implementation of **heat pumps**. However, the Air Pollution Prevention and Control Action Plan[97] published in 2013 sets out targets to improve air quality in key regions by reducing the burning of coal. This has driven a 70% switch in household heating fuel use[98] in northern provinces, with a proportion of households in some areas choosing to use heat pumps.

China's Mid-Century Long-Term Low Greenhouse Gas Emission Development Strategy[99] indicates that around 40% of new vehicles sold in 2030 will be either electric, hydrogen-powered, or use natural gas or advanced biofuels. Subsidies for new energy vehicles (NEVs) (including battery, hybrid and fuel cell electric vehicles) ended[100] in 2022, although tax exemptions[101] for consumers will continue until the end of 2023. The long subsidy programme has made NEVs competitive: 30% of new vehicles sales were in this category in early 2023.

European Union

The European Union has a comparatively long history of **climate legislation** and policy targets relating to greenhouse gas emissions reductions. This includes the European Climate Law[102], which sets a legally binding goal of climate neutrality by 2050 and an interim reduction target of 55% less net greenhouse gas emissions by 2030 compared with 1990 levels.

The European Green Deal[103] was presented in 2019 as a comprehensive growth strategy covering various policy areas and goals. It aims to transform the EU into a climate-neutral economy and environmentally sustainable region. Fit for 55[104] refers to a package of legislative proposals and policies designed to ensure the EU achieves the emissions reduction targets of the European Climate Law while ensuring the transition is "fair and competitive". It is so far the most comprehensive set of climate laws proposed globally, with most being adopted by summer 2024.

In 2023, the European Commission presented the Green Deal Industrial Plan[105]. Its aim is to create a supportive environment to realise the European Green Deal and Fit for 55 goals by scaling up manufacturing capacity of zero-carbon technologies within the EU. It is clear that it has been presented as the EU's response to the US Inflation Reduction Act.

The most relevant EU laws and strategies for this report include:

- The Net-Zero Industry Act[106] – this proposal focuses on accelerating the development and production of **net-zero technologies**, including solar energy and other renewables, battery storage and heat pumps. The proposal sets a benchmark for net-zero technologies to meet at least 40% of the EU's annual technology deployment needs by 2030.

- REPowerEU[107] – this plan seeks to decrease the EU's dependence on Russian fossil fuels. Key measures include the deployment of solar energy with a target of over 320 GW by 2025 and almost 600 GW by 2030, introducing a legally binding EU solar rooftop obligation and doubling the deployment rate of individual heat pumps, alongside other measures. The proposed increase of the EU's **renewable energy target to 42.5%** has been enshrined in law, with an aim of reaching 45% by 2030.

- New CO2 emissions standards for cars and vans[108] – this regulation includes a 100% emissions reduction target for 2035 for cars and vans, replacing internal combustion engine (ICE) cars and vans with **electric vehicles** (EVs).

- RePowerEU on heat pumps – this goal covers the installation of 10 million additional **heat pumps** by 2027[109]. The EU Heat Pump Action Plan[110] is currently being developed by the European Commission and adoption is planned for the last quarter of 2023. Discussions on ending new sales of gas boilers are ongoing at the EU level and in many European countries.

United States

The US has a target of **reducing greenhouse gas emissions** by 50-52% below 2005 levels by 2030[111]. Key parts of this will be **decarbonising the electricity system** by 2035[112], and electrifying energy end use.

The US passed three landmark pieces of legislation on climate and energy in 2021 and 2022. Taken together, the Inflation Reduction Act, the Bipartisan Infrastructure Law (or Infrastructure Investment and Jobs Act) and the CHIPS and Science Act are seen as representing the biggest commitment to addressing climate change in US history.[113]

The Inflation Reduction Act (IRA)[114] was passed in August 2022 and contains a broad range of measures, including investing in clean energy[115] production and its promotion. The overall focus of the Inflation Reduction Act is on driving the deployment of new and zero-carbon technologies through the use of subsidies, which contrasts with the EU approach[116] that focuses on innovation and developing new technologies through regulation and the carbon market.

One of the main policy levers in the Inflation Reduction Act is the provision of tax credits for the construction of clean energy projects (Investment Tax Credit), as well as producing energy from **renewable sources** (Production Tax Credit). Credits are also available for households installing heat pumps, rooftop solar and using electric vehicles. Businesses benefit when investing in critical minerals, and in the clean energy and storage supply chains. These credits include a "local content" requirement intended to drive the development of domestic supply chains by disincentivising the purchase of technologies or materials sourced overseas. The Inflation Reduction Act has clearly been framed to improve competition with China and to create jobs in the US.

The Bipartisan Infrastructure Law (BIL)[117] is intended to enable the rapid expansion of the infrastructure needed for the decarbonisation of the US' energy systems, particularly electricity. Measures in the act include modernising the electricity grid to allow new generation to connect more easily, building a nationwide electric vehicle (EV) charging network, strengthening the battery supply chain, and investing in clean energy.

The CHIPS and Science Act[118] focuses on technology innovation and development, including renewables. It emphasises the semiconductor industry, where innovation continues to be essential for the deployment of renewable energy technologies.

The US has no specific target for **heat pumps**, but there is support for deploying this technology in the Inflation Reduction Act and some individual states have set targets.[119]

The Biden administration has a target of 50% of new **light vehicle sales to be electric** by 2030[120] and all new medium and heavy duty vehicles to be zero emission by 2040[121]. This is complemented by the EPA's proposed new emissions standards for cars and trucks.[122]

Japan

In October 2020, Japan announced its commitment to achieving a **Net-Zero Emission target by 2050**[123]. The Government of Japan incorporated this target into the amended Act on Promotion of Global Warming Countermeasures[124] in 2021.

