

The Switch Report 2022

Knowledge partner



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Foreword

It's only the tip of the iceberg for renewable energy

The main finding of this report is straightforward. Once dominated by fossil fuels, long-term energy investment has switched to renewables – and it's hard to see this changing. The analysis, carried out jointly by fDi Intelligence, the foreign investment monitor of the Financial Times, and Enel Foundation, the research think tank promoted and financed by Italian power company Enel, is based on figures tracking foreign direct investment announcements, a powerful proxy for long-term investors' sentiment (for full methodology details, pls see page 3). It shows the extent to which the energy transition has redrawn the global investment map.

Back in 2005, renewables accounted for just a fraction of global FDI, fossil fuels for over one fifth. Fast forward to 2021, the table has turned. Fossil fuels made up a fraction of global FDI, renewables about 15%. Remarkably, renewables have dethroned fossil fuels as the biggest magnet of global FDI across all the sectors since 2019. Beyond figures, the switch is happening on the ground. Solar and wind power plants are mushrooming the world over. Decommissioned coal and gas power plants are being repurposed to accommodate battery energy storage systems, which are a useful element to maximize the benefits of clean energy. New technologies are coming on stream too, such as green hydrogen.

The implications of this switch are far-reaching. The global oil and gas trade has forged alliances, and rival factions alike, between a few producing nations and energy-thirsty economies. The resulting geopolitical order has proven functional for the development of a burgeoning global economy, but also fragile at times. It was about to be shattered by the oil crisis of the 1970s. It's once again on the line following Russia's invasion of Ukraine.

Although their distribution varies, renewable energy sources are ubiquitous, which gives a chance to each country to loosen,

if not break altogether their dependence on fossil fuels imports. Developed economies in the West and fast-growing economies in the East are rewriting their energy security agendas accordingly. The development of renewable energy sources, which had already been bolstered by ambitious national and corporate net-zero targets, stands at the heart of this adjustment alongside energy efficiency.

Inevitably, this switch has its challenges. The sudden volatility of Russian gas supplies has left industries across Europe and other regions scrambling for readily available alternatives, renewable or not. Besides, the value chains of basic equipment like solar panels, or batteries remain concentrated in the hands of a few players, which brings along new geopolitical implications. Thankfully, the genie is out of the bottle. "The key solution to today's energy crisis – and to get on track for net zero emissions – is a dramatic scaling up of energy efficiency and clean energy," IEA's executive director, Dr Fatih Birol, argued in May.

Long-term net-zero commitments, combined with heightened energy security needs, all point in the direction of a future powered by widespread, easily accessible renewable energy sources. Investment data does too. FDI into renewable energy in the first quarter of 2022 remains three times as high as FDI into fossil fuels.

If innovation and scale have already turned the likes of solar and wind into a viable, competitive alternative to fossil fuels energy, unlocking major investment into the sector, the gulf between reality and long-term needs remains wide. Irena estimates that installed capacity of renewable energy has to grow by a factor of 10 to limit global temperature rise to 1.5°C and bring CO2 emissions to net zero by 2050. That would require a total of \$131tn of total investment into renewable energy and energy efficiency technologies.

For as much as the investment switch articulated in this report is a watershed moment for global energy investment, it's only the tip of the iceberg. Provided short-term headwinds are withstood, FDI into renewables faces a steep upward trajectory ahead as the world strives for energy sustainability and energy security.

Jacopo Dettoni is the editor of fDi Intelligence

Methodology

Data access

The analysis featured in this report is based on the fDi Markets database, a service by the Financial Times. fDi Markets tracks greenfield and brownfield foreign direct investment (FDI) projects, detailing for each one the investment amount and its jobs creation dividend. Both data points refer to the figures disclosed by the interested companies at the time of the project announcement.

The data from fDi Markets is a real time indicator of the real investment companies are making in their overseas subsidiaries and, ultimately, a proxy of investors sentiment. fDi Markets data also includes estimates for capital investment and job creation derived from algorithms when a company does not release the information.

fDi Markets data differs from official headline FDI data collected by central banks and other institutions, which are based on asset/liability criteria or directional presentation and track an FDI inflow/outflow only when it materialises into a balance of payment movement. Besides, fDi Markets only focuses on greenfield and brownfield FDI projects, whereas official headline FDI figures also reflect crossborder mergers and acquisitions (M&A) and intracompany loans.

fDi Markets data is collected largely from primary and secondary sources:

- official company statements;
- official statement by the locations hosting the investment project;
- statements by over 2,000 industry organisations and investment promotion agencies;
- Financial Times newswires and internal

information sources;

- thousands of media sources, including all of the world's top business sources;
- data purchased from market research and publication companies.

The timeframe for data gathering is 2003-2022

Analysis

After a general overview/comparison between FDIs in the fossil sector and FDIs in the green energy sector, highlighting the "Switch" from fossil to green in terms of FDIs at the global level (showing the different trajectories of fossils and green over the 2003-2020 period), the analysis focuses on the green energy value chain, taking into account various parameters:

- Number of projects/investments (in absolute terms) on a year
- Amount of capital invested (to be checked availability of data)

Source countries (countries that are investing more abroad in the green energy domain)

- Number of projects
- Capital invested

Destination countries (countries attracting more green energy investments from abroad)

- Number of projects
- Capital invested
- Jobs created

Based on the data available, it is possible to adopt a twofold approach for the analysis of the sector:

- "Dynamic", showing how green investments have evolved in the last 17/15 years, in terms of quantity, capex, and geographies (of both investors/investee), technologies/sub-sectors.
- "Static", making a detailed snapshot looking at the same parameters in the last year available.

After an initial assessment of the general trends in the green energy sector at large, the analysis will move to the different green technologies/sub-sectors considered in the study.

For each of them, the analysis is based on the parameters defined above (number of projects, capex, source and destination [considering also jobs creation]) and will rely on the same twofold approach, "dynamic" and "static".

While looking at the subsectors, it is possible also to further dig into the dataset, by looking at the most active companies in each of them, and by identifying the most promising project(s) of the year (based i.e. on capex or jobs creation projections).

Data gathering and analysis activities have been jointly run by fDi Intelligence and Enel Foundation on the basis of the data available through fDi Markets.

Chapter 1

The investment switch



The investment switch

Foreign direct investment (FDI) is a powerful proxy for investors' sentiment. Unlike fluid financial investment, where securities change hands in the blink of an eye, FDI requires companies to take the long-term view. Only projects that guarantee a degree of success over a 20- to 30-year period provide the business case for investors to move capital, equipment and employees across borders. While not an exact science, the analysis of global FDI outlines the main forces that are shaping up the economy and the geopolitics of the future, with the energy transition emerging as the most disruptive of them all.

The generation of electricity through the use of renewable energy sources (RES) and smart systems to store and distribute it have become the biggest magnet of global FDI. No other sector currently attracts as much FDI as green energy technologies. Its rise has come at the expense of fossil fuels, which used to dominate global investment. The energy transition has prompted FDI to literally switch from one to the other. Power utilities have been building global portfolios of RES assets as they clean their energy matrix. Battery energy storage systems (BESS) have risen from the ashes of decommissioned coal and natural gas plants. Electric vehicles (EVs) are replacing traditional internal combustion engines (ICEs). Even oil and gas companies have started allocating multi-billion dollar budgets to the development of renewable energy, including green hydrogen.

The data is unambiguous. FDI into renewables peaked at \$116.6bn in 2019, eclipsing for the first time fossil fuels, which attracted \$115.5bn in that same year. The trend of increased renewable

Global energy FDI in 2021

\$90.8bn

Renewables projects

\$16.2bn

Fossil fuel projects

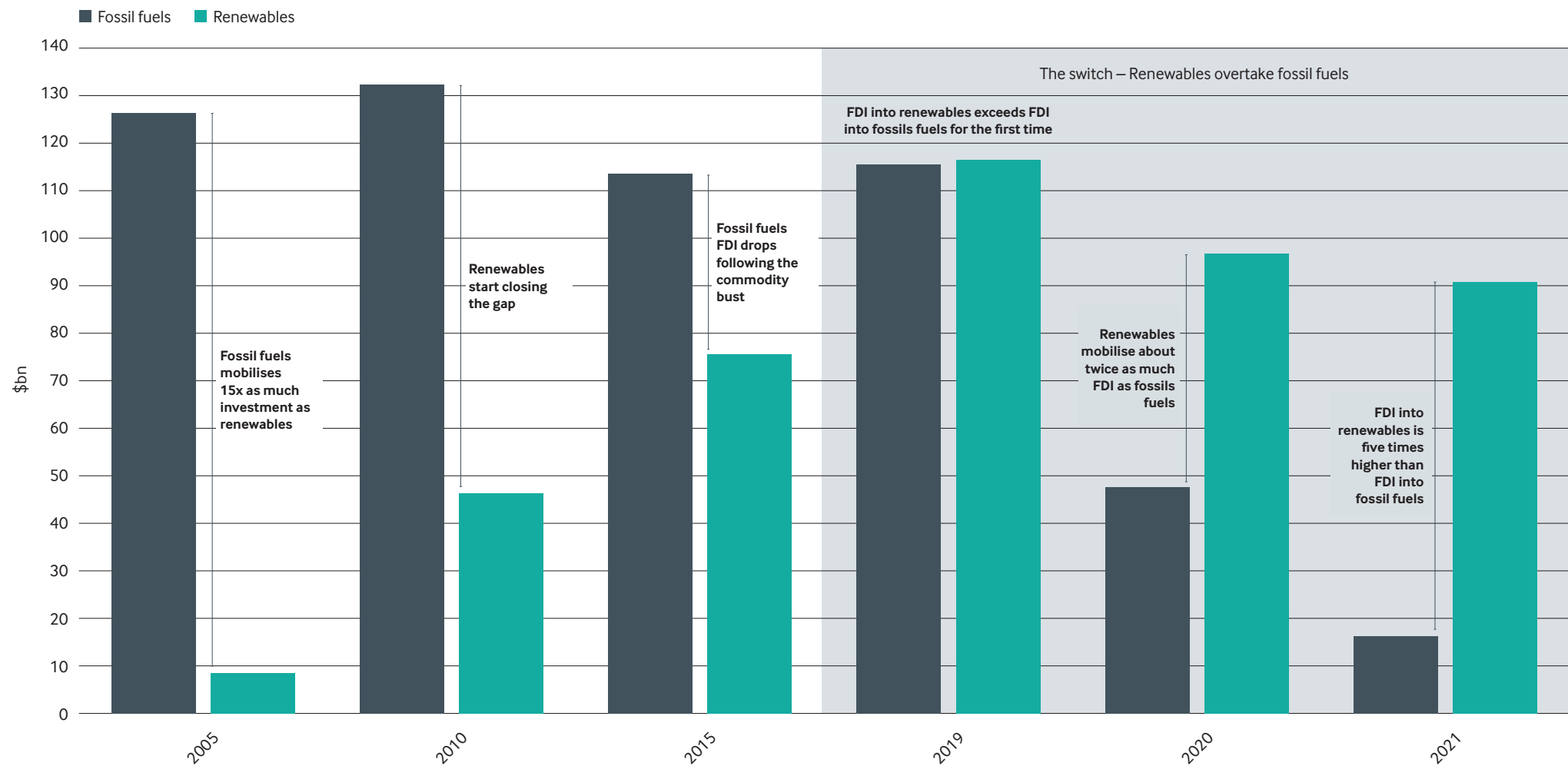
energy investments and decreasing fossil fuel investments held strong in the next two years as the Covid-19 crisis enhanced the case for a more sustainable economy. Although not spared by the pandemic, FDI into renewables stood at \$96.7bn in 2020 and \$90.8bn in 2021, below the record high touched in 2019, but above the \$66.6bn annual average of the 2010s. Meanwhile, foreign investments into coal, oil and gas plummeted to \$47.5bn in 2020 only to touch a new record low at \$16.2bn in 2021.

The energy transition and renewables penetration have also had an effect on the labour markets. The estimated number of jobs created by cross-border renewable energy projects has eclipsed those generated by coal, oil and gas – once a major source of employment across geographies. In 2020, FDI into renewables created twice as many jobs as FDI into fossil fuels; five times

as many in 2021. Total active jobs in the RES value chain increased to 12 million in 2020, according to Irena, up by 40% from 7.3 million in 2012.

The switch is not just about technology and jobs. It has changed the very dynamics of energy investment. FDI into fossil fuels inevitably chases large deposits of hydrocarbons that happen to be concentrated in specific geographies. Countries hosting those deposits have great leverage over prospect investors as there is little alternative. The renewables game is a very different one. Although potential still varies across geographies, RES are way more ubiquitous than hydrocarbons. Facing a much more level playing field, investors factor in other elements like the availability of specific RES regulations and incentives, as well as a stable business environment as a whole. In fact, those countries with the highest solar and wind energy potential are not necessarily those attracting the highest levels of RES investment. As a result, the switch has redrawn the whole geography of global energy investment.

The inflection point: renewables overtake fossil fuels in 2019
Announced greenfield foreign direct investment in renewables and fossil fuels since 2005*



Source: fDi Markets * includes estimates

The geography of the switch

For decades, the world's energy map has been built on relations between Western consuming nations and oil producing and exporting countries. With 75% of the oil reserves located in the Middle East and North Africa and Venezuela and over 50% of the gas reserves in Russia, Iran and Qatar, the use of fossil fuels has created a map of global interdependencies - and connected geopolitical tensions - which have deepened with the entry of China and India into the global economy as fossil fuel consumers.

Renewable energy sources (RES) have turned this paradigm upside down. Given their ubiquitous nature, the dichotomy between importers and exporters becomes obsolete. Geographies the world over have a chance to harvest local RES to meet domestic energy demands and lessen their dependence on imports of fossil fuels, limiting the geopolitical value traditionally attached to the energy sector, but rather spurring cooperative patterns. In this perspective, the degree of success they can achieve hinges on their capacity to attract investment by international RES developers that have the capital and know-how to develop such projects for profit.

Rule of law, strong policy direction and public incentives thus put developed countries at the forefront of RES investment between 2005 and 2022. The UK and the US are cases in point. World-class RES potential, combined with consistent and rewarding government schemes, gained them a global leadership in renewables investment. Overall, the UK attracted \$145.7bn in renewable energy FDI between 2005 and 2022, although its numbers are inflated by the wave of capital

“Renewables have made the dichotomy between importers and exporters obsolete”

intensive offshore wind projects that mounted in the decade; the US \$115.2bn, more evenly spread mostly between solar, wind and other RES. Similarly, Australia's RES attracted \$61.2bn in FDI in the period. Although no other country has installed as much green power as China in the period, the country's RES development has been almost exclusively a domestic play with no FDI involved.

Despite this long-term trend, data suggest that RES investment came of age only in the wake of the global financial crisis. Shrinking public incentives in the West, combined with plummeting technology costs for solar and wind farms, gave RES developers a chance to look for alternatives in emerging economies that could combine a relatively stable business landscape with high RES potential. This new, more market-oriented phase saw FDI into renewables spread more evenly across geographies. Latin American countries of the likes of Chile and Brazil emerged as major destinations of FDI into renewables, attracting,

respectively, a total of \$43.3bn and \$48.5bn between 2005 and 2022. India and South Africa followed a similar trajectory with, respectively, \$43bn and \$19.8bn. While concentrated in a few geographies in the 2010s, FDI into renewables has now become a truly global play.

If renewable energy projects spread more evenly across geographies than fossil fuels ones, at first glance the sources of capital and technology remains relatively concentrated, with European power utilities being the dominant force in the global RES market. Between 2005 and 2022, they accounted for 60% of global cross-border investment into renewables, followed at distance by their Asian (20%) and North American (14%) peers. More specifically, Italian Enel stood out as the biggest renewable energy investor in the period, with total investment commitments of \$44.8bn, followed by Spanish Iberdrola with \$38.8bn, French EDF with \$24.6bn and German RWE with \$23bn. The only non-European company in the top 10 is Singapore-based Sun Cable.

The leadership of European power utilities becomes more nuanced when considering that US developers are powerhouses on their own, but they mostly focus on the domestic market and generate relatively little FDI. At the same time, electricity generation remains formally or informally out of the reach of foreign companies in many countries, most notably in China, where domestic power companies dominate the market and are no match for foreign investors despite a gradual liberalisation of the market. Taking into account domestic investment, also the sources of investment into RES appear relatively global and

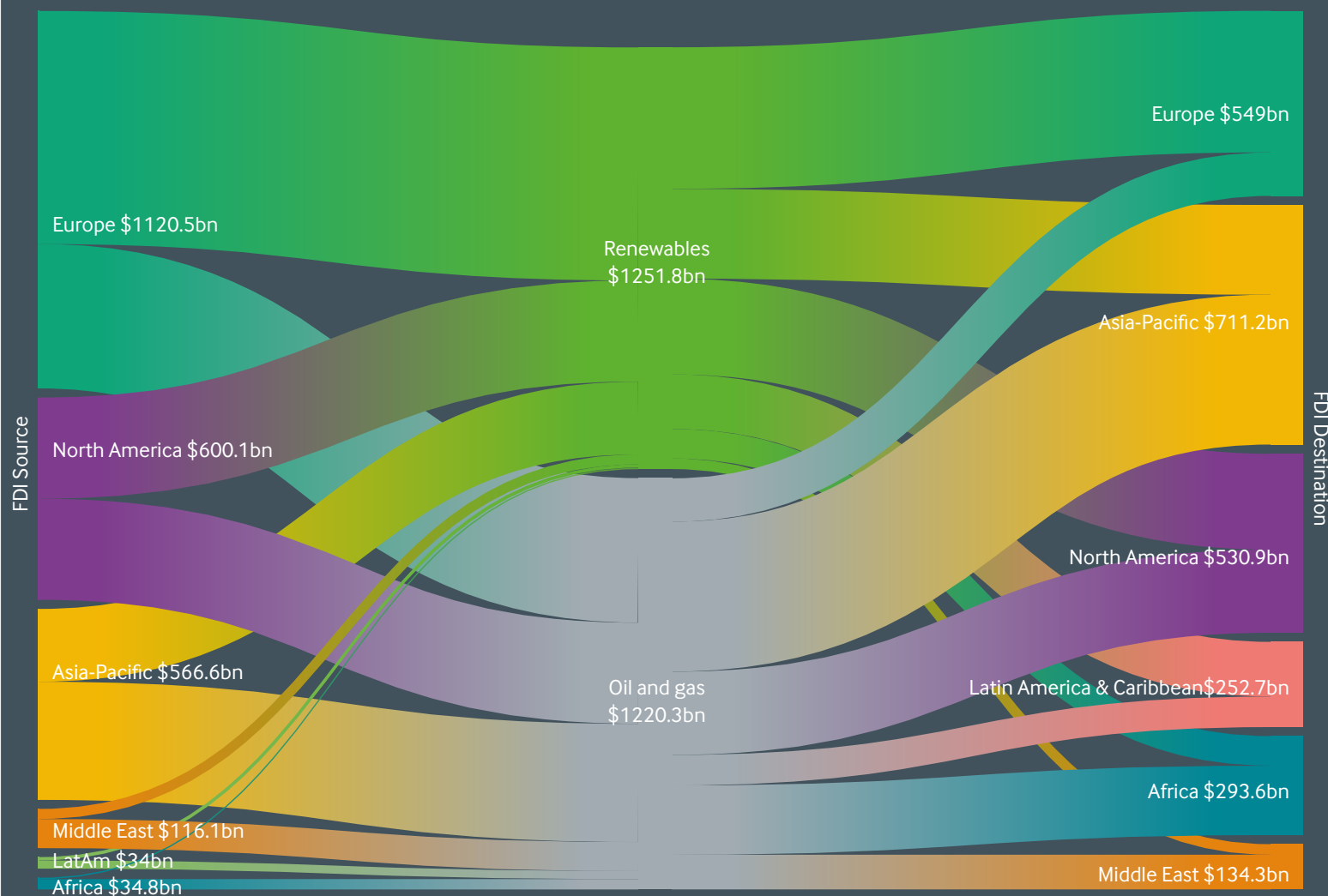
distributed, which further breaks the close circle of interdependencies created by fossil fuels.

