2. Enabling technology: Power-to-X and green hydrogen

Future clean energy systems call for large-scale integration of wind and renewable power, enabled by technological solutions for flexibility, storage at varying durations and responsive management of demand and supply. Power-to-X is set to become one of the breakthrough solutions which will dispatch green power to different end-use sectors to reduce their dependency on fossil fuels, from heating to manufacturing.

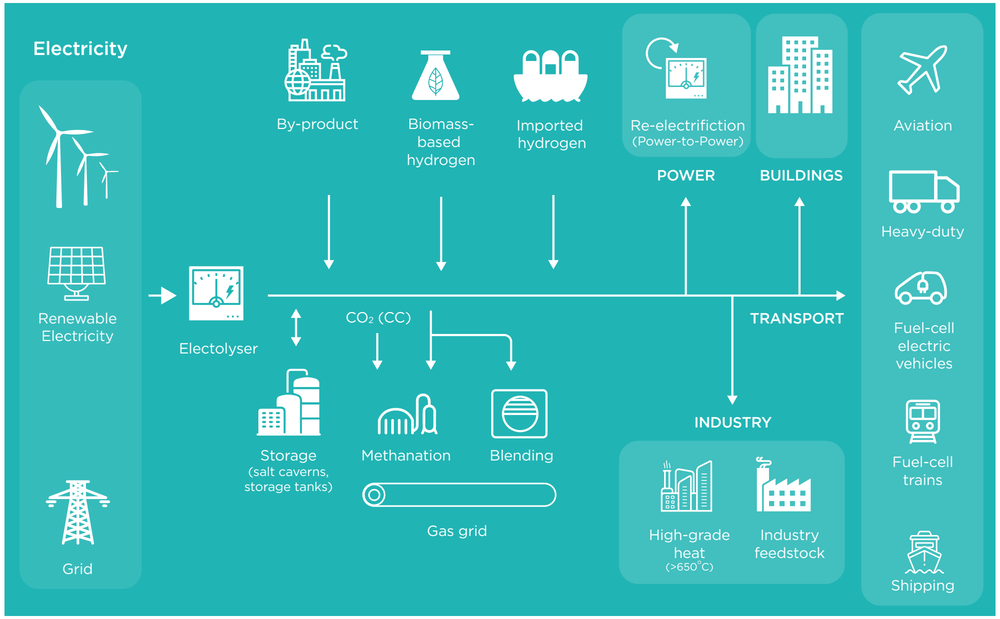
Like many innovative solutions, while technically proven, widespread deployment of Power-to-X must be backed by strong government policies and investment, uptake of new business models by end-users and power grid reinforcement which puts flexibility at the core of generation, transmission and distribution systems. IRENA's Deeper Decarbonisation Perspective, which outlines a path to carbon neutrality before 2060, calls for US$38 trillion in cumulative investment from 2016-2050 for renewable energy (three times the volume of investment under planned policies) and US$27 trillion for electrification, storage and grid infrastructure (double the volume of investment under planned policies).

Concurrent to the transformation of infrastructure to enable grid interconnectivity and sector coupling, the production of green hydrogen as a key storage solution will need to be economically viable. With hydrogen playing a prominent role in national energy strategies, from Germany to Australia to Chile to South Korea, it is no longer meaningful to dismiss it as over-hyped. But it is worth examining the political and economic constraints of Power-to-X and green hydrogen to understand the degree to which they can accelerate the shift to carbon neutrality, and whether we are indeed headed towards the age of the "hydrogen economy".

Innovation for multiple end-uses

Power-to-X is a promising and innovative storage solution for wind for a myriad of uses. Stored electricity can be electrolysed into hydrogen to be used as feedstock, to produce bulk chemicals like methanol or ammonia for industrial processes (Power-to-Gas or Power-to-Chemicals) or combined with captured CO_2 to make carbon-neutral liquid fuels such as crude, gasoline, diesel and aviation fuels (Power-to-Liquid Fuels). Stored green power can generate heat through heat pumps or electric boilers for houses and factories (Power-to-Heat), or contained in underground formations such as salt domes and fed back to the gas grid or transformed into electricity when needed (Power-to-Heat and Power-to-Power).

According to the IEA, the power sector accounts for nearly 40% of CO_2 emissions worldwide, and this share is declining due to the expansion of renewable generation; transport and industry make up nearly half of remaining global emissions, with buildings comprising around 10%. Each sector and end-use requires targeted solutions. Energy carriers and chemical products provide significant versatility in renewable energy storage,



transport and subsequent conversion to end-use products. The sector-coupling approach of Power-to-X is a critical response to the "hard-to-electrify" sectors, such as aviation, maritime shipping, steel production and chemicals manufacturing.

