GWEC | GLOBAL WIND REPORT 2022

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Global Wind Energy Council
Rue de Commerce 31
1000 Brussels, Belgium
info@gwec.net
www.gwec.net

Lead Authors
Joyce Lee, Feng Zhao

Contributors and editing by
Ben Backwell, Emerson Clarke, Rebecca Williams, Wanliang Liang, Anjali Lathigara, Esther Fang, Reshmi Ladwa, Marcela Ruas, Wangari Muchiri, Ramón Fiestas, Liming Qiao, Mark Hutchinson, Thang Vinh Bui, Lisias Abreu

Valuable review and commentary for this report was received from:

- Dan Wetzel (IEA)
- Dolf Gielen, Roland Roesch, Michael Renner, Celia García-Baños (IRENA)
- Nils Askær-Hune, Emil Damgaard Grann (Ørsted)
- Jon Lezamiz, Song Cheng, Carolina Clemente, Fergus Costello, Aidan Cronin (Siemens Gamesa Renewable Energy)

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Design
lemonbox
www.lemonbox.co.uk

Xabier Viteri Solaun
Managing Director,
Iberdrola Renewables

More than ever action cannot be delayed if we want to deliver the necessary wind capacity to reach climate objectives on time. As was made clear at the Glasgow Climate Summit, there is broad consensus on the urgency of promoting rapid and effective decarbonization. Electrification with renewables should act as a lever for global change as the most cost-efficient way to decarbonise the economy.

The latest geopolitical events have put a spotlight on the urgent need to reinforce security of supply, reduce energy dependency and shield against market disruptions caused by high prices. Again, this can only be achieved with a massive deployment of renewables.

There is a clear understanding on the role of wind in the race to reach the Paris Agreement goal of 1.5°C global warming. GWEC is playing an important role in supporting the development of the wind industry around the world, and this report shows we are moving in the right direction, but there is still a way to go to reach the path of zero-carbon.

I firmly believe that the transition to a carbon-neutral economy by 2050 is technologically possible, economically feasible and socially necessary. The decarbonisation of the economy is a tremendous opportunity to create wealth, generate employment and improve both the condition of the planet and people's health.

As is already well known at this point, wind is a key and strategic part of the mix to achieve a green economy. 2021 was a record year for the industry, but we need to keep moving at pace. The new report of the UN's Intergovernmental Panel on Climate Change (IPCC) stated that the Earth is already 1.1°C warmer than before industrialisation. Our response to this is still not enough; we need to push harder to achieve the goals on time.

We have always believed strongly in wind and committed to leading this part of the energy transition. Two decades ago, we were a pioneer in onshore wind energy. We have invested €120 billion in the energy transition since then, and now we are also pioneers in offshore wind. During 2021, offshore wind energy has established itself as one of our company's major growth drivers.

The wind industry is doing its part, ready and committed to step up, however permitting is the main roadblock hindering our progress. Policy barriers must be lifted. Overcoming permitting bottlenecks should be a priority by all countries and policymakers.

A massive deployment of renewables requires huge levels of investments and this requires clear and stable regulatory frameworks. Any unexpected changes on rules causes uncertainty and will result in a reduction in the appetite to

> The decarbonisation of the economy is a tremendous opportunity to create wealth, generate employment and improve both the condition of the planet and people's health.

deploy new renewable capacity. Policy is critical for the industry and needs to be consistent and progressive in its thinking.

It is also paramount to create an environment that boosts innovation to be able to harness every opportunity to unlock the full potential of wind. Technology improvements will be one of the main enablers of the energy transition. One of the key game-changers is floating offshore wind, which is ready to take off and will soon bring wind technology to dozens of new sea basins.

Together with innovation in supply, optimal grid planning and dimensioning is crucial. Investments should also be directed towards smart grids, transmission and distribution networks, as well as in energy storage, essential infrastructures for the integration of the energy in the system and bringing renewable energy to users.

Last but certainly not least, we must also work on building a strong and sustainable supply chain that will give the industry a robust platform to support expansion and the high production volumes required. Some regions are promoting local and regional supply chain hubs, sometimes linked to new opportunities at technological level. These initiatives would reduce geopolitical risk and improve energy security, as well as creating new green jobs and economic growth for those regions. This is the core that underpins the industry, and it is of extreme importance to strengthen every link of the chain, from design, to manufacturing to equipment.

Iberdrola Group seeks to create economic, social and environmental value in all its markets, and we operate with a more sustainable future in mind. Ensuring a strong co-existence with local communities and other wind power interests should remain one of the top priorities for our industry. Our desire is to promote this new model in partnership with all the players involved in the sector, so that society as a whole can share in its benefits.

A holistic approach is of the essence. The goals are shared and clear. Now, it is time to work together as an industry and focus our efforts in the same direction.

Word from the Chairman

Morten Dyrholm
Chairman, Global Wind Energy Council

If the global journey to meeting the Paris Agreement were a mountain to climb, the past months have shown that there is increasingly difficult terrain to navigate before we reach the summit.

Although political momentum to accelerate the energy transition increased over 2021, we see short-term market stagnation instead of growing markets. Permitting bottlenecks around the world are still limiting the build-up of a net-zero compatible project pipeline. And while auctions incentivise decreasing bid levels, the wind industry needs to cope with skyrocketing raw material and transport prices, supply chain disruptions and protectionist trade measures, leaving wind turbine manufacturers and their supply chain squeezed up- and downstream.

By removing permitting bottlenecks, drastically scaling up renewable energy build-out, expanding power grids and incentivising flexibility solutions on the supply and demand side (e.g. storage, demand-side management), governments will reap another, often overlooked, benefit of the energy transition: enhanced energy security. Wind and sunshine don't cost anything, and nations that embrace renewables as the backbone of their energy systems will be protected from the price swings of volatile fossil fuels.

Energy security has become a critical issue alongside the climate crisis. Energy systems built on the foundation of wind and solar are not only critical to cut greenhouse gas emissions, they are necessary to ensure our resilience against the heightening volatility around fossil fuels, and to the uncertainty stirred by geopolitical conflicts. As these uncertainties become more complex, governments around the world would be advised to respond by accelerating the energy transition and not by slowing it down, thereby increasing planetary and societal return on investment.

To unlock wind energy's next era of growth, GWEC's role is becoming more important than ever. Our growing industry alliance across GWEC will be an asset in driving progress.

With wind and solar delivering 9% and 3% of our world's electricity, and electricity making up just 20% of global total final energy consumption, the challenge ahead of us is significant - but so are the opportunities. Let's embrace these. Let's partner with stakeholders across the global energy system to unlock the value creation of the clean energy transition. Let's step up our involvement in key topics such as removing permitting bottlenecks, resilient supply chains, market re-design, power system flexibility and electrification. And let's continue to deliver on our sustainability ambitions. Seizing these engagement opportunities is the only way to ensure we are building a brighter future for generations to come.

At GWEC, we are committed to supporting our industry through the imminent obstacles, and ensuring we are ready for the prosperous future ahead. I look forward to this transformation.

Welcome to the Global Wind Report 2022

Taking decisive action to put the energy transition on track and ensure energy security

Welcome to the Global Wind Report 2022. As I write this foreword, the world is facing an unprecedented challenge to energy security and the vital goals of achieving climate targets and averting dangerous global heating.

The current global power crisis has revealed the continued dangers of depending on fossil fuels for our energy supply, while the brutal Russian invasion of Ukraine has seen entire countries held hostage to energy supply, used once again as a tool to achieve geopolitical aims.

Economies and consumers have been left exposed to record high power and fuel prices, while at the same time, 2021 saw a historic high in global CO_2 emissions, putting the goals of the Paris Agreement at risk.

As the Global Wind Report shows, 2022 was another big year for wind installations and particularly for the fast-growing offshore wind sector, with a total of 94 GW of wind installed around the world – 21 GW in offshore.

However, despite progress in policy commitments and the hopeful messages from the world's governments at COP26 – many of whom met with GWEC in Glasgow – we need to be honest: We are not currently on-track to meet the objectives of net zero by 2050 or the aims of the Paris Agreement. For wind energy alone, we should be installing four times the current level of annual installations to stay on a net zero pathway.

There is strong appetite from both the public and business to move decisively, but governments are simply not acting fast or effectively enough.

While Russia's invasion of Ukraine has exposed the starkest challenges of energy security and fossil fuel dependence, the energy crisis is global. Global coal and gas prices rose sharply throughout 2021, leading to massive price spikes and even industry shutdowns across Asia and Europe. The resulting high power prices impacted economic growth and living standards across the entire world.

It is clearer by the day that we are witnessing a colossal policy and market failure in terms of providing the necessary investment signals for the energy transition. Fossil fuel companies, including coal producers, are seeing record profits – ultimately paid for by consumers – while renewable energy companies struggle to break even or invest in new capacity. All of this makes a mockery of the collective international action promised at COP26.

The only permanent fix for the three related problems of energy security, climate change and affordability is a determined and accelerated effort to carry out the energy transition and move away from fossil fuels to renewables. Policymakers have been both too slow and too hesitant in carrying out the transition, leading to what the IEA and others have referred to as a "disorderly transition," where the world is exposed to extreme fossil fuel volatility.

Ben Backwell
CEO, Global Wind Energy Council

The only permanent fix for the three related problems of energy security, climate change and affordability is a determined and accelerated effort to carry out the energy transition and move away from fossil fuels to renewables.

Unfortunately, the effects of the current crisis will be with us for several years at least. However, we can take decisive actions now that will immediately improve the situation, while avoiding policy decisions which further lock us into fossil fuel dependency and risk even worse crises in the future. Taking urgent action to accelerate the deployment of renewables will start to ease economic pain, lower costs and put us on a net zero pathway.

The wind industry is a key resource which will help the world to find a practical way out of the current mess. There are literally terawatts (TW) of "shovel-ready" projects that would lessen dependence on fossil fuels and unlock huge amounts of investment almost immediately, if governments take emergency measures to remove permitting and other administrative barriers.

Looking to the mid-term, an even bigger wave of construction and investment can be unlocked if governments come forward with simpler, more practical frameworks for market access, pricing and procurement. The Global Wind Report begins to outline these recommendations, and GWEC is working with the wind industry to compile a simple set of proposals which – if adopted – will allow policymakers to quickly enable progress on the transition.

This year's report also looks further to the future to kickstart vital discussions about the emerging and evolving challenges to renewables in the energy transition, ranging from critical minerals and supply to spatial expansion, public acceptance and the threat of organised disinformation.

Working together constructively and determinedly among policymakers, community, investors and industry, we can resolve today's challenges and those that lie ahead, and play our part in moving the world to a peaceful, prosperous and sustainable future.

EXECUTIVE SUMMARY

Feng Zhao
Head of Strategy and Market Intelligence, Global Wind Energy Council

The Data: 2021 was the wind industry's second-best year

The wind industry has enjoyed its second-best year ever, with growth in 2021 only 1.8% behind a record 2020. Almost 94 GW of capacity was added, despite a second year of the COVID-19 pandemic. This is a clear sign of the incredible resilience and upward trajectory of the global wind industry.

Market status

The 93.6 GW of new installations in 2021 brings global cumulative wind power capacity to 837 GW, showing year-over-year (YoY) growth of 12%.

The onshore wind market added 72.5 GW worldwide. That is 18% lower than the previous year due to a slowdown in China and the US, the world's two largest wind markets. However, there was record-high growth in Europe, Latin America and Africa & the Middle East, where new onshore installations increased by 19%, 27% and 120%, respectively.

In China, the termination of the Feed-in-Tariff (FiT) led to a 39% drop in installations to 30.7GW as the market caught its breath following a rush to install within the FiT environment. In the United States, a 25% decline to 12.7GW was mainly due to COVID-19-associated supply chain issues and disruptions.

Onshore wind additions in Asia-Pacific and North America have decreased by 31% and 21% compared to the enormous growth rates seen in 2020, but the two regions combined still made up more than two-thirds of global onshore wind installations in 2021.

The offshore wind market enjoyed its best ever year in 2021, with 21.1GW commissioned. That represents three times more than the previous year. New offshore installations represented 22.5% of all new installations last year, helping bring the world's total offshore capacity to 57GW, which is 7% of global installations.

Almost 94 GW of capacity was added, despite a second year of the COVID-19 pandemic. This is a clear sign of the incredible resilience and upward trajectory of the global wind industry.

China contributed 80% of that offshore growth, the fourth year that China has led the way in new installations. Once again, an FiT cutoff at the start of 2022 drove this growth – a situation replicated in Vietnam, where 779 MW of intertidal (nearshore) projects were commissioned – making it the third -largest market for offshore installations in 2021.

Europe is the only other region to

report new offshore wind installations last year, driven by a record year for the UK, where more than 2.3 GW was connected to the grid. Even though the UK relinquished its title as the world's largest offshore market to China, it leads the way with floating offshore wind, with 57 MW installed last year, bringing total capacity to 139 MW.

Market dynamics

The wind industry is continuing to manage disruptions from COVID-19. Sky-high freight costs and increasing commodity prices last year further squeezed the margins from turbine and component suppliers and developers, which were already under price pressure as the result of market design that has created "race to bottom" conditions.

Uncertainty around COVID-19 may have slowed down project commissioning in markets such as the US, India and Taiwan, but auction activities in 2021 demonstrate the desire to continue wind's growth around the world. Auctioned capacity was up 153% on 2020, with 88 GW awarded globally. Onshore wind makes up 69 GW (78%) of that, with offshore counting for 19 GW.

China played a leading role by awarding a total of 52 GW wind capacity in 2021, of which 49.2 GW are onshore "grid parity projects", demonstrating that wind power is economically competitive and the country is on-track to reach its ambitious "30-60" targets.

In Europe, the picture was more mixed with the reality of permitting and regulation-associated challenges showing in auction results. Procurement was undersubscribed in key markets including Germany, Italy and Poland, with only 10 GW of the 20 GW of new onshore capacity put to auction being awarded. Offshore wind brings Europe to 18.1 GW in 2021, but it is simply not enough volume, considering that the EU needs 32 GW of new wind capacity each year until 2030 to reach its carbon neutrality target by 2050.

The effect of clear policy direction was shown in the US, where 2021 was a record year for offshore wind solicitation. Four states awarded 8.4 GW, reflecting a strong desire to deliver on President Biden's target of 30 GW offshore wind by 2030.

In Latin America, less than 1 GW of wind power was awarded through public auctions last year as a result of policy barriers and COVID-19 related issues in key markets. However, the cost-competitiveness of wind energy has enabled private auctions and bilateral PPAs to gain popularity in this region, and helped Brazil to achieve a record year with nearly 4 GW in new installations in 2021.

Floating offshore wind has the potential to expand rapidly to deliver the capacity the world needs, and 2021 witnessed further breakthroughs into the sector from oil and gas majors. Large European oil and gas companies won offshore wind project auctions in Europe and North America, and won seabed leasing tenders on either side of the Atlantic Ocean. These companies have unparalleled offshore engineering skills and financial strengths which will take floating wind from the current demonstration stage into full commercialisation by the middle of this decade.

Last year was also the year carbon neutrality went mainstream. National net zero targets set by November 2021 covered more than 80% of global GDP and 77%

1. https://www.ox.ac.uk/news/2021-11-01-80-world-economy-now-aiming-net-zero-not-all-pledges-are-equal

of global greenhouse gases (GHG).[1] But these ambitions won't be delivered without clear plans: Countries which have strong targets and clear plans to deliver net zero only cover 10% of global GDP and 5% of GHG emissions.

Market outlook

Commitment to Net zero gathered global momentum at COP26 in Glasgow. Wind power is poised to play a vital role in accelerating the global energy transition. Coupled with growing energy security concerns triggered by Russia's invasion of Ukraine, the mid-term outlook for wind energy is positive.

The CAGR for the next five years under current policies is forecast as 6.6%. GWEC Market Intelligence expects that 557 GW of new capacity will be added in the next five years – that equates to more than 110 GW of new installations each year until 2026.

The CAGR for onshore wind in the next five years is 6.1%, with average annual installations of 93.3 GW. In total, 466 GW is likely to be built in 2022-2026. The CAGR for offshore wind in the next five year is 8.3%.

The annual global offshore market is expected to grow from 21.1 GW in 2021 to 31.4 GW in 2026 under current policies, bringing its share of global new installations from today's 22.5% to 24.4% by 2026. In total, more than 90 GW of offshore capacity is expected to be added worldwide from 2022-2026.

Despite two years of enormous numbers, the current rate of wind growth is simply not rapid enough to allow the world to reach its Paris Agreement targets or a net zero by 2050 goal. It is important to emphasise that the energy policy environment is in flux and GWEC expects a wave of new policy initiatives to address the gap between current installation rates and the trajectory needed to achieve net zero and energy security.

Given the energy system reform packages underway in Europe and other regions, in light of the Ukraine crisis as of Q2 2022, GWEC Market Intelligence notes that its five-year forecast could be significantly revised upward this year. But policymakers must accelerate permitting procedures for wind projects in the near term and initiate structural market design changes in the mid-term to enable an acceleration in renewable energy deployment.

The Story: Wind energy's next era of growth

Joyce Lee
Head of Policy and Projects,
Global Wind Energy Council

In 2021, the wind industry continued its global expansion. We reached new shores and seabeds, and installed more than three times the volume of offshore wind compared to 2020. We were at the heart of international climate negotiations both leading up to and during COP26, as governments and institutions increasingly recognised the central role of wind energy in achieving our Paris Agreement goal of 1.5°C global warming by 2100.

However, we are collectively falling behind in our climate action goals. The first instalment of the Intergovernmental Panel on Climate Change's (IPCC) AR6 report, provides a reality check: Without immediate, rapid and large-scale reductions to greenhouse gas (GHG) emissions in this decade, limiting global warming to close to 1.5°C or even 2°C will be beyond reach.

Russia's invasion of Ukraine in February 2022 provided another clear message to governments: Dependency on imported fossil fuels is not only dangerous for environmental and human health, but a grave threat to geopolitical and energy security.