Equipment manufacturing is a different story, though. The international perspective of RES developments has created strong incentives for equipment manufacturers to seek efficiencies by linking to global value chains. With China emerging as the factory of the world in the period of hyperglobalization between 1990 and 2010, most of the production of RES equipment has localised within the Asian country.

China and Chinese companies dominate the supply chain for solar photovoltaic panels, with a 70% share of global manufacturing as of 2021, according to consultancy Wood Mackenzie. This uneven balance of manufacturing power not only risks recreating a pattern of dependency, it also falls foul of the new trade and geopolitical barriers between West and East. Despite notable public and private attempts to re-establish a strong supply chain in Europe, focusing on innovative and state-of-art technologies and processes, walking away from Chinese producers is no easy endeavour. The US introduced heavy tariffs on imports of PV panels from China in 2018. Three years later, 99% of solar PV panels used in solar parks in the US still came from Asia – not from China, but rather Malaysia, Vietnam, Thailand and South Korea, according to a Rystad report.

However, the report also highlights that modules originating in these countries are typically manufactured by Chinese enterprises “that have offshored the assembly phase, the last step in PV module production”, while the production of solar cells themselves remains located in China.

The geography of the switch in 2010-2022



Source: fDi Markets

Tech breakdown

Harnessing the sun and the wind to power human activities is nothing new. But in the last two decades, solar and wind technologies have become the overarching symbols of renewable energy, jostling for supremacy in cross-border investments in the renewable energy sector.

Initially, wind was winning, with 53.5% of the share of global FDI in 2008. But as solar panels and cells became cheaper, solar FDI first exceeded wind investment in 2010, and then again in 2013, gaining a lead it has retained to date. Overall, between 2005 and 2022, solar FDI made up 37.5% of foreign investment into renewables, wind 35%.

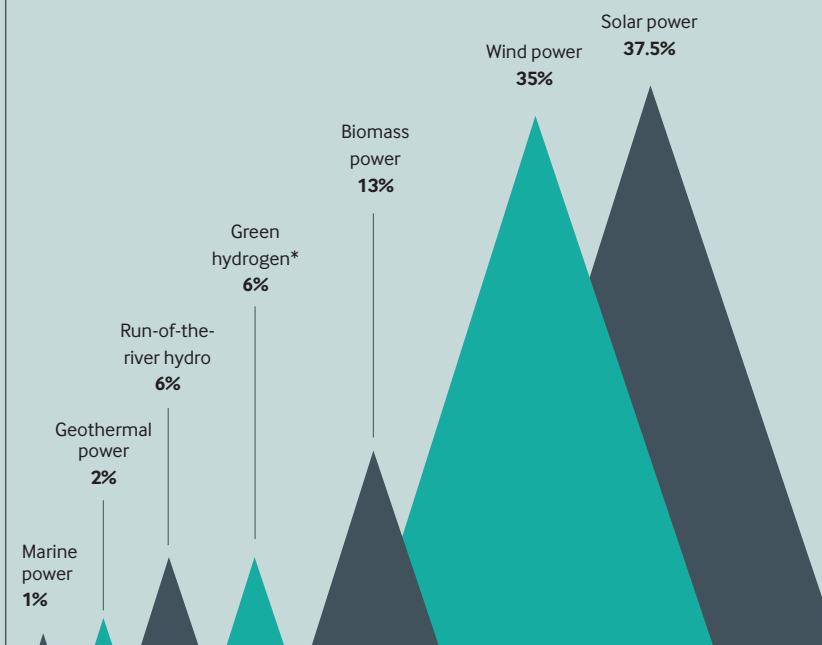
Following the first wave of investments into wind and solar energy, efforts to decarbonise and electrify personal and public transport boosted investments into batteries – the energy carriers needed to replace internal combustion engines (ICEs). Batteries are also required to balance the intermittencies from wind and solar and FDI projects in renewable energy with a battery energy storage system component have been increasing over the past few years. This all translated into booming demand for the manufacturing of batteries. From 2015 to 2022, foreign investment into the production of batteries increased to \$17.1bn in 2021, from \$1.1bn in 2015 (including US interstate investment).

Batteries is only one of the emerging technologies for storing and stabilising green power and the development of battery energy storage systems (BESSs) piggybacks on the booming production capacity needed to meet demands coming from EVs and the mobility sector. Green hydrogen has also emerged as a popular alternative for turning RES-generated power into a stable energy source for hard-to-abate sectors (aviation, heavy-duty transport, shipping etc.). The green hydrogen hype quickly mounted in the past couple of years, with foreign investment announcements into green hydrogen projects surpassing the \$25bn mark in 2021, having totalled \$8bn in 2020.

The green hydrogen market remains fragmented with a number of diverse players – from renewable energy companies, oil and gas majors and industrial gases companies. Power utilities consider it an alternative way to add value to their RES generation. Industrial

gas, as well as oil and gas companies have jumped on the green hydrogen bandwagon as they see it as a chance to embrace the energy transition by leveraging their expertise in hydrocarbons. Some of the projects being announced in the green hydrogen space mirror the oil and gas mindset as they concentrate major capacity in specific locations that will serve as export hubs. Major oil and gas countries themselves, particularly in the Middle East, are betting on switching some of their oil and gas capacity to green hydrogen, which would be a step forward from an environmental standpoint, but would maintain, rather than blur, the current division between energy exporters and energy importers with all their geopolitical implications.

Renewables FDI technology breakdown 2005-2022



Source: fDi Markets * Includes other emerging renewable energy technologies

Ukraine war and 1Q22

From an energy perspective, the Ukraine war has once again laid bare the delicate geopolitics of a world economy powered by fossil fuels. On the one hand, there is a bunch of major producers with extreme leverage that often ends up strengthening the rule of authoritarian elites like in Russia; on the other hand developed, energy-thirsty economies - still too reluctant to embrace a full-speed energy transition - that struggle to lessen their dependence on oil and gas imports even when the ground for trade and cooperation with oil suppliers collapses. Ultimately, the Ukraine war strengthens and accelerates the energy transition as a key tenet of sustainability, as well as energy security and affordability.

"The new geopolitical and energy market reality requires us to drastically accelerate the clean energy transition and increase Europe's energy independence from unreliable suppliers and volatile fossil fuels," the European Commission wrote on March 8 as it announced REPowerEU, a plan to make Europe independent from Russian fossil fuels before 2030.

Against a backdrop of weakening cross-border investment flows because of rising geopolitical risks, investment into renewables held strong in the first quarter of 2022, when it stood at \$24.9bn, the second best first quarter performance on records after 1Q09, particularly thanks to major investment announcements in capital-intensive offshore wind and hydrogen projects.

In the short term, however, investment into fossil fuels might temporarily rebound as the result of a needed diversification away from Russian oil,

gas and coal.

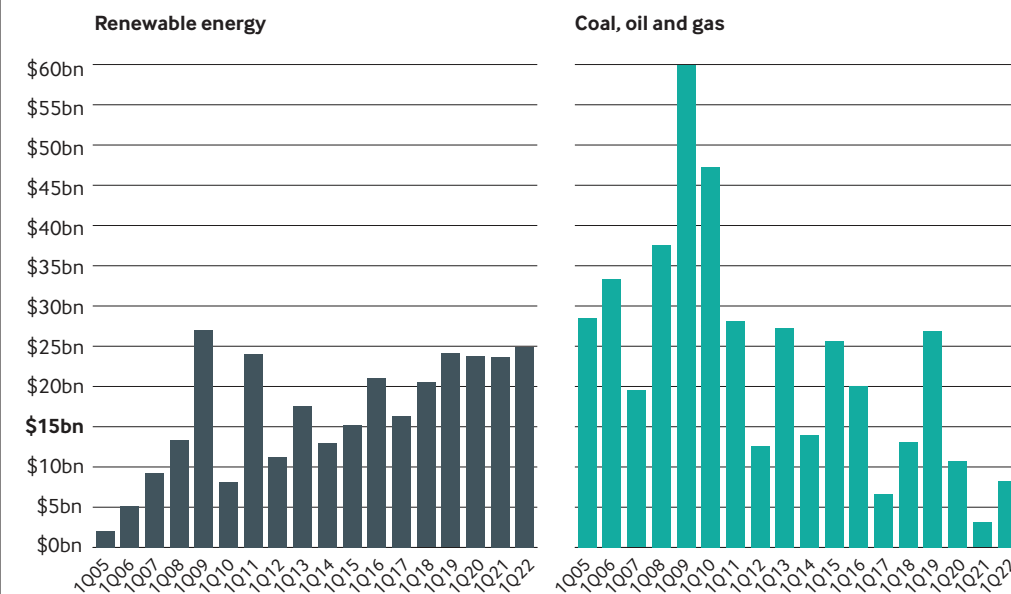
Policy-makers in Japan, the US, the EU and the UK have all committed to reducing, if not banning, imports of Russian hydrocarbons. While they accelerate their energy transition plans, they are also looking for available alternatives to imports of Russian hydrocarbons, sending a strong demand signal to the oil and gas industry, which has reacted accordingly. FDI into coal, oil and gas rebounded to \$8.3bn in the first quarter of 2022, from \$3.1bn in the same period of the previous year. However, from a

historic perspective, it remains the third weakest performance on records after 1Q21 and 1Q17.

The Ukraine war has thus added new momentum to the energy industry as a whole, at least in the short-term. But in the long run the trajectories of RES and oil and gas are set to decouple again as net-zero commitments inevitably shore up the former, while weakening the business case of hydrocarbons. The different magnitude of FDI that has flown into the two sectors in the immediate wake of the Ukraine war confirms their different perspectives.

Ukraine war impact on energy FDI

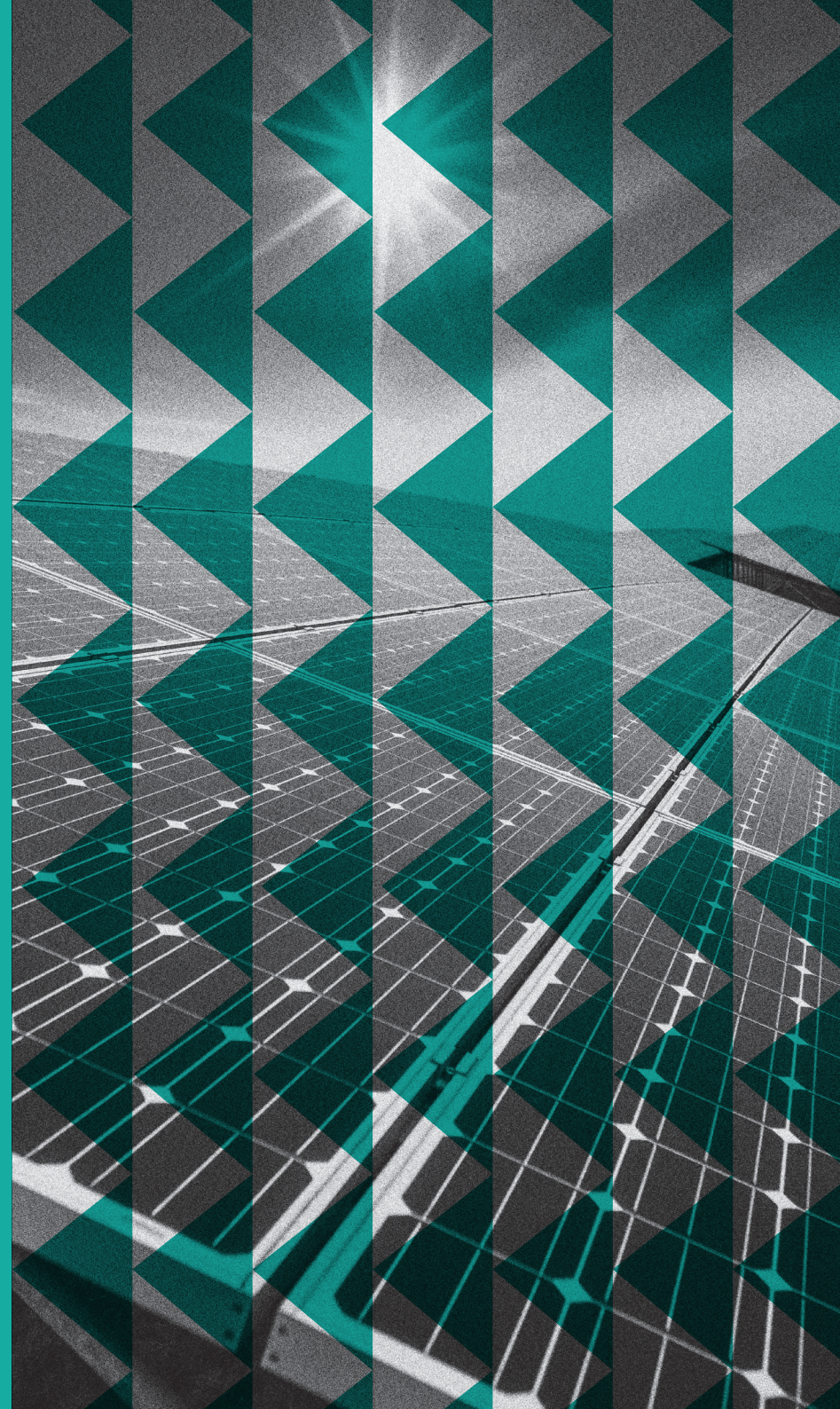
Announced foreign direct investment in the first quarter of each year by technology



Source: fDi Markets

Chapter 2

Solar power FDI



The dawn of a global solar market

Long touted as the most widely available energy source, solar energy has come of age in the past 17 years. Solar photovoltaic (PV) in particular has experienced tremendous levels of innovation and scale, thus becoming truly ubiquitous.

"Among renewable technologies, solar PV installations have seen the fastest growth, with a 21-fold increase in the 2010-21 period, as a result of major cost reductions backed by technological advancements, high learning rates, policy support and innovative financing models," Irena writes in its Energy Transition Outlook 2022.

After passing the milestone of 100GW of installed capacity in 2012, global solar PV installed capacity reached 843GW in 2021.

Analysts expect this to be only the tip of the iceberg and solar PV to lead the renewable energy revolution moving forward and become more and more of a key pillar in any decarbonisation effort. Under the 1.5°C scenario, installed capacity is expected to reach 5200GW by 2030 and 14,000GW by 2050, according to Irena estimates.

Foreign direct investment (FDI) has been instrumental to the rapid growth and diffusion of solar energy applications. Energy companies, particularly from Europe have triggered a first wave of cross-border FDI into solar energy in the 2000s. Their peers from North America and Asia followed suit in the following decade, accelerating the globalisation of the solar energy market.

FDI into solar energy projects has been on a natural upward trajectory since 2005, peaking in 2019 at \$61.4bn, according to figures from foreign investment monitor fDi Markets. In total,

Top investing region
Western Europe

Top three investing countries
Spain, Germany, US

Top destination region
Asia-Pacific

Top three destination countries
Australia, US, UK

\$388.6bn of foreign capital has gone into solar generation between 2005 and 2022.

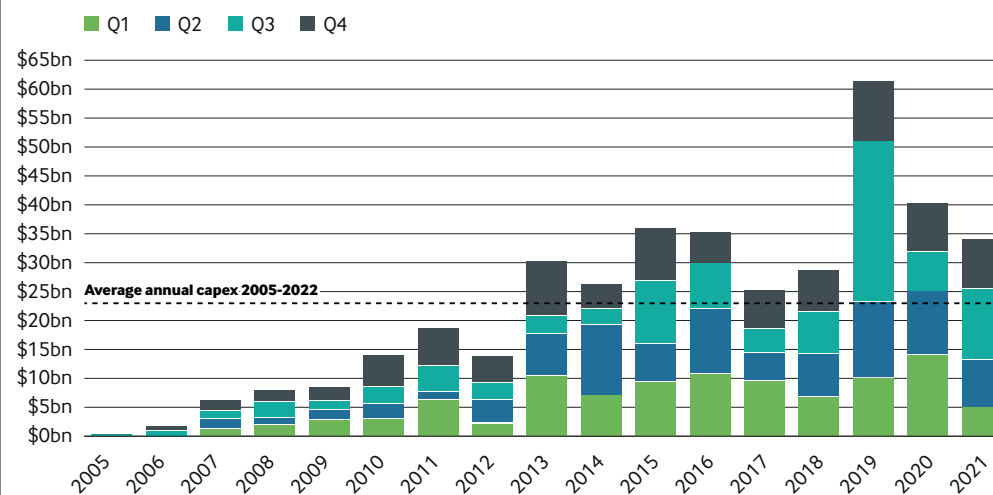
There are many nuances to this upward trajectory, particularly when it comes to its geographic distribution.

FDI in the solar energy sector has moved from being concentrated mostly in western Europe and governed by policy incentives to becoming ubiquitous across the world and driven by falling prices – the global weighted-average levelised cost of electricity (LCOE) of newly commissioned utility-scale solar PV projects fell by 85% between 2010 and 2020, that of concentrated solar power (CSP) by 68%, according to Irena figures.

Plummeting costs limited the need for public

Solar investment rises up

Announced foreign direct investment in solar energy projects by year and quarter



Source: fDi Markets

incentives for solar to be competitive vis-a-vis other energy sources – in fact, solar PV is already the cheapest source of energy in countries with high-quality resources even not considering fossil fuels negative externalities –, which levelled a playing field originally skewed in favour of European countries with deep public budgets.

Solar FDI goes global

If FDI into solar used to be an almost exclusive European play in the 2000s, with European producers chasing incentives across European countries, by the mid 2010s the flows of capital have started to include destinations with high direct normal irradiance (DNI) beyond Europe, particularly in Latin America and Africa.