Government ambition is in place for green hydrogen to take off

Despite several false starts for hydrogen over the last few decades, 2020 saw several governments integrate hydrogen into pandemic recovery plans and long-term climate strategies. By the end of 2020, at least 33 countries had published or were preparing national hydrogen strategies, including the European Commission's Europe-wide hydrogen strategy targeting 40 GW of electrolyser capacity for green hydrogen by 2030.

Some have hailed the dawn of the "hydrogen economy" – a system-wide application of hydrogen as a storage solution with Power-to-X deploying it to heat homes, create gasses for industrial use and power airplanes and ships. In this scenario, hydrogen is transported via new and existing pipelines and transport channels, exported to different markets and used to make fertiliser, fuel, steam, power and more.

Given the commercial constraints of large-scale deployment and the urgency of the climate challenge, it is likely that hydrogen will need to work alongside widescale electrification to offer a diversified approach to sector decarbonisation, depending on the energy yield and storage option required. Where wind, sunshine and other sustainable energy sources can be harnessed for affordable green power and exported via interconnectors, this will be the cost-effective solution for the power, heating and cooling in buildings, short-distance transport and certain industrial sectors.

Hydrogen-specific targets send positive signals for a future cost reduction pathway. Now, concrete policies and regulation are needed to bring hydrogen to commercial scale, which will reinforce large-scale deployment of renewables and increase balancing capabilities for grids reliant on large shares of renewable power. As costs for electrolysers decline, they can also be used to produce hydrogen with curtailed generation that might otherwise be wasted during particularly windy or sunny periods when renewable supply exceeds demand on the grid.

Production must ensure that net zero is achieved

While much has been made of hydrogen's applications, the key is production: Hydrogen is a clean-burning gas which emits only water at the point of combustion. The emissions challenge is related to production: Conversion of fossil fuels with heat or steam is currently the primary method of production, but this process emits CO_2 and creates so-called "grey hydrogen". Most hydrogen production today is grey, based on methane and coal, and emits 830 million tonnes of CO_2 annually, according to Carbon Brief.

"Blue hydrogen" pairs this process with carbon capture and storage (CCS) technologies which are currently capital-intensive. "Green hydrogen" is produced via electrolysis, fed by green power sourced from an adjacent renewable asset or on the grid.

Expansion and investment of enabling infrastructure for hydrogen must emphasise green production, with support from blue production – this is not only an imperative to meet carbon neutrality goals, but also reflects the economics of declining costs for renewable power, electrolysers and CCS. Driven by R&D and economies of scale in manufacturing facilities, cost reduction and learning rates could make electrolysers 40% cheaper and green hydrogen cost-competitive as soon as 2030, according to IRENA.

A natural match: Wind-to-Hydrogen

Of all renewable energies, offshore wind and wind/solar hybrid projects have the highest potential to improve the economics of green hydrogen projects due to cost-competitiveness and scalability. Onshore wind became one of the cheapest new sources of electricity in 2020, while offshore wind has delivered incredible global LCOE reduction of more than 67% over the last 8 years, according to BNEF, and costs will decline by another third by 2030.

GW-scale wind projects at falling costs, paired with hydrogen, highlight the opportunity to achieve commercial viability by the end of the decade. The pipeline is certainly growing: 2020 saw 50 GW of green hydrogen projects announced for development, out of a total 80 GW in the global pipeline. The costs for transporting hydrogen through gas infrastructure from offshore sites could also be as, if not more, cost-effective then transporting power through cabling, especially in areas farther out to sea.

The massive NortH2 project (Equinor, Gasunie, Groningen Seaports, RWE, Shell Nederland, with backing from the Groningen provincial authority) off the coast of the Netherlands aims to generate 4 GW of green hydrogen from offshore wind by 2030 and more than 10 GW by 2040, with a feasibility study due by end of 2021.

Green hydrogen innovation is also on the rise: At the top of 2021, Siemens Gamesa announced joint funding with Siemens Energy to develop an electrolysis system integrated into its 14 MW offshore wind turbine for a scalable offshore wind-to-hydrogen solution, with a full-scale demonstration targeted by 2026. A 20 MW green hydrogen facility is also being deployed for a steel pipe facility in Italy, while a 700 MW electrolysis project called Westküste100 brings together end-users including a cement manufacturer, with plans to produce synthetic green fuels for the aviation sector.

On the other side of the world, the massive 15 GW hybrid wind/solar Asian Renewable Energy Hub in Western Australia is expected to deliver first power by 2027. This will scale up to 26 GW of renewable power with green hydrogen and ammonia production for domestic use and export. In Hebei Province, China,

Case study: Is green hydrogen the perfect match for floating offshore wind?