The target is supported by a broad ranging industrial growth strategy: the Green Growth Strategy through Achieving Carbon Neutrality in 2050[125] (2020). The strategy outlines 14 fields[126] with growth potential and presents action plans based on both industrial and energy policies. The Green Growth Strategy is supported by a number of initiatives, including:

- The Green Innovation Fund[127] – this provides a budget of 2 trillion JPY over ten years to support private sector research and development (R&D) on the priority fields identified in the Green Growth Strategy.

- The Green Transformation (GX)[128] – this programme is intended to provide the framework for decarbonisation while also ensuring security of supply. The measures target improved energy efficiency, increased use of renewable technologies and electricity grid expansion. Yet it also proposes an increase in nuclear power and the use of hydrogen and ammonia as fuels, plus the continued use of hybrid vehicles.

The sixth **Strategic Energy Plan**[129] published in 2021 sets out plans for energy sector development until 2030. It includes a target of up to 36-38% renewables generation by 2030[130], double the 2019 level and well above its previous 2030 target of 22-24%. This includes establishing renewable energy promotion zones and a new emphasis on accelerating offshore wind projects under the Act on Promoting the Utilisation of Sea Areas for Marine Renewable Energy Generation Facilities.[131]

Japan does not have an explicit target for **heat pump** deployment. However, the Sixth Strategic Energy Plan[132] signals the government's general support for the technology, particularly for industrial use, while the GX programme[133] identifies industrial heat pumps as an export growth opportunity. There is also indirect support through the policy emphasis on decarbonising Japan's building stock[134] which looks to reduce primary energy consumption as well as improving insulation. Despite the lack of specific measures, heat pumps are growing in popularity in Japan with sales increasing 13% in 2021 and 19% in 2022.[135]

Japan is actively promoting the **Electrified Vehicle (xEV) Strategy**[136] as part of its long-term vision for 2050. This aims to ensure that all vehicles produced by Japanese automakers will be electrified by 2050, and that all passenger vehicles will be electrified by 2035[137]. These electrified vehicles comprise battery electric vehicles, plug-in hybrid electric vehicles, hybrid electric vehicles, and fuel-cell electric vehicles, with hybrid vehicles expected to dominate electric vehicle sales[138] in the short term at least. In addition, Japan plans to increase domestic production[139] capacity for in-vehicle batteries to 100 GWh by 2030 and to install 150,000 charging stations for public use, including 30,000 quick chargers.

Japan's primary support for electric vehicles (EVs) and fuel cell vehicles (FCVs) has been purchase subsidies[140]. The level of support depends on the type of technology, the model and the year.

India

India's NDC[141] states that it will **reduce the emissions intensity** of its GDP by 45% by 2030, in part by increasing its **non-fossil fuelled electricity generation** capacity to 50%. In the longer term it aspires to achieve net zero by 2070. Its overall approach to decarbonising the economy is set out in the Long-Term Low-Carbon Development Strategy.[142]

India's general strategic development is outlined in its Vision-2030,[143] which includes a focus on electric vehicles (EVs) and renewables as one of ten dimensions. A draft National Energy Policy[144] published in 2017 identifies four key interlinked objectives: access to affordable energy, improved energy security, greater sustainability, and economic growth. Improved security is seen as the foundation of the draft policy, and feeds into the measures to deliver its objectives. These include increased levels of renewables, improved energy efficiency and expansion of the electricity grid. This approach differs from the other economies in this report in that the focus is less on driving an overarching economic and energy transition and more on developing specific sectors (solar photovoltaics (PV), EVs and recently offshore wind).

India has a history of supporting the **development of solar energy**, in particular through the National Solar Mission[145] – a set of policy measures designed to encourage the rapid deployment of solar PV through the country. India saw a four fold increase in renewables capacity[146] between 2014 and 2022, much of this from solar PV. This growth is projected to continue, with the most recent National Electricity Plan[147] (2023) projecting that non-fossil fuel capacity will increase to around 57.4% of the total electricity mix by the end of 2026-2027, growing to 68.4% by 2031-2032. Much of this will be delivered by utility-scale solar PV and wind, although there is also a significant emphasis on the development of off-grid and decentralised renewables under a framework for Promoting Decentralised Renewable Livelihood Applications.[148]

The government also has recently signalled significant support for rapidly developing **offshore wind**. In 2015, it announced a target of 30 GW by 2030,[149] which increased in 2022 to 37 GW.[150]

India does not have specific policies on **heat pumps**, as the country's main focus is on cooling,[151] although some cities or regions[152] have their own heating and cooling targets. There is also an active solar water heating sector.

India recently adopted a comprehensive plan to drive the adoption of **electric vehicles**, targeting the whole transport sector rather than solely concentrating on cars. The government's de facto goal[153] is to have EVs constitute 30% of private car sales, 70% of commercial cars, 40% of buses and 80% of two- and three- wheelers by 2030.

The key policy package to achieve this is the Faster Adoption and Manufacturing of Electric Vehicles in India (FAME) scheme, which is already in its second iteration. FAME should provide subsidies and other support[154] for about 55,000 passenger cars, 7,000 electric and hybrid buses, and around 1.5 million two- and three-wheelers.[155] These targets are complemented by a plan to develop 12 gigafactories for manufacturing lithium ion (Li-ion) batteries[156] for both the domestic market and export.

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Wind turbines in Navarra, Spain.
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