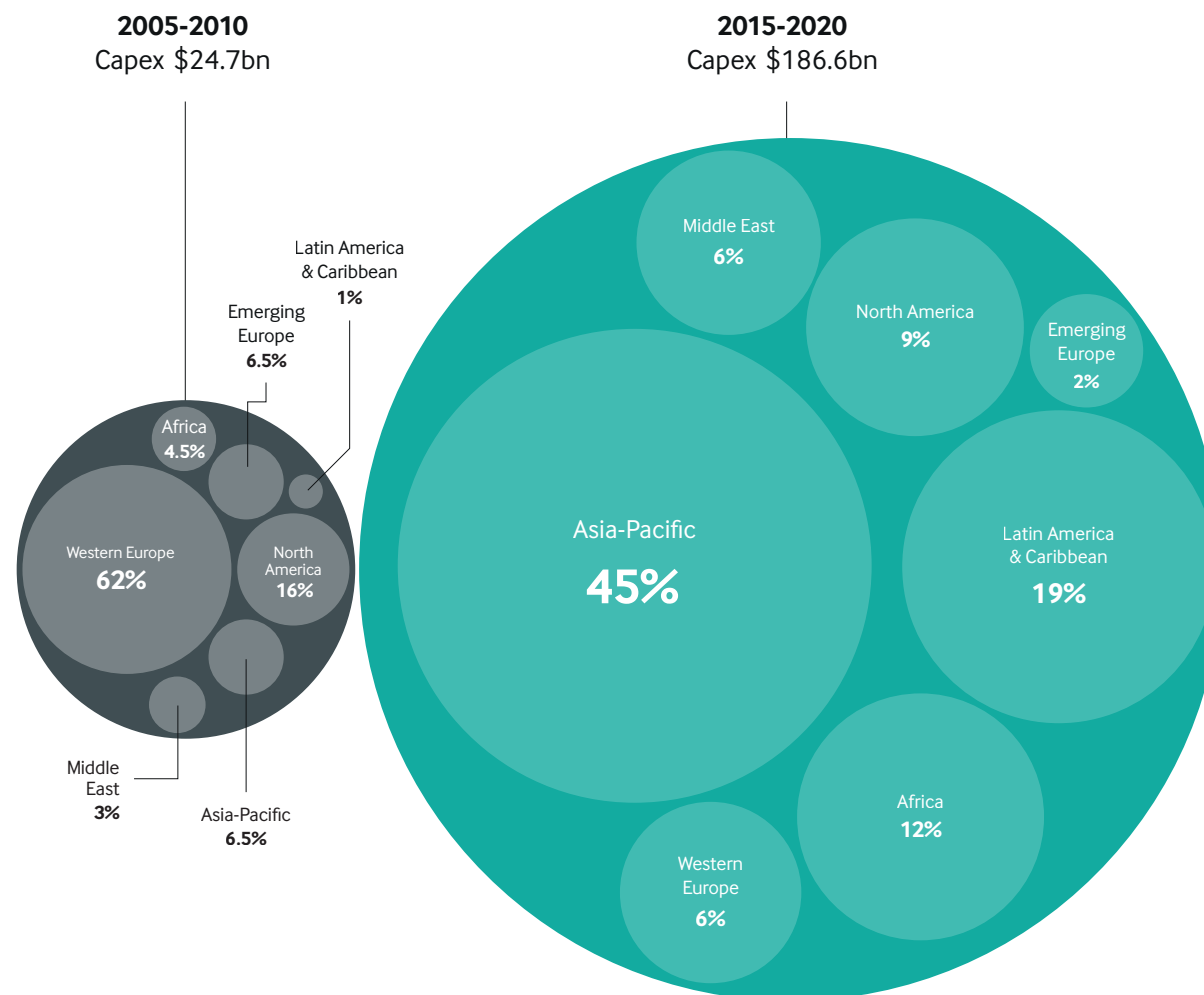
Chile, thanks to its irradiation levels – the second highest in the world after Namibia's, according to World Bank data – big industrial clients like mining companies and an improving, market-driven regulatory framework, became a poster child of this new wave of solar FDI. Foreign investors announced solar projects worth \$18.2bn in the country between 2010 and 2020. Most of them (75%) came from Europe, with Spanish companies leading the way.

Chile became the catalyst for booming European, as well as North American investment across the whole of Latin America. Investments by Western European companies into solar power developments in the region surged by a factor of 17 to \$7.7bn between 2010 and 2020. Meanwhile, investments from North American companies in Latin America went from negligible in 2010 to \$1.9bn in 2019, although in a more volatile fashion.

Foreign investment also started flowing into

Solar investment rises up

Geographic distribution of FDI into solar energy by region in selected periods



Source: fDi Markets

countries with top-class solar resources in other geographies, once again signalling a maturing market. Among others, solar FDI into Egypt hit \$5.4bn in 2015, while Australia saw annual investment flows of above \$3bn from 2015 onwards, peaking at \$20.3bn in 2019 thanks to one particular project: Singapore-based Sun Cable's plans to build a A\$22bn (\$15.6bn), 10GW solar power plant in the Tennant Creek area of Australia and a subsea cable connecting Australia with Singapore.

By the time FDI into solar projects peaked in 2019, its global spread was dramatically different than at the beginning of the decade.

In the record year of 2019, roughly 45% of overall foreign investment in solar went to Asia Pacific, roughly 19% to Latin America, while western Europe recorded a little under 4% and North America roughly 12%. In 2010, North America and Europe combined represented nearly 59.5% of the solar destination market.

If the spread of investments looks less European-centric as of 2019, there are regional quirks to this new global solar market. Asia-Pacific, for instance, remains a regional solar market with over 65% of solar investments coming from fellow Asian countries in 2019.

China is a story of its own. Beijing's clear policy input in support of solar energy – enshrined in successive five-year plans since the early 2000s –, set in motion the country's production machine to meet the resulting booming demand for solar PV panels. Its cumulative installed solar power capacity swelled from 4.2GW in 2012 to 253.4GW in 2020, the world's largest according to IEA figures. With Beijing also keen to promote

“By the time FDI into solar projects peaked in 2019, its global spread was dramatically different than at the beginning of the decade”

a “Go Global” agenda for the private sector and thus export some of the often redundant production capacity built at home, Chinese solar developers became active foreign investors in the mid-2010s. In 2014 alone, foreign investments in solar generation by Chinese companies reached a peak of 17 projects worth a total of \$6.5bn and spread across Japan, India, the UK and Morocco. However, they have gradually retreated in recent years as sensitive sectors like energy became subject to greater FDI scrutiny, and priorities at home changed. Chinese FDI into solar fell to \$1.7bn in 2019, \$2.4bn in 2020 and merely \$361m in 2021.

The overall impressive growth in investments has not only contributed to bring forward decarbonization processes, but it also had an important impact on socio-economic dynamics in those destination countries where investments brought about new jobs and labour opportunities. Over the period 2005 to 2020, it is estimated that 83,362 direct jobs have been created globally as a result of solar FDI – roughly 30% of the total estimated jobs created from renewables FDI. According to Irena, 3.8 million jobs were created in the solar industry in 2019, up from 1.4 million in 2012.

Resilience through the pandemic

The solar sector remained resilient throughout the pandemic years. Coming off a record 2019, Covid-19 did slow the market momentum by bringing along economic uncertainty, supply chain disruptions and labour shortages. However, it also accelerated the public debate around sustainability and decarbonisation, strengthening even further the long-term fundamentals of solar and renewable energy as a whole.

Between the years 2020 and 2022, an average of \$37.1bn worth of foreign investment poured into solar projects globally, with \$40.3bn recorded in the first year and \$34bn in the second. Despite being far from the peak of 2019, both years remain well above the annual average of \$29bn of the previous decade.

Investors from western Europe still stood out as the epicentre of solar projects development in the 2020-2021 period. They accounted for more than half (54%) of the solar FDI announced globally. Asian investors came in at a distant second place (20%), followed by North American investors (15%).

French firms led the European pack across both years, with their FDI commitments to solar projects reaching \$8.5bn in the period. Their investment horizons span across continents, from the US to the UAE, from the UK to South Africa, Brazil and Cambodia.

Overall, almost a third of the global FDI into solar tracked in 2020 and 2021 went to the regional European market, while 21.5% flowed into Asia Pacific, 19% into North America, 16.5% into Latin America and the Caribbean, 8% into

Growth (%) of solar FDI in Texas in 2021 from 2020

+80.2%

Source: fDi Markets

Africa and 5.1% into the Middle East.

US solar rises up

During the pandemic years, no other country attracted as much FDI into solar energy as the US did, with several states emerging at the forefront of global solar energy developments.

This is the case of a traditional oil state like Texas, where solar investors such as multinationals Enel, Samsung and Orsted, became more bullish and pushed 2021 state-level solar FDI to \$2.8bn, up by 80.5% from the previous year. This outstanding performance of Texas contrasts with a decline in inbound solar investments in the US, which overall showed a 18% fall in 2021 from 2020.

In aggregate, 32% of the solar projects into the US in 2020 and 2021 have gone into Texas, proving its capacity to reconvert and attract investment inflows from one energy sector to another.

Foreign investors have been chasing new opportunities for solar energy developments in the Asia-Pacific region too, particularly in

countries like Australia, Indonesia, Taiwan and India, which have been able to attract high levels of investments and new ambitious solar projects.

The biggest project of 2021 in the Asia-Pacific region was indeed Singapore-based Sunseap's \$2bn 2.2GW floating solar complex with battery storage in Batam on the Riau Islands, Indonesia.

The demand for electricity in southeast Asia is set to increase substantially and solar is the one renewable source set to step in. The Asean's 6th Energy Outlook by the Asean Centre for Energy, 2017-2040 estimates that from 2018 to 2040 solar will grow faster than any other electricity source, with a CAGR of 10.4%.

Elsewhere in the region, solar is the fastest growing source of electricity and foreign investors have remarked upon this in particular in Australia and Taiwan, both of which have ambitious solar energy targets. Australia plans to generate additional 33,000GWh of renewable energy every year until 2030 and Taiwan announced in 2019 that it would add 25GW of solar energy installed capacity to meet its 20% renewable energy generation target by 2025.

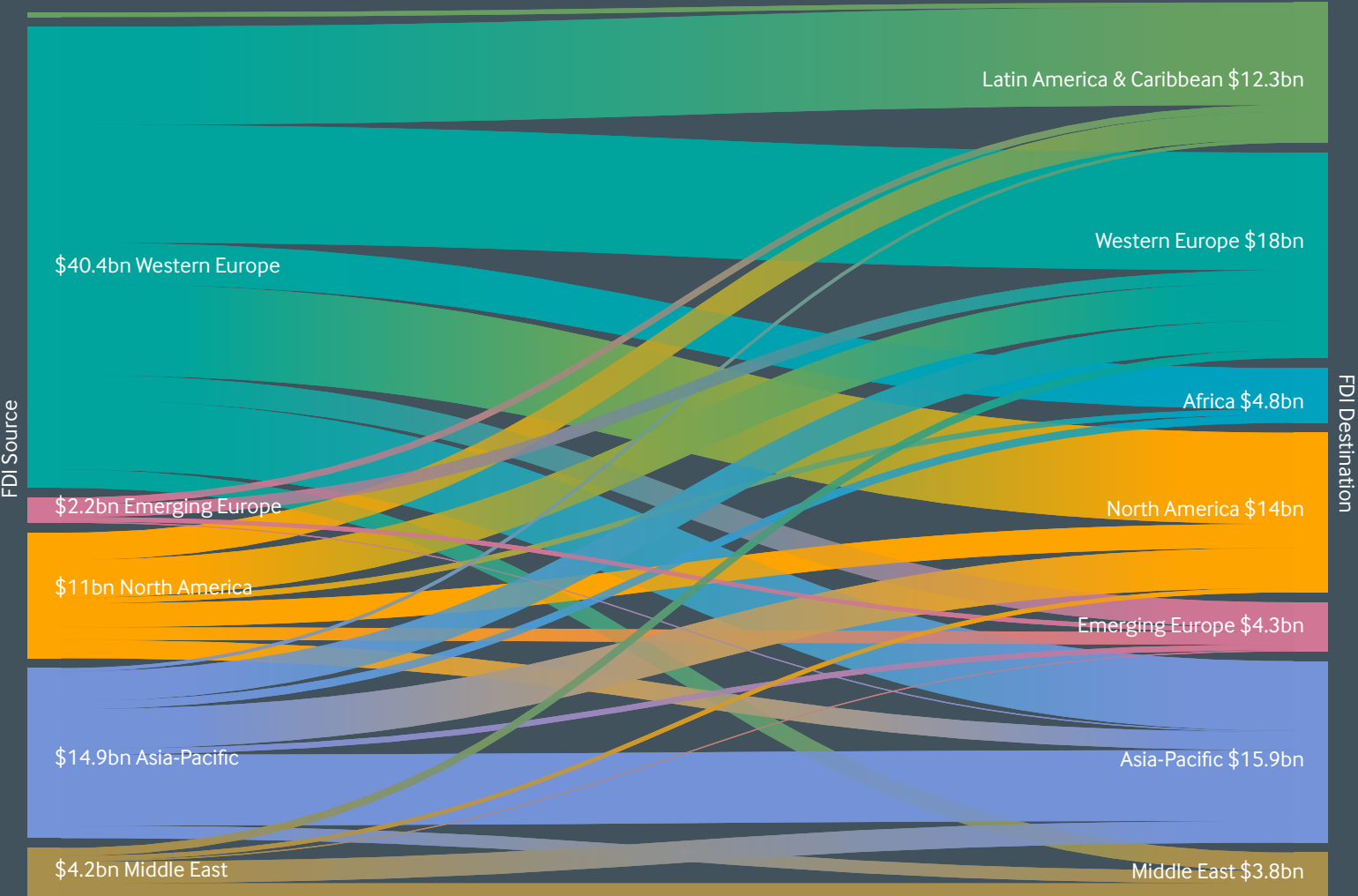
Australia and Taiwan both received 7 solar projects in 2021, worth \$1bn and \$1.8bn, respectively. Taiwan had received no foreign investment in solar projects in 2020, according to fDi Markets, but had welcomed roughly \$1.2bn in solar projects in 2019.

On the other hand, some major solar energy FDI destinations have had to deal with challenging policy environments that took a toll on FDI inflows into the sector. The UK saw foreign investment fall away in 2021 owing to the effects of specific policy moves, like the removal

of its feed-in-tariff in 2019. Once a pioneer for attracting solar projects, the country received only \$498m in 2021, after \$2.9bn poured into the sector the year before. In comparison to the boom years of 2010 to 2015, the country's allure has lost its sheen, as year-on-year ground mount installed capacity has been slowing, according to Solar Media market research. Policy constraints limited solar energy in Mexico too, where solar FDI dried up altogether in 2021, falling to zero from \$1.5bn worth of projects in 2020, thanks in no small part to new legislation restricting foreign renewable energy companies operating in the country.

Looking forward, Irena estimates that global investment in solar PV and rooftop installations has to grow to annual \$338bn between 2021 and 2030 under the 1.5°C scenario, from an annual average of \$115bn between 2017 and 2019, which would create an even bigger role for foreign investors to play in meeting this demand for investment.

Patterns of solar investment during the pandemic years
Origin (left) and destination (right) of foreign direct investment in 2020-2022



Source: fDi Markets

Punching above, or below, the solar weight

Unlike the evolution of fossil fuels, which have to be mined and drilled in specific places on earth, the geographical development of solar energy has been largely determined by national policies, governmental budgets and the appetite of the private sector. It follows, then, that the countries which have emerged as solar pioneers over the past decade are not necessarily the most propitious places DNI-wise for solar to thrive.

Although European countries have been the best at attracting investments, some of them have the least favourable conditions for solar worldwide, while more favourable countries in the Middle East and Africa have not seen the windfall in accordance with their potential.

The analysis of foreign investments into solar by country in 2020 and 2021 against the World Bank solar PV index illustrates which countries are over-performing and underperforming relative to their potential and their peers.

This is not an analysis of installed capacity but rather of foreign investment across these two years, meaning that this should be treated rather as an indicator of how well these countries have been able to attract foreign investment through policy incentives and frameworks in the 2020-2021 period.

In this context, the solar investments into the US, totalling nearly \$14bn, appear extremely out of kilter. Spain, Brazil and Australia, which have better solar potential than the US, are shown to be some way ahead of other countries with equal if not better solar conditions too. This underscores the value of government strategies and policies over the past fifteen years in the

development of foreign-funded solar projects, somehow determining the positioning of these countries in the global market for solar power development and generation.

According to this specific perspective, Chile is ranked as having the best solar potential globally and boasts nearly \$5bn in invested solar FDI in 2020 and 2021. As discussed in previous chapters, this has a lot to do with the country's national strategy, business environment and self-promotion as an investment destination, which turns Chile's solar sector into an enticing destination for foreign companies.

Despite being geographically least favourable to solar – the bottom 13 countries in terms of solar potential are all European – Europe has long supported the transition to solar energy attracting investments that contributed to deploy relevant generation capacity.

The UK's position as fourth most invested solar destination, mostly due to its strong performance in 2020, is a case in point how a country with one of the lowest solar potential in the world can achieve impressive results without being world

famous for its sunshine.

Not all European countries are punching above their weight, however. For instance, some countries in south-eastern Europe, like Bulgaria, are shown to have attracted very little investment despite having a potential score that is akin to that of emerging global solar players such as Indonesia, which accumulated \$2bn in foreign investments in the sector.

Untapped potential

Elsewhere, many of those with the biggest solar potential in the Middle East and sub-Saharan Africa remain largely untapped, owing to a lack of incentives, bankable infrastructure and generally risky business environments.

South Africa and the UAE represent probably the two main regional exceptions to this rule, however: the former put subsidies in place as of 2011 and the latter put forward an energy strategy in 2018 and removed foreign ownership limits as of 2019, policies that contributed to boost international investments inflows and to expand generation capacity. Both stand out as regional pioneers in attracting investment, with South Africa receiving a quarter of solar investment into Africa between 2011 and 2022 and the UAE over 40% of solar investment into the Middle East over the same period.

On the contrary, among countries that might be expected to perform better, emerge the cases of Israel and Morocco.

Israel introduced ambitious solar energy targets in 2020, when the government stated that solar energy would cover 80% of electricity demand at peak hours by 2030. That did not

Solar FDI into Chile in 2020-2022

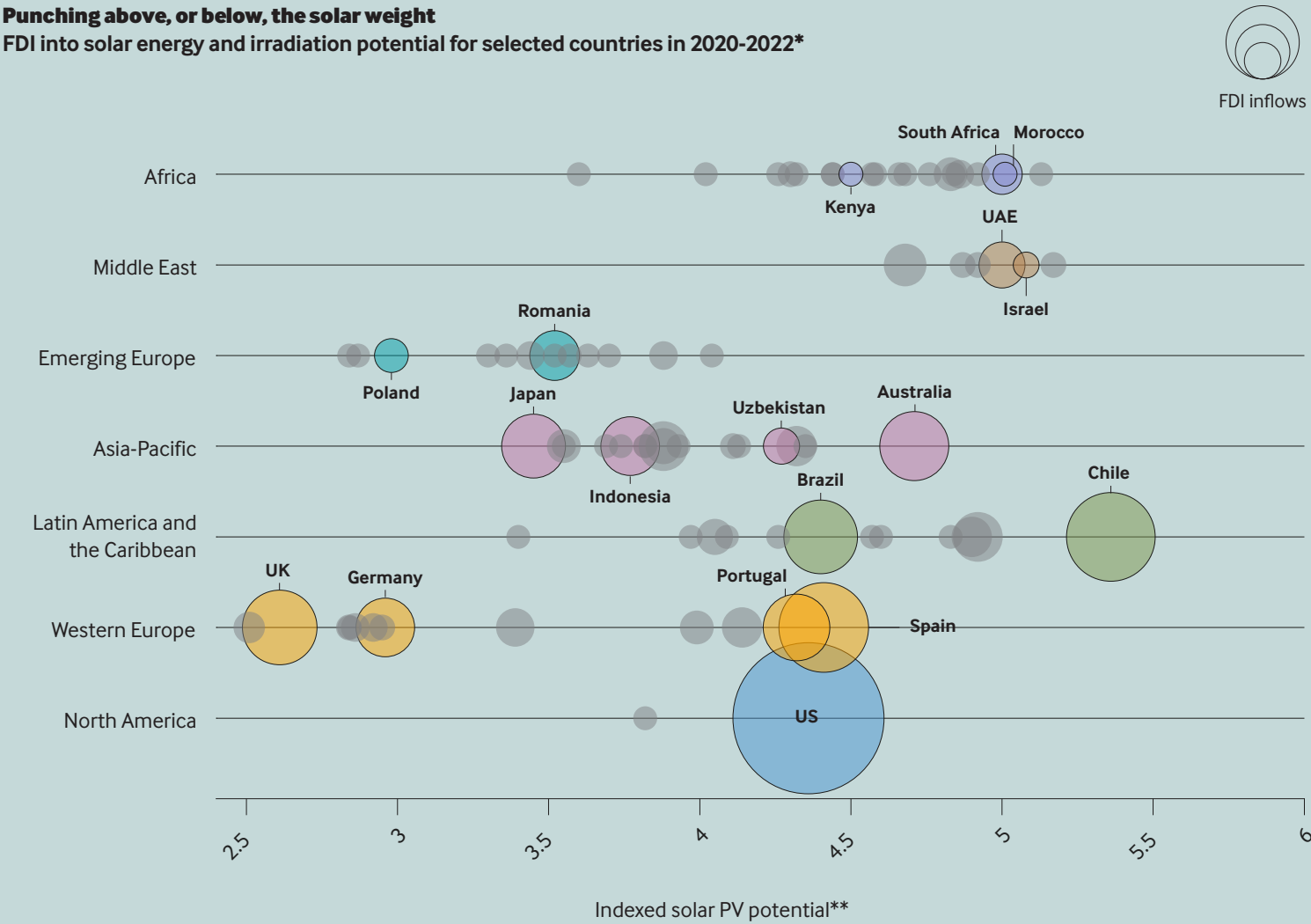
\$5bn

Source: fDI Markets

immediately translate into FDI inflows. The country's recorded FDI in solar in the 2020-2021 period was limited to \$361m.