Provided by: Principle Power

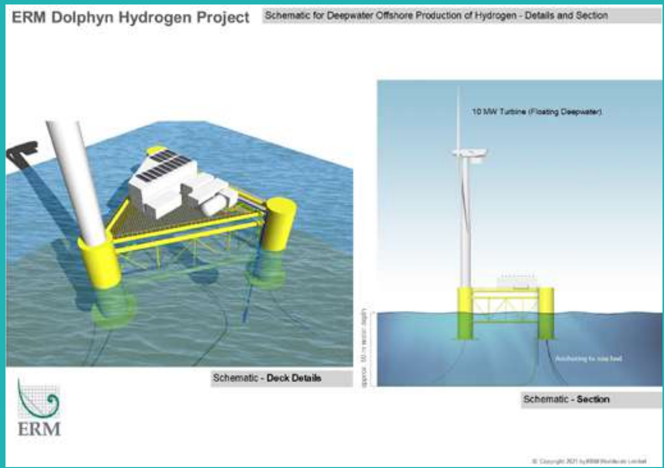
With global energy demand increasing, and an urgent need to decarbonise the current energy mix, hydrogen has emerged as an alternative to fossil fuels that has catapulted to the forefront of the net zero toolbox. Hydrogen energy is extremely versatile, in that it can be stored in either gas or liquid form and can be converted into electricity or transportation fuel when needed, with water as the only by product.

The bulk of hydrogen currently in use is derived from fossil fuel feedstock using energy intensive and polluting processes (grey hydrogen). If hydrogen is to truly deliver on its environmental potential, it needs to be produced from our planet's vast renewable energy resources (green hydrogen).

The ERM Dolphyn project aims to produce green hydrogen from floating wind turbines situated miles out to sea, a world-first.

The design is currently at FEED (front end engineering design) stage and consists of a large-scale floating wind turbine with an integrated water treatment unit and proton exchange membrane (PEM) electrolyser for localised hydrogen production. It incorporates its own standby power unit, supplied by hydrogen stored on the facility, and is therefore completely autonomous, requiring no electrical connection to shore. The first phase is initially aiming to get a 2MW proof of concept unit up and running by 2024.

The concept is being developed and led by ERM with support from industry frontrunners including Tractebel Engie and Principle Power, who are responsible for the floating sub-structure design and the wind turbine. Principle Power's WindFloat® platform will be



equipped with a V80 2 MW wind turbine and a platform deck supporting the hydrogen production factory. The hydrogen will then be exported to shore under pressure via a pipeline.

The Dolphyn concept allows the wind turbines to operate completely independent of the grid, removing the need for complex and costly electrical equipment, and setting the roadmap for cost competitiveness with grey hydrogen. When deployed at industrial scale, this innovative technology, coupling floating wind with hydrogen production, offers the potential to deliver the immense volumes of hydrogen that will be required to decarbonize everything, from electricity to transportation to heavy industry.

a 200 MW onshore wind farm that will use electrolysis to produce 10 MW of green hydrogen is due to be commissioned in 2021.

The unprecedented momentum for green hydrogen worldwide coupled with the improving economics of Power-to-X could provide a much-needed boost to global decarbonisation efforts. This transition will not happen overnight. Renewable plant capex, hydrogen capex (electrolysis, compression and balance-of-plant) and production incentives will be sensitive variables for increasing economic viability. However, technological understanding, urgency and willingness to invest are increasingly aligned across government, industry, financial backers and end-users.

This moment is reminiscent of the renewable energy revolution of the 2000s, which exceeded expectations in terms of cost and growth. Today, with broader commitment from the public and private sectors and a precedence of large-scale innovations, there are strong reasons to be optimistic about Wind-to-X via green hydrogen.