Wind energy is not growing nearly fast or widely enough to realise a secure and resilient global energy transition. At current rates of installation, GWEC Market Intelligence forecasts that by 2030 we will have less than two-thirds of the wind energy capacity required for a 1.5°C and net zero pathway, effectively condemning us to miss our climate goals.[2]

This year's Global Wind Report examines the full challenges of scaling up wind energy in an increasingly interconnected world. As the industry gains scale and mass, its impacts will reverberate in the political, socioeconomic and environmental settings in which it operates. As it grows, the industry will confront old and new frontiers like supply chain geopolitics, social impacts, disinformation, cybersecurity and cryptocurrencies.

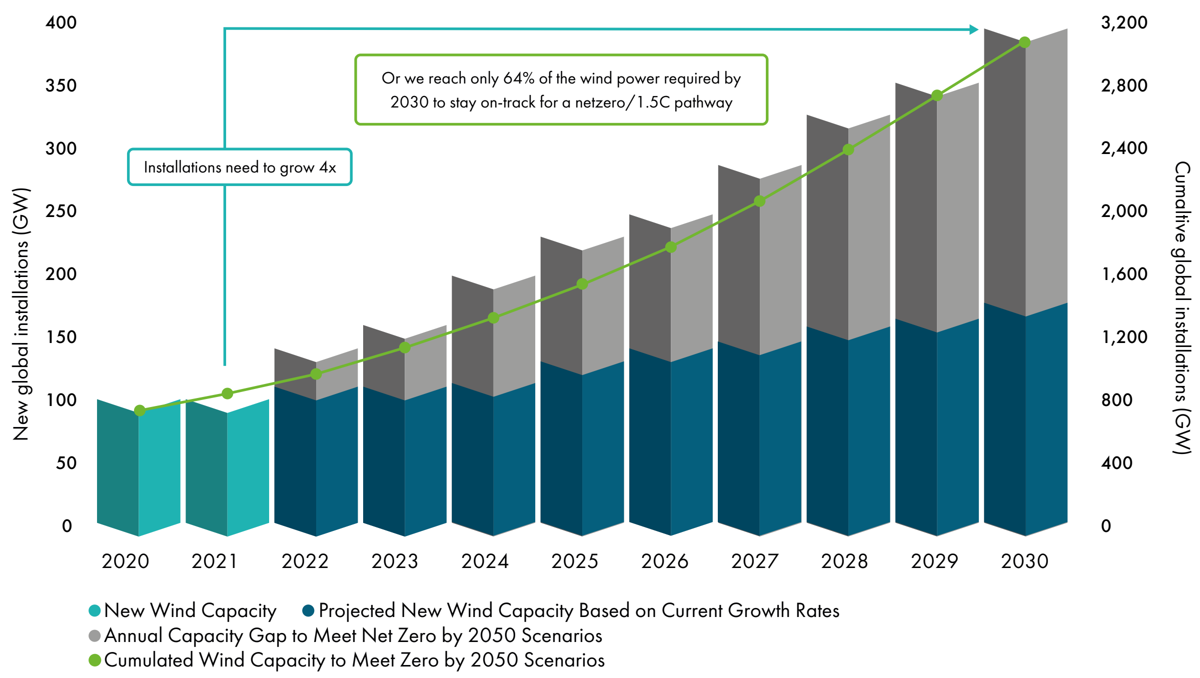
Wind energy's role as a protagonist of the energy transition will depend on ensuring the industry's growth is sustainable, just and socially responsible, while resting on a clear and viable economic proposition.

We can already see a landscape of challenges ahead, both in the short term and beyond 2030. Evolving events, like the global reverberations of Russia's invasion of Ukraine, will also impact the growth trajectory for wind energy. In some countries, the crisis has intensified pressure to switch to renewables and decrease dependency on - mostly Russian - natural gas, while in other countries it has revived calls for shale gas extraction and nuclear power.

The long-term effect these challenges have on wind energy's growth depends on how prepared the industry is to meet them. The industry could suffer the casualties of boom-bust cycles and

The IEA Net Zero by 2050 Roadmap sets out a global electricity generation mix of wind (35%), solar (33%), hydropower (12%), nuclear (8%), bioenergy (5%), hydrogen-based (2%) and fossil fuels with carbon capture utilisation and storage (2%). The IRENA World Energy Transitions Outlook: 1.5° Pathway report sets out a global electricity mix of two-thirds wind and solar (comprising 8,174 GW of wind and 14,878 GW of solar by 2050, with wind generating a slightly higher overall share of global electricity) and the remainder comprising hydropower, bioenergy, geothermal, tidal/wave and hydrogen-based generation.

Lagging growth in this decade leads to wind energy shortfalls by 2030



Source: GWEC Market Intelligence; IEA Net Zero by 2050 Roadmap (2021). Projected new wind capacity from 2026-2030 assumes a ~6.6-7.0% CAGR, based on GWEC's projected CAGR from 2021-2026. It also accounts for ~34 GW in global decommissioned capacity from 2026-2030 based on 25-year turbine lifetime. Capacity gap figures are estimations based on the IEA Roadmap milestone for 2030. Cumulative global installations for wind energy are roughly in alignment with the IRENA World Energy Transitions Outlook: 1.5°C Pathway (2021). This data represents new capacity, cumulative capacity and decommissioned capacity, and does not include an estimate of repowering installations to replace the ~34 GW in decommissioned turbines globally.

disorderly system transformation. Or a stronger and more sustainable industry could emerge from holistic system planning, supply chain transformation and positive community engagement.

Here are 10 takeaways from this year's Global Wind Report to ensure that wind energy can achieve sustainable and unprecedented growth in the three decades ahead to 2050:

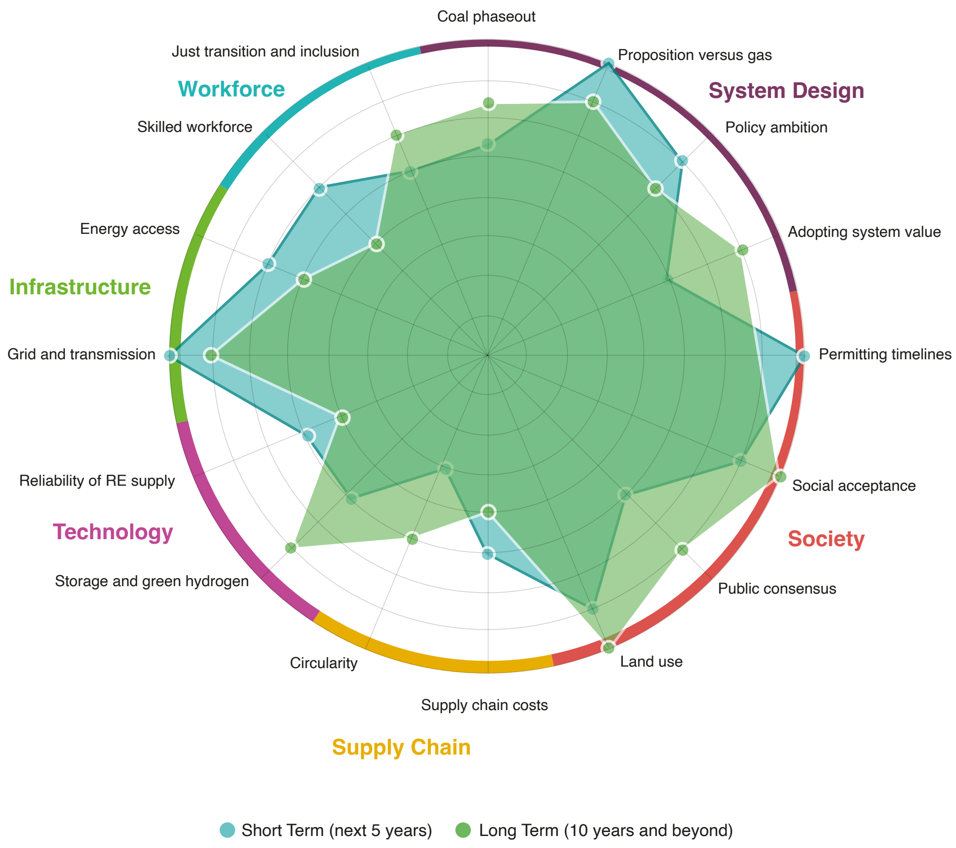
1. Scaling up to 2030: We need to scale up annual wind energy installations by four times in this decade to get on-track for a 1.5°C world. The global clean energy transition is in everyone's self-interest and will bring net-positive socioeconomic value.

2. The energy system is increasingly complex and interconnected: Energy remains at the epicentre of geopolitics. Trust and cooperation between countries and communities will be ever more important for an effective response to climate change. If countries and communities work against each other, the transition to clean energy will be slow and disorderly.

3. System design is struggling to meet the pressures of the transition: The current energy crisis is the consequence of energy markets built around fossil fuels. Governments and regulators must tackle the enormous demands of energy market reform to increase security of supply, support sustainable pricing for renewable energy generation and develop more flexible and resilient energy systems.

4. The wind industry faces higher costs amid perverse market design: Auctions are leading to a "race to the bottom" in cost, heaping financial pressure on developers and the wind supply chain. Current energy systems are disincentivising investment in the wind business. Policymakers need to reevaluate markets to align with economic and social objectives

Transversal challenges to wind energy's growth in the short and long term



Short term (within next 5 years) and long term (more than 10 years ahead) challenges which could slow down deployment of wind energy. Nodes closer to the outer circle are considered more severe challenges, while nodes closer to the centre are considered low or moderate challenges

System Design

Coal phaseout: The pace of countries exiting and retiring coal-based generation.

Proposition versus gas: The enabling policy environment for wind energy versus natural gas/LNG, based on market and socioeconomic value.

Policy ambition: The visibility and predictability of countries' wind energy growth targets, and the reflection in transparent and long-term procurement schemes.

Adopting system value: The shift away from marginal value-based electricity markets towards a system value framework.

Society

Permitting timelines: The ease of obtaining the necessary permits, licenses and approvals for wind project deployment, including legal challenges.

Social acceptance: The scale of support versus opposition encountered by wind projects in host communities.

Public consensus: Public education and awareness about climate change and the needs of the energy transition, and the resulting social and political support for wind energy.

Land use: Availability of land and seabed for wind energy projects.

Supply Chain

Supply chain costs: The rise and certainty of market prices for materials, minerals, metals and other inputs to the wind energy supply chain.

Circularity: The reuse, repurposing, recyclability and recovery of wind farm components including wind turbines, and the reduction of waste and environmental impacts generated in the wind project lifecycle in line with a circular economy approach.

Technology

Storage and green hydrogen: The pace of cost reduction and commercialisation of enabling storage and green hydrogen technologies, which will boost demand for wind energy.

Reliability of RE supply: The pace of cost reduction and integration of enabling balancing and flexibility technologies, such as demand-side response tools, which will enable large-scale integration of wind energy.

Infrastructure

Grid and transmission: The pace and scale of grid reinforcement, buildout and modernisation, ensuring sufficient grid availability to increase wind deployment.

Energy access: The expansion of infrastructure to enable universal clean energy access and electrification of power and other sectors.

Workforce

Skilled workforce: The availability of a ready and able workforce with the necessary training and skills for the wind industry.

Just transition and inclusion: The socioeconomic welfare of stakeholders concerned with the energy transition, and the development of a diverse and inclusive workforce which can harness all talents to grow the wind industry.

Sources: GWEC Market Intelligence and a survey of GWEC's national wind and renewable energy industry association members, Q1 2022. Note: This graphic is not inclusive of all challenges and factors impacting the growth of wind energy in different markets, and is meant to be used as a general guide to transversal issues.

5. Wind energy must be a custodian of the energy transition: The journey to here has involved fractious debate and disinformation, blurring the boundaries of public interest. To continue building social consensus around large-scale renewables deployment, the industry must ensure that social and environmental values are synonymous with wind power.

6. Cut the red tape for a green future: Too many countries are unable to leverage the enormous interest from investors to deploy wind energy projects due to overly complex and permitting schemes. Without streamlining the procedures to grant permits, including land allocation and grid connection, there will be a surplus of projects "stuck in the pipeline."

7. Public-private cooperation is needed to confront the new geopolitics of the wind supply chain: There must be a stronger international regulatory framework to address the increased competition for commodities and critical minerals. Threats to price and supply risk must be mitigated, while materials recovery and recycling must advance.

8. The demise of baseload: Flexibility will be the chief currency of a renewables-led system, which will require greater investment in enablers like digitalisation, hybrid projects, green hydrogen and energy storage. System operators will need to develop the tools and regulatory frameworks to send accurate signals to the market.

9. Unprecedented grid investment is needed to keep pace with renewables: Infrastructure is a global challenge affecting economies of all stages of development. Electricity networks are the primary area of need for transition-enabling infrastructure. Investment in grids must treble from current levels through to 2030.

10. The wind energy industry has a primary role in a just and equitable energy transition: Workers from carbon-intensive industries can find a place in the wind industry as it grows. Social uncertainty from the transition can be mitigated with sensitive and participatory dialogue, as well as greater public-private collaboration on training and education. Workforce planning for large-scale renewables deployment should be an early policy priority.

WIND ENERGY: THE NEXT ERA OF GROWTH

Introduction

In 2021, the wind industry continued its global expansion. We reached new shores and seabeds, and achieved huge technological milestones in areas from blade sustainability to floating offshore wind models. We installed more than three times the volume of offshore wind compared to 2020 and are closing in on 850 GW of total wind installations worldwide. We were at the heart of international climate negotiations both leading up to and during COP26, as governments and institutions increasingly recognised the central role of wind energy in achieving our Paris Agreement goal of 1.5°C global warming by 2100.

And yet, we are collectively falling behind in our climate action goals. The first instalment of the Intergovernmental Panel on Climate Change's (IPCC) AR6 report, published in 2021, provided a reality check from the global scientific community: Without immediate, rapid and large-scale reductions to greenhouse gas (GHG) emissions in this decade, limiting global warming to close to 1.5°C or even 2°C will be beyond reach.

Russia's invasion of Ukraine in February 2022 provided a second reality check to energy consumers around the world: Dependency on imported fossil fuels is not only dangerous for environmental and human health, but a grave threat to geopolitical and energy security.

In the International Renewable Energy Agency (IRENA) and International Energy Agency (IEA) roadmaps for a 1.5°C pathway published last year, wind energy becomes a central pillar of the global energy system by 2050, with more than 8,000 GW of wind capacity generating more electricity than any other energy source.[1] These roadmaps put us on-track to reach global carbon neutrality by 2050, under measures for widescale electrification, energy efficiency, grid and green infrastructure buildout and renewable energy deployment.

> At current rates of installation, we will have less than two-thirds of the wind energy capacity required by 2030 for a 1.5°C and net zero pathway.

But wind energy is not growing nearly fast or widely enough to realise this future. **At current rates of installation, GWEC Market Intelligence forecasts that by 2030 we will have less than two-thirds of the wind energy capacity required for a 1.5°C and net zero pathway, effectively condemning us to miss our climate goals.** Without drastic action to scale up wind energy installations, the industrial footprint of wind energy

1. The IEA Net Zero by 2050 Roadmap sets out a global electricity generation mix of wind (35%), solar (33%), hydropower (12%), nuclear (8%), bioenergy (5%), hydrogen-based (2%) and fossil fuels with carbon capture utilisation and storage (2%). The IRENA World Energy Transitions Outlook: 1.5° Pathway report sets out a global electricity mix of two-thirds wind and solar (comprising 8,174 GW of wind and 14,878 GW of solar by 2050, with wind generating a slightly higher overall share of global electricity) and the remainder comprising hydropower, bioenergy, geothermal, tidal/wave and hydrogen-based generation.

faces critical financial pressures, and we miss the opportunity to maintain and grow a productive economic sector that employs more than 1.25 million people worldwide. Finally, we will also fail to decarbonise the power, industry, transport, heating and other sectors, and significantly expand green hydrogen production.

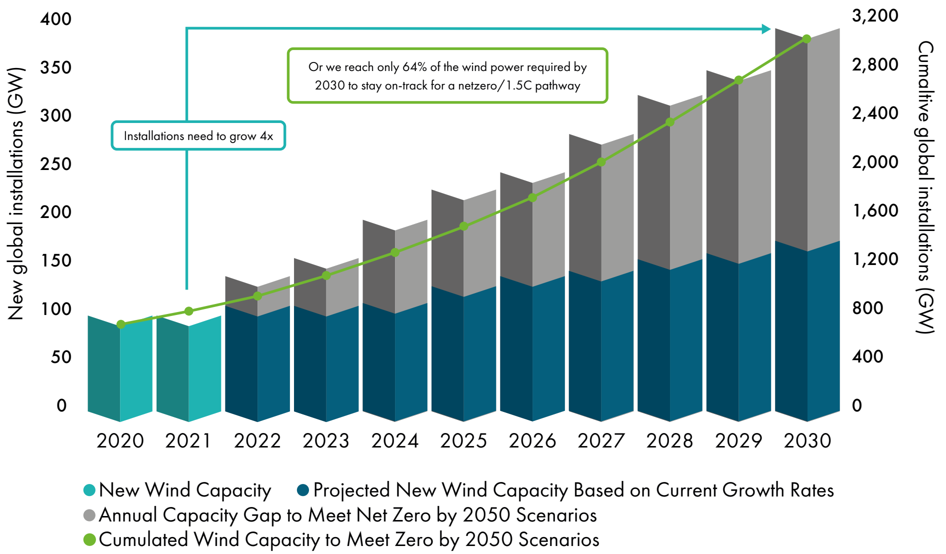
Wind energy installations worldwide must quadruple from the 94 GW installed in 2021 within this decade to meet our 2050 goals. The longer we delay this dramatic scale-up of growth, the more challenging it will be to meet our targets.