Similar story in Morocco, where ambitious policy directives and well developed regulatory frameworks have not yet been matched by sustained foreign investments into the domestic solar sector. Morocco already houses the largest concentrated solar power complex in the world, the Noor Power plant. Despite a slowdown in solar FDI inflows in the last few years, its policy efforts are expected to create the condition to further international investments in the future.

Punching above, or below, the solar weight
FDI into solar energy and irradiation potential for selected countries in 2020-2022*



Source: Source: fDi Markets, the World Bank • *Only countries that registered any FDI activity in 2020-2022 were considered
**The higher the bigger

Top investing companies

The western European and North American majors, such as Enel and Canadian Solar, have dominated the ranking of top solar investors over the past 16 years. In line with the globalisation of the solar sector, the incumbents have diversified their geographic range. In parallel with European/North American dominance of the market, in the last few years newcomers from Asia and the Middle East have come on to the scene with big ticket investments.

Italian energy company Enel tops the list for solar projects between 2005 and 2022 with \$15.6bn invested in more than a hundred overseas projects, followed by Ontario-based Canadian Solar with \$13.9bn invested in 64 solar generation projects. Singapore-based Sun Cable invested \$15.6bn in one single project.

Throughout the 2010s, Enel's European projects gave way to projects further afield. In 2011, Enel made its first foreign solar investment in a solar power plant in Mochovce, Slovakia, while numerous projects in Greece followed before it moved out the European continent investing \$0.3bn in 2012 to build its first PV 0.1GW plant in Chile in the Antofagasta region. Expanding its international profile and becoming the largest private renewable energy company at the global level, the Italian energy giant then moved to invest in the US, South Africa, Brazil, Mexico, Panama, Spain and Australia.

With a strong focus on China, Canadian Solar's first project was a joint venture with Chinese GD Power Development, a subsidiary of state-owned China Guodian Corporation, in 2009

Top 10 foreign investors in solar energy (2005-2022)

Parent company	Projects	Capex (USDbn)	Avg capex (USDbn)	Jobs created
Enel	103	15.6	0.2	3,880
Sun Cable	1	15.6	15.6	300
Canadian Solar Inc (CSI)	64	13.9	0.2	4,017
SkyPower	24	9.1	0.4	2,371
Abengoa	14	8.4	0.6	1,526
Electricite de France (EDF)	38	7.0	0.2	1,612
SunEdison Inc (MEMC Electronic Materials)	35	6.4	0.2	1,786
OPDE	35	5.8	0.2	1,718
Hanwha	30	5.2	0.2	1,006
Scatec AS	34	5.2	0.2	1,374

Source: fDi Markets

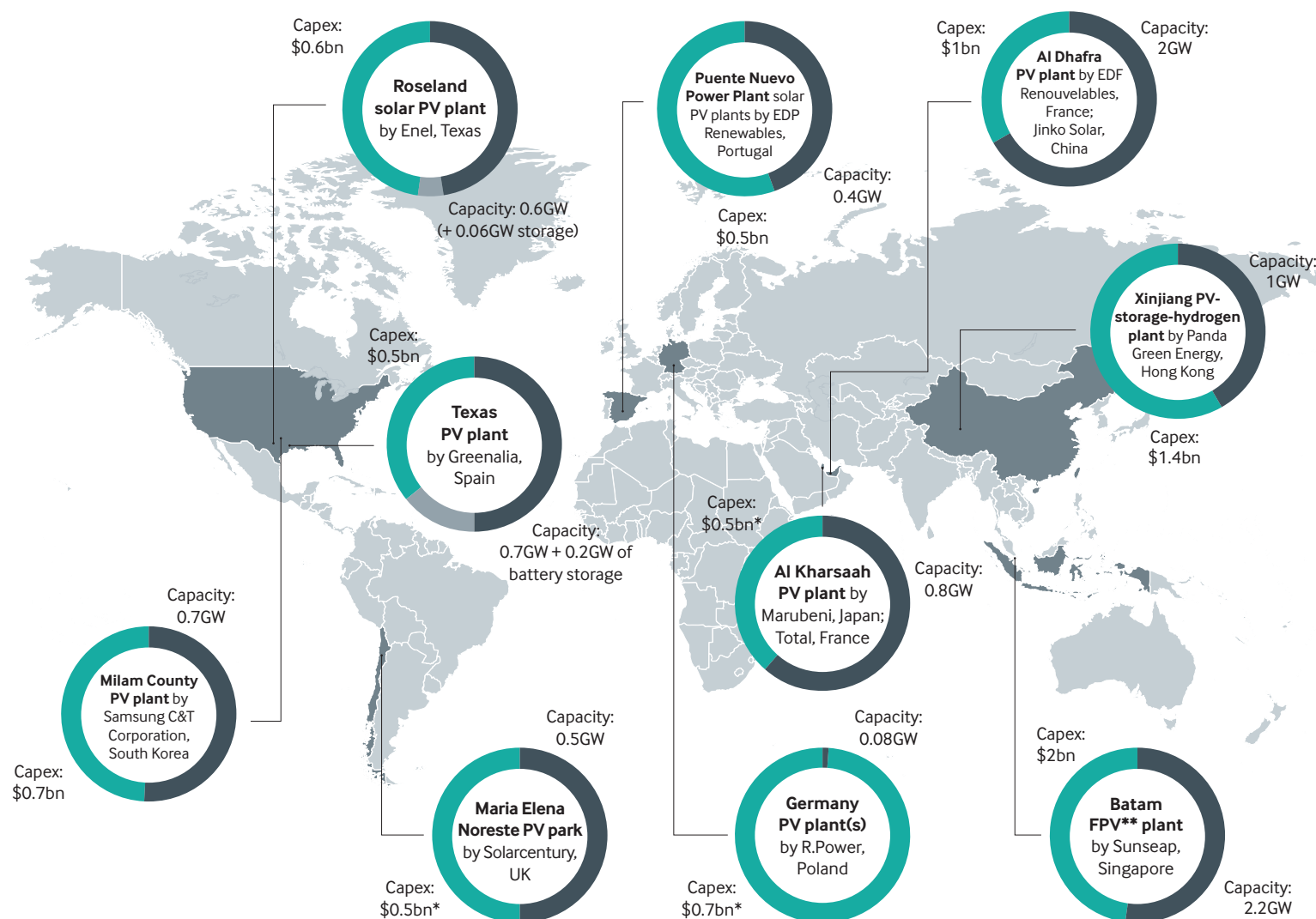
“Western European and North American majors have dominated the ranking of top solar investors”

to build photovoltaic power stations in Inner Mongolia, Gansu province and Ningxia province. The company had set up all of its manufacturing operations in China. During the years, its FDI solar portfolio expanded, encompassing countries such as Japan, Australia, UK, US, Brazil, Italy, among others.

In the years 2020-2021, Enel was joined by EDF (Electricite de France) in its market leadership. The French company announced solar FDI projects worth \$3.04bn in the period, versus Enel's \$34bn. One standout project is EDF's involvement in a JV with China's Jinko Solar to build the 2GW Al Dhafra solar project.

Western investors still feature highly on the list in the pandemic years, with North American and European companies numbering 7 out of the top 10. Yet, Middle Eastern and Asian investors

Top 10 solar FDI projects by capex 2020-2022



Source: fDi Markets

Note: *Estimate, **Floating photovoltaic

have joined the group becoming a prominent part of foreign solar investment in 2020-2021, in line with the emerging trend of a more diversified source of investors.

In this context of greater geographic diversification, Masdar – the renewables subsidiary of the UAE's sovereign wealth fund Mubadala – has become a notable solar investor, ranking as the fourth biggest solar investor over the course of 2020-2021.

The first international projects by Masdar were deployed in the framework of its joint venture with Spanish company Cespa in January 2020 to develop solar projects in Spain and Portugal. In 2021, fDi tracked projects in Armenia, Iraq and Uzbekistan, worth an estimated total of \$1.5bn.

Energy and solar subsidiaries of South Korean conglomerate Hanwha - basically absent from the solar international market before 2020 - have also been active in the last few years. It ranks 6th among the top solar investors across 2020-2021 and in terms of project numbers across this period, Hanwha comes second only to Enel. In 2021, its subsidiary 174 Power Global announced a \$0.2bn investment to develop a 0.2GW solar power plant in Pueblo County, Colorado, US. Like Masdar, fDi had tracked no solar projects by Hanwha before 2020.

Chapter 3

Wind power



European firms breathe life into global wind market

Wind energy takes credit for first proving the concept of large-scale renewable energy developments. With the debate around energy security and climate change mounting in the early 2000s, wind power emerged as a viable, although perfectable, alternative for countries and power utilities to diversify and clean their generation matrix.

Global installed wind energy hit the 100GW mark already in 2008 – four years before solar did. It created hundreds of thousands of jobs along the way as the sheer scale of wind turbines, whose transport requires costly logistics solutions, has traditionally strengthened the argument for shorter, if not domestic, supply chains.

FDI flows into wind energy lay bare the forces that emerged in those early days and would consolidate in the following years to take the whole industry to the next level. Namely: the leadership of European power utilities and wind turbine suppliers; the rise of China, the US and Europe as the biggest wind energy geographies, with emerging markets of the likes of India, Brazil and Mexico also achieving major progress; the role of the UK as the destination of choice of FDI into large-scale offshore wind projects.

European countries like Germany and Spain started experimenting with utility-scale wind energy development in the 1990s. Denmark did it even earlier, as the first policy input to develop wind energy traces back to the oil crisis of 1973 and the Danish government's commitment to loosen the country's dependence on fossil fuels. Those early developments gave local

Top investing region 2005-2020
Western Europe

Top three investing countries
Spain, Germany, France

Top wind destination region
Western Europe

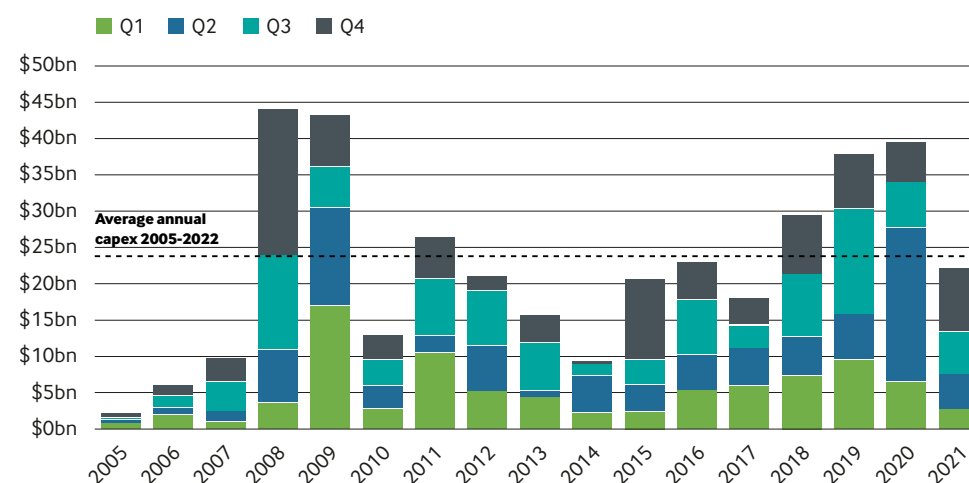
Top three destination countries
UK, US, Germany

wind developers and power utilities a major competitive edge as soon as climate change entered the public debate in the early 2000s and demand for wind power went global as countries started committing to renewable energy targets. European power utilities thus became the dominant foreign investors in the market, accounting for 77% of global FDI into wind energy between 2005 and 2020.

The UK emerged as their destination of choice early on. European investors poured as much as \$64.9bn of FDI into wind energy projects across the Channel between 2005 and 2020. No other country has received as much wind FDI in the period. In spite of its

The ups and downs of wind FDI

Announced foreign direct investment in wind energy projects by year and quarter



Source: FDI Markets

notoriously windy weather, back in the early 2000s the country appeared slower than other European peers in making the most of its wind resources because of a mixture of opposition to development at a local level and lack of clear government policy. Things changed in 2008 when the Crown Estate, the government’s agency in charge of managing the sea bed and the coastal waters, announced that land for 25GW of offshore development could be available in UK coastal areas while the government announced ambitious wind energy generation targets in its Renewable Energy Strategy published in the same year. A first wave of capital-intensive offshore projects of the likes of the 630MW London Array wind farm or the 576MW Gwynt y Môr wind farm mounted right away. Today, the UK is the world’s leader in offshore wind power with 10.2GW of installed capacity at the end of 2020, followed by China (10GW) and Germany (7.7GW), according to figures by the Global Wind Energy Council (GWEC).

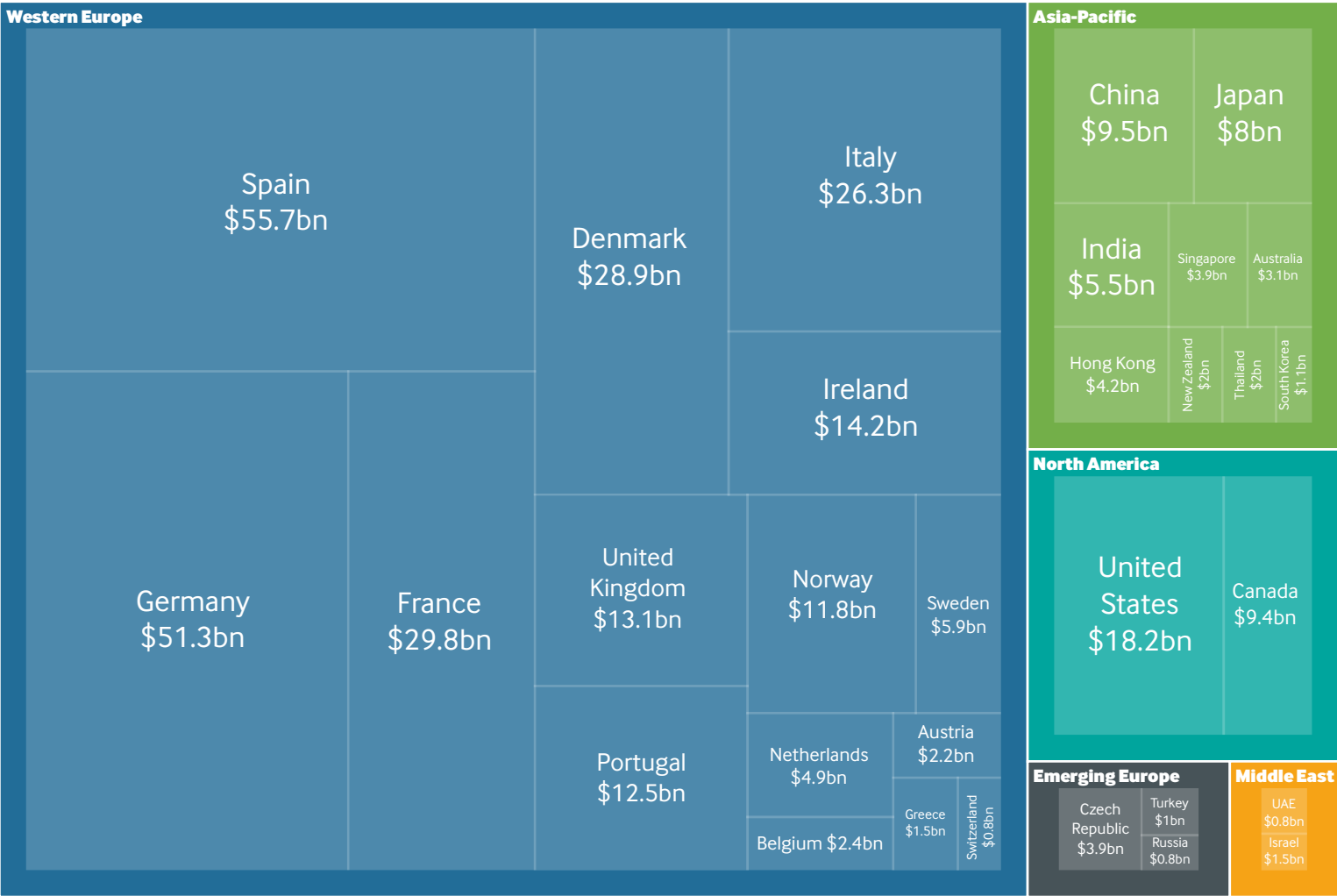
European investors also started looking across the Atlantic seeking for opportunities

Share (%) of global wind FDI originated by European utilities (2005-2020)

77%

Source: fDi Markets

European firms dominate global wind investment
Announced FDI by source region and country of investing company (2005-2020)



Source: fDi Markets

outside the region. The largest consumer of electricity in the world, the US, has emerged as one of the biggest onshore wind markets since the mid-2000s, also thanks to a largely successful federal incentive – the production tax credit, a 10-year inflation adjusted federal income tax credit for each kilowatt hour of wind electricity generated – that has provided domestic and foreign investors with a the long-term stability to pull the trigger on their wind farms projects. Among others, Portuguese EDP announced in late 2009 it would invest \$4bn in wind farms in the US. Fast forward to present time, the company operates 58 wind farms across the US, Canada and Mexico.

Major offshore and onshore projects in the UK and the US contributed to the first spike of FDI into wind energy in 2008 and 2009, when foreign investors committed \$47.1bn and \$46.1bn, respectively, to wind energy developments globally.

However, wind FDI scaled down in the wake of the global financial crisis, and took years to fully recover. The financial crisis forced investors to reset and look for returns beyond shrinking public budgets and incentives. As a result, the industry's FDI horizon started expanding to embrace new geographies offering high, unexplored potential and improving regulatory frameworks.

European investors announced wind projects worth \$8.7bn and \$7.5bn in Mexico and Chile, respectively, their biggest investment destinations outside Europe and the US in the decade of the 2010s. In the same period, they also committed another \$7bn in Brazil, \$5.6bn

“Global FDI in the production of wind turbines is equally concentrated in the hands of a few European producers”

in Australia and \$4.1bn in South Africa.