Selected Wind-to-Hydrogen projects under development

Project and Electrolyser Capacity	Location	Developers	Commissioning	Status as of Feb 2021
Asian Renewable Energy Hub (14GW)	Pilbara, Western Australia	InterContinental Energy, CWP Energy Asia, Vestas, Macquarie	2027-28	Utilising 16GW of onshore wind and 10GW of solar, the project is now being fast-tracked through permitting as the federal government has awarded it "major project status".
NortH2 (at least 10GW)	Eemshaven, northern Netherlands	Shell, Equinor, RWE, Gasunie, Groningen Seaports	2040 (1GW by 2027, 4GW by 2030)	Fully powered by offshore wind, feasibility study to be completed by mid-2021.
AquaVentus (10GW)	Heligoland, Germany	A consortium of 27 companies and research institutions, such as RWE, Shell, Siemens Gamesa, Vestas and more	2035 (30MW by 2025, 5GW by 2030)	Early stage, project announced mid-2020.
Murchison Renewable Hydrogen Project (5GW)	Near Kalbarri, Western Australia	Hydrogen Renewables Australia and Copenhagen Infrastructure Partners	2028	Early stage with a demonstration phase ahead that would produce H2 for transport fuels with onshore wind and solar; expansion stages would blend H2 into local natural gas pipelines and produce H2 for export to Asia.
Beijing Jingneng Inner Mongolia (5GW)	Eqianqi, Inner Mongolia, China	Chinese utility Beijing Jingneng	2021	Project using onshore wind and solar, under construction.
Helios Green Fuels Project (4GW)	NEOM, northwest Saudi Arabia	Air Products, ACWA Power, Neom	As early as 2025	Early stage, project announced in mid-2020.
Greater Copenhagen (1.3GW)	Denmark	Orsted, Maersk, DSV Panalpina, DFDS, SAS	2030 (10MW pilot as soon as 2023, 250MW by 2027)	Feasibility study under way for this full offshore wind to hydrogen project, with a view to a final investment decision in 2021.
Fuel Cells and Hydrogen 2 Joint Undertaking (FCH2-JU)	Europe	A consortium of Orsted, Siemens Gamesa, ITM Power and Element Energy	2021-2024	Investigating feasibility of offshore wind and 'fully marinised' electrolysers in a shoreside pilot trial.
'Deep Purple' Seabed Hydrogen Storage Pilot	Norway	A consortium led by TechnipFMC along with Vattenfall, ABB, DNV GL and more	2021-2023	Construction will commence in late 2021.
VindØ	Denmark	A consortium of PensionDanmark and PFA, utility company Andel and CIP	2030	Artificial island with initial 3GW of offshore wind capacity; plan to connect 10 GW offshore wind and host energy storage and Power-to-X facilities.

Source: GWEC Market Intelligence and industry media, February 2021

3. Net zero country case studies

China

In recognition of the strengthening global and domestic consensus behind climate action, China has made a series of climate pledges over the last six months. At the UN General Assembly in September 2020, President Xi Jinping announced that China will upgrade its NDC by targeting peak CO_2 emissions before 2030 and carbon neutrality by 2060. This pledge from the world's second-largest economy and a leading carbon-emitting nation formed one of the key global milestones to tackling climate change since the 2015 Paris Agreement.

The net zero target was followed by a series of commitments to scale up wind and renewable energy capacity, with various ministries and provincial-level bodies now undertaking strategic measures for planning and implementation.

Not all regions will be able to reach peak emissions at the same time. The initiation of China's 14th Five Year Plan (2021-2025) in 2021 requires each province to create its own development plan for renewable energy and timetable for emissions peaking, and earlier achievements may come where onshore and offshore wind capacity is targeted for development. For instance, Jiangsu aims to be the first province to reach peak emissions and is targeting cumulative onshore wind capacity of 12 GW and offshore wind capacity of 15

Six months of momentum to net zero

September 2020
President Xi Jinping announces that China aims for peak carbon emissions before 2030 and carbon neutrality by 2060.

December 2020
President Xi further commits to 1,200 GW of wind and solar installed capacity and 25% share of non-fossil fuels in a primary energy consumption by 2030.

January 2021
MEE (Ministry of Ecology and Environment) requires local governments to set goals for peak emissions and the issues regulations for the national carbon market.

February 2021
NEA (National Energy Administration) releases a notice to raise targets for renewable power utilization for 2030.

February 2021
Provinces begin issuing development plans (2021-2025) for renewable energy and timetables for the peak emissions.

February 2021
The State Council releases guidelines for low-carbon development and green transformation of the economy and society.

Source: GWEC Market Intelligence, February 2021

Carbon reduction commitments made by state-owned generators in China

Company	Peaking Target	Capacity Target
SPIC	Emissions peak by 2023	Clean energy accounts for 60% by 2025 and 75% by 2035
CHN Energy	Emissions peak by 2025	70-80 GW renewables added by 2025
Datang	Emissions peak by 2025	Clean energy accounts for 50% by 2025
Huadian	Emissions peak by 2025	75 GW new energy added by 2025, and clean energy accounts for 60% by 2025
Huaneng	Not disclosed yet	80 GW new energy added by 2025, and clean energy accounts for 50% by 2025 and 75% by 2035
CGN (China General Nuclear)	Not disclosed yet	30 GW renewables added by 2025
CTG (China Three Gorges)	Emissions peak by 2023	New energy reaches 70-80 GW by 2025 and carbon neutrality by 2040

"New energy" refers to non-hydro renewable energy sources. Source: GWEC Market Intelligence, February 2021