In the current environment, there is much work to do to ensure that action to implement the clean energy transition keeps pace with climate targets. Even with full implementation of all countries' submitted Nationally Determined Contributions (NDC) to 2030 under the Paris Agreement as of November 2021, the world is on-track for a 2.4°C global temperature increase.[2] If we factor in full achievement of longer-term net zero pledges, global warming could be limited to 2.1°C – this scenario is closer to our Paris Agreement goal, and will require unprecedented rates of renewable energy deployment and action to lower barriers to growth. Full compliance will the Paris goals will require even more decisive action.

As outlined in this report, the experience of wind energy's global expansion to date has already shown some of the challenges to growth: inconsistent policy environments focused on short-term political aims; badly designed markets which do not enable bankable renewable energy projects; infrastructure and transmission bottlenecks; a lack of adequate industrial and trade policies related to renewable technologies; and hostile political or misinformation campaigns. All these factors have led to underperforming or stop-go growth across many areas of the world. These lessons must be taken to heart, so that wind energy can continue to scale up in the three decades ahead to 2050, delivering its role in mitigating climate change and transforming communities for good around the world.

This year's Global Wind Report goes beyond the immediate situation to examine the full challenges of scaling up wind energy in an increasingly interconnected world. As the industry gains scale and mass, its impacts will reverberate in the political, socioeconomic and

Lagging growth in this decade leads to wind energy shortfalls by 2030



Source: GWEC Market Intelligence; IEA Net Zero by 2050 Roadmap (2021). Projected new wind capacity from 2026-2030 assumes a ~6.6-7.0% CAGR, based on GWEC's projected CAGR from 2021-2026. It also accounts for ~34 GW in global decommissioned capacity from 2026-2030 based on 25-year turbine lifetime. Capacity gap figures are estimations based on the IEA Roadmap milestone for 2030. Cumulative global installations for wind energy are roughly in alignment with the IRENA World Energy Transitions Outlook: 1.5°C Pathway (2021). This data represents new capacity, cumulative capacity and decommissioned capacity, and does not include an estimate of repowering installations to replace the ~34 GW in decommissioned turbines globally.

2. https://climateactiontracker.org/global/cat-thermometer/. Climate Action Tracker further notes that the effect of net zero emissions targets adopted or being discussed in more than 140 countries could limit warming to as low as 1.8°C by 2100; as this scenario includes non-binding and unratified targets, it is not included in the main body of this report.

environmental settings in which it operates. These impacts will be nonlinear, as the industry confronts old and new frontiers like supply chain geopolitics, social impacts, disinformation, cybersecurity and cryptocurrencies.[3]

Evolving events, like the sweeping international sanctions applied to Russian entities after Russia's invasion of Ukraine, will also impact the growth trajectory for wind energy. In some countries, the crisis has intensified pressure to switch to renewables and decrease dependency on (Russian) natural gas, while in other countries it has revived calls for shale gas extraction and nuclear power.

We can already discern a landscape of challenges, both in the short term and beyond 2030, which could inhibit the growth of wind. These range from: a slow fossil fuels phaseout which inhibits renewables acceleration; investment imbalances that generate crises like the current power price spikes in Europe and Asia; perverse price signals and market design which challenge supply chain financial sustainability; the spatial impact of the industry on land and at sea, and social and political consensus to occupation of space by wind energy; supply chain resource impacts on economics and on natural environments; the need for industry materials circularity; market readiness of enabling technology for renewables penetration; buildout of grid and other infrastructure; and availability of a trained workforce, among others.

The impact of these challenges on wind energy's growth will depend on how well prepared the industry is to meet them. A stronger and more sustainable industry could emerge from holistic system planning, supply chain transformation and positive community engagement, spurred by a fundamental redistribution of burdens and benefits across the wind value chain and wider energy system. Or the industry could suffer the casualties of boom-bust cycles and disorderly system transformation.

Wind energy's role as a protagonist of the energy transition – a far-reaching shift in how the world produces and consumes – will depend on ensuring the industry's growth paradigm is sustainable, just and socially responsible, while resting on a clear and viable economic proposition.

Wind energy in a changing world

We have set the destination: Scaling up annual wind energy installations by four times in this decade to get on-track for a 1.5°C world. The global clean energy transition is in everyone's self-interest and will bring net-positive socioeconomic value.[4] But the landscape of actors and dependencies on this journey is vast and profound, forcing us to look beyond long-term forecasting based on ceteris paribus assumptions.

The physical assets to support the next era of wind demand monumental investment: grid and transmission buildout; electrification measures, including in sectors like transport and industry; energy efficiency; power system modernisation; large-scale commercialisation of electrolysers for green hydrogen, with resulting cost reductions; utility-scale storage solutions; interconnections which support response from the demand side; and last but not least, logistical infrastructure like highways, ports and charging stations, among others.

IRENA estimates that annual transition-related investment in the energy system must increase by 2.7 times in this decade, from $2.1 trillion in 2019 to $5.69 trillion each year to 2030; the IEA forecasts around $4 trillion each year to 2030 is required for clean energy investment.[5]

These investments will boost global economic growth, while helping to avoid the costs of adapting to and compensating for

3. Technological advances can have unforeseen consequences on the speed and stakes of the energy transition. For instance, Bitcoin mining now accounts for 0.4% of the world's energy consumption, using more electricity in a year than Belgium, according to the Cambridge Bitcoin Electricity Consumption index. Miners in China have an outsize impact due to reliance on coal-powered generation.

4. A 1.5°C pathway would increase GDP growth by 2.4% within the decade to 2030, compared to current policies, and global economy-wide employment would be 1.4% higher than average, translating to 26 million additional jobs. See: World Energy Transitions Outlook: 1.5°C Pathway, IRENA, 2021.

5. IRENA (2021), World Energy Transitions Outlook: 1.5°C Pathway, International Renewable Energy Agency, Abu Dhabi. IEA (2021), World Energy Outlook 2021, IEA, Paris.

unfettered climate change. Continued global economic growth will benefit the expansion of renewable energy, with more resources and investment available for transition-enabling technology, infrastructure and systems.

But as global GDP increases,[6] the world is not necessarily growing wealthier. Extraordinary challenges have exposed inequality and disparities between countries, from the COVID-19 pandemic to spatial competition. Major natural disasters linked to climate change are now a volatile threat to emerging markets and developing economies (EMDEs). **The modes of trust and cooperation between countries and communities will become ever more important for an effective shared response to climate change.**

We are in an age where energy is at the epicentre of geopolitics, and renewables are equated with freedom. If countries and communities work against each other on matters like job creation, critical economic sectors, climate policy and integration of renewable energy, the transition to clean energy will be slow and "disorderly," as some analysts have labelled it.[7] Areas which resist adapting to the transition will lose competitive advantage, and be less resilient to shifts in capital flows. Those who do actively invest in the transition must carefully manage disruption to livelihoods to maintain social cohesion. Poorly regulated power markets could create trading monopolies or devalue the cost of carbon, while geopolitical conflict could impact global supply chain security and grid integration.

The march for clean energy has been called "unstoppable." This rhetoric is marked by the historic agreement on phasing out coal and inefficient fossil fuel subsidies in the Glasgow Climate Pact in November 2021.[8] But after two tough years confronting a pandemic, to a great extent, the world appears to be getting back to "business as usual" (BAU) when it comes to energy.

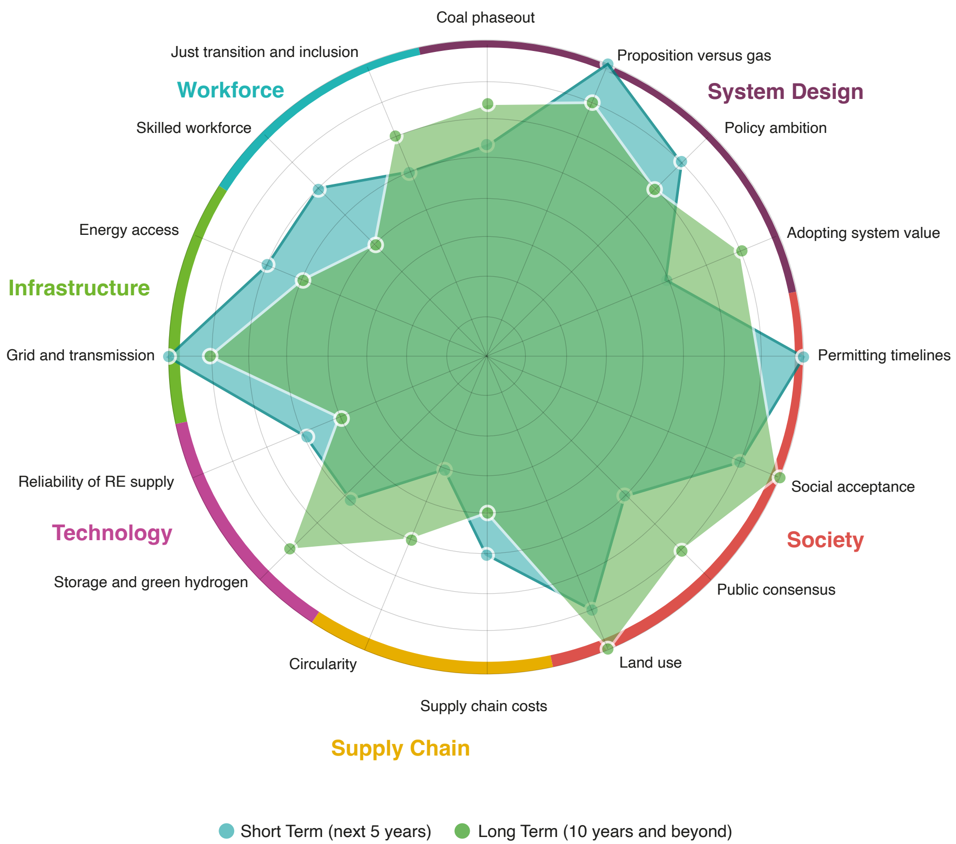
The global economy is still heavily dependent on fossil fuels. Global concentrations of CO2 in the atmosphere rose faster in 2020 than in the entire last decade, and increased further through 2021.[9] The last five years (2017-2021) saw the hottest average surface temperatures on record in large parts of North Africa, the Middle East, East Asia, the eastern United States (US) and Latin America.[10] Despite its dimming economics, coal is not yet out the door, and is not leaving soon enough. Coal power generation reached a record-high in 2021, riding the rebound of economic recovery, and coal demand is set to achieve an all-time high from 2022 to 2024.[11]

With such high stakes, we cannot afford the future of renewable energy to be left on auto-pilot. The energy transition calls for a hard look at some of the historical practices which have damaged the reputation of the wider energy sector – runaway growth at high cost to the environment and human health, procurement practices which are not always equitable or transparent, and misinformation campaigns which breed public distrust, to name a few. These practices have eroded social consensus around energy system priorities, and where space is needed for renewables to grow, they have sometimes set the stage for false dichotomies between the public interest and that of industry.

We will have to prepare to overcome these hurdles on the path to a 1.5°C world and on the Race to Zero.[12] The sooner we can acknowledge and address the known and unknown challenges of the wind industry's growth, the clearer our pathway ahead.

6. The IMF World Economic Outlook forecasts real GDP growth increase of 4.4% in 2022 and 3.8% in 2023, with higher growth in emerging markets and developing economies. https://www.imf.org/en/Publications/WEO/Issues/2022/01/25/world-economic-outlook-update-january-2022
7. https://www.weforum.org/reports/global-risks-report-2022/shareables; https://www.mckinsey.com/business-functions/sustainability/our-insights/the-economic-transformation-what-would-change-in-the-net-zero-transition
8. https://gwec.net/cop26-a-wind-industry-score-sheet/
9. https://public.wmo.int/en/media/press-release/greenhouse-gas-bulletin-another-year-another-record. It is worth noting that inertia in climate systems means that global warming and the resulting impacts will continue for some time, even after reaching net zero emissions (see: https://www.carbonbrief.org/explainer-will-global-warming-stop-as-soon-as-net-zero-emissions-are-reached).
10. https://public.wmo.int/en/resources/united_in_science
11. https://www.iea.org/news/coal-power-s-sharp-rebound-is-taking-it-to-a-new-record-in-2021-threatening-net-zero-goals
12. The IPCC defines net zero emissions, or carbon neutrality, as "achieved when anthropogenic emissions of greenhouse gases to the atmosphere are balanced by anthropogenic removals over a specified period." https://www.ipcc.ch/sr15/chapter/glossary/

Transversal challenges to wind energy's growth in the short and long term



Short term (within next 5 years) and long term (more than 10 years ahead) challenges which could slow down deployment of wind energy. Nodes closer to the outer circle are considered more severe challenges, while nodes closer to the centre are considered low or moderate challenges

System Design	**Coal phaseout:** The pace of countries exiting and retiring coal-based generation.
	Proposition versus gas: The enabling policy environment for wind energy versus natural gas/LNG, based on market and socioeconomic value.
	Policy ambition: The visibility and predictability of countries' wind energy growth targets, and the reflection in transparent and long-term procurement schemes.
	Adopting system value: The shift away from marginal value-based electricity markets towards a system value framework.
Society	**Permitting timelines:** The ease of obtaining the necessary permits, licenses and approvals for wind project deployment, including legal challenges.
	Social acceptance: The scale of support versus opposition encountered by wind projects in host communities.
	Public consensus: Public education and awareness about climate change and the needs of the energy transition, and the resulting social and political support for wind energy.
	Land use: Availability of land and seabed for wind energy projects.
Supply Chain	**Supply chain costs:** The rise and certainty of market prices for materials, minerals, metals and other inputs to the wind energy supply chain.
	Circularity: The reuse, repurposing, recyclability and recovery of wind farm components including wind turbines, and the reduction of waste and environmental impacts generated in the wind project lifecycle in line with a circular economy approach.
Technology	**Storage and green hydrogen:** The pace of cost reduction and commercialisation of enabling storage and green hydrogen technologies, which will boost demand for wind energy.
	Reliability of RE supply: The pace of cost reduction and integration of enabling balancing and flexibility technologies, such as demand-side response tools, which will enable large-scale integration of wind energy.
Infrastructure	**Grid and transmission:** The pace and scale of grid reinforcement, buildout and modernisation, ensuring sufficient grid availability to increase wind deployment.
	Energy access: The expansion of infrastructure to enable universal clean energy access and electrification of power and other sectors.
Workforce	**Skilled workforce:** The availability of a ready and able workforce with the necessary training and skills for the wind industry.
	Just transition and inclusion: The socioeconomic welfare of stakeholders concerned with the energy transition, and the development of a diverse and inclusive workforce which can harness all talents to grow the wind industry.

Sources: GWEC Market Intelligence and a survey of GWEC's national wind and renewable energy industry association members, Q1 2022. Note: This graphic is not inclusive of all challenges and factors impacting the growth of wind energy in different markets, and is meant to be used as a general guide to transversal issues.

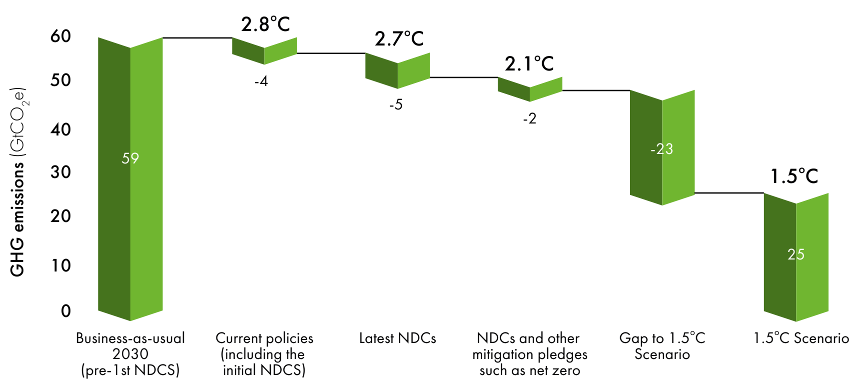
PART ONE: SYSTEM DESIGN

Part One: System Design

Following the darkest periods of COVID-19 in 2020 and the first half of 2021, economies are re-opening and global energy demand is on the rebound. The temporary curtailment of global CO2 emissions was reversed by the end of 2021, driven by a surge in coal and gas generation.[1] Worldwide oil consumption is set to return to pre-pandemic levels, while natural gas consumption bounced back nearly 5% last year.

On this road to economic recovery, have we learned any lessons about decarbonising the global energy system? The global community has certainly reached a consensus on what needs to happen: By the end of COP26, all 197 Parties to the Paris Agreement agreed on a call to "rapidly scale up clean power generation and accelerate efforts towards the phasedown of unabated coal power and phase-out of inefficient fossil fuel subsidies."[2]

Contribution of NDCs and other pledges to limiting global warming, as of November 2021



Sources: IRENA (2022), NDCs and renewable energy targets in 2021: Are we on the right path to a climate-safe future?, International Renewable Energy Agency, Abu Dhabi. The main data used in this analysis comes from UNEP (2021) except the 'Pre-1st NDC' estimate of 59 $GtCO_2e$ which was sourced from (WRI, 2021a) also based on analysis from UNEP (2021a) and Climate Watch. Although the data and methodologies tends to vary in some aspects across different sources, the overarching message in all remains consistent.

But there is a dramatic mismatch between clean energy targets in NDCs and national energy policies; according to IRENA, energy policy in 178 countries is insufficient to achieve their respective NDCs.[3] There is a clear gap between words and action, as NDCs themselves are non-binding pledges – national and sub-national policy implementation is urgently required to enact the energy transition.

Course corrections are not happening with the urgency required to stave off the risks of a continued fossil fuel-based global energy system, which must meet the rising pressures of power demand, economic growth and electrification. The current energy crisis – where natural gas and power prices have hit all-time highs, particularly in Europe and Asia – is a consequence of an outdated system.

Gas market tightness has been driven by downtime of gas infrastructure, reduced supply from key exporters, a steep post-pandemic rise in energy demand and lower-than-usual storage levels which have decreased system flexibility.[4] As many electricity markets depend on gas as a marginal resource to determine wholesale prices, the resulting wholesale price spikes have imposed a heavy burden on all actors in these power markets, from large businesses to households.