Wind energy FDI as a whole finally jumped back to pre-financial crisis levels when new wave of offshore wind projects, originating in regulatory changes, as well as the rise of ESG finance and deep-pocketed investors looking for the kind of scale and yields that offshore projects can guarantee, started mounting towards the end of the 2010s. Always driven by yield thirsty investors, developers also started flirting with floating offshore wind farms, which reduce costs and thus boost the overall profitability of wind projects – in 2017 Norwegian Equinor opened the first full-scale floating offshore wind farm in Hywind Scotland. Power-to-x projects, where wind and solar power is used to create green hydrogen through electrolysis, added to the mix too.

Eventually, in 2019, right before the pandemic, FDI into wind energy projects breached the threshold of \$40bn for the first time since 2008.

Global FDI in the production of wind turbines is equally concentrated in the hands of a few producers whose origin once again traces back to the early progress of wind energy pioneers in Europe.

Only four European companies – Danish Vestas and LM Wind Power (acquired by GE in 2017), German Siemens and Spanish Gamesa (which merged with Siemens Wind in 2016) – made up about half the \$17.4bn in FDI projects in the production of wind turbines announced worldwide between 2005 and 2020.

They all chased booming demand for wind energy developments in a handful of

geographies – first and foremost, the US and China, where they concentrated, respectively, 35.5% and 16.7% of their investment commitment between 2005 and 2020.

If the US has achieved tremendous progress in wind energy developments since the mid-2000s, China has experienced an even steeper development curve. Beijing's commitment to diversify away from coal prompted wind power installed capacity to double every year between 2005 and 2010 and post double-digit growth in the following decade. The enormous Chinese market became a magnet for European suppliers, as well as local wind turbine producers like Goldwind or Envision, while power generation itself remains largely off-limits for foreign investors.

Today, China is by far the largest single producer of wind energy in the world (278.3GW at the end of 2021), followed by the US (122.3GW). The EU plus the UK combine for 215.5GW.

Irena estimates that in order to under the 1.5°C scenario, installed capacity of onshore wind will have to reach 3,000GW, four times that of 2020, and offshore wind will have to scale up to 380GW, 11 times more than in 2020.

Offshore wind unleashed, onshore holds strong

The case for renewable energy grew even stronger during the pandemic years (2020 and 2021) as major economies committed to net-zero targets and electric mobility. FDI into wind energy spread across geographies beyond Europe and nearly matched the peak recorded in 2008, totalling \$42.2bn, up 5% on the previous year, only to fall back to \$23.6bn in 2021.

Offshore wind developments carried the strong investment momentum of the late 2010s into the pandemic and shored up overall FDI flows in the 2020-2021 period as onshore wind continued to attract big-ticket investment projects.

The UK cemented its leadership in offshore wind in line with long-term trends and fresh government policy. In 2020, the government announced a target of 40GW of installed offshore wind capacity by 2030, from 10.21GW at the end of 2020, and is expected to raise it further to 50GW. Foreign investors, mostly from Europe, answered the call. Among others, led by Norwegian Equinor and British SSE, they announced the £9bn (\$11bn) Dogger Bank wind farm, the largest FDI wind project ever recorded, in 2020. Overall, the UK received \$23.9bn in FDI in its wind sector in 2020 and 2021, far more than any other country.

While the UK raised the stakes of its burgeoning offshore wind industry, other major European markets have also managed to stir the interest of foreign investors. In 2022, president Emmanuel Macron targeted 40GW of offshore wind operating in French waters by 2050, as its first offshore wind farm – the 500MW Fécamp

Expected investment into Dogger Bank offshore wind farm

£9bn

Source: Dogger Bank

offshore wind farm off the coast of Normandy, a joint venture between Canada-based Enbridge Energy in association with Germany-based WPD and France-based EDF – is set to come online this year off the coast of Saint-Nazaire.

Italy also managed to rack up \$1.2bn in wind energy FDI over 2020-21 largely thanks to the country's first offshore wind park. Danish Copenhagen Offshore Partners (COP) and Copenhagen Investment Partners (CIP) invested €741m (\$834m) into a 250MW floating wind installation off the coast of Marsala, Italy. Final authorisation for the project is still pending.

US opens up to offshore wind

But the development that is expected to have the biggest impact on the global wind industry is the US administration finally paving the way for the development of its offshore wind resources.

In early 2021, US president Joe Biden issued a green signal to the industry with a strategy to increase deployment of offshore wind capacity to 30GW by 2030, as foreign investment announcements mounted throughout the year.

Announced wind FDI into the country nearly doubled in 2021 from the previous year to \$4.7bn, nearly three quarters of which went into offshore wind.

Despite the strong potential for offshore on both coastlines, the US had merely installed 35.3MW of capacity as of 2020. For decades, the sector had been stymied by regulatory minefields involving multiple federal and state agencies. Today, with a slew of projects supported by auctions underway, and the first offshore utility-scale offshore project being built off the coast of Massachusetts – the 800MW Vineyard offshore wind farm – the US is set to join the likes of the UK and China as one of the largest offshore markets by 2024, the IEA expects.

While big funds like CIP and Equinor are showing an appetite for capital-intensive offshore projects with a pronounced risk-reward profile, traditional power utilities continue to chase opportunities onshore. Several big ticket projects came through in the 2020-2021 period. Among others, Spanish Acciona announced a 1.03GW onshore wind power complex in Queensland. Chinese PowerChina an 800MW onshore wind farm in Ukraine. Overall, Italian Enel was the most active onshore wind investor in the period as it announced wind parks across the Americas in the US, Brazil, Colombia and Chile.

Enel confirms the global leadership of European investors as the major forces behind FDI into wind energy in the 2020-2021 period, when their total share of wind investments hovered between 83-5%. Their investments spanned Europe, the Americas, but also Africa and the Asia-Pacific region.

Beyond offshore wind and a more global reach, there was an added push to localise wind supply chains, as governments' offshore wind ambitions now coincide with a commitment to local jobs and manufacturing.

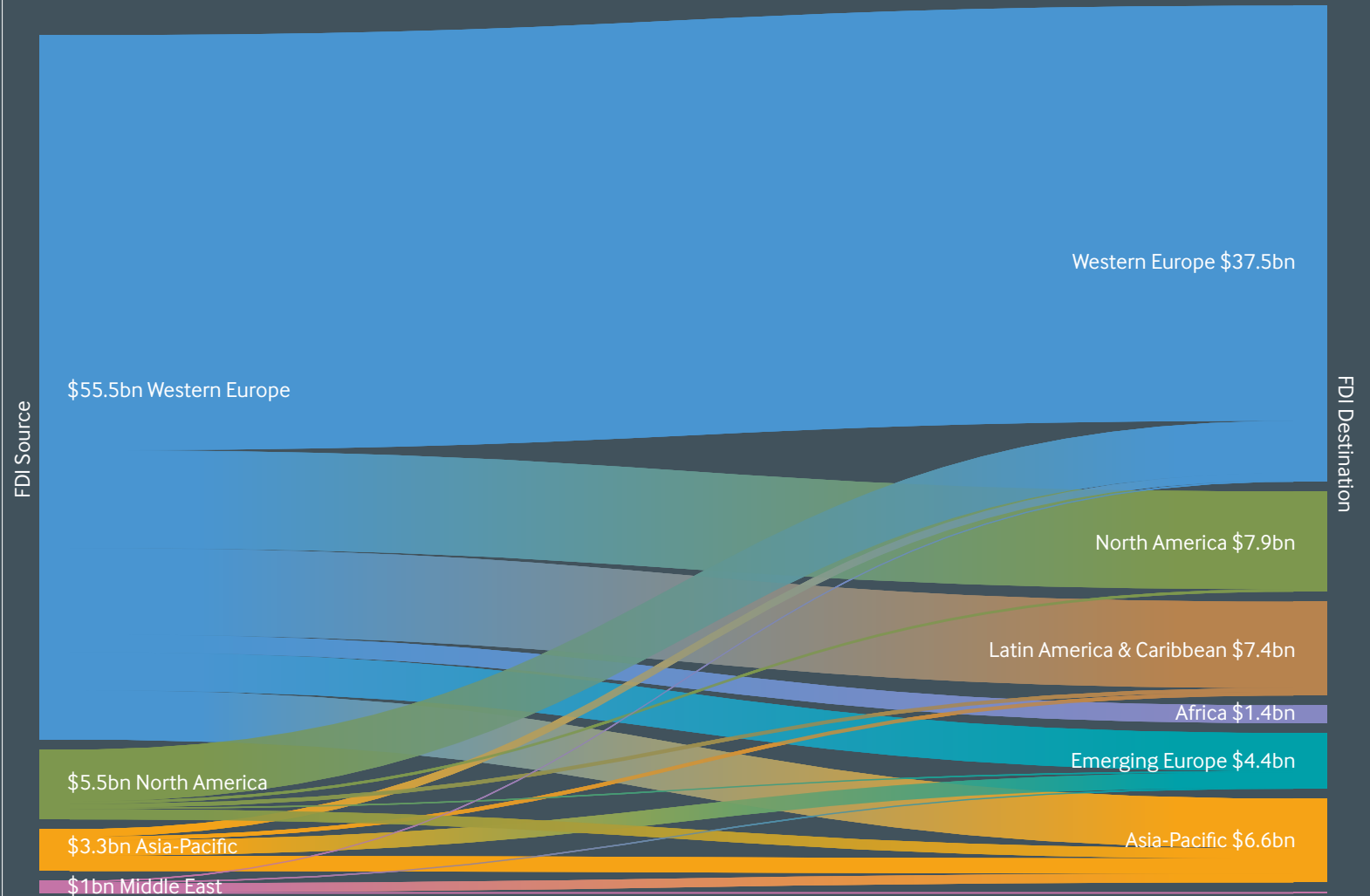
In 2019, the UK government committed to increase UK content to 60% by 2030 and invest up to £250m in the UK supply chain. According to RenewableUK, 2021 was a record year with major investment announcements in offshore wind manufacturing totalling over £900m in new factories.

In its 2021 annual review on renewable energy and jobs, Irena remarks that "the integration of local content and local employment remains a challenge, particularly in wind energy, and requires further efforts in contracting arrangements, technical development and cooperation, and local capacity development".

As the US looks towards its offshore wind future, it is wasting no time to address these problems early. In 2022, New York state invested \$500m into ports, manufacturing and the supply chain infrastructure needed to strengthen its offshore wind industry. The US government predicts that offshore wind will create 44,000 direct and almost 33,000 indirect jobs. Siemens Gamesa has also built the world's first turbine and blade manufacturing facility in Le Havre to supply the 500MW Fécamp offshore wind farm, among other nascent projects.

Patterns of wind investment during the pandemic years

Origin (left) and destination (right) of foreign direct investment in 2020-2022



Source: fDi Markets

Wind power potential

In a similar vein to solar, countries that have come to be pioneers of wind are those that have made themselves favourable to the market through feed-in-tariffs (FiTs) or contracts for difference (CFDs).

Save for Australia and Brazil, wind destinations that are punching above their wind potential are located in Europe and North America, while countries with even higher potential, such as Chile and Argentina, have recorded comparatively lower wind FDI in 2020 and 2021.

As well as having secured the crown for having the best solar potential, Chile is ranked as having the best wind potential globally. The country received \$1.7bn in foreign wind investments in the 2020-2021 period.

The analysis of wind FDI in 2020-2021 against wind potential by country illustrates to what extent different geographies are fulfilling the potential of their wind resources and translating it into investment opportunities. The wind potential for each country has been assessed by the department of wind energy at the Technical University of Denmark (DTU Wind Energy) and the World Bank. For the purpose of this analysis, the mean wind speed at 100 metres above the ground of the 10% windiest areas for all the countries that recorded any wind FDI signal in the 2020-2021 period has been considered. Wind potential data refers to land areas only, although it can give a loose indication of offshore wind potential too. FDI data includes both onshore and offshore wind projects.

If only eight countries have done better in the whole world, its wind potential suggests the country has room to accommodate even

Wind FDI in the UK between 2020-2022

\$23.9bn

Source: fDi Markets

higher levels of investment. Domestic and foreign investors alike are already equipping to further exploit this potential. Local power utility Colbun, for example, announced in September 2021 plans to develop the Horizonte onshore wind farm, which is expected to become Latin America's biggest development of its kind with an installed capacity of 778MW and budgeted investment of \$850m. Italian Enel expects to break ground on two onshore wind farms totalling 226MW of installed capacity plus an additional 60MW in batteries in 2022.

Neighbouring Argentina, which also boasts world-class wind resources, has yet to fulfil its wind potential because of a challenging market environment and its pipeline of projects remains in limbo amid uncertainty. Foreign investors announced only \$134m of wind projects in the country in the 2020-2021 period.

Denmark, Norway, and Ireland also feature among the countries that seem to be underperforming the market – attracting less FDI than their wind potential would suggest. However, the three countries already feature among the world's biggest wind energy producers when looking at per capita data and have limited room to accommodate major FDI into the sector, also considering the major role that local players of the likes of Danish Orsted or Norwegian Equinor play in the domestic market.

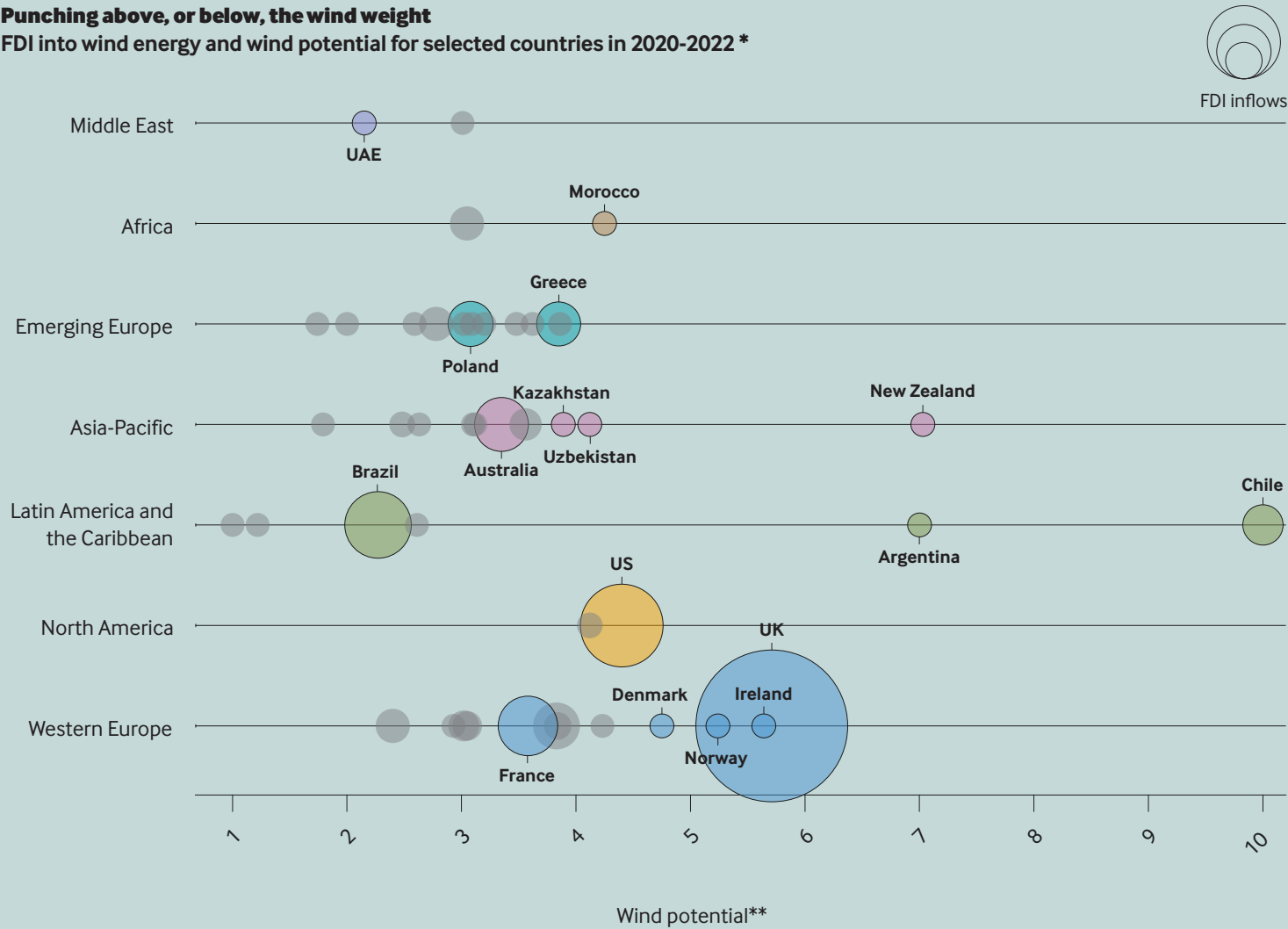
That room is definitely bigger for emerging markets of the likes of Uzbekistan, Morocco, Kazakhstan, which all have remarkable wind resources, all need to clean up their energy matrix and all have seen some early wind energy projects being announced in the past couple of

years. Although investment inflows remain below the market trend for that level of wind resources, the recent wind energy projects announced in these countries point in the direction of an improving regulatory and business framework, also thanks for support of multilateral institutions like the European Bank for Reconstruction and Development, which has supported wind projects in each one of these countries.

The usual suspects lie at the other edge of the spectrum. The UK and the US have relatively high wind energy resources, and are certainly making the most of them, with the former racking up an unmatched \$23.9bn in wind FDI in the 2020-2021 period, and the latter chasing at distance with \$7.1bn.

Wind is coming of age in other emerging European wind markets that have been able to attract strong FDI inflows in 2020-2021 despite average wind resources. Greece and Poland have both attracted more than \$2bn of wind FDI each thanks for favourable policy frameworks, particularly in the latter, where the government has reduced barriers to both onshore and offshore wind developments.

Punching above, or below, the wind weight
FDI into wind energy and wind potential for selected countries in 2020-2022 *



Source: Source: fDi Markets, Technical University of Denmark (DTU Wind Energy) and the World Bank • *Only countries that registered any FDI activity in 2020-2022 were considered
**The higher the bigger

Top investing companies

European majors, like Iberdrola, Enel and RWE, have been the biggest wind investors over the period 2005 to 2022. Over the past two years, Norwegian Equinor and French Total have entered the fray, both thanks to multi-billion dollar investments in offshore wind in the UK.

Iberdrola remains the biggest wind investor over the past 17 years, having tracked \$31.6bn worth of investments. The company has been early to move into key offshore wind sectors, like the UK's in the late 2000s and the US's in 2021. In 2008, the Spanish energy giant entered a joint venture (JV) with Danish energy company Orsted (then Dong Energy), worth \$2.6bn, to build a 389MW offshore wind farm in Cumbria, UK. In 2021, it announced its JV with Danish CIP to invest into the emblematic 800MW Vineyard farm off the coast of Massachusetts. Within that, its portfolio has tracked the widening of scope among investors, to include other non-European destinations such as Mexico, Brazil and, recently, Vietnam.

The second biggest investor, Italy's Enel, with \$22.9bn worth of wind investments, showed a preference for Europe initially before betting heavily on Latin America, in line with its solar portfolio.