Overview of China's Net Zero Plans	
Net-zero target, if any	• Net zero carbon emissions by 2060
Status of the legislation	• Medium-term targets under the net-zero goal will be formulated in Five-Year Plans, including 14th Five-Year Plan (2021-2025)
Public investment announced alongside the net-zero target	• No such announcement available yet.
NDC, as of February 2021	• Lowering carbon intensity by more than 65% by 2030 from 2005 levels
Renewable energy targets	• Reduce share of non-fossil fuels in primary energy consumption to around 25% by 2030 • Increase installed capacity of wind and solar power to more than 1,200 GW by 2030.
Installed wind capacity as of end of 2020	• 272 GW onshore and 9 GW offshore
Key technology strategy on energy transition	• Wind and solar power will take a leading role, with nuclear and hydropower as subsidiary elements • Innovative grid system • Storage, hydrogen, CCS technologies to scale up
Other drivers of clean energy transition	• National carbon trading market will be established in 2021 • Promoting industrial restructuring • Improving energy efficiency (industry, building, transportation, public institutions) • Establishing market mechanisms (pricing, taxes, financial) for low-carbon development • Increasing carbon sequestration capacity

GW by 2025. Guangdong is planning to raise the share of non-fossil fuels in primary energy consumption to around 30% by 2025, when it is targeting cumulative offshore wind capacity of 15 GW.

In October 2020, more than 400 companies in the Chinese wind industry adopted the Beijing Declaration which aims for 50 GW of annual installations from 2021 to 2025 and 60 GW from 2026 onwards. This would bring China's

Case study: How to meet the "Beijing Declaration" targets

Provided by: Techstorm

Last autumn, China announced the plan to reach peak emissions before 2030 and achieve carbon neutrality before 2060. To support this commitment, the wind industry has released the "Beijing Declaration on Wind Energy" with the ambition of installing 3,000 GW of wind power by 2060.

This will require an average annual installation of 50 GW over the next five-year period (2021-2025) and at least 60 GW annually after 2025. At the same time China is scaling down both onshore and offshore wind subsidies. Turbine manufacturers will therefore keep focusing on LCOE reduction.

Techstorm believes that China's targets can be met mainly through the following improvements:

- Development of bigger turbines
- More efficient materials and production processes

As a leading resins and adhesives supplier, used to produce the blades, moulds and nacelles, Techstorm has developed new materials with increased mechanical properties, which help their customers to:

- Increase blade length
- Reduce costs
- Reduce cycle times

In order to meet increasing demand, Techstorm will open a new high-tech factory in Shanghai later this year to increase capacity and efficiency. Additionally, the company is also investigating recyclable materials and packaging solutions and plans to bring these new sustainable options to their global customers soon.

cumulative wind capacity to 800 GW by 2030 and 3,000 GW by 2060.

The tremendous showcase of China's wind industry growth in 2020 shows that 50 GW annually is not only possible, but would bolster the country's progress toward its goal of peak emissions before 2030 and ensure a cost-efficient path towards carbon neutrality in 2060.

Japan

In his first policy address in the Diet in October 2020, Prime Minister Suga declared Japan's ambition to reach carbon neutrality by 2050. This was an unambiguous statement from the newly appointed leader, but will require urgent action over the next few years to deliver.

As the world's third-largest economy by nominal GDP and fifth-largest carbon-emitter, Japan must implement a strict set of reforms to course-correct its emissions while maintaining economic health. Strategies for electrification of industry, transport and buildings will need to go hand-in-hand with market mechanisms like carbon pricing and funding incentives to accelerate the country's coal phaseout and shift to clean energy.

Since its net zero declaration, Japan has initiated a Green Growth Strategy calling for investment in 14 key fields. The strategy also increases the renewable share of power generation target to triple to 50% by 2050, building on its current target of 22-24% by 2030. In 2021, Japan is expected to improve its NDC – currently graded "highly insufficient" for a 1.5°C temperature limit by Climate Action Tracker – which will be a litmus test for the strength of climate-focused public policy interventions ahead.

With 4,437 MW of wind installations as of the end of 2020, including 65 MW of offshore wind, wind energy is becoming a mainstream source of support for Japan to reach its net zero target and decarbonise its heavy industry, such as steel manufacturing and shipping. As a densely populated island nation with complex permitting processes for onshore wind projects, offshore wind has been embraced as a particular solution of choice for large-scale renewable capacity, with opportunities for coupling with hydrogen and ammonia production.

Following strong government-industry coordination, led by the Japan Wind Power Association (JWPA) and GWEC, the government unveiled its Offshore Wind Industry Vision in late 2020. This vision outlines a plan to allocate 1 GW of offshore wind capacity annually through 2030, as well as a supply chain development and cost reduction pathway to reach JPY 8-9/kWh of LCOE by 2035 and 30-45 GW of cumulative capacity by 2040, cementing Japan as one of Asia's offshore wind leaders.