Coal prices also spiked last year, with a resurgence in power demand driving prices up four-fold from September 2020 to August 2021.[5] This was primarily due to by a return of industrial and economic activity in coal-dependent markets

1. Global carbon emissions declined by 5.4% in 2020 due to pandemic-related impacts, but are forecast to have rebounded by 4.9% in 2021. See: https://www.globalcarbonproject.org/carbonbudget/21/files/Norway_CICERO_GCB2021.pdf.
2. https://gwec.net/cop26-a-wind-industry-score-sheet/
3. NDCs and renewable energy targets in 2021: Are we on the right path to a climate-safe future?, IRENA, 2022
4. https://www.iea.org/commentaries/europe-and-the-world-need-to-draw-the-right-lessons-from-today-s-natural-gas-crisis
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in Asia, such as China, India, Japan and South Korea, as well as in Europe and the US. Some disruptions to coal exports from Indonesia, Australia and other countries also played a part.

High power prices have depressed production in energy-intensive industries like metals and fertilisers production, further inflating prices for these commodities. Transitory inflation driven by high energy prices, and the ripple effect of price increases across sectors, especially power-intensive ones, are being felt across many economies.[6] Elevated inflation is expected to near 4% in advanced economies and 6% in EMDEs through 2022, largely due to the surge in energy prices.[7]

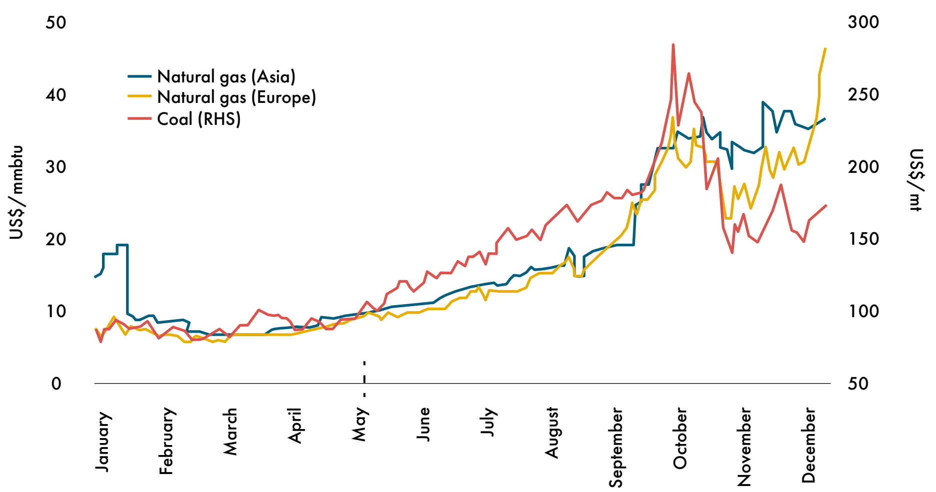
The ongoing power price surges have sharpened the call for shifting to indigenous and cost-competitive wind and solar energy. However, renewable energy developers and supply chain actors are under intensive pressure to deliver clean power at increasingly competitive prices, even in markets where utility-scale renewables are still gaining a footing. While wind companies are even paying back the difference between agreed tariffs and inflated wholesale prices to governments under a Contracts for Difference (CfD) model, or are tied into long-term fixed-price power purchase agreements (PPAs) which do not allow for price readjustments, fossil fuel generators are seeing record levels of windfall profits.

Energy market design which is based on short-term marginal costs and does not account for long-term system value has created a distorted set of signals.[8] Instead of incentivising renewables, wind and solar are now under pressure to compete at prices that lead to wafer-thin margins, while fossil fuel supply shortages are bolstering the continued investment case for fossil fuels.

Governments and regulators must untangle the Gordian knot around energy market design to shore up security of supply, support sustainable pricing and prepare for the clean energy transition. If policymakers and system planners are serious about these priorities, then energy market design must shift to reflect the systems of the future: flexible, responsive to demand, reliable and dependent on a majority share of renewable energy.

The necessary actions include: removing direct and hidden subsidies or advantages for fossil fuels generation; prioritising land/seabed allocation, procurement, construction, grid connection and dispatch for renewables-based generation; accounting for the socioeconomic and environmental costs of carbon; and realigning electricity markets to consider system value more widely. Technology innovation and scale are also necessary for supporting stability, flexibility and responsiveness as fossil fuels are phased out (see Part Four: Technology).

Demand and supply shocks in coal and natural gas



Sources: Bloomberg; World Bank. Note: Last observation is December 16, 2021.

5. https://theconversation.com/the-coal-price-has-skyrocketed-in-2021-what-does-it-mean-for-net-zero-166117
6. https://www.spglobal.com/platts/en/market-insights/latest-news/lng/090221-analysis-high-lng-prices-trigger-gas-demand-destruction-in-chinas-downstream-sectors; https://www.brookings.edu/wp-content/uploads/2021/12/FP_20211214_global_energy_crisis_gilbert_bazilian_gross.pdf
7. https://blogs.imf.org/2022/01/28/global-inflation-pressures-broadened-on-food-and-energy-price-gains/
8. A system value approach, as opposed to comparison of energy sources on Levelised Cost of Electricity (LCOE) alone, accounts for Interplay of positive (e.g. lower carbon emissions, high market value, reduced fuel costs etc.) and negative effects (e.g. additional grid infrastructure costs, re-dispatch costs/curtailment etc.) of a power generating technology on the system. See: GWEC, Global Wind Report 2019.

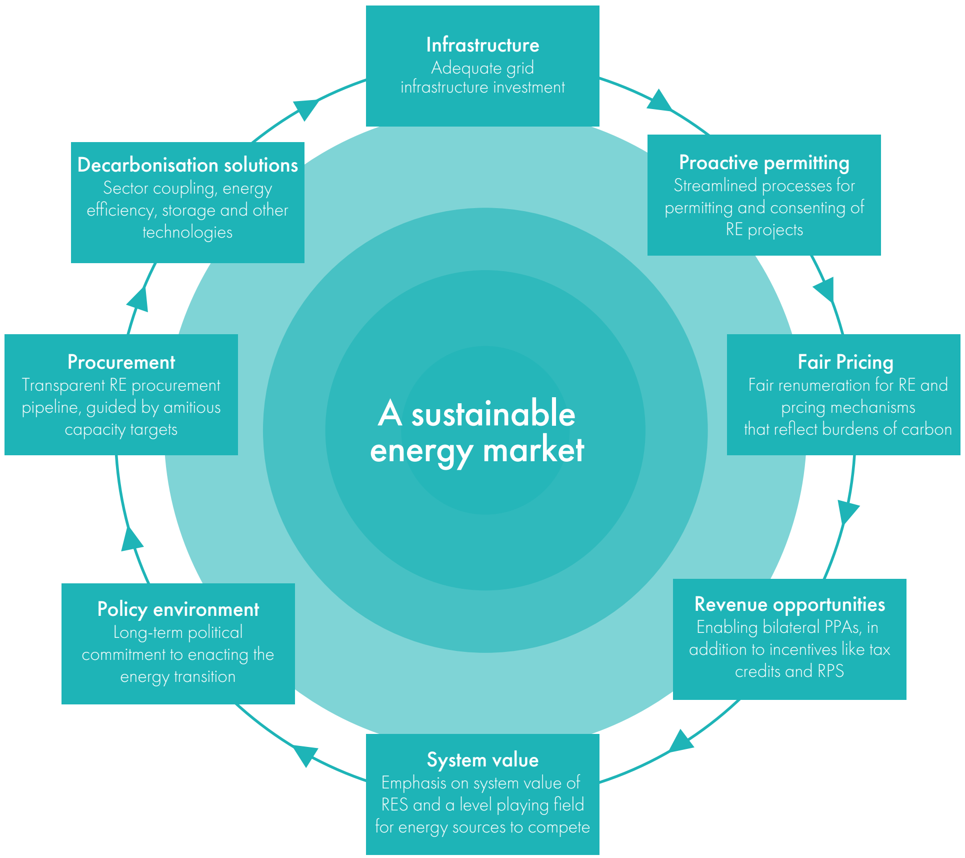
System value, a "holistic framework that evaluates economic, environmental, social, and technical outcomes of potential energy solutions," should be adopted by governments for impactful policy and cost-effective investment.[9] System value accounts for a range of factors, including the **costs** attached to externalities like carbon emissions, water footprint, impacts to human health and air quality and resilience and security of energy supply. It also addresses **investments** required in electricity access, grid flexibility, system upgrades, energy productivity and systemic efficiency. Finally, these are weighed against the economic **benefits** of jobs and positive socioeconomic impacts, and the market attractiveness for FDI and competitiveness of investment.

As volumes of wind and renewable energy increase in energy systems, this approach also highlights where investment is needed to develop more flexible and resilient energy systems, such as in grid and transmission infrastructure, digitalisation, balancing solutions and storage. The result of expanding our focus from Levelised Cost of Electricity (LCOE) to whole system value is inclusive and wide-lens decision-making for the clean energy transition.

Fossil fuels-based generation should be more accurately priced for the costly social, economic and environmental burdens attached to them. Once the impacts of externalities like climate change, human health and air pollution are factored into electricity market design and taxation systems, market signals should provide a clear pathway to a rapid replacement of fossil generation by renewables, as well as electrification of key non-power sectors. It is essential that markets are designed to enable a rapid transition to renewable energy sources like onshore and offshore wind energy, which carry the lowest quantifiable external costs to energy systems and society.[10] Inappropriate market signals not only confuse investors, but even penalise those willing to take the lead.

Systems with high shares of renewables (around half of power supply scaling up to 100%) are already in operation around the world, from Norway to Costa Rica to New Zealand. Renewables-based systems are technically and economically feasible but require robust investment and a level

Sustainable energy market design



9. https://www.weforum.org/projects/system-value#:~:text=System%20Value%20is%20a%20holistic,beyond%20cost%20to%20include%20value
10. https://trinomics.eu/wp-content/uploads/2020/11/Final-Report-External-Costs.pdf

playing field to enable large-scale renewable energy deployment. They will also require widescale electrification to ensure that renewables can displace the role of fossil fuels in powering the transport, heating and industry sectors.

Security in the age of the clean energy transition

As in the 1970s energy crisis, geopolitics and ongoing turbulence in power markets demonstrate the hazards of economies relying on finite (and for many, non-indigenous) fuel sources. Market dynamics are vulnerable to supply-side geopolitical events, externalities like pandemic-related lockdowns and adverse weather patterns.

The impacts of climate change will further impose pressure on markets, for instance with drought and La Niña weather patterns already affecting hydropower generation. Severe winter or summer periods can trigger spikes in energy demand for heating or cooling purposes, tightening supply of gas and driving up power prices once again.

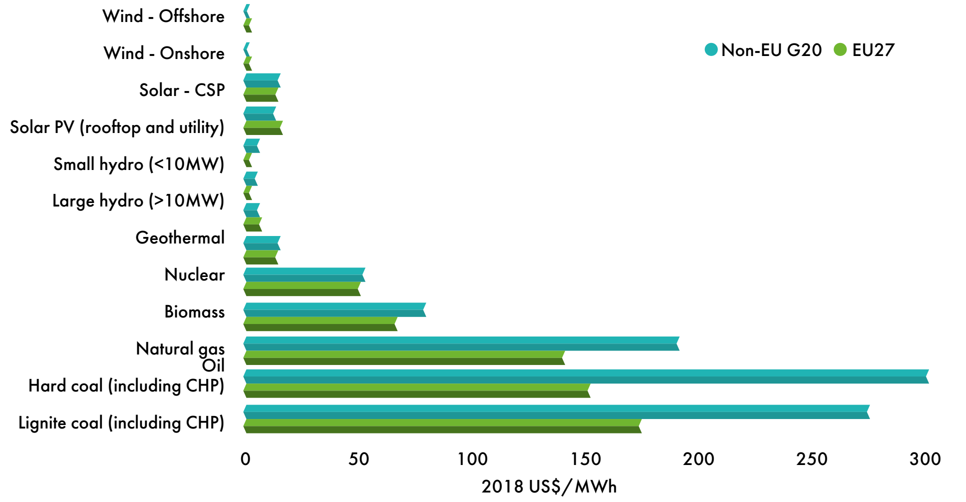
Global power demand is projected to double by 2050 under current policies. The IEA's 1.5°C pathway requires a trebling of electricity demand by 2050; IRENA's 1.5°C pathway has even stronger emphasis on electrification and the role of renewable electricity.[11] As electricity takes a larger role in powering economies, it is imperative to insulate the power sector from the boom-bust cycle of hydrocarbons by promoting renewables-based generation.

The stakes are high: Energy price volatility can lead to outages, supply insecurity and affordability issues. Consumers are already shouldering unexpectedly high tariffs in the present crisis; in the UK, for example, electricity bills are set to increase by nearly 50%, pushing 10% of households into energy poverty.[12]

Liquefied natural gas (LNG) spot market prices in Asia have hit both an all-time low and an all-time high in the last two years. As one Brookings Institute report notes, this "volatility is neither accidental nor a bug in current energy systems; it is a feature, created by energy system design choices that value short-run marginal optimisation, largely ignore interconnected markets, and fail to balance between central regulatory control and decentralised market forces."[13]

Average external costs of electricity technologies, US$/MWh

A comparison of the weighted average external costs of electricity technologies, including those related to: climate change; particulate matter (disease damages to human health from air pollution); resource use of fossil fuels, minerals and metals; non-cancer human toxicity; land use and soil quality.

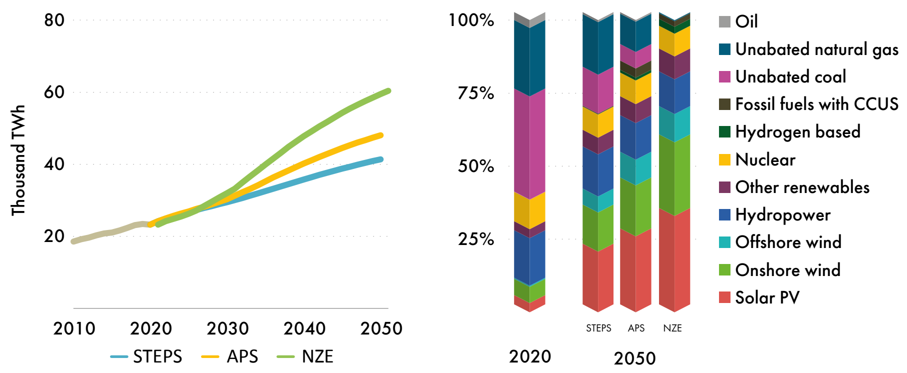


Source: Final Report External Costs: Energy costs, taxes and the impact of government interventions on investments, European Commission, authored by Trinomics, 2020. Note: Values originally provided in 2018 Euros, and have been converted to US Dollars at the average 2018 conversion rate. External costs include national internalisation of carbon tax and pricing.

The reserve capacity which serves as the conventional security buffer to ensure sufficient generation capacity for power systems, as a percentage of peak power demand, may be an outdated approach. To enable greater shares of wind and solar generation, energy systems need to become responsive to daily

11. For instance, IRENA foresees 78,700 TWh generation by 2050 in its scenario, and more than half of total final energy consumption (TFEC) comprising electricity. See: IEA, World Energy Outlook 2021; IRENA, World Energy Transitions Outlook, 2021.
12. https://www.bloomberg.com/news/articles/2022-02-02/u-k-price-shock-will-pitch-1-in-10-into-energy-poverty
13. https://www.brookings.edu/wp-content/uploads/2021/12/FP_20211214_global_energy_crisis_gilbert_bazilian_gross.pdf

Growth of global electricity demand to 2050 in three scenarios



Source: IEA, World Energy Outlook 2021. Note: STEPS = Stated Policies Scenario based on prevailing policy settings; APS = Announced Pledges Scenario where all announced net zero pledges and NDCs as of mid-2021 are met in full and on time; NZE = Net Zero Emissions by 2050 Scenario where the global energy sector achieves net zero CO2 emissions by 2050.

and seasonal energy demand and supply profiles, as well as more flexible with grid-based storage, hydropower and other forms of renewable energy. Integrated planning is needed between grids operating at subnational, national and international level, as well as forecasting and modelling for demand scenarios that account for increased electrification, renewables generation and transmission buildout. As discussed in the Technology section of this report, with decentralised and real-time response to demand, a power system becomes dynamic and would not be reliant on a static reserve margin calculation.

Leapfrogging the legacy energy sector where electrification is low

Unequal distribution of global income and CO2 emissions undoubtedly raises challenges around "fair shares" of resources dedicated to the mitigation of climate change. This debate has become particularly acute in the face of the undelivered $100 billion in annual climate finance pledged at the COP conference in Copenhagen in 2009. The discussion has since shifted to the creation of a loss and damage facility under the COP framework for the EMDEs most vulnerable to the impacts of climate change.[14]

The bottom 50% of the world's population by income level represent only 8.5% of total global income, and contributes a fraction of total CO2 emissions.[15] This bottom half is concentrated in sub-Saharan Africa, South Asia, Southeast Asia and to an extent, Latin America and the Caribbean. In these regions, there are higher shares of households which lack modern energy access.[16]

System design for the clean energy transition will require a different approach in regions where energy access is a challenge. Deploying large-scale wind and solar projects may depend on the adequacy of grid infrastructure and affordability of access, leading to a combination of on-grid and off-grid solutions. This may be the case for areas like East and West Africa, which have electrification rates around 50%, as well as Central Africa which has rates closer to 30%.

Lack of grid reliability has led to load shedding in several countries in Africa, while energy demand is only increasing with population and economic growth. Public and development finance should target investment in grid stabilisation and transmission expansion for such countries, which can help to mobilise private-sector investment in renewables. This is especially the case in places where renewable energy resources are high, and power demand is growing rapidly.[17] Africa has some of the most attractive wind and solar resources in the world, and energy demand is expected to double on the continent by 2040.