Of the \$3.9bn the Italian company invested in wind over 2020 and 2021, over half poured into Brazil, Chile and Colombia. Among others, it pledged over \$1bn into the Lagoa do Ventos project in Brazil, spanning three onshore wind farms, in the north-eastern state of Piaui, the Italian company's biggest onshore wind project worldwide. It also invested in one wind farm in

Top 10 foreign investors in wind energy 2005-2022

Parent company	Projects	Capex (USDbn)	Avg capex (USDbn)	Jobs created
Iberdrola	101	31.6	0.3	8,581
Enel	119	22.9	0.2	5,876
RWE	60	18.1	0.3	3,986
Equinor (Statoil)	16	17.2	1.1	2,816
Orsted (Dong Energy)	50	17.1	0.3	3,622
Energias de Portugal (EDP)	56	14.2	0.3	4,014
Electricite de France (EDF)	62	14.1	0.2	3,042
Mainstream Renewable Power	37	11.0	0.3	2,979
Acciona	40	9.9	0.2	2,348
E.On	33	9.2	0.3	1,728

Source: fDi Markets

Lagoa do Ventos onshore wind farm expected investment

\$1bn

Source: Enel

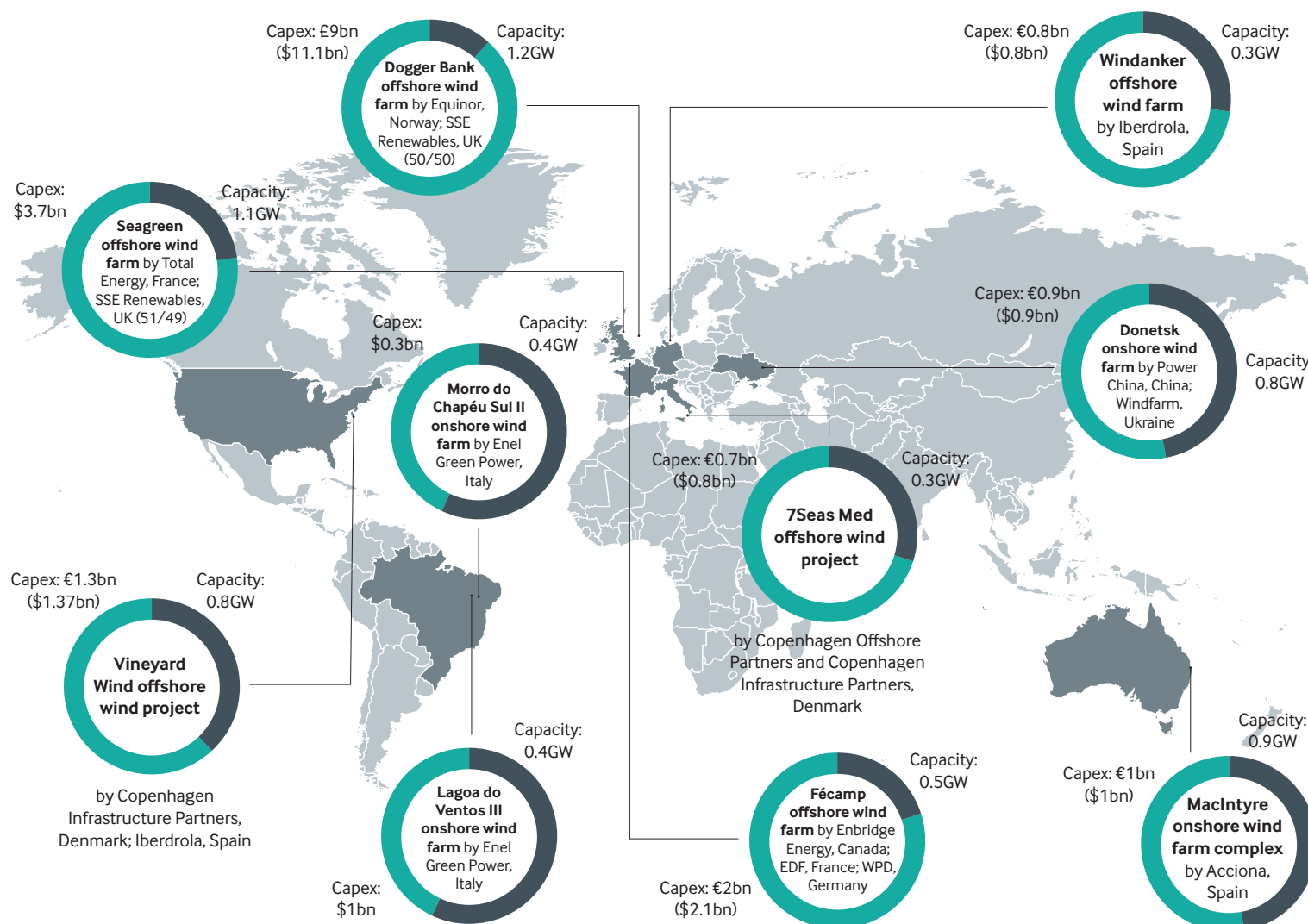
the north coastal region of La Guajira in Colombia (plus another two to be developed).

Other top investors, such as German RWE, have stuck with their preference for the UK for offshore wind and the US for onshore wind. Notably, it has thrown its weight behind big projects in the UK, such as the 750MW Gwynt y Môr Offshore Wind Farm in Wales in 2008 and the 1.4GW Sofia project on Dogger Bank in 2019, as well as wind farms like the 240MW Blackjack Creek facility in Texas in 2021.

Equinor and Total more recently emerged as big wind investors owing to fresh large-scale commitments in the UK in 2020. Equinor is teaming up with UK-based SSE to build the Dogger Bank offshore wind farm, which is considered the biggest of its kind to date.

French oil and gas giant Total also announced

Top 10 wind FDI projects by capex 2020-2022



Source: fDi Markets
Note: *Estimate

plans in 2020 to develop the 1140MW Seagreen wind farm in the Firth of Forth off the coast of Scotland, also in a joint venture with SSE.

Of the top 10 wind foreign investors between 2005 and 2022, all are European, ranging from energy giants like Iberdrola and Equinor to renewable power developers like Irish Mainstream Renewable Power. Of the top 20 investors, only three are not European: China's Sany; India's Suzlon Energy; and Canada's Northland Power.

All three have set their sights on non-European wind markets. In 2016, Suzlon Energy announced plans to invest roughly \$3bn to collaborate with local partners to develop wind farms in Australia. It accounts for a 17% share of the Australian wind energy market as of 2021. In 2017, Sany invested \$1.5bn to build wind power facilities in the state of Punjab in Pakistan. Northland Power has announced plans to build and operate three wind farms off the coast of Changhua County in Taiwan.

Chapter 4

Battery power



The rise of the battery supply chain

Batteries stand at the heart of the energy transition. The competitiveness of cleaner technologies for electricity generation and transportation, which together account for two thirds of global greenhouse gas emissions, hinges on their growing levels of energy density and falling costs.

They provide the energy that electric vehicles (EVs) need to become a viable alternative to internal combustion engines; they also store the back-up energy that smart grids need to accommodate the fluctuating generation of solar and wind energy.

If the manufacturing of batteries as an industry has moved its first steps in the 2010s – there

Top investing region
Asia-Pacific

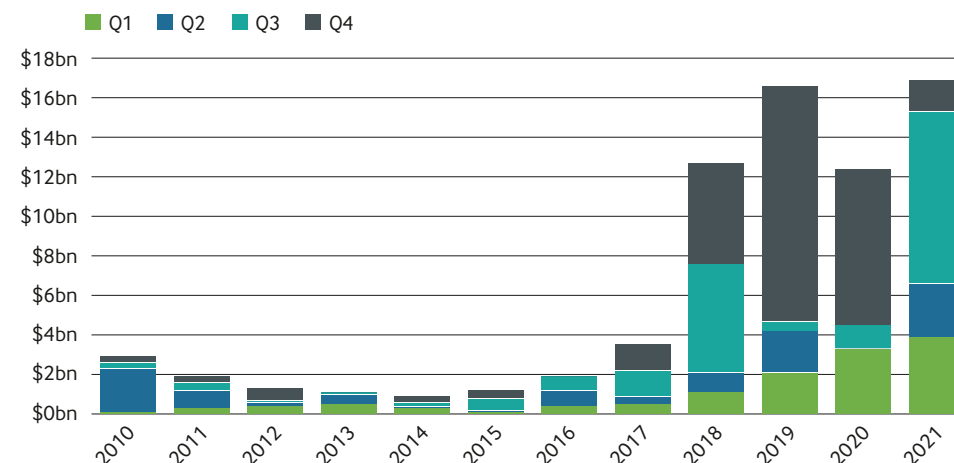
Top three investing countries
South Korea, US, China

Top destination region
Asia-Pacific

Top three destination countries
US, China, Germany

EV battery investment booms with the rise of e-mobility

Announced foreign direct investment in the manufacturing of EV batteries by year and quarter*



Source: *Includes US interstate investment, fDi Markets

was barely any capacity in the system in 2010 – Bloomberg estimates that the cumulative lithium-ion battery demand for EV and energy storage applications is set to skyrocket to 9,300GWh in 2030, from 526GWh in 2020.

Dominant Asian producers as well as challenger producers from Europe and the US are triggering multi-billion dollar investment campaigns in major economies to cater to this growing demand, particularly in EVs, turning the battery industry into one of the biggest and fastest-growing forces of global FDI.

While original equipment manufacturers (OEMs) were already upgrading their vehicle offerings to adjust to regulations introducing gradually more stringent fleetwide CO2 emission targets, the Covid-19 pandemic dramatically accelerated the industry's shift to e-mobility. Governments across the globe introduced net-zero targets and put the energy transition at the heart of post-pandemic recovery plans.

With clearer policy inputs, OEMs have finally embraced the paradigm shift, allocating billions of dollars to electrify their offer and industrial base after years of mixed feelings. The demand for electric vehicle (EV) batteries has grown accordingly and the whole EV value chain now faces a buoyant outlook.

However, while the production of vehicles per se is ubiquitous, the manufacturing of EV batteries is heavily concentrated in the hands of a few companies. More than 85% is currently controlled by of Asian producers from China, South Korean and Japan. That's a key feature in an industry where batteries account for about 40% of the final value of an electric vehicle. In other

words, controlling the battery value chain equals controlling the market.

Policy-makers and OEMs alike are well aware of it. The former, particularly in the West, see in the almost absolute dependence on Asian producers, whose manufacturing base is largely located in China, a major element of weakness in e-mobility value chains, a socio-economic drawback in terms of occupational perspectives, if not even a source of geopolitical tensions. The latter face the risk of plummeting profits margins as they exert little if any leverage over the value chain of the single costlier component of EVs.

The development of regional, if not local value chains for EV batteries has thus become one of the mantras of e-mobility strategies in major automotive markets, prompting Asian producers to gain a footprint in major automotive markets closer to final customers, while a new generation of battery producers from Europe and North America is trying to catch up.

The first gigafactory investment ever recorded – and from where the term derives – was US-based Tesla and Japan-based Panasonic's \$5bn joint venture in Nevada, US in 2013. On one half of the industrial site, Panasonic produced lithium-ion battery cells, while the other half was dedicated to Tesla's module and pack assembly.

Despite a few early gigafactories, the acceleration of investment did not start until the latter half of the 2010s. In 2015, battery producers announced FDI projects into the manufacturing of EV batteries for \$1.1bn. Six years later, they announced FDI projects for a record \$17.1bn (figures include US interstate investment).

FDI pledges into the manufacturing of batteries in 2021

\$17.1bn

Source: fDi Markets

Asian producers have been the major force behind this spike in investment. They made up 57% of the total FDI that flowed into the manufacturing of EV batteries between 2015 and 2022 as they chased opportunities in some of the biggest and fastest growing EV markets in the world.

South Korean powerhouses LG and SK announced projects worth \$5.1bn in China between 2015 and 2022. China is by far the single largest EV market in the world, and also boasts the most advanced and comprehensive EV batteries ecosystem – in fact, China largely dominates the whole value EV battery value chain, from the processing of battery grade metals such as lithium and cobalt, to the battery components themselves, namely cathodes, anodes and partially separators too.

In the US, South Korean producers chose to locate close to OEMs clients typically located in the rustbelt (Ohio and Michigan) or in automotive clusters in the South (Georgia in particular). They also closed joint venture deals with the likes

of Ford and GM for the production of the EV batteries both companies need to realise their fresh e-mobility commitments.

In Europe, they set up shop in Poland and Hungary, turning them into the region's main hubs for EV battery development. Meanwhile, Chinese CATL, the world's leader in EV battery production, made multi-billion commitments in Germany, as well as Indonesia.

Playing catch-up

Facing a monumental gap, European producers have been playing catch-up. In recognition of its paltry cell production capabilities, the European Commission launched the European Battery Alliance (EBA) in 2017, bringing together EU governments, industry and the scientific community, in a bid to build up battery technology and production capacity in the EU.

Some first European EV battery producers have made inroads since then. Most notably, Swedish Northvolt has become the hope of European battery ambitions as the company tries to compete with Asian market leaders by exploring innovative battery technologies and a vertically integrated approach to production. The company has one gigafactory up and running in Sweden, and three others in the pipeline – two in Germany and another one in Sweden. The likes of Volkswagen and Volvo have already secured part of the company's future production through multi-billion dollar deals. French Saft, a subsidiary of TotalEnergies, has also made major progress, particularly in the form of ACC, a joint venture between the company and automakers Stellantis and Mercedes-Benz, which is also leveraging on

IPCEI (Important Project of Common of European Interest) on Batteries, a framework aiming to create a complete supply chain in Europe for batteries, which is providing about €6bn of state aid from the member states participating (mainly Germany, France and Italy). Overall, there are 25 battery gigafactories under planning or construction in Europe, according to data by Vitoria-based research centre CIC Energigune.

While there are dozens of projects in the pipeline in both the US and Europe, China will continue to dominate the production of EV batteries in the foreseeable future. The country already counts 125 battery gigafactories and is on track to have 3,733GWh of lithium-ion battery cell capacity by 2031, more than double the total capacity expected in the rest of the world combined, according to data provider Benchmark Mineral Intelligence (BMI).

If e-mobility has been the main catalyst for fast rising investment in gigafactories across the world, renewables further strengthened their business case by creating additional, rapidly growing demand. One of the main drawbacks of the likes of solar and wind power has been the fluctuating nature of their generation curve, which strains electricity networks and can be out-of-sync with demand. The development of energy storage systems – along with smart grids – have been a way to address these shortcomings, and a growing number of wind and solar projects have a battery storage component.

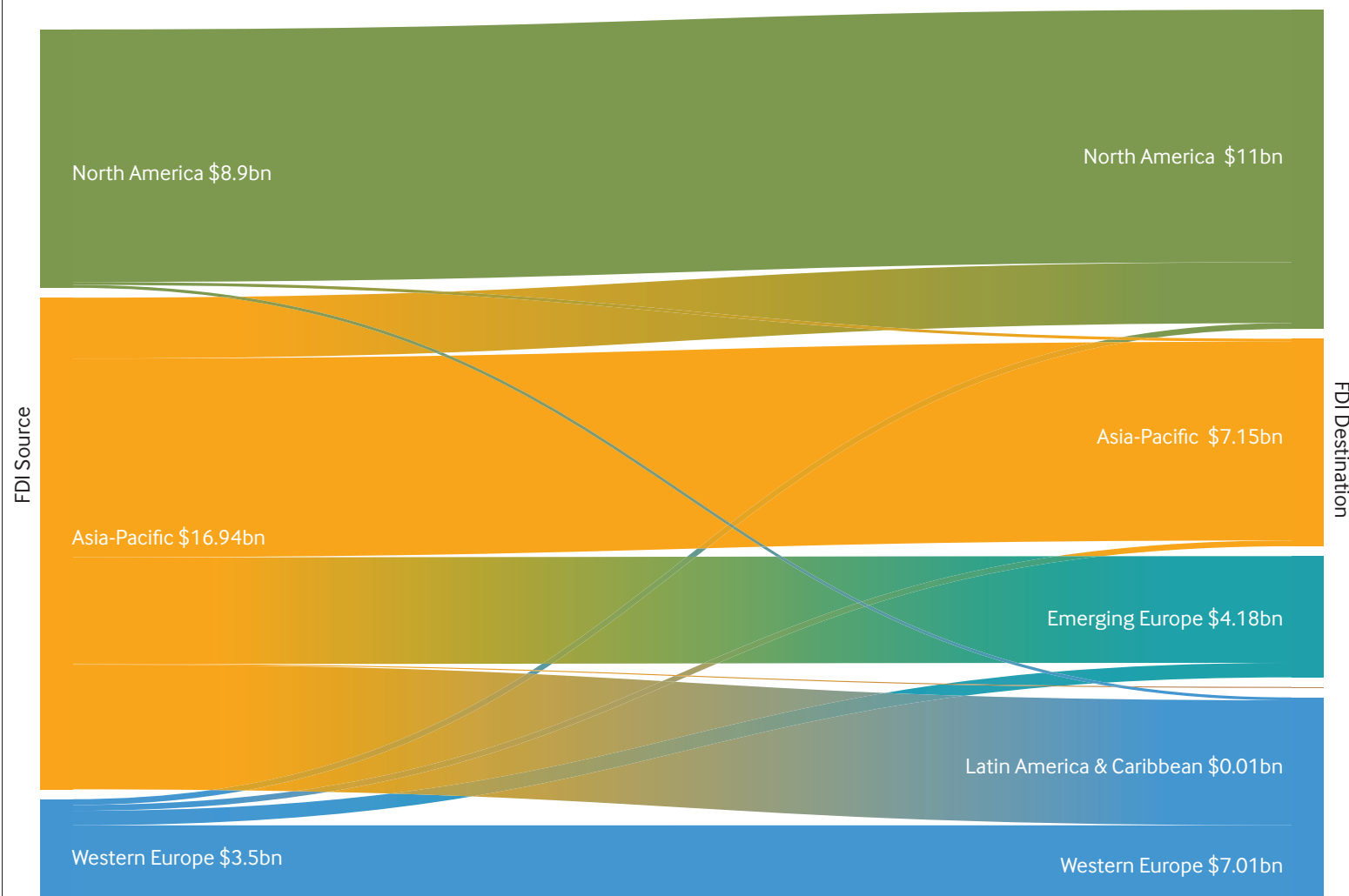
FDI projects in renewable energy with a battery energy storage system component have been rapidly soaring in the past four years. In 2021 alone, foreign investors announced 31

such projects worth a total of \$5.6bn, the highest annual level recorded so far. European power utilities of the likes of Enel and EDF, as well as new players in the renewable energy space like Total Energy, again make up for the lion's share of these projects. Overall, Western European companies originated 60.5% of the FDI investment into pure BESS projects, or renewable energy projects with a BESS component, announced between 2015 and 2022, followed at distance by Asian (21%) and north American (12.4%) firms.