The clear targets, along with the rollout of fixed offshore wind centralised auctions in 2020, are an affirmation of public-sector ambition and confidence. The vision also sets out a long-term goal for 60% local content in the offshore wind supply chain by 2040, providing industry and other actors with enough runway to invest and reorganise. Critical to the success of the centralised auctions will be well-designed grid planning; Japan is aiming to expand grid in locations of high future, based on a forthcoming plan by the Organization for Cross-regional Coordination of Transmission Operators.

The next Basic Energy Policy is due in 2021 and set to reflect

Overview of Japan's Net Zero Plans	
Net-zero target, if any	• Net zero GHG emissions by 2050
Status of the legislation	• Not yet enshrined in national law, though Basic Energy Policy in 2021 is set to outline net-zero roadmap
Public investment announced alongside the net-zero target	• Green Innovation Fund of JPY 2 trillion (US$18.8 billion) over 10 years • Tax incentives to stimulate JPY 1.7 trillion (US$15.9 billion) in private investment
NDC, as of February 2021	• Expected update in 2021 to upgrade NDC from current reduction of 26% total national GHG emissions by 2030 from 2013 levels
Renewable energy targets	• Target 22-24% share of renewable energy in the 2030 power mix • Offshore Wind Industry Vision in late 2020 targets 10 GW cumulative capacity by 2030 and 30-45 GW by 2040
Installed wind capacity as of end of 2020	• 4372.2MW for onshore wind and 65.2 MW for offshore wind
Key technology strategy on energy transition	• "Green Growth Strategy" action plan targets 14 key fields, including offshore wind, electric vehicles and a strategic hydrogen roadmap and electric vehicles
Other drivers of clean energy transition	• From 2030, all new buildings and homes will be subject to zero emissions standards • Aim to increase annual hydrogen consumption to 3 million tonnes by 2030 and 20 million tonnes by 2050 • Aim to achieve 20% use of ammonia as a mixed combustion fuel at thermal power stations by 2030 • Planning for a carbon pricing scheme in progress

greater volumes of wind within an increased 2030 power generation target, as well as a net zero roadmap to 2050. Together, an action-oriented plan for carbon neutrality and programmatic vision for wind energy will reinforce Japan's capacity to achieve its decarbonisation commitments.

Beyond this, the factors which can accelerate the country's clean energy transition include: easing of overly complex permitting processes for onshore wind; availability of land for renewable projects; grid preparedness; change of curtailment rules; the ability to foster a competitive bilateral market for corporate procurement; continued momentum by large trading houses to divest fossil fuel assets and investments; and uptake of clean energy and storage solutions by Japan's heavy industries.

South Korea

With input from: Korean Wind Energy Industry Association (KWEIA)

South Korea's pledge, in October 2020, to reach net zero by 2050 was a major pronouncement from an Asian industrial powerhouse. The target is a tall order for the world's eighth-largest carbon-emitter and fourth-largest coal importer by value, home to significant activity from "hard-to-abate" sectors like steel and shipping. But it turned an election promise of a Green New Deal into a commitment to building a carbon-neutral nation.

In its 3rd Energy Master Plan (EMP) launched in 2019, the government aims to increase the share of renewable electricity from the current 6.5% to 20% by 2030 and then 30-35% by 2040. Implementation of the 9th Basic Plan for electricity to 2030 is expected to strengthen energy regulatory guidelines in line with the new net zero pledge.

To deliver these objectives, South Korea is targeting 9.2 GW of wind power by 2025 and 16 GW by 2030, of which 12 GW will comprise offshore wind. This may be an over-reach, considering the 1.5 GW of onshore wind and 145 MW of offshore wind installed today.

Still, there is no denying the country's ambition. The Moon administration's Green New Deal is a US$60.9 billion stimulus package designed to accelerate the energy transition with solar and wind projects, expansion of electric vehicles and smart green cities. As a signal of rising investor confidence, the government recently announced plans to build the world's largest 8.2 GW offshore wind farm by 2030 primarily financed by private capital.

A promising outlook in South Korea comes with barriers. The country followed its net zero pronouncement with an updated NDC in 2020, which now uses an absolute mitigation target instead of a reduction compared to a BAU scenario. However, the emissions target itself was not strengthened, leading Climate Action Tracker to maintain its assessment of South Korea's NDC as "highly insufficient" to limit global warming to even 2°C.