Governments, communities and industry must persist in working together to carry out the energy transition in countries with lower electricity access and weaker network infrastructure. This can include public-private initiatives for mobilising investment in grid infrastructure, scaling up dispatcher training and increasing regional integration between electricity authorities and grids, as

14. "Climate meeting of ministers discusses national plans to cut methane emissions," Financial Times, 28 January 2022; "The broken $100-billion promise of climate finance — and how to fix it," Nature, 20 October 2021.
15. Income level is measured at Purchasing Power Parity after pension and unemployment benefits, and before income and wealth taxes. See: https://wir2022.wid.world/.
16. Energy access is defined as access to electricity and clean cooking capabilities, such as through the use of improved stove equipment.

seen in the West African Power Pool (WAPP).

A prolonged dependence on often-imported fossil fuels leaves such countries even more vulnerable to commodity price volatility, undermining their energy security and curtailing social and economic productivity. It also deteriorates balance of payments at national level, endangering fiscal autonomy.

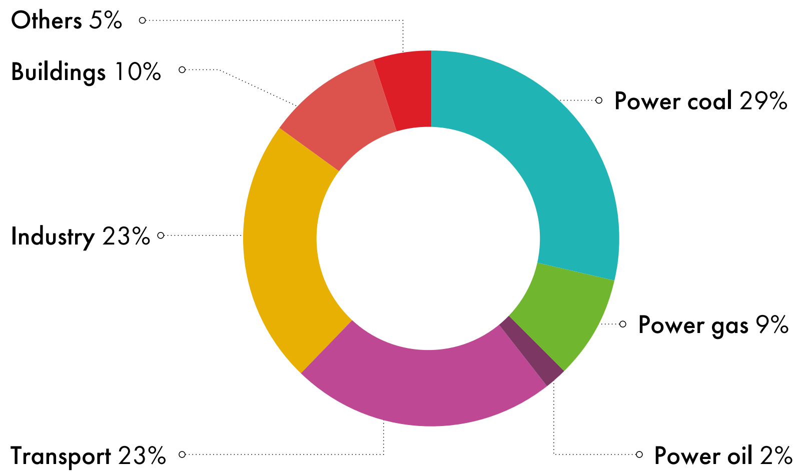
Where countries have primarily fixed energy tariff regimes, like in Indonesia and to an extent in India, government subsidies are required to step in at times of high prices; the alternative is for state utilities to operate at a deficit. Either way, the public ultimately bears the cost of underinvestment and reliance on obsolete technology.

Where energy access is a challenge, renewables-based power generation should leapfrog the legacy energy sector, and the risk of stranded assets should be avoided as much as possible.[18] Integrated and regionally holistic spatial planning, electrification measures and buildout of green infrastructure can support a low-carbon and resilient pathway to urbanisation in fast-growing EMDEs.

No half measures in the phaseout of fossil fuels

Public and private investors are increasingly betting against fossil fuels, due to the political and commercial risks attached. Nearly 1,500 institutional investors representing more than $39 trillion assets under management (AUM) have committed to some form of fossil fuel divestment – including entities like the Rockefeller Foundation, founded by oil profits.[19] From shareholder activism to stakeholder capitalism to Environmental, Social and Governance (ESG) investment criteria, there is a deteriorating case for coal generation and a contentious case for gas.

Global energy-related CO2 emissions by sector



Source: IEA, Global energy-related CO2 emissions by sector, Paris, 2021.

However, this political and commercial momentum has not yet translated into a decline in fossil fuel demand. Coal demand is on-track for record highs in 2022 and 2023, while gas demand in North America and Europe has increased to replace coal and nuclear generation.[20] Improvements to energy security and balance of trade by decreasing dependency on imported fossil fuel commodities are being left on the table. Some countries have transitioned coal power generation almost entirely to natural gas, and still depend on inelastic and unsustainable fuel imports – a Pyrrhic victory of the transition now reflected in consumer bills.

A system transformation to diversify the energy mix will require coherent demand- and supply-side reform. It cannot be a series of half-measures, where energy consumption is targeted (e.g. electric alternatives to gas boilers in homes) without efforts to scale up renewable power

17. https://www.giz.de/en/downloads/Study_Renewable%20Energy%20Transition%20Africa-EN.pdf
18. Stranded assets are assets which cannot provide an economic return before the end of their economic lifetime, due to economic, physical or regulatory changes associated with the clean energy transition. For example, a coal plant which still has 30 years of operating lifetime but can no longer sell power to a state offtaker due to policy shifts away from fossil fuels generation. See: https://carbontracker.org/terms/stranded-assets/.
19. https://oilprice.com/Energy/Energy-General/Investors-With-392-Trillion-In-Assets-Pledge-To-Divest-From-Fossil-Fuels.html
20. https://www.iea.org/news/coal-power-s-sharp-rebound-is-taking-it-to-a-new-record-in-2021-threatening-net-zero-goals

generation. Similarly, the strengthening of carbon compliance markets, such as in the EU's Emissions Trading Scheme and proposed Carbon Border Adjustment Mechanism (CBAM) and China's National Emissions Trading Scheme, must be accompanied by rapid and sustained efforts to accelerate renewables deployment.

Undertaking a transport decarbonisation scheme will require investment in large volumes of utility-scale wind and solar projects, as well as transmission and distribution infrastructure, to provide clean power to passenger vehicles. It will also likely incorporate hydrogen fuels for shipping and possibly aviation. The ramp up of hydrogen production will be most effective if large-scale renewables deployment is coordinated with demand centres for green hydrogen, such as steel production centres.

For policymakers, power sector policy should take advantage of the cost-competitiveness and value contribution of wind and solar projects, as well as the falling costs of battery energy storage systems (BESS), when it comes to designing an energy mix.[21] Mitigation requirements should be integrated into the design stage of infrastructure, such as buildings and coastal planning where ports may be equipped for large-scale offshore wind projects, and considered in the industry sector, such as in the standards for refining processes and construction materials. For heavy industry, cleaner fuel alternatives and methods demand investment in research and innovation.

This virtuous cycle of decarbonising the energy system is only possible with strongly coordinated cross-sector policy across multiple levels of government. Renewable energy ambitions should be mainstreamed across energy, economic and national security portfolios, not to mention workforce departments that help develop the human capital to serve a future renewables-based system. This level of policy coordination will be needed to strengthen market signals in support of the energy transition and sustain economic productivity while exiting fossil fuels.

Is coal in a death spiral yet?

The share of cancelled coal plants in the global pipeline has been increasing steadily over the past five years, and in 2021, major public financiers of coal projects like China, Japan and South Korea pledged to end international financing of coal projects. At COP26, nearly 40 signatories pledged to end international public support for unabated fossil fuels by 2022, including development banks like the Agence Française de Développement (AFD), East African Development Bank (EADB) and European Investment Bank

21. https://about.bnef.com/blog/global-energy-storage-market-set-to-hit-one-terawatt-hour-by-2030/

(EIB).[22] But the global consensus to phase down coal generation has not been accompanied by concrete international initiatives for rapid retirement or cancellation of plants.

Nearly 700 GW of current operating coal generation, equivalent to one-third of global capacity in operation, have a plant age of 9 years and below; without early retirement, these plants could continue to operate for another 3-4 decades.[23] Asia accounts for the vast majority of the new coal capacity built over the last two decades, primarily in China, India and Southeast Asia. A further 300 GW of global coal plant capacity is currently under construction or approved, as of mid-2021.

The existing global coal fleet is set to generate power and emit GHGs for decades to come. Without early retirement, the cumulative CO2 emissions of existing coal generation by 2040 will be five times the entire energy sector's CO2 emissions in 2018.[24] Beyond the environmental and social hazards this poses, coal capacity also yokes countries to a dependency on a volatile and often imported energy commodity.

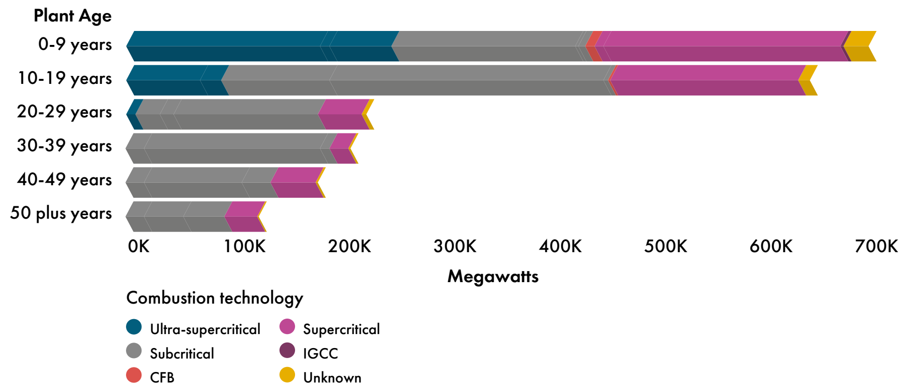
In late 2021, coal shortages in China sparked widespread power outages and industrial shutdowns in the northeast of the country, while India experienced rolling outages due to coal stockpiles nearing a three-year low amid high coal prices.[25] Due to coal shortages at home, in January 2022 Indonesia, the largest exporter of coal globally, temporarily banned coal exports. This caused a spike in global coal prices to $249/tonne (from a historical $50-90/tonne range) and brought uncertainty to regional markets.[26]

The knock-on effects of coal-related energy insecurity and stranded asset risk will only increase as the world faces a bumpy road to economic recovery, factoring in inflation, national debt burdens and income inequality. Once the current backlog of consumer and industrial demand built up over the pandemic has been met and lending facilities retract, the World Bank estimates that global growth will decelerate through 2023.[27]

This deceleration will detract from government resources to enact energy system transformation, such as through a grid modernisation programme or energy efficiency measures. Thinning public resource will be especially felt in EMDEs, where recovery is projected to be slower. Energy transition-related investments already fell 10%, or $67 billion, from 2019 to 2020, as investors shifted capital to more developed economies amid the pandemic.[28]

EMDEs will be more vulnerable to a slow transition, especially those which rely on domestic commodities like coal and gas for export revenue (e.g. Indonesia or

Global coal plants in operation by plant age and type



Source: Global Energy Monitor, Global Coal Plant Tracker, as of July 2021. Note: IGCC = Integrated Gasification Combined Cycle. CFB = Circulating Fluidized Bed.

22. https://ukcop26.org/statement-on-international-public-support-for-the-clean-energy-transition/
23. https://globalenergymonitor.org/projects/global-coal-plant-tracker/dashboard/
24. "On the basis that plant operations and economics are in line with stated policies, CO2 emissions from the existing coal fleet would emit a cumulative 175 GtCO2 over the period to 2040 – equivalent to 5 times total energy sector emissions in 2018 – despite annual emissions steadily declining to about 60% of today's levels." See: https://www.iea.org/reports/the-role-of-ccus-in-low-carbon-power-systems/the-co2-emissions-challenge.
25. https://www.reuters.com/world/china/china-energy-crunch-triggers-alarm-pleas-more-coal-2021-09-28/; https://www.bloomberg.com/news/articles/2021-10-04/energy-crisis-deepens-in-india-as-power-plants-brace-for-outages
26. https://www.fitchratings.com/research/corporate-finance/apac-thermal-coal-prices-to-ease-on-end-of-indonesia-export-ban-14-02-2022
27. https://www.worldbank.org/en/news/press-release/2022/01/11/global-recovery-economics-debt-commodity-inequality
28. https://about.bnef.com/blog/emerging-market-clean-energy-investment-slid-as-covid-19-spread/

Case study: Capturing green recovery opportunities from wind power in developing economies

The benefits of wind energy are wide-ranging and expand beyond clean power generation – they include sustainable job creation, public health cost savings which would otherwise be spent redressing the impacts of fossil fuel generation, water consumption savings which would otherwise be used for thermal generation, and a significant capital injection in a local value chain.

For developing economies facing the difficult balance of restarting economic growth while maintaining energy security and resilience, investment in the wind sector offers a pathway to a robust and sustainable recovery.

In Q1 2022, GWEC released a report in collaboration with BVG Associates, "Capturing green recovery opportunities from wind power in developing economies," which reflects a study of wind energy potential in five emerging economies over the next five years, from 2022-2026, with the aim of highlighting the vast and largely unexploited socioeconomic and environmental opportunities attached to wind energy.

The five countries examined in the report are Brazil, India, Mexico, South Africa and the Philippines. Across these five countries, a green recovery approach could generate nearly 20 GW of additional wind power capacity and an additional 2.23 million jobs compared to a BAU scenario. This would in turn potentially save an additional 714 million metric tons of CO2e over the 25-year wind farm lifetimes.

In Brazil, for example, the potential upsides compared to a BAU scenario equate to nearly 5 GW of additional installed wind capacity, half-a-million more jobs created in the wind value chain, 8 million more homes powered by clean electricity, and more than 180 million metric tons of CO2e saved.

The study identifies three common barriers facing wind energy deployment in developing economies and provides recommendations on how these barriers can be overcome: greater clarity and ambition for wind energy policy; investing to expand transmission system infrastructure; and simplifying permitting frameworks for renewable energy.

Russia) or which draw a large portion of GDP from high-emissions sectors like manufacturing and agriculture (e.g. India, South Africa, Thailand or Turkey).[29] Drastic expansion of renewables capacity and industrial decarbonisation will be needed to avoid the risk of stranded assets and energy insecurity.

The economics of renewable energy technology are there: It would be cheaper to build new wind and solar plants than continue operating two-thirds of the world's existing coal capacity as of 2021, according to analysis by TransitionZero.[30] The rapid closure of coal plants worldwide beginning in 2022, and compliance with decommissioning and phaseout schedules already in place, is crucial to enacting the transition. This will result in enormous savings in energy procurement and public health costs, which can then be funnelled towards investment in clean energy, storage and flexibility technologies.

Early retirement mechanisms are being piloted, but must address concerns around transparency, accountability and valuation of assets to reach a fair and balanced formula for compensation and future investment. For instance, the Asian Development Bank's (ADB) Energy Transition Mechanism initiative aims to purchase high-emissions coal plants locked into long-term PPAs in Indonesia and the Philippines, and retire them within 15 years.[31] Both countries have a significant pipeline of coal projects which have been announced, permitted or under construction (30.3 GW in Indonesia and 5 GW in the Philippines, as of July 2021).[32]

But without effective guardrails, an early retirement mechanism could provide a source of revenue to coal asset owners, often state-owned or state-affiliated entities, under a valuation covering the full remaining lifetime of the plant. Book values for buyouts should neither be fully insulated from the market pressures of decarbonisation or underperformance, particularly given the international solidarity around coal phaseout and deteriorating financing environment for coal. It will be important to ensure that financing for coal retirement is not used to subsidise further fossil fuels generation, but shifted into projects which enable the energy transition.

Natural gas in a disorderly and delayed transition

The phaseout of coal is inevitable – the question is whether it will be enacted in time. Along the way, natural gas and LNG are seen by

29. https://www.mckinsey.com/business-functions/sustainability/our-insights/how-the-net-zero-transition-would-play-out-in-countries-and-regions
30. https://www.transitionzero.org/blog/world-must-close-nearly-3000-coal-plants-by-2030
31. https://ieefa.org/ieefa-coal-lock-in-in-southeast-asia-presents-a-challenge-for-the-asian-development-banks-coal-retirement-plan/
32. https://globalenergymonitor.org/projects/global-coal-plant-tracker/summary-tables/

some as "transition technologies" or "bridge fuels" which can support countries in the period between reducing coal and nuclear dependency and increasing renewables generation. Today, the global gas plant capacity totals around 1,800 GW, with the largest absolute volumes operating in the US, Russia, China, Japan and Iran.[33] There is more than 615 GW further under proposal or construction, with the largest pipelines in Asia (China, Vietnam and Bangladesh) as well as the US and Brazil.

Competition with coal has generally stabilised wholesale prices in the power sector, as both coal and gas function as the marginal resources to set prices.[34] But as coal is being phased out, power markets are left exposed to the volatility of gas prices. The increasingly global nature of gas markets – previously formed around regional hubs in North America, the Asia Pacific and Europe – exacerbates this risk, as the rise of LNG and long-distance transport pipelines link regional markets closer together.[35]

LNG, offering easier transport of gas in a liquefied state, has made market interconnectedness more acute. Trade of LNG grew by more than 80% between 2006 and 2018, while its share of the global gas trade rose from 26% in 2000 to 45% in 2020.[36] The main exporting countries are Australia, Qatar, the US, Malaysia and Algeria; other countries which have ambitions to become large producers are Russia, Mozambique and Argentina. Demand for LNG is concentrated in Asia (Japan, China and South Korea), although the recent Russia-Ukraine conflict is likely to prompt demand for LNG to pick up in Europe.[37]

Market volatility and uncertain public support

To date, LNG procurement has not followed the more generous coal model, which benefits from long-term agreements and government guarantees.[38] Contracting in the LNG industry has slowly evolved over the last 15 years away from long-term contracts (characterised by price caps, floors, "S" curves, etc.) towards shorter and more flexible contracts supplemented with sport market purchases.

This does not, however, account for power consumption fluctuations, changes in weather patterns, or policy shifts towards carbon pricing and a cleaner energy matrix which would impact the demand side. European Title Transfer Facility (TTF) spot market gas prices hit $135/MWh in December 2021 – a 429% increase from prices in 2019, which in turn contributed to a 230% increase in wholesale electricity prices in the EU measured over the same period.[39] This is a deeply unfavourable comparison to renewable energy prices captured at auction worldwide, which averaged $49.2/MWh in 2019 for onshore wind and $55.8/MWh for solar.[40]

Gas is still generally exempt from the type of financing restrictions imposed by development donors and export credit agencies (ECAs) on coal. But as with coal, continued public support for gas production and storage is not guaranteed – this was already targeted in an international pledge at COP26 – which will impact pricing dynamics in the sector.[41]

State-owned or state-affiliated entities are somewhat insulated from shareholder pressure; however, they are still subject to public opposition. For instance, the Netherlands amended legislation in 2018 to prohibit new buildings from being connected to the natural gas grid, while New York City followed suit with the same measures in 2021. For companies exposed to capital markets, there is a growing movement of institutional and private investors pledging to divest fossil fuels assets, including all or some types of gas projects.