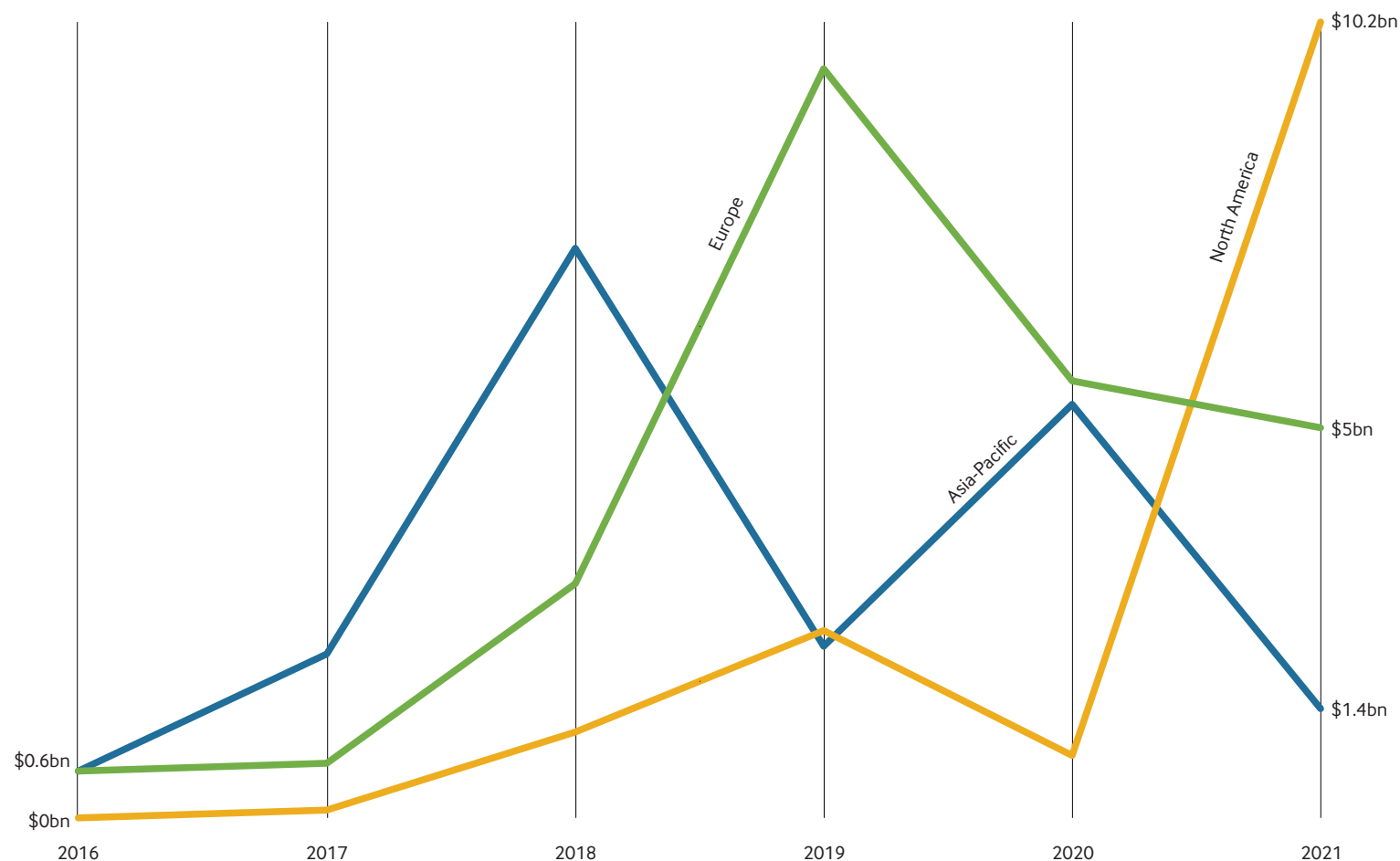
In terms of destinations, investors are expressing a clear preference for developing renewable energy projects with a BESS element in Australia and the US, which together attracted more than half the FDI into such projects between 2015 and 2022. Australia added 600GWh of BESS generation capacity in 2021, thus pushing overall generation capacity beyond 1GWh – utility-scale, front-of-the-metre project made up 75% of it, according to figures from market intelligence specialist SunWiz, which also added that about 8% of all the new PV systems installed in the country in 2021 had a battery component. The country has become a poster child for the potential of BESSs, with its largest power utilities now planning to replace coal power plants with utility-scale BESS, including Origin's plans to develop a 700MW BESS at the site of the 2.9GW Eraring plant, the biggest coal power plant in the country that is to be decommissioned in 2025. Overall, the country has seen the pipelines of announced BESS projects soar to 26GW at the end of 2021, according to research by Cornwall Insight Australia (CIA).

Patterns of EV battery investment*

Origin (left) and destination (right) of foreign direct investment in 2020-2022



Source: fDi Markets *Includes US interstate investment

US and Europe try to close the battery gap**Annual foreign direct investment into the production of batteries by region**

Source: fDi Markets

In the US, utility-scale BESS generation capacity quadrupled to 10.8 GWh in 2021, according to the latest annual figures from the trade body American Clean Power Association (ACP). California led the country in new utility-scale installations, with power company Vistra bringing online 400MW / 1,600MWh at the Moss Landing Storage Facility, which occupies the site of a former gas-fired power plant.

Beyond Australia and the US, FDI projects with BESS applications were recorded across major renewable energy markets of the likes of Germany, Spain, Chile, South Africa and the UK.

The energy storage market is now expected to grow ninefold through 2031, according to estimates by consultancy Wood Mackenzie, with China and the US leading the way in terms of grid-scale deployments. The company defines energy storage as predominantly (95%) lithium-ion batteries, while 5% covers alternative technologies.

It anticipates the regional volumes of installed capacity in energy storage by 2031 to be as follows: 160GW in the US; 10GW in the rest of Americas; 63GW in Europe; 7GW in the Middle East and Africa; 162GW in China; and 70GW in Asia Pacific excluding China.

Major producers are already refining their offer to meet this growing demand from the energy market. Among others, Northvolt has set aside \$200m to establish a dedicated battery energy storage solutions production site in Poland. In 2022, US-based Powin signed a memorandum of understanding with Indian renewable energy company O2 Power to provide battery storage to the Indian market.

The top battery supply chain companies

Top 10 foreign investors in the manufacturing of batteries 2015-2022

Parent company	Projects	Capex (USDbn)	Avg capex (USDbn)	Jobs created
SK Holdings (SK Group)	11	9.2	0.8	25,265
Contemporary Amperex Technology (CATL)	6	7.6	1.3	5,818
LG	13	6.9	0.5	14,714
Samsung Group	6	2.5	0.4	7,077
Honeycomb Energy Technology	1	2.3	2.3	2,000
Envision Energy	3	2.1	0.7	5,586
Lithium Werks	1	1.8	1.8	3,000
Farasis Energy	2	.8	0.4	1,161
Murata Manufacturing	2	.7	0.3	3,561
Johnson Controls International	4	.6	0.2	3,115

Source: fDi Markets

South Korean and Chinese cell manufacturers lead the list of battery supply chain investors, followed by American and European automakers, in line with the broader evolution of the industry.

SK Group tops the list of the most active foreign battery supply chain investors between 2015 and 2022 with \$9.2bn, while Chinese CATL announced projects worth \$7.6bn over the same period. Fellow South Korean LG trails not far behind with \$6.9bn worth of projects.

Over the course of the last six years, SK Group, mostly through its subsidiary SK Innovation, has invested roughly \$3.1bn in Hungary, \$2.6bn in China, \$1.7bn in the US and \$1.4bn in Poland. In 2021, it also invested \$1bn into an EV battery copper foil manufacturing plant in Malaysia

through its other subsidiary SK Nexilis.

Chinese CATL's biggest project in the period was a manufacturing plant for EV batteries in Indonesia, worth \$5.1bn, followed by a €1.8bn (\$2.2bn) production and R&D facility in Erfurt, Germany.

In spite of little production, Northvolt is looking to close the gap in Europe with a pipeline of manufacturing capacity under development at over 170GWh. In 2022, it announced plans to establish a battery manufacturing plant in Heide in northern Germany.

Elsewhere, it is a mushrooming market of joint ventures. In the US, American titans, Ford and GM, have teamed up with South Korean battery incumbents to pour billions into new cell manufacturing plants. In 2021, Ford and

SK Innovation invested \$11.4bn to build three battery production plants and one assembly plant. As of January 2022, Ultium Cells, the joint venture between General Motors and LG, had invested over \$7bn in three battery manufacturing plants in Ohio, Tennessee and Michigan.

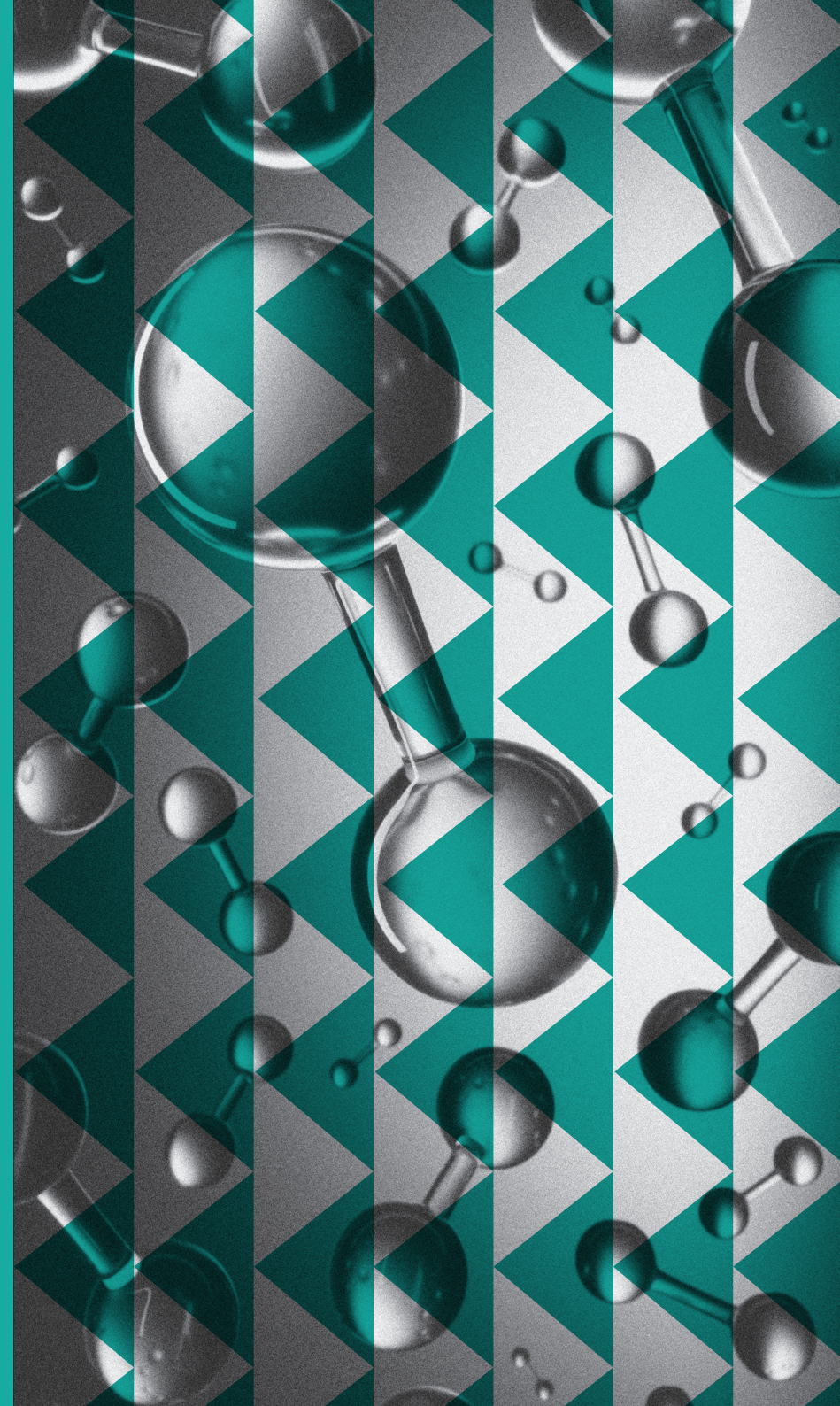
In Europe, ACC, the joint venture formed between French energy company Total, its subsidiary Saft and automotive multinational Stellantis, brought in German Mercedes-Benz in 2021 and launched the target of reaching 120GWh of cell capacity by 2030. In March 2022, it unveiled its industrial centre in Nersac to produce the first EV batteries "made in France". ACC has also signed a contract with Bruxelles-based mining firm Umicore in April 2022 to secure the supply of cathode materials produced in Poland thus starting in Europe also this important vertical along the supply chain.

On the demand side, exclusively with regard to BESS applications, as mentioned European energy companies lead the pack. Between 2019 and 2022, Enel announced seven projects across the US and Chile with a BESS component, and is developing another two battery-powered wind farms in Chile. Besides, the company also launched a pure BESS facility in Cremzow, Germany.

In the same period, French TotalEnergies, particularly through its subsidiaries Neoen and Strata Solar, also announced a slew of major BESS applications in the US and Australia, as well as Finland and El Salvador. French EDF announced BESS projects in the US, UK and South Africa.

Chapter 5

Green hydrogen



Green hydrogen's moment in the sun

Dating back to the nineteenth century as an energy fuel, hydrogen has recently emerged as the Swiss army knife of the green transition. While neither an energy source nor a like-for-like fossil fuel alternative, the most abundant chemical element on the earth's surface can be used to decarbonize hard-to-abate sectors, at least if produced from renewables.

Although it is today still predominantly produced using fossil fuels, the falling price of electrolyzers and the concomitant falling price of renewables-generated electricity have introduced the green production of hydrogen as a bankable concept — where wind and solar are used to power electrolysis (splitting of water into oxygen and hydrogen).

Tied to governments' net zero targets, top-down policy directives have given way to a spate of moonshot green hydrogen investments as long-term policy commitment remains the enabling element for a technology whose competitiveness has yet to come of age. Starting with Japan in 2017, over 30 countries have issued hydrogen strategies, from the sustainable frontrunners in Europe to outsiders like Oman and Uzbekistan, which gives the industry a chance to avoid since its outset the overconcentration of production that has historically been the typical trait of oil and gas.

The overall value of the existing pipeline of announced projects in green hydrogen has reached an estimated \$500bn through 2030, according to estimates from the Hydrogen Council.

Off the back of the hydrogen hype,

Top investing region
Western Europe

Top three investing countries
US, Australia, Germany

Top destination region
Western Europe

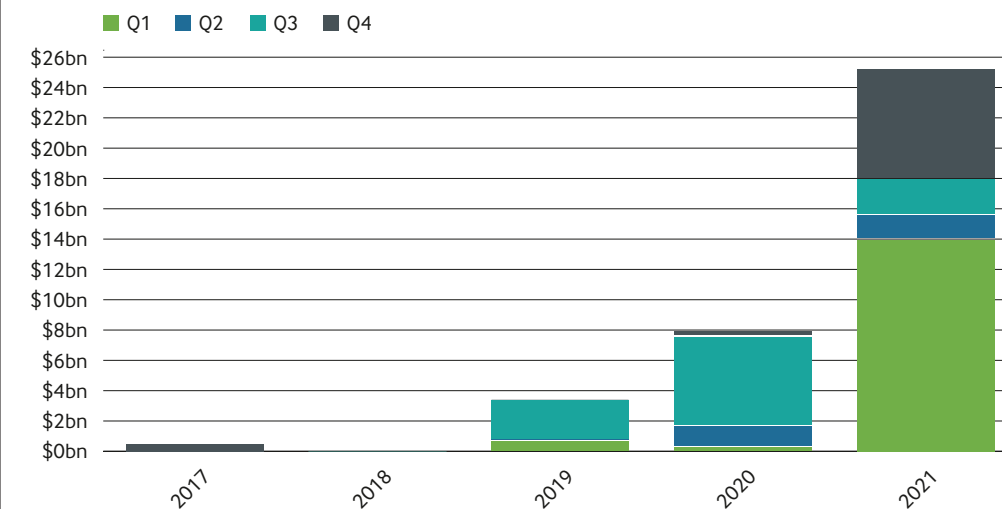
Top three destination countries
Brazil, Saudi Arabia, Namibia

accelerated by the pandemic, investors announced FDI projects into hydrogen produced from renewable energy for a record \$25.2bn in 2021, from \$8bn in 2020 and \$3.3bn in 2019.

But proof of concept has yet to come through. Beneath the hype, there is not one utility-scale green hydrogen project that serves as an example of how green hydrogen works in practice. Above all, there is uncertainty over what the future demand for hydrogen will be from industrial users or hydrogen fuel cell developers and what infrastructure will be needed to transport it. The question of how green hydrogen production can be certified internationally also needs to be addressed. This is all set in a context where the

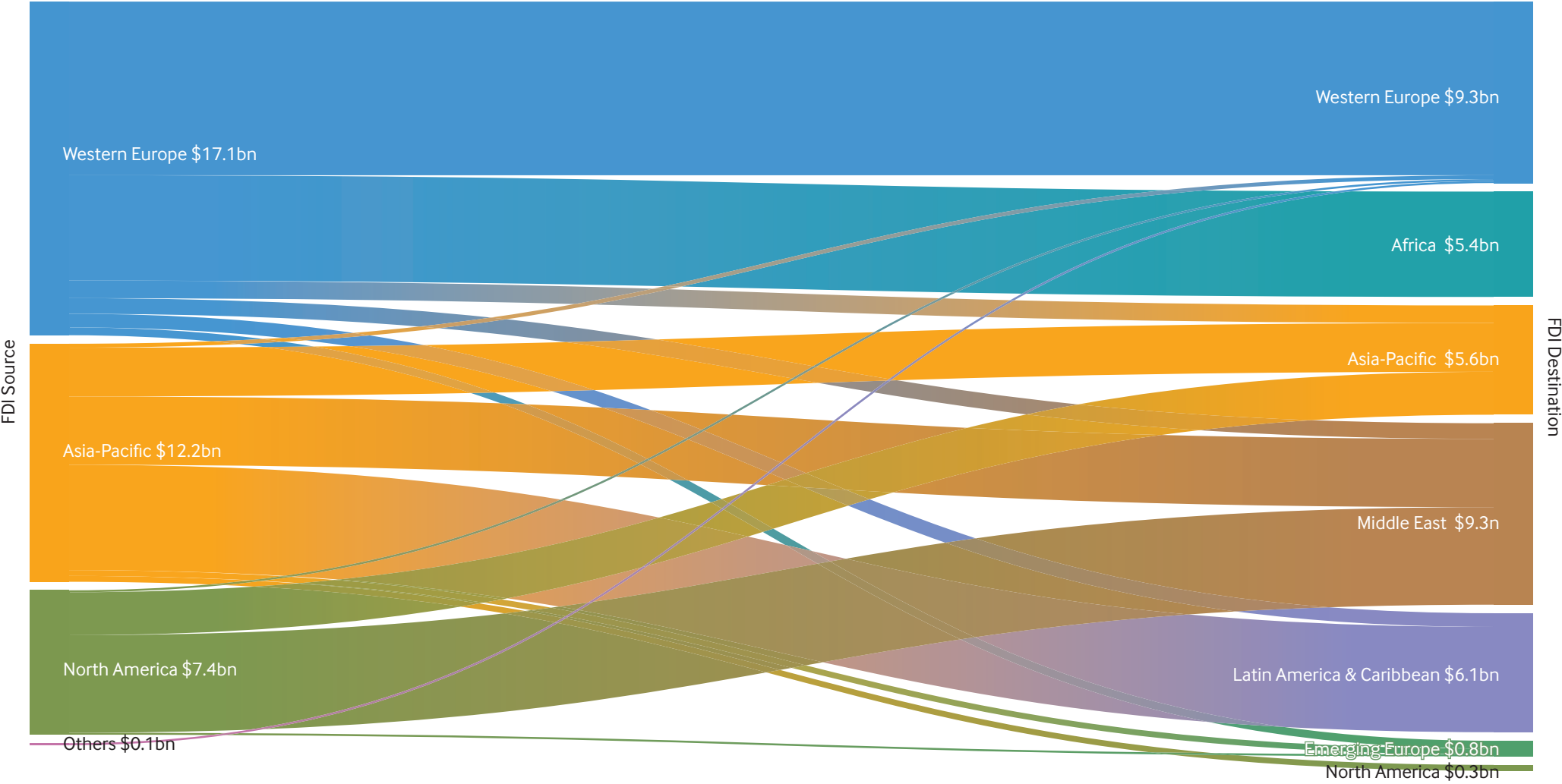
Hype or hope

Announced foreign direct investment in green hydrogen projects



Source: fDi Markets

Patterns of green hydrogen investment
Origin (left) and destination (right) of foreign direct investment in 2017-2022



Source: fDi Markets

cost of producing green hydrogen (renewable-fed electrolytic hydrogen) is still high, mainly owing to the cost of equipment and to the large amount of energy needed per kg of hydrogen produced. Nevertheless, economies of scale driven equipment cost reduction and cheaper and cheaper renewable energy could bring green hydrogen on par with fossil originated hydrogen well before 2030 and below 1\$/kg by 2050.