Additionally, the aggressive expansion of wind and renewables

Overview of South Korea's Net Zero Plans	
Net zero target, if any	• Net zero carbon emissions by 2050
Status of the legislation	• Net zero commitment has not been passed into legislation, as of February 2021. • Various proposed laws relate to net zero, including: (i) the Framework Act on the Implementation of Carbon-Free Society (ii) the Act on the Management of Climate Crisis, (iii) the Act on the Support for the Conversion of Energy, and (iv) the Act on the Promotion of the Green Financing.
Public investment announced alongside the net-zero target	• KRW1.9trillion (US$1.69 billion) to support carbon neutrality strategy
NDC, as of February 2021	• Reduce total GHG missions by 24.4% by 2030 compared to 2017 levels, equivalent to 709.1 $MtCO_2e$
Renewable energy targets	• Increase the share of renewable energy in the power mix to 20% by 2030 and 30-35% by 2040 • Targeting 9.2 GW of wind capacity by 2025 and 16 GW by 2030, including 12 GW of offshore wind • 2040 target of 77.8 GW of renewable energy capacity, including 25 GW of wind
Installed wind capacity as of end of 2020	• 1,500MW for onshore wind and 145 MW for offshore wind
Key technology strategy on energy transition	• R&D for smart grids, energy storage systems and smart heating • Promotion of a hydrogen-based economy
Other drivers of clean energy transition	• Nation-wide Emissions Trading Scheme • Forest management for carbon sinks • From 2020, all new public buildings to be subject the zero-energy standards, and from 2030, all new public and private buildings subject to the standards • Deployment of smart and low-carbon farming practices • Stated intention to create new job opportunities in new, alternative industries and provide re-training support to fossil fuels workers

faces a degree of local opposition and bureaucratic approval processes. As a result of overly complex consenting and under-resourced stakeholder management, offshore wind projects require 5-7 years for development in South Korea.

The government is making efforts to streamline permitting and provide clearer compensation guidelines for local communities with an offshore wind collaboration plan released in July 2020. The plan sets out specific measures to speed up large-scale offshore wind project development and clarify the benefits to local stakeholders:

1. **Government-led siting and streamlined permitting:** Mapping "offshore wind consideration zones" and providing a one-stop-shop to grant all required permits.

2. **Encouraging stakeholder acceptance:** government-led demonstration projects, public consultations and stakeholder participation/ profit-sharing models.

3. **Enhancing industrial competitiveness:** bolstering economic feasibility with low-interest loans, revising the REC scheme, expediting construction and grid connection.

While these measures alone are unlikely to fully resolve the complex challenges around wind growth, South Korea's ambition has exemplified how a country has captured the momentum of a green recovery response to COVID-19 and invested in a more sustainable development pathway. Charged by a powerful engine of political consensus, financial resources and increasing decarbonisation commitments from the country's industrial actors, the wind market is moving into pole position to support South Korea's road to net zero.

India

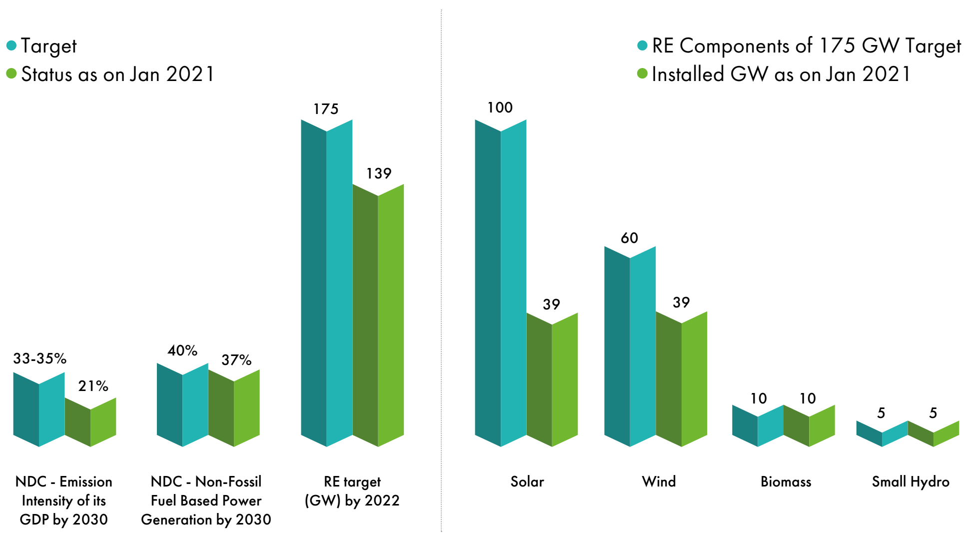
India is the world's fourth-largest energy consumer, and an important vector in the global trajectory to limit global warming. However, with more than 1.35 billion people, its per capita carbon footprint is only around 2 tonnes CO_2e, compared to the footprint of a country like Australia at 17 tonnes CO_2e. Due in part to this issue of "climate equity" and having ambitious renewables targets already in place, India has refrained from setting a net zero target to date.