33. https://globalenergymonitor.org/projects/global-gas-plant-tracker/
34. This is the general case in most hours of the year, with gas plants providing the price-setting units for the largest share of hours. Other factors include market prices in interconnected countries, carbon pricing floors and other determinants. See: https://neon.energy/Blume-Werry-Faber-Hirth-Huber-Everts-2021-Eye-on-the-price.pdf
35. https://www.brookings.edu/wp-content/uploads/2021/12/FP_20211214_global_energy_crisis_gilbert_bazilian_gross.pdf
36. https://www.enerdata.net/publications/executive-briefing/lng-rise.html
37. https://www.offshore-energy.biz/germany-to-break-free-from-russian-gas-with-two-lng-terminals/
38. Most coal contracts are still settled against benchmark indices, which still exposes them to price fluctuations.
39. TTF is a natural gas trading point in the Netherlands which uses Euros/MWh for trades. See: https://fsr.eui.eu/skyrocketing-energy-prices/.
40. https://www.irena.org/Statistics/View-Data-by-Topic/Policy/Renewable-Energy-Auctions
41. The pledge sought to "end new direct public support for the international unabated fossil fuel energy sector by the end of 2022, except in limited and clearly defined circumstances that are consistent with a 1.5°C warming limit and the goals of the Paris Agreement." See: https://ukcop26.org/statement-on-international-public-support-for-the-clean-energy-transition/.

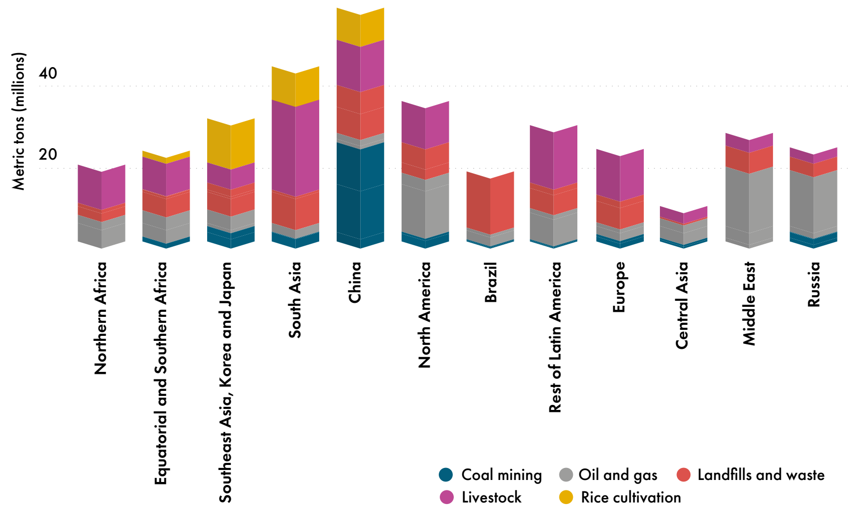
IEEFA estimates that fundamental project constraints and unfavourable market conditions could already reduce the pipeline of LNG projects in South Asia and Southeast Asia by more than 60%, as of December 2021.[42] These market constraints include commodity price volatility, foreign exchange volatility, higher power tariffs for end-users, higher public subsidy burdens, fuel supply insecurity, stranded asset risk for investors and more. A further 20% of the remaining pipeline faces risk of delays in reaching financial close, particularly in Vietnam, the Philippines, Myanmar and Bangladesh.

Accounting for the environmental impact of gas

Investment in technologies which can lower emissions intensity have been floated as a solution for "cleaner" gas, from reducing methane leakage to procuring renewable power for gas plant operations. However, taking full GHG lifecycle emissions into account and including emissions from combustion of natural gas, it is difficult to justify investment in new gas generation under a "Do No Significant Harm" (DNSH) principle of decision-making which would avoid activities that undermine climate change mitigation, environmental protection, pollution prevention and protection of biodiversity.

Scope 1 and 2 emissions only account for around one-quarter of average full lifecycle GHG emissions for natural gas.[43] There is a wide spread in emissions intensity depending on the source and trade route; the IEA has found that the top 10% of production is around four times more emissions-intensive than the bottom 10%. LNG projects, which must cool the LNG with massive compressors before shipping, are among the most emissions-intense in the oil and gas sector.[44] The investment in enhancing traditional gas operations to make them "state-of-the-art" could instead be shifted to renewable energy, especially to sectors like offshore wind where oil and gas companies can leverage their experience in large-scale engineering and construction projects.

Methane emissions by sector and region, 2017



Source: Saunois et al, The Global Methane Budget 2000-2017. Earth Syst. Sci. Data, 12, 1561–1623, 2020.

An increasingly prominent factor undermining the comparative environmental benefits of gas generation to other fossil fuels is methane leakage and emissions, from the production stage to distribution. The IPCC's 2021 report found that methane concentration in the atmosphere is at an all-time high, and has a global warming impact 84 times that of CO2, when measured over a 20-year period.[45] This prompted 105 countries to sign the Global Methane Pledge at COP26, whereby the EU member states, the US, Japan, Brazil, Canada, Vietnam, the Philippines and other countries commited to reducing methane emissions by 30% by 2030, compared to levels in 2020.[46]

42. http://ieefa.org/wp-content/uploads/2021/12/Examining-Cracks-in-Emerging-Asias-LNG-to-Power-Value-Chain_December-2021.pdf
43 Scope 1 emissions cover direct emissions from the gas industry, while Scope 2 emissions originate from the generation of energy purchased by the gas industry. Scope 3 emissions cover the combustion of gas by end users. See: https://iea.blob.core.windows.net/assets/4315f4ed-5cb2-4264-b0ee-2054fd34c118/The_Oil_and_Gas_Industry_in_Energy_Transitions.pdf.
44. https://www.woodmac.com/news/opinion/carbon-capture-and-the-future-of-lng-in-asia/
45. https://unece.org/challenge; https://www.ipcc.ch/2021/08/09/ar6-wg1-20210809-pr/
46. https://ec.europa.eu/commission/presscorner/detail/en/statement_21_5766

While coal mining, livestock, rice fields and landfills are also sources of methane emissions, the gas sector is the primary source of methane emissions in North America, the Middle East, Russia and Central Asia. Driving down emissions in these regions will require intervention in the sector, such as cancelling new plants in the pipeline.

Gas in the merit order of green investment

Despite these investment and environmental risks, in some jurisdictions gas has found a home in the green taxonomies designed to direct sustainable finance towards climate and net zero goals. A focal point in this debate has been the inclusion of gas generation in the European Union's (EU) Taxonomy for Sustainable Activities, approved by the European Commission in February 2022.[47] The taxonomy, a voluntary framework that sends signals to investors on criteria for climate and net zero compliance, labels gas plants as a transitional investment until 2030 if specific emissions intensity targets and proportions of low-carbon gases are met.

Green taxonomies are designed to facilitate financing for assets, projects and sectors which support climate and sustainability objectives. They provide a merit order for investment screening based on national and international environmental and socioeconomic standards. They encourage transparency of disclosures, and alignment of investment with science-based targets and DNSH criteria. Green taxonomies also provide confidence to public, private and institutional investors to allocate trillions in capital in compliance with the Paris Agreement targets of a 1.5°C pathway and net zero goals.

Inclusion of gas generation in taxonomy frameworks is risky and short-sighted, reshuffling financial resources away from other green technologies in the precise time when a boost to renewables investments is required to reach net zero targets on time. It encourages new gas generation in this decade, which will lock in emissions along the full value chain of gas, from production to end-use, for decades to come. Plants unable to meet efficiency targets may become stranded assets, while funding for the technologies and retrofitting work to modify existing plants could otherwise be used for clean energy research and innovation. Some estimates have found that the large-scale modifications to allow existing Combined Cycle Gas Turbine (CCGT) plants to co-fire with hydrogen and meet EU taxonomy standards may require months of downtime – further exacerbating the transitional supply gap which gas plants are being positioned to resolve.[48]

China has opted to exclude gas and "clean coal" from its green finance rulebook, the Green Bond Endorsed Project Catalogue.[49] However, other countries are leaving room for gas in their sustainable finance frameworks. South Korea's K-taxonomy system, finalised in late December 2021, includes LNG and mixed-gas generation below a generous emissions threshold of 340g CO2/kWh – more than three times the threshold in Russia's taxonomy – among "transition sector" investments from 2030 to 2035. This has been criticised as incompatible with the country's net zero by 2050 goal.[50]

The first version of the Association of Southeast Asian Nations (ASEAN) Taxonomy for Sustainable Finance released in November 2021 avoids labelling gas as a "red activity" and includes carbon capture, utilisation, and storage (CCUS) as an "enabling sector." [51]

Other countries and financial institutions will use these frameworks to set their own merit order of sustainable investments. The implications will be significant in the Global South, given gas projects in low- and middle-income countries currently receive as much as four times more international public finance than wind or solar projects.[52] Public finance flows play a large role in mobilising private investment, and should be directed with DNSH criteria and wider sustainable growth principles in mind. It is important that governments tighten

47. https://ec.europa.eu/info/publications/220202-sustainable-finance-taxonomy-complementary-climate-delegated-act_en
48. https://www.transitionzero.org/blog/including-gas-in-eu-taxonomy
49. https://www.climatechangenews.com/2022/02/02/european-commission-endorses-fossil-gas-transition-fuel-private-investment/
50.https://energytracker.asia/south-korean-green-taxonomy-declared-gas-is-green/
51. https://asean.org/wp-content/uploads/2021/11/ASEAN-Taxonomy.pdf
52. https://www.iisd.org/publications/natural-gas-finance-clean-alternatives-global-south

their signals on the role of natural gas in the energy transition, so that the international financial sector and developer community can respond effectively.

Easing gas dependence with effective market signals

While investor and social pressures heat up in the gas industry, policymakers must support the transition with effective market signals that can shift gas demand. The majority of GHG emissions from the oil and gas sector is attributed to end-use sectors like transport, covering passenger vehicles, aviation and industry. This means that a coordinated reduction of demand for natural gas end-use may also be needed to curb the sector's emissions, such as government schemes to fit buildings with efficient heating solutions, incentivise investment in hydrogen and biofuel alternatives for the transport sector and encourage behavioural change in travel.

Otherwise, as gas production ramps down due to depletion or policy change in some regions (e.g. Southeast Asia), other suppliers will gain an outsize share of the market and could end up wielding significant commercial and geopolitical clout in a global value chain. Here it is worth noting the concentration of national oil companies (NOCs) and state-owned entities in gas production. Around 60% of gas reserves and 50% of global production are under the control of state-owned entities worldwide, from national oil companies like Saudi Aramco, Qatar Petroleum, Petrobras and the Nigeria National Petroleum Corporation to international NOCs like PetroChina, Gazprom and Petronas.[53]

The concentration of state-owned entities adds a geopolitical dimension to control of the supply chain, which only grows stronger in times of market instability. It also means that international disputes or strategic controls of supply on the other side of the world could impact fuel availability at home, driving up prices and stoking social discontent.

Fuel price volatility can spill over into political instability and social anxiety about welfare and livelihoods, as observed in the political and military ramifications of European dependence on imported Russian gas in the context of Russia's invasion of Ukraine, as well as recent unrest in Kazakhstan, protests over the lifting of fuel subsidies in Ecuador in late 2021 and the "yellow vest" protests over fuel taxes in France which began in 2018.

53. https://www.iea.org/data-and-statistics/charts/shares-of-gas-reserves-gas-production-and-gas-upstream-investment-by-company-type-2018; https://www.iea.org/reports/the-oil-and-gas-industry-in-energy-transitions

The geopolitical and supply risks in the gas supply chain increases as the commodity becomes more expensive, making it ever more imperative for countries to avoid dependency on natural gas in the course of the energy transition. A diversified energy mix based in indigenous energy sources like wind improves energy self-sufficiency and security.

Fundamental shifts in commodity value are already visible in the transformation of oil and gas companies, as they move from fuel actors to diversified energy investors and suppliers. As demand for coal, natural gas and crude oil ultimately decreases, the use of electricity, green hydrogen and hydrogen derivatives will rise. IRENA has predicted that the 2020s will be the era of a big race for technology leadership, as regional infrastructural hubs of large-scale renewable energy and green hydrogen production emerge. [54]

A key consideration for countries undertaking rapid economic growth and industrialisation is the competitive advantage attached to the supply of renewable electricity, hydrogen and green energy carriers. This will require investment in the technologies and infrastructure which can store and deliver renewable energy – less than 30% of public and private energy investment today targets storage and grid management solutions, and this needs to step up.[55] Countries which can adapt by becoming sources of low-emissions energy and fostering hubs of clean technology and innovation, rather than of fuel, will be more resilient to the thumps and shocks of the transition.

Industry sustainability: Higher costs, perverse markets

The wind industry has been highly successful over the last decade, showing itself capable of both scaling up production volumes and capacity installations, while dramatically reducing the LCOE of both onshore and offshore wind. According to IRENA, global weighted-average LCOE for onshore wind declined by nearly 60% over the last decade to $0.04/kWh by 2020, while fixed-bottom offshore wind LCOE nearly halved to reach $0.08/kWh.[56]

Indeed, this steady reduction in costs, accelerated by a global tendency to move towards procurement through competitive auctions, has been a major factor in persuading policy makers that wind energy can play a central role in energy decarbonisation efforts, as wind has shown definitively that it is more cost efficient than fossil fuel-based generation in most markets around the world.

However, there is increasing evidence that the wind industry has become a victim of its own success. International institutions, think tanks and policymakers have a misguided assumption that LCOE will continually fall in the coming years and decades. The industry faces increasing challenges related to global trade barriers and local content requirements. Without addressing underlying energy market dynamics, auctions are leading to a "race to the bottom" which leaves the wind industry supply chain with wafer-thin or negative

54. https://www.irena.org/publications/2022/Jan/Geopolitics-of-the-Energy-Transformation-Hydrogen
55. https://www.strategy-business.com/article/A-rising-tide-of-green-capital
56. Renewable Power Generation Costs in 2020, IRENA, 2021. We note that further information on cost reduction for onshore and offshore wind are provided in GWEC's Global Wind Report 2021 and Global Offshore Wind Report 2021, while floating wind LCOE is charted in GWEC's 2022 report Floating Offshore Wind – A Global Opportunity. See: https://gwec.net/

margins, while developers and suppliers are highly vulnerable to shifts in commodity prices or financial conditions.

Recent seabed leasing auctions in the UK and New York saw enormous bids for fixed and floating offshore wind development sites. These totalled $1.1 billion in option fees for around 8 GW in the UK Offshore Wind Lease Round 4, $955 million in option fees for 25 GW in the ScotWind Leasing round and $4.37 billion for up to 7 GW in the New York Bight auction. These volumes of investment reflect the intense appetite for investment in offshore wind – but they also take up greater shares of project CAPEX, leaving developers more exposed to cost fluctuations and PPAs at low prices.

These dynamics have intensified the financial pressure on wind turbine original equipment manufacturers (OEMs), component manufacturers and wind energy producers. Over the last year, these pressures have been compounded by a sustained rise in the cost of key commodities and logistics, just as the post-pandemic recovery has squeezed supply chains and created bottlenecks and fierce competition for raw materials (see Supply Chain).

The Financial Times described the situation in the global wind industry in February 2022 as a "perfect storm" of higher costs and logistics challenges, which have squeezed wind energy companies margins and wiped tens of billions off stock prices.[57] With auctions becoming more prevalent and competition for critical minerals and commodities only set to increase in the clean energy transition, the current "storm" cannot be dismissed as a temporary setback and upward pricing pressure is set to continue.

The introduction of qualitative criteria reflecting social and economic value in auctions is a step towards recognising the value creation of wind energy, but does not itself fix market failures. If left unresolved, these pricing dynamics can intervene in the medium- and long-term growth trajectory of wind energy by inflating project costs, reversing the cost reduction achieved through technology innovation and learning curves, as well as introducing uncertainty into project investment. This will be particularly acute in EMDEs at the early stage of renewables development, where supply chain infrastructure is often less developed and investments can carry higher premiums – yet wind developers and investors are under high pressure to deliver the first wave of wind projects at extremely low cost.

57. https://www.ft.com/content/29832c31-b3be-43cf-8dab-6970daa57ebb

As a result of narrowing margins for cost recovery in clean energy, current energy systems are disincentivising investment in the business of wind, when more resources than ever are needed to power wind expansion and innovation.

Price sensitivity in the wind supply chain

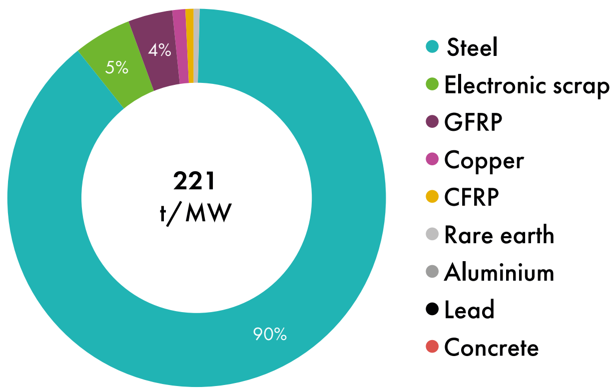
The sudden recovery of industrial production following the pandemic shock of 2020 has led to both fierce competition among different industries for raw materials and an ongoing bottleneck in manufacturing capacity and transport logistics such as shipping. This has had a significant impact on the wind industry as procurement and freight for raw materials and commodities of wind turbines, including steel, concrete, copper, nickel and a small but high-value volume of rare earth elements (REE), and their subsequent manufacturing into wind turbine components make up the lion's share of wind project CAPEX.

For onshore wind, turbine capital costs are estimated to contribute 70% of total CAPEX; viewed as a measure of LCOE across a 25-year project lifetime, nearly 50% of onshore wind project LCOE is made up of turbine costs.[58] For offshore wind, turbine capital costs are estimated to contribute 34% of total CAPEX; viewed as a measure of LCOE across a 25-year project lifetime, 23% of offshore wind project LCOE is made up of turbine costs.