Besides, at pixel time the current volatility in the gas market caused by the Ukraine war is already weakening the competitiveness of blue hydrogen vis-a-vis green hydrogen.

Green hydrogen heats up in 2020-2022

Born at the heart of the renewable energy boom, green hydrogen has emerged as a global phenomenon from the outset – at least with regards to deployed capacity, while a handful of countries, mostly in Europe, are clear frontrunners in the manufacturing of electrolyzers. Of the total \$25.2bn invested in 2021, 35% flowed into Europe, 24% went into Latin America and the Caribbean, 22% went into Africa, 14% into the Middle East and 5% went into Asia-Pacific.

In terms of single countries, the emerging contours of the green hydrogen map tell a tale of two business models. Some countries are pursuing a capital-intensive, exports-driven model that borrows a leaf from the oil and gas book; others are adding the green hydrogen component to their ongoing renewable energy plans to meet domestic demand.

Big ticket, exports-driven projects propelled the likes of Brazil, Saudi Arabia and Namibia at the top of the list of countries that received

the highest level of announced FDI into green hydrogen. Between 2016 and 2022, foreign investors announced green hydrogen projects worth \$6.1bn in Brazil, and \$4.4bn in Namibia.

These inflows are heavily, if not entirely, weighted towards single utility-scale green hydrogen projects, like Australian company Enegix's \$5.4bn, 3.4GW project in the port of Pecem, Brazil; and Germany's Hyphen Hydrogen Energy's \$4.4bn, 2GW bet on Namibia. Both the state government of Ceara', where Pecem is located, and the national Namibian government are aiming to take advantage of their wind and solar resources to create green hydrogen hubs.

The hydrogen hype has carried into 2022 with several countries now willing to leapfrog the green transition by going straight into renewable energy-based green hydrogen production. In Morocco, Total Eren announced in 2022 that it will invest \$10.3bn in a hydrogen and green ammonia project in the south of the country with a 10GW capacity using wind and solar. Even African countries that have been at the margin of energy markets and global value chains are willing to seize the green hydrogen opportunity. Mauritania, for example, signed an MoU with Australian developer CWP Global to develop a green hydrogen project that could mobilise as much as \$40bn, although lack of details still make it a very far-fetched outcome.

Beyond large-scale, exports-oriented projects, whose feasibility and business model have yet to be tested in real life, several developed countries with major domestic markets and RES capacity have launched green hydrogen strategies balancing domestic needs with exports

“Born at the heart of the renewable energy boom, green hydrogen has emerged as a global phenomenon from the outset”

opportunities or imports needs.

Australia published a National Hydrogen Strategy in 2019, in which it outlined its ambitions to create domestic demand for hydrogen so as to develop its exporting capabilities. The Australian government has also signed deals with both Japan and South Korea to export hydrogen. The Australian Renewable Energy Agency predicts that demand for hydrogen exports could surpass 3 million tonnes per year by 2040, worth \$10bn annually.

Overall, foreign investors announced 13 green hydrogen projects in Australia worth \$1.9bn

between 2019 and 2022. In 2019, Neoen, a subsidiary of French Total, kicked off feasibility studies for a \$500m (\$355.1m) hydrogen superhub at the Crystal Brook Energy Park in Australia. It will include up to 125MW of wind and up to 150MW of solar PV generation, up to 130MW of lithium-ion battery storage capacity. Other investors have added to their existing operations. In 2021, UK-based Eco Energy World is investing AU\$500m (\$388.4m) into a 200MW hydrogen plant at its solar plant in Raglan in Australia. It expects to produce 33,000 tonnes of green hydrogen annually.

With support from the federal and state governments, Australia has come to be one of the key players in the global pipeline of green hydrogen projects, according to consultancy Rystad. Australia sits alongside Western Europe, Central Asia, West Africa and the Middle East as the top five regions by planned green hydrogen capacity.

On the other hand, the EU is also keen on adding green hydrogen to the energy mix, yet it will not be totally able to rely on internal production.

Spain and Germany have led the way in green hydrogen developments in Europe, while 22 EU members and Norway signed a manifesto in 2020 which committed to launch 'important projects of common European interest' (IPCEIs) in the hydrogen sector.

In 2020, Spain released a hydrogen roadmap in which it laid out that it is targeting 4GW of electrolyzers by 2030 – a tenth of the total targeted by the EU before REPowerEU re-targeting. It also outlines that Spain is betting on

boosting the hydrogen value chain through the creation of technology clusters. It counts five publicly funded clean hydrogen projects and nearly 30 others. Foreign investors have taken note with the country tracking \$4.1bn over 17 projects in 2021.

In 2022, a consortium of 33 companies and organisations, led by Spanish oil giant Repsol, has invested €3.2bn (\$4.4bn) to target 500MW of green hydrogen capacity by 2025 and 2GW by 2030.

As the beating heart of European industry, Germany was early to present a hydrogen strategy in 2019 – even before the EU – and has even bigger ambitions than Spain. It has set aside \$10bn to develop electrolyzers and plans to build a production capacity of 5GW by 2030. In 2021, the German government announced it will invest €8bn into large-scale hydrogen projects.

But as explained above, Germany and the EU are also aware that they cannot domestically meet all of their internal demand at competitive costs. In December, the European Commission approved a €0.9bn (\$1bn) German scheme to support investments in the production of renewable hydrogen in non-EU countries to then be imported and sold in the EU.

Without enough resources to domestically meet the internal demand at a competitive cost, it is possible that part of the green hydrogen produced in geographies like Africa is sent to Europe. In its 2020 Hydrogen Strategy, the European Commission targets 40GW of installed renewable hydrogen electrolyzers within the EU by 2030, and another 40GW in what it calls the “EU neighbourhood” with export back to the

EU's 2030 green hydrogen capacity target

40GW

Source: European Commission

EU. A large proportion of this neighbourhood is expected to be in North Africa, due to the latter's geographical proximity to the bloc, the availability of excellent renewable resources and, in the case of Morocco, the already well developed renewable market.

Even with imports need to be met, it is still a glass half full for Europe as the region is the world's main supplier of electrolyzers. As it stands, the region has 40% of global installed capacity in the production of electrolyzers. Global capacity of electrolyzers doubled over the previous five years to reach just over 300MW by mid-2021, according to the IEA, and this could reach up to 54GW by 2030.

The geography and level of feasibility of green hydrogen developments will heavily hinge also on the availability of its main production input – water. A 2021 Rystad report points out, the locations of planned green hydrogen projects, like Australia, Saudi Arabia or Namibia, are to a large extent in areas constrained by water shortages, meaning that an additional desalination market needs to be created as water is the main input of electrolysis. In such instances, even in regions far from the coastline, water transport could be considered in addition to desalination. This will of course increase the cost of water supply, but it will still represent a relatively small share of the total hydrogen production cost, reaching levels as low as \$0.05/kgH₂ and representing 1-2% of the energy consumption of the electrolyzer.

Low carbon hydrogen and the 'switch'

The hydrogen sector represents an additional means for governments and businesses of all kinds to embrace the green transition: renewable energy developers have a strong case to build utility-scale projects to power up electrolysis; to a certain degree, oil and gas majors can make use of some of their existing gas infrastructure and expertise to accelerate the shift to hydrogen and fossil fuel exporting countries can swap natural gas for hydrogen supplies; and industrial sectors that cannot be electrified can still go green.

But as hydrogen is a conversion business rather than an extraction business, it is unlikely to yield the same sort of revenues as well as the same global trade dynamics as oil and gas today, according to a report from Irena, The Geopolitics of the Energy Transformation: The Hydrogen Factor.

"Hydrogen can thus not be considered a new, zero-carbon version of oil," it says. "The hydrogen business will be more competitive and involve more players than oil and gas. As the costs of green hydrogen fall, new and diverse participants will enter hydrogen markets."

There is clear ambition globally, especially among the hydrocarbon-based economies of the Middle East and oil and gas majors, to leverage oil and gas expertise to ride the hydrogen wave. In this regard, proof of concept has yet to be validated, though. Some companies have leaned on "blue" hydrogen, which is produced using natural gas where the carbon dioxide emitted is captured using carbon storage (although this step is far to be proven at the required scale); others have committed

"The hydrogen business will be more competitive and involve more players than oil and gas"

the whole nine yards to green hydrogen at required scale, taking the blue hydrogen off the table of possible decarbonization options today. Under whatever shade, they are able to keep a foothold in the fossil fuel-adjacent camp of the future, retaining an industrial customer base, while separately developing renewable assets to supply clean electricity to the grid.

The plummeting demand for oil, and parallel fall in value, during the initial months of the Covid-19 pandemic augured an oil-reduced world, prompting oil and gas producers to take advantage of existing infrastructure to make and possibly transport hydrogen, when commercially viable.

Over the past year, oil majors have made clear moves to develop zero- or low-carbon hydrogen exporting sites – many of them starting either in their home countries or transforming their existing fossil fuel assets.

In 2021, BP announced that it is developing both a blue and green hydrogen project in Teesside, in the North of England, to serve an industrial customer base. Together, HyGreen Teesside and H2Teesside have the potential to deliver 30% of the UK's 2030 target for hydrogen production. Total and Engie signed a cooperation agreement to develop a green hydrogen project powered by 100MW of solar to feed into the biofuel production process at Total's La Mède biorefinery. It aims to be France's largest renewable hydrogen production site.

In Spain, Portuguese EDP invested €550m to swap coal for clean hydrogen. In 2021, the company announced that it will transform its previous coal-fired power plant in Los Barrios in

“Fossil fuel exporting countries are also keenly aware of hydrogen’s potential and, due to their wind and solar potential, have looked towards green hydrogen development”

Spain into a green hydrogen production facility. The power plant had already been approved for closure and the dismantling processes had begun. The project is part of a broader initiative worth €1bn focused on greening both the Puente Nuevo and Los Barrios power plants.

In Germany, Dutch oil and gas giant Shell, alongside Swedish power company Vattenfall and Japanese multinational Mitsubishi Heavy Industries, signed a letter of intent in 2021 to develop a 100MW electrolyser and green energy hub at the Moorburg power plant, near Hamburg, which is operated by Vattenfall.

Fossil fuel exporting countries are also keenly aware of hydrogen’s potential and, due to their wind and solar potential, have looked towards green hydrogen development. Saudi Arabia, the UAE, Russia and Australia all released net zero targets in 2021 ahead of COP26, with the low-carbon production of hydrogen identified as a means of getting there.

While FDI between 2017-21 into green hydrogen into the Middle East stands at 24.8% of the global share, significant joint ventures and strategic alliances in the Gulf have kept the hype buoyant.

Saudi Arabia is targeting both blue and green hydrogen production of 2.9m tonnes per year by 2030. The \$5bn green ammonia project in its planned city Neom is a joint venture between Saudi ACWA Power, Neom and the offtaker US-based industrial gases company Air Products and Chemicals. In the UAE, French energy company Engie and Masdar, the renewables subsidiary of the Emirati sovereign wealth fund, the Mubadala Investment Company, signed

a strategic alliance agreement worth \$5bn in 2021 to develop projects with a capacity of at least 2GW by 2030. The main aim of which is to develop a green hydrogen hub with local value chains so as to export clean hydrogen to Europe and Asia further down the line.

Blue vs green hydrogen

However, the real feasibility of either option – green or blue hydrogen – eventually hinges on their competitiveness and technology readiness. While green hydrogen relies on tested renewable energy generation and hydrolyser technologies whose costs decrease with scale and efficiency, blue hydrogen depends on natural gas costs, currently under great upward pressure, as well as on the development of carbon capture and storage (CCS) technologies – at the moment, there is only one commercial CCS project up and running the whole world over (Climeworks’ Orca plant in Iceland), whose capacity is only a fraction of the capacity blue hydrogen projects would require, only when CCS becomes scalable at a competitive cost will blue hydrogen become a viable option.

The top green hydrogen companies

In line with the immediate globalisation of green hydrogen, the top investors are Australian, American, German, Indian and Italian with projects in Brazil, Saudi Arabia, Namibia and Oman. Unlike wind and solar, the companies involved in green hydrogen production range from renewable energy developers to chemical companies to oil and gas majors.

The top four renewables-based hydrogen investors between 2017 and 2022 all owe their place to individual mega projects. Australian Enegix Energy tops the list with \$5.4bn invested over the period, followed by American Air Products and Chemicals with \$5bn and German Hyphen Hydrogen Energy, a subsidiary of independent energy company Enertrag, with \$4.4bn. Indian ACME Group comes in fourth place having invested \$3.5bn to establish a green ammonia project at the Duqm Special Economic Zone in Oman.

In fifth place, Italian Enel announced investments for 12 projects in its countries of presence with a focus on Italy, Chile, Spain and the US by working with major industrial partners such as ENI, Saras and AME. In order to contribute to the cost reduction needed for green hydrogen to become a commercially-viable technology, the company announced NextHy, an industrial platform located in Sicily integrating a full-scale production plant and a testing lab dedicated to the testing of innovative technology components.

Portuguese EDP is also investing in Spain. It has pledged over \$1.5bn in clean hydrogen investments: one investment to transform its previous coal-fired power plant in Los Barrios in Spain into a hydrogen production facility; another a

Top 10 foreign investors in green hydrogen energy 2017-2022

Parent company	Projects	Capex (USDbn)	Avg capex (USDbn)	Jobs created
Enegix Energy	3	5.4	1.8	2,576
Air Products and Chemicals	1	5.0	5.0	2,697
Enertrag	1	4.4	4.4	1,500
ACME Group (ACME Cleantech Solutions)	1	3.5	3.5	3,000
Enel	12	2.7	0.2	1,298
8 Rivers Capital	1	2.2	2.2	113
Ineos	5	2.0	.4	1,346
Energias de Portugal (EDP)	2	1.5	.8	620
Beijing Energy International (Panda Green Energy Group)	1	1.4	1.4	71
Siemens	3	0.8	.3	167

Source: fDi Markets

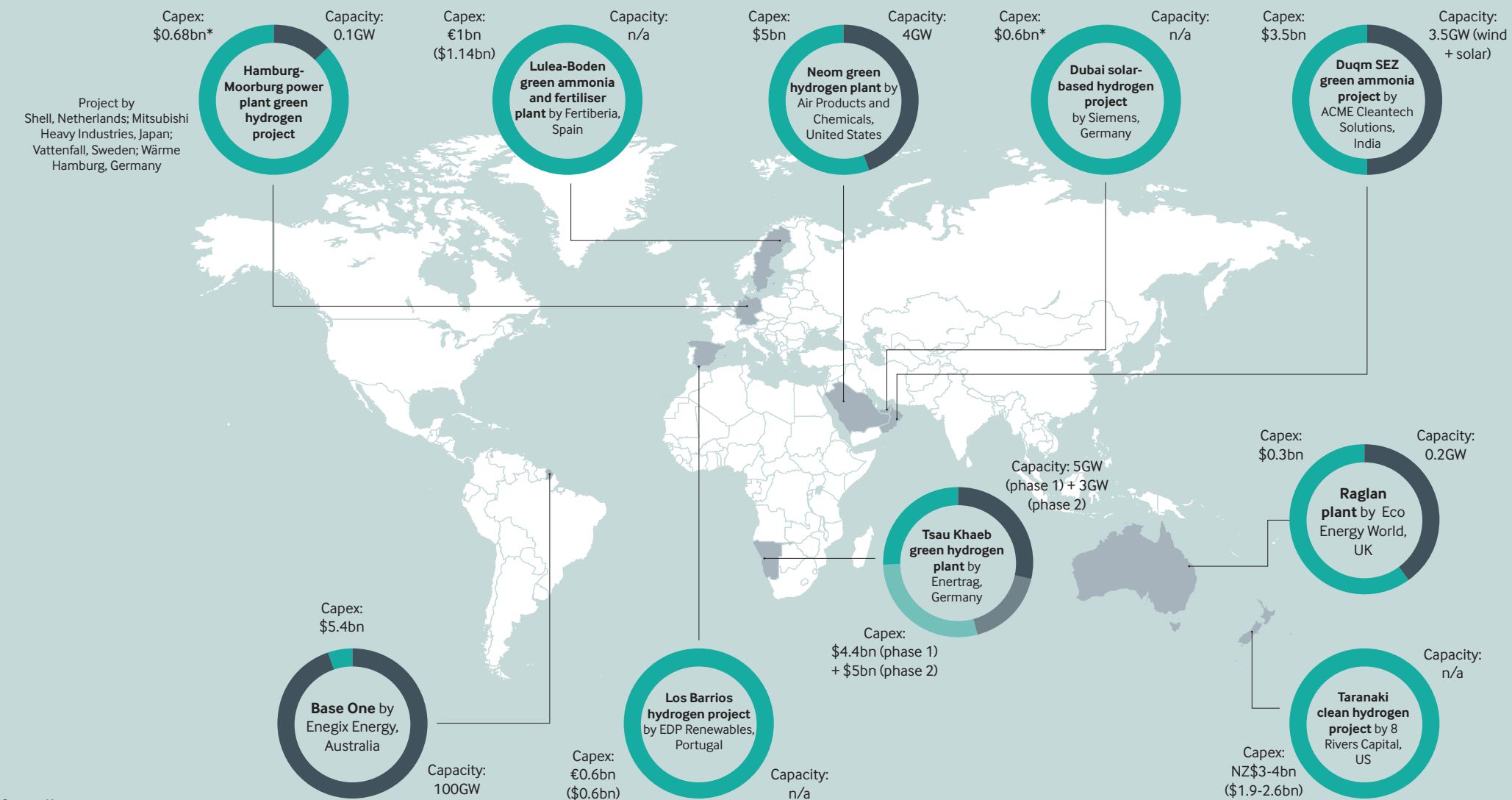
“Oil majors have also repositioned themselves by investing in green and blue hydrogen projects”

green hydrogen plant in Galicia in partnership with a Spanish energy company.

The mixture of independent renewable energy developers, energy companies and industrial businesses, such as industrial gases company Air Products and Chemicals, point to a range of developers and offtakers already involved in this fledgling sector.

Oil majors, namely BP, Total, Shell and ExxonMobil, have also repositioned themselves by investing in green and blue hydrogen projects. These range from the transformation of pre-existing assets to large-scale industrial projects, such as BP's Teesside hydrogen hub, which is expected to generate 30% of the UK's targeted hydrogen production.

Top 10 green hydrogen projects (2020-2022)



Source: Xxxxxxxxxx
Note: *Estimate,