India's steeply rising power demand has largely been fuelled by coal-fired generation to date. But political shifts have directed India towards a clean energy transition since 2015, when India pledged an NDC of 33-35% reduction in carbon emissions intensity of its economy by 2030 compared to 2005 levels. The country remains vulnerable to the impacts of climate change, with a series of droughts, floods, deforestation and depleting groundwater levels contributing to the shift in public opinion towards sustainability.

As a developing nation, India is still on a pathway to poverty eradication and middle-income status. Nonetheless, it has pursued an ambitious palette of low-carbon programmes, including liberalisation reforms to the power sector, 24/7 green power, clean cooking and energy efficiency.

India's renewable energy target of 175 GW by 2022 includes 60 GW onshore wind. As of February 2021, there was 39 GW of wind capacity

India's clean energy transition progress versus targets



installed, comprising 10.25% of the power mix. Growth of wind over the next five years will be driven by the expiry of the inter-state transmission (ISTS) charges waiver in 2023, as well as the trend of hybrid tenders combining wind, solar and storage technologies. The government has also shared its vision for longer-term renewable energy targets of 450 GW by 2030, including 140 GW of wind.

However, installations are falling short of the levels needed. Climate Action Tracker has deemed India "2°C compatible", i.e. on-track to achieve its NDC target and contributing a fair share of the global effort, but still falling short of the deeper reductions required to limit warming to 1.5°C. The government's 2022 targets may also be missed, due to constraints around land allocation, grid availability, recurring financial instability of DISCOMs, tender design and PPA sanctity. Reviving a long-term national mission to scale up wind and renewables by resolving these challenges, such as through increased government-industry coordination and knowledge-sharing, will provide a much-needed boost to the sector.

With wind and solar prices beating fossil fuel-based generation across India's grid, the expansion of affordable renewables can support decarbonisation of energy-intensive industries such as steel, iron, cement, transport and agriculture. Via the National Electric Mobility Mission Plan 2020, the Modi administration has already enacted an aggressive electric and hybrid vehicle scheme and aims to shift railways from coal dependency to the world's first net zero railway network by 2030. The government has also announced that green hydrogen auctions will be launched in 2021, although tender documents have not yet been issued, as of February 2021.

Meeting India's clean energy targets in the absence of a broader carbon neutrality strategy will require urgent and targeted implementation of regulatory reforms. Accelerating wind growth is also in line with the government's principles of Aatmnirbharta (self-reliance) and "Make in India" for energy security and supply chain competitiveness. The development of offshore wind and green hydrogen capacity will further support India's shift to a more flexible, resilient and clean energy system.

Overview of India's Net Zero Plans	
Net zero target, if any	• N/A
Status of the legislation	• N/A
Public investment announced alongside the net-zero target	• N/A
NDC, as of February 2021	• Reduce emissions intensity of GDP by 33-35% by 2030 from 2005 levels • Raise renewables to 40% of total power generation capacity by 2030 • Create additional carbon sink of 2.5-3 billion tonnes CO_2e through afforestation by 2030
Renewable energy targets	• 175 GW by 2022, including 100 GW Solar; 60 GW Onshore Wind; 5 GW Offshore Wind; 10 GW Biomass; 5 GW Small Hydro • 450 GW by 2030, including 30 GW of offshore wind
Installed wind capacity as of end of 2020	• 38.6 GW onshore wind
Key technology strategy on energy transition	• Ambitious targets for wind and solar capacity • Round the Clock tenders, including hybrid tenders combining wind and solar with energy storage • National Hydrogen Energy Mission to expand green hydrogen uptake in steel, chemicals and transport sectors
Other drivers of clean energy transition	• Green Energy Corridor, Green Term Ahead Market and 'Aatmnirbhar Bharat' • National Electric Mobility Mission Plan 2020 • National Mission for Enhanced Energy Efficiency • Smart City Mission

Source: GWEC Market Intelligence, February 2021

United States

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Currently the net zero goals for the United States are targets and not enshrined in binding federal legislation. The country's federal legislative priorities are first focused on addressing the pandemic and the vast economic disruption it has caused to the US economy.

However, the new administration under President Joe Biden has many levers of power under the executive branch. The administration unveiled a series of Executive Orders (EO) in late January that aim to combat climate change and achieve a carbon pollution-free power sector by 2035 and a net zero economy by 2050.

EOs are actions that a president's administration can put into effect on Day 1 of taking power and can govern wide swaths of the federal government's power, within limits. EOs are limited by existing laws