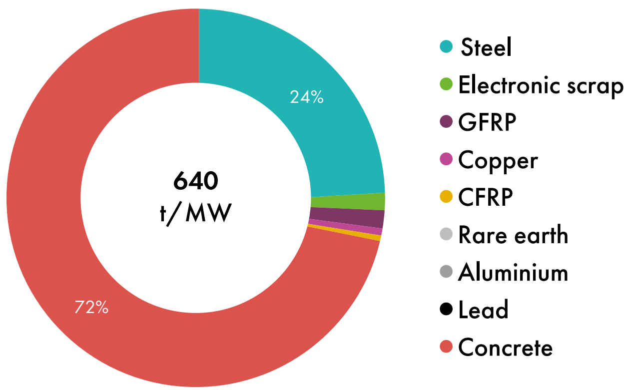
These substantial capital expenditures on turbine procurement of raw materials and commodities make the wind supply chain highly sensitive to upstream cost inflation and trade protection measures. Price spikes for raw materials, as well as price fluctuations for the electricity to power heavy manufacturing operations, affect cost recovery and timely delivery for suppliers fulfilling contracts for wind turbine components. Changes in electricity and fuel prices, commodities and raw materials, freight and logistics can in turn significantly impact the economic feasibility and commissioning timelines of projects.breakdown for typical fixed-bottom offshore wind farm operating for 25 years, 2020.

Materials breakdown for onshore and offshore wind farms

Offshore wind farm



Onshore wind farm

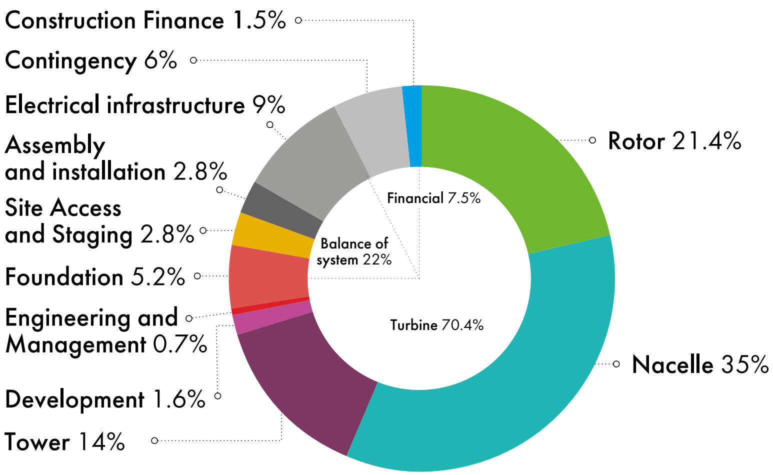


Source: BloombergNEF. Note: GFRP = Glass fiber reinforced plastic. CFRP - Carbon fiber reinforced plastic.

To illustrate the changes in some key cost inputs over the last two years, steel prices have increased by 50% from the start of 2020 to the end of 2021 (and have seen further dramatic increases since the invasion of Ukraine), while copper prices have increased by 60%. Prices for neodymium and dysprosium, the two key REEs for direct drive and hybrid drive wind turbines, have tripled in price over the same period.

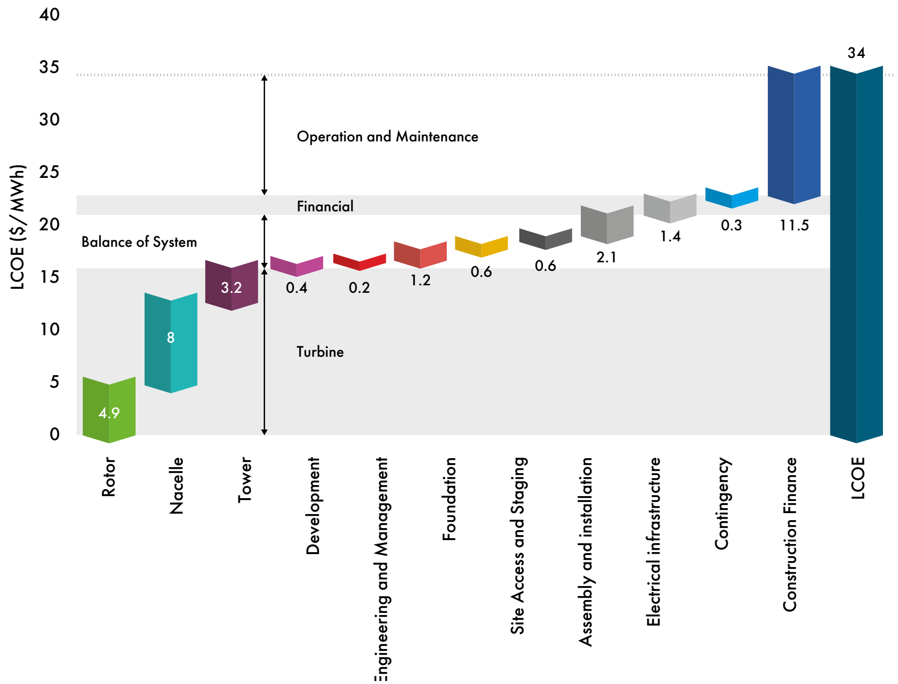
58. https://www.nrel.gov/docs/fy22osti/81209.pdf

CAPEX for typical onshore wind farm, 2020



Source: 2020 Cost of Wind Energy Review, Tyler Stehly and Patrick Duffy, National Renewable Energy Laboratory, 2021. Note: The reference project represents a typical 600 MW fixed-bottom offshore wind project comprising 75 wind turbines at 8.0 MW each, operating for 25 years with no major O&M events.

Component-level LCOE breakdown for typical onshore wind farm operating for 25 years, 2020



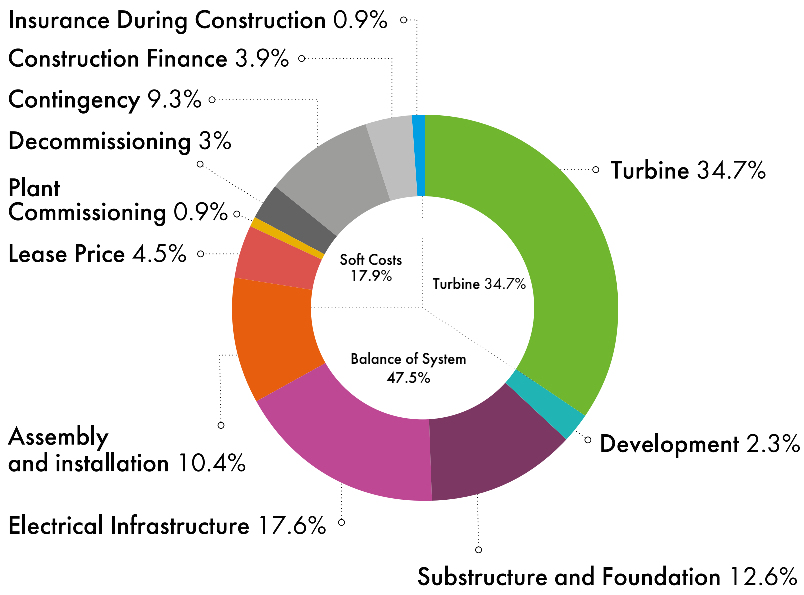
Source: 2020 Cost of Wind Energy Review, Tyler Stehly and Patrick Duffy, National Renewable Energy Laboratory, 2021. Note: The reference project represents a typical 200 MW onshore wind plant in the interior US, comprising 73 wind turbines at 2.8 MW each, operating for 25 years with no major O&M events.

Where most industries would be able to pass on such costs to consumers, **turbine prices for projects are negotiated years in advance of manufacturing and delivery, meaning that prices are already locked in.** In the interim, this leaves OEMs exposed to price volatility and logistics risks out of their control.

It is important to note that commodity price volatility can be hedged at a cost, **but commodity hedging does not protect the industry against the simultaneous squeeze on logistics.** Delivery of some key components has increased from 5 weeks to as much as 50 weeks, and these disruptions make turbine manufacturers vulnerable to penalties related to delivery deadlines and delayed projects. Freight costs have also risen: By the middle of last year, spot rates for a 40-foot ocean freight container from Asia to the US reached a record-high 10 times higher than rates just a few years ago, particularly as freight contract rates rose after the Suez Canal crisis in March 2021.

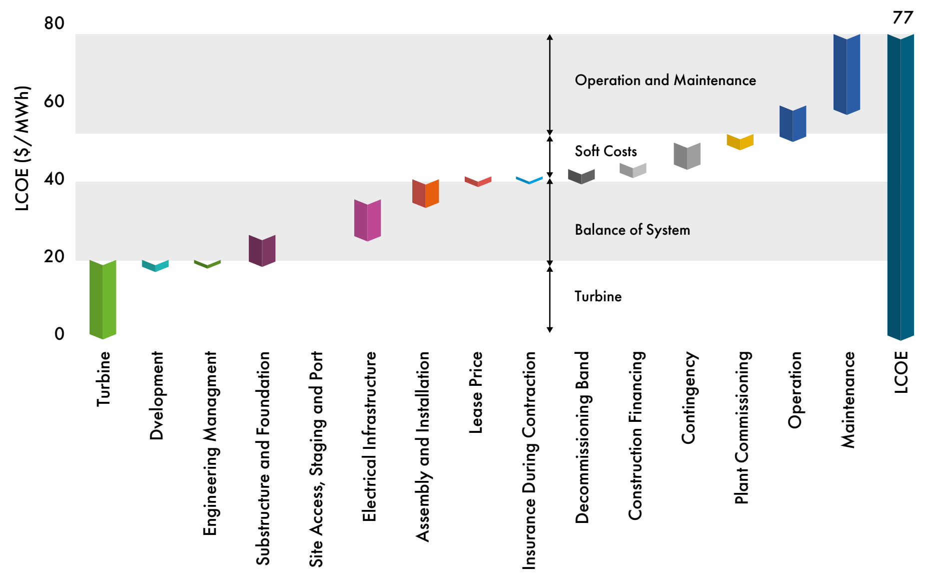
As a result, turbine prices for future projects are forecast to rise by 9% in the second half of 2021, according to the BNEF turbine pricing index. **The hike in total CAPEX and project lifetime cost calculations will make it even more challenging for wind**

CAPEX for typical fixed-bottom offshore wind farm, 2020



Source: 2020 Cost of Wind Energy Review, Tyler Stehly and Patrick Duffy, National Renewable Energy Laboratory, 2021. Note: The reference project represents a typical 600 MW fixed-bottom offshore wind project comprising 75 wind turbines at 8.0 MW each, operating for 25 years with no major O&M events.

Component-level LCOE breakdown for typical fixed-bottom offshore wind farm operating for 25 years, 2020



Source: 2020 Cost of Wind Energy Review, Tyler Stehly and Patrick Duffy, National Renewable Energy Laboratory, 2021. Note: The reference project represents a typical 600 MW fixed-bottom offshore wind project comprising 75 wind turbines at 8.0 MW each, operating for 25 years with no major O&M events.

energy to continue to compete for razor-thin margins in tenders and procurement schemes around the world.

One of the key questions for the industry is how long the current cost crunch will last. On the one hand, logistics bottlenecks should ease as more transport capacity comes into the market to meet demand, and backlogs related to historical incidents like the Suez Canal blockage are cleared.

However, there is fierce debate among economists and experts as to whether we are facing a short-term crunch in commodities caused by the rebound of industrial demand and fulfilment of demand built up during the pandemic, or if this will be a longer-term super-cycle. It is clear that the long-term effects of the energy transition will translate to a continually expanding need for particular raw materials. The wind industry is among these drivers of demand, and is also in direct competition with other cleantech industries, such as the REEs used for electric vehicle (EV) motor manufacturing.

In the long term, the wind industry will respond to price shocks by optimising supply chains and innovating to substitute expensive materials through alternatives or recycling solutions (see Supply Chain). For now, however, we can expect turbine prices to continue increasing as key commodities and materials become more valuable.

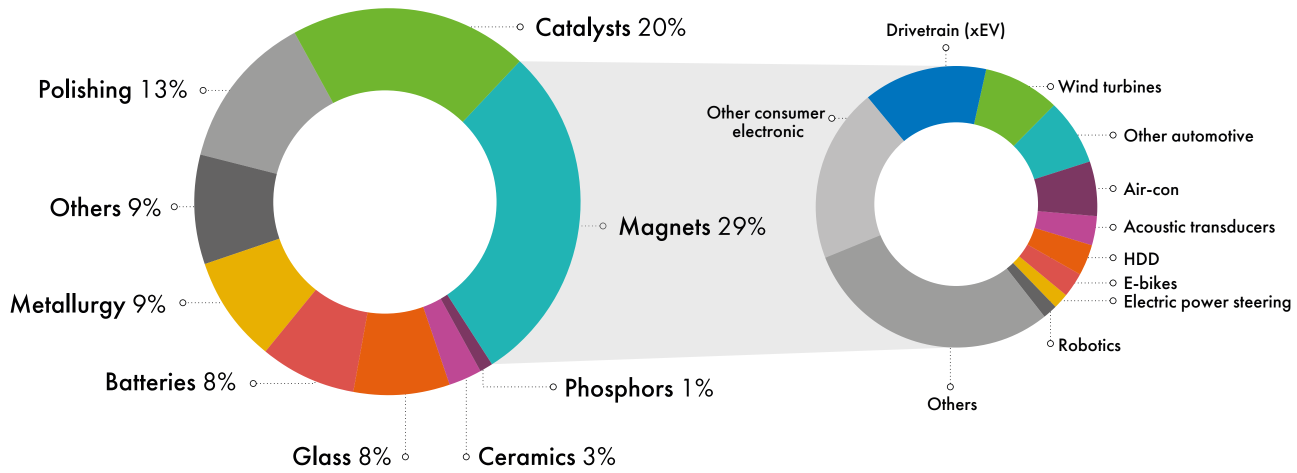
Competitiveness in the new energy market

The increase in turbine prices means average prices are back to levels not seen since 2015, reversing several years of cost reduction in the supply chain. A "sandwich effect" has left OEMs squeezed on costs at either end of the wind value chain. This presents a market dilemma, as the subsequent higher LCOE for wind energy will make it more difficult for wind and renewable energy to rapidly replace fossil fuel generation.

These changing dynamics exist against a background of two major trends: first, increased urgency to phase out fossil fuel generation, including schemes to adequately price the cost of carbon through regional carbon markets, carbon border tax mechanisms, removal of subsidies and other initiatives; second, a global increase in power prices due to volatility in gas and coal supply, which has only continued to spike through Q1 2022 amid Russia's military invasion of Ukraine.

Wind is already extremely competitive on LCOE terms with fossil fuels, and is likely to remain so. However, the current crisis has also shown the need to move beyond making policy decisions and market regulations based solely on LCOE.

Rare earth elements demand by sector and breakdown of magnets, 2020



Source: Rare Earths Market Outlook Report, Roskill, 2021.

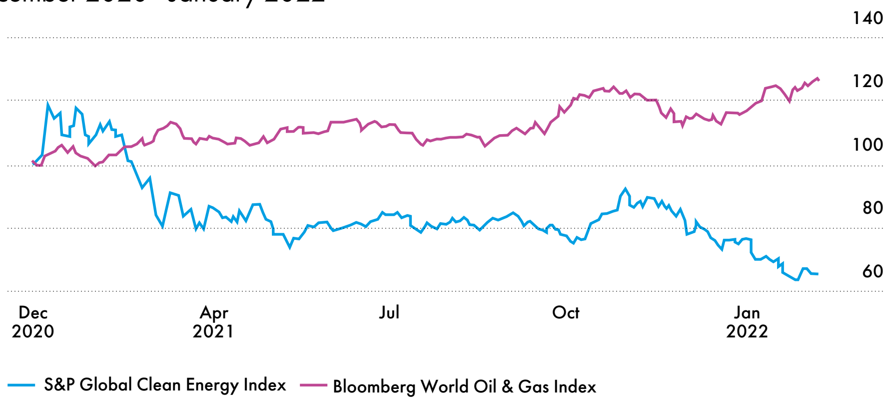
Addressing systemic market failures

While the immediate crisis for wind energy companies has been caused by spikes in the prices of raw materials and logistics challenges in the post-pandemic recovery period, the underlying causes of the industry's profitability squeeze lies in market design (see System Design).

In order to reach net zero and achieve a more secure and resilient energy system based on renewables, policymakers need to look towards the full system value of competing energy technologies and design markets that provide investment signals compatible with vital societal objectives and needs. The current pressure on renewable energy providers will not be sustainable, and only serves to demonstrate the deep and systemic market failure that is preventing us from reaching global climate and energy system goals.

To illustrate this colossal market

Share performance of fossil fuel companies versus clean energy companies, December 2020 - January 2022



failure, the current situation has seen sharp increases in electricity prices driven by fossil fuel-related supply issues but shouldered by consumers. In parallel, there are record profits for fossil fuel companies, including a revival in fortunes for "Big Coal", and a simultaneous squeeze on profitability for renewable energy companies. Governments must urgently intervene if the world is going to get on track to reach the Paris Agreement and net zero targets, both through short-term fixes which can ease supply tightness and longer-term market reform. It is essential that the economic and social value of green electrons are adequately recognised, and that investment in the clean energy industry is economically viable.

The energy transition cannot be a race to the bottom on prices, otherwise the wind industry cannot continue to deliver at scale and at pace. It is important that the wind industry continues to deploy projects on a large scale and to expanding geographies, especially in this crucial decade of action. The industry also needs the margins to maintain well developed global supply chains and industrial footprints, make crucial investments in research, technology and innovation – such as hybrid projects, supply chain circularity, social and community programmes and other areas which will enable sustainable growth.

As well as ensuring that sufficient incentives exist for investment in renewables, stronger market signals are needed to discourage investment in further fossil fuel generation and ensure that society is not providing perverse incentives which will add friction to the push for net zero. Whether this involves higher carbon taxes or even windfall taxes on fossil fuel profits, it is essential to address the current market failure through robust measures to push carbon generation off the system and incentivise faster and sustainable deployment of renewables.

PART TWO: SOCIETY

Part Two: Society

Public support for renewable energy has been building, as reflected in public opinion polls, international strikes and protests and institutional support for campaigns like Race to Zero and RE100. Meanwhile, the number of climate change-related litigation cases more than doubled from 2015 to 2021, including 37 "systemic mitigation" cases which challenge government inaction on climate goals around the world[1]

But as wind energy enters new and diverse geographic domains and continues to penetrate mature markets, and as its constituents grow to become the next green supermajors, the industry will undoubtedly disrupt the global energy system. This means confronting accepted social and commercial value systems. **Despite the broader trend of general public support for renewables, challenges around social acceptance continue to manifest locally when it comes to building wind projects.**

With disinformation and recent populist movements blurring the boundaries of the public interest, a social consensus around the energy transition cannot be guaranteed. The energy transition may be perceived to have a regressive impact on some communities, reflected in labour displacement in sunset industries to shifting consumer demand, as businesses chase localities which can supply them with renewable energy. These short-term setbacks could foment resistance and dangerous resentment of the "winners" of the transition.

Wind energy must be a custodian of the energy transition, and not merely one of the winners. As wind energy expands and green supermajors become global powerhouses, how can the wind industry shift away from the traditional orthodoxies of growth in the legacy energy sector which have eroded public trust or – alternatively – won fealty in niche communities? The industry must develop under cohesive and inclusive policies which dedicate public and private resources to a people-centred transition. Otherwise, the industry's expansion may generate enough friction to significantly slow down deployment rates – at a time when it is more urgent than ever to accelerate.

This friction has already manifested around the world into delays for project development and construction, commonly initiated by:

- **Challenges or lawsuits by interest groups which fear disruption and discord with the wind industry,** as in the recent case of a US fishing group filing a legal challenge to the US Interior Department and Bureau of Ocean Energy Management (BOEM) on the approval of the 800 MW Vineyard Wind offshore wind project in Massachusetts.[2] An offshore wind farm near Jeju Island in South Korea was the subject of public protests in 2020 by haenyeo, or female divers belonging to a local fishing village. [3]
- **Overzealous restrictions which limit the available space for wind projects to be built,** as in the case of the now-relaxed 1-kilometre minimum distance setback rule proposed by the federal German government.[4] The relaxation allowed states to set their own rules up to a maximum of 1-kilometre, although Bavaria maintained a "10-H," or 10 times height, rule which mandates that projects with a 200m tip height are located at least 2 kilometres away from dwellings. This is fairly extreme, given the setback rules are around 500 metres in Spain and France.

1. https://www.lse.ac.uk/granthaminstitute/publication/global-trends-in-climate-litigation-2021-snapshot/
2. https://renews.biz/75330/roda-to-sue-us-government-over-vineyard-approval/
3. http://koreabizwire.com/jeju-haenyeos-call-for-cancellation-of-offshore-wind-power-project/170413
4. https://windeurope.org/newsroom/news/german-government-drops-the-idea-of-a-nationwide-1000m-distance-rule/

- **Environmental challenges on the grounds of biodiversity protection.** A robust, inclusive and sensitive siting process combined with thorough Environmental Impact Assessments (EIA), which are required to develop any onshore and offshore wind project, will indeed address most concerns. However, the industry's expansion into new geographic areas has raised the need for further studies. For instance, $2.5 million in long-term and continuous bird surveys have been commissioned for the 640 MW Yunlin offshore wind farm under development in Taiwan.[5]

- **NIMBY-based (Not In My Backyard) challenges by local communities** which oppose wind projects for visual purposes or anxiety about turbine noise or declines in property values. One individual tracking purported community opposition of wind projects has found that more than 320 wind projects in the US have been the subject of opposition at town or county level since 2015.[6]

- **Land acquisition conflict** owing to multiple shareholder models, outdated and un-digitised land registries or protracted negotiations on compensation.[7] For instance, leasing revenue land for wind project construction in India is incredibly complicated, requiring clearances from numerous public entities including the state revenue department and local panchayats. Private land purchases are often slow due to high costs and several smaller parcels owned by multiple entities; lack of digitisation and inconsistent record-keeping has also resulted in multiple claimants for the same parcel.[8]

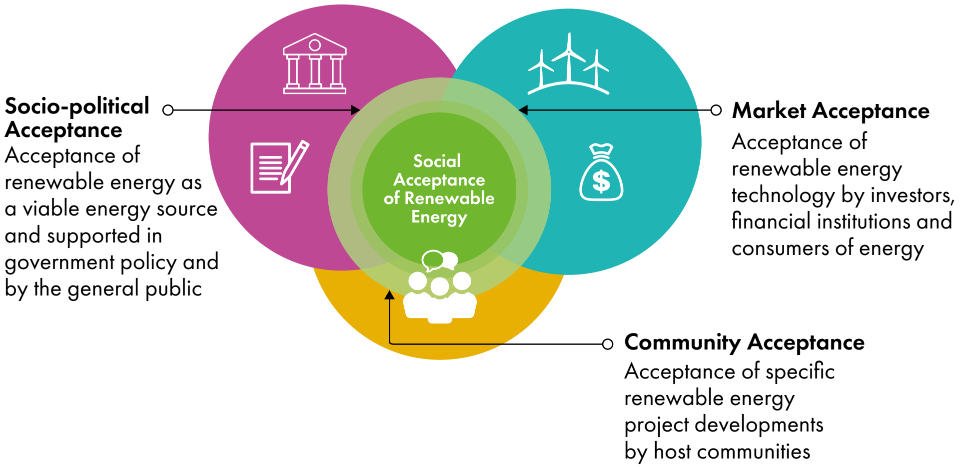
A common barrier is **extremely complex permitting schemes,** which straddle the social and regulatory domain. Obtaining the right licenses and consents for a wind project to proceed is necessary before a financial investment decision (FID) is reached and before construction can begin. As outlined below, these procedures are too often overly bureaucratic and inefficient, managed by under-resourced approval bodies. In some cases, permitting and government legal aid favours the actions of small, unrepresentative groups that object to wind farm projects, even when these projects enjoy strong support among the community as a whole.

Delays arising from complex regulatory procedures or interest groups which represent a minority interest pose impediments for government, civil society and industry to work together effectively to meet common climate goals. When social discord resulting from industry expansion is left unaddressed, the consequences can be long-lasting. Anxiety and disagreement with community developments can lead to political change, which can in turn lead to policy U-turns and variability.

Highlighting and equitably distributing the net-positive value creation that renewable energy brings can improve social cohesion around the energy transition. IRENA analysis shows that enacting a 1.5°C-compliant development pathway results in a loss of 14 million jobs related to fossil fuels, but a gain of 40 million jobs from transition-related investments such as large-scale wind and renewable energy deployment, grid enhancement and energy efficiency.[9] These jobs are spread across different disciplines, including marketing and administrative personnel, engineers, professional experts, labourers and technicians. Overall human welfare, according to an index of social, environmental, economic, distributional and access dimensions, increases by 11% by 2050 and global GDP is boosted by 1.2%, compared to a scenario of current energy policies. Further public benefits extend from water consumption savings to compatible co-location

5. https://www.4coffshore.com/news/yunlin-bird-survey-collaboration-between-germany2c-japan2c-and-taiwan-nid17553.html
6. It should be noted that this individual has written articles in opposition to the expansion of wind energy, especially in rural areas; while not a neutral source and not independently vetted, the collection of incidences is nonetheless telling: https://robertbryce.com/renewable-rejection-database/.
7. The Politics of Renewable Energy in East Africa, Oxford Institute for Energy Studies, 2018.
8. https://shaktifoundation.in/wp-content/uploads/2018/01/Study-Report-Addressing-Land-Issues-for-Utility-Scale-Renewable-Energy-Deployment-in-India.pdf; Kumar, A., Pal, D., Kar, S.K. et al. An overview of wind energy development and policy initiatives in India. Clean Techn Environ Policy (2022).
9. World Energy Transitions Outlook: 1.5°C Pathway, IRENA, 2021.

Dimensions of social acceptance of wind energy



Credit: Wüstenhagen, R., Wolsink, M. and Bürer, M. J., 'Social acceptance of renewable energy innovation: An introduction to the concept', Energy Policy, Vol. 35, No 5, 2007, pp. 2683-2691; REN21, Renewables 2020: Global Status Report, 2020.

models with the farming industry.[10]

The public and private sector must work together to provide meaningful change as the wind industry expands. Steering the transfer of benefits to communities is a critical component of a fair and just energy transition. The concept of a social license to operate (SLO) which emerged primarily from the mining industry, wherein energy projects need to foster long-term relationships with host communities and be sensitive and responsive to ongoing issues, would be relevant for the wind industry to implement as it grows.

Social and environmental value must become synonymous with wind power, whether captured by workforce transition schemes that identify alternative sustainable employment opportunities in clean energy for workers in sunset industries, or participatory dialogues with civil society during project development.

Social responsibility and responsiveness are increasingly fostered by institutions applying ESG criteria to wind project investments. According to the UN Principles for Responsible Investment, the 'S' pillar of ESG is a challenge to assess as ''social issues are less tangible, with less mature data to show how they can impact a company's performance. But issues such as human rights, labour standards and gender equality—and the risks and opportunities they present to investors—are starting to gain prominence.''[11] As more qualitative and quantitative criteria are outlined for social performance, wind project developers can strengthen their practices accordingly.

While wind power is seen as a climate change solution, it must also consistently be seen as a win-win for nature preservation in order to foster community, socio-political and market acceptance. Renewable energy and the protection of nature are both inherently necessary for sustainable growthand harmonious co-existence of society and the natural world. A comprehensive public strategy on environmental protection and biodiversity must therefore recognise the need to accelerate renewable energy deployment to displace fossil fuels.

Further research and technical studies can yield information to help redesign project structures or layout to mitigate adverse environmental impacts. Where impacts cannot be avoided or meaningfully mitigated, the industry has also provided compensation measures to restore or replace nature, such as peatland restoration around wind farms in Scotland. Some wind projects go beyond maintenance to generate ''nature-positive'' outcomes, such as offshore wind farms in the North Sea which provide artificial reef habitats and restore degraded flat oyster beds to a healthier condition.[12]

Early, effective and sensitive siting and spatial impact assessments, which account for biodiversity protection needs and natural areas which may already function as natural carbon storage, are crucial for ensuring that project design

10. See: http://socialacceptance.ch/.
11. https://corpgov.law.harvard.edu/2020/06/28/time-to-rethink-the-s-in-esg/
12. Bennun, L., van Bochove, J., Ng, C., Fletcher, C., Wilson, D., Phair, N., Carbone, G., (2021). Mitigating biodiversity impacts associated with solar and wind energy development. Synthesis and key messages. Gland, Switzerland: IUCN and Cambridge, UK: The Biodiversity Consultancy.

and implementation does not come into conflict with NGOs and other stakeholders down the road. This process needs to be participatory, inclusive of industry, relevant government agencies, conservation NGOs and local civil society.

Without localised social consensus on the pace and scale of wind energy expansion, the industry will continue to face protracted battles with communities and bureaucracy on the ground, and we will miss our Paris targets. While policymakers and scientists have convened around the need to deploy renewable energy at speed on a global scale, an enabling social and regulatory environment is crucial to delivering a sustainable pipeline of projects.

For a green future, cut the red tape

The window to act for a 1.5°C pathway has been called "narrow but achievable," "tough but possible," "ambitious but within reach," and other phrases which reflect the same truth: The decisions made in this decade will set the course for this century.

For the wind industry, this means getting on-track for a massive increase in installations and industrial capacity exceeding 8,000 GW of wind energy by 2050 – around 10-fold the existing capacity today.[13] At the same time, the wind sector is committed to grow in alignment with sustainable development, circular economy, harmonious co-existence with host communities and local stakeholders and adherence to high environmental and social standards.

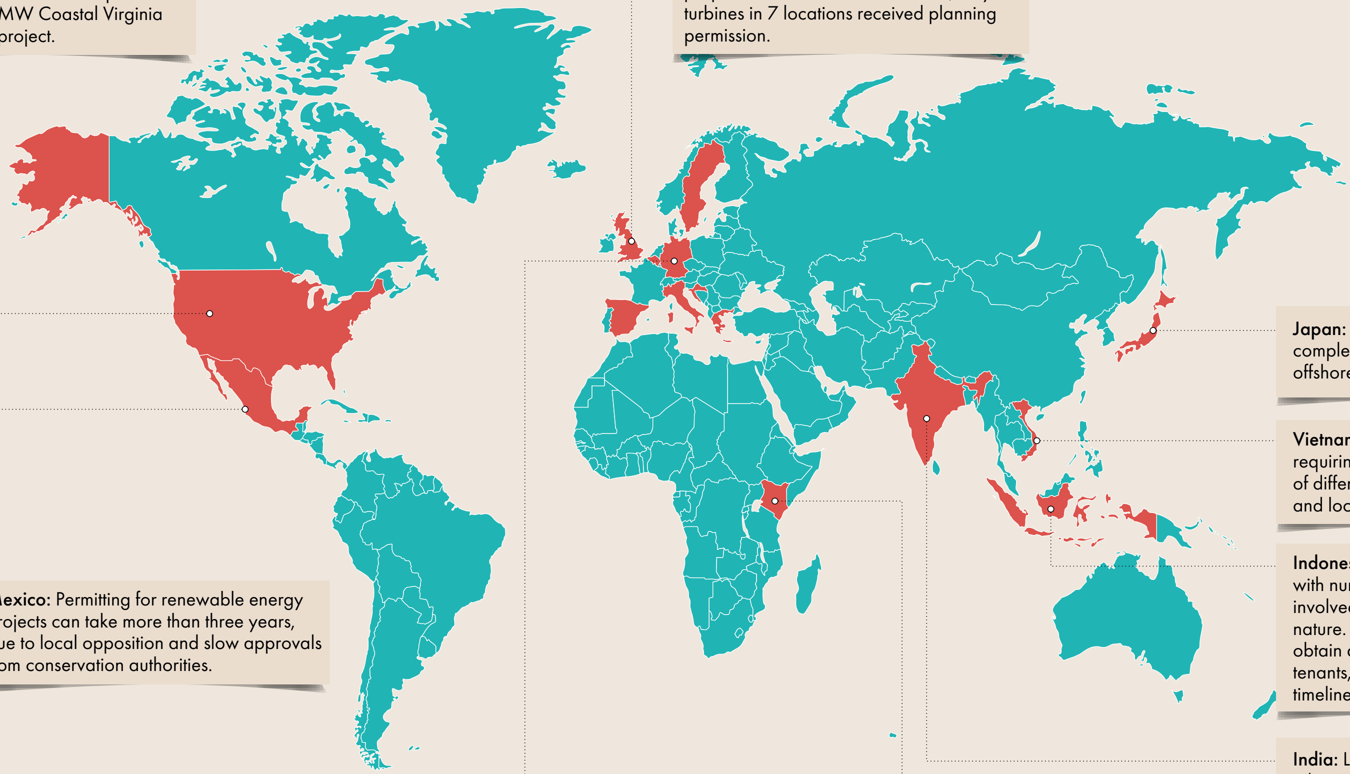
But current policy and market frameworks are creating a widening gap between ambition and reality. Too many countries are unable to leverage the enormous interest from investors to deploy wind energy projects due to overly complex and bureaucratic permitting schemes. These schemes are critical – they are designed to understand, assess and mitigate impacts of wind projects to local environments and communities, as well as equitably distribute burdens and benefits. But taking several years to complete, they are weakening national energy transitions all over the world.

Permitting lead times – which cover spatial planning, environmental and social impact assessment, planning authorisation, grid connection and legal challenges – are slowing down wind energy deployment in countries at various stages of the energy transition. Without streamlining the procedures to grant permits, including land allocation and grid connection, there will be a surplus of projects "stuck in the pipeline" and we will miss our climate targets.

Labour- and resource-intensive permitting processes increase transaction costs and development risks for wind projects, and undermine the investment case. The number of jurisdictions involved in a utility-scale wind project, from ministries of finance to transport, is large; without a centralised system or authority, the process of navigating approval procedures among multiple institutions is formidable. These delays mean deferred opportunities to realise capital

13. World Energy Transitions Outlook: 1.5°C Pathway, IRENA, 2021; Net Zero by 2050: A Roadmap for the Global Energy Sector, IEA, 2021.

Wind energy faces permitting barriers around the world



US: Offshore wind projects generally require at least 6 years for permitting. It took almost eight years to obtain permits for the two-turbine 12 MW Coastal Virginia offshore wind pilot project.

UK: Onshore wind must meet strict planning requirements, with under-resourced local authorities and a lack of guidance on demonstrating community support for a project. Between 2016 and 2020, only 16 turbines in 7 locations received planning permission.

Japan: Up to 8 years to complete the complex EIA process for onshore and offshore wind projects.

Vietnam: A complex permitting environment requiring nearly 20 approvals from dozens of different authorities at national, provincial and local levels.

Indonesia: Permitting is slow and uncertain, with numerous government agencies involved and some permits discretionary in nature. Land ownership evidence is hard to obtain and can be disputed with traditional tenants, while there is no guaranteed timeline for land certification.

Mexico: Permitting for renewable energy projects can take more than three years, due to local opposition and slow approvals from conservation authorities.

Spain, Italy, Greece, Sweden, Belgium and Croatia: Permitting can take more than 8 years for onshore wind, including the time taken by any legal challenges.

Kenya: Acquiring land is laborious and has led to legal challenges for wind projects in Lamu County, partly due to an under-re-sourced National Lands Commission. Wind projects often face local opposition and disagreement regarding compensation or resettlement.

India: Land acquisition for wind projects takes 6 to 24 months. Some states such as Rajasthan lack a streamlined dispute resolution process, resulting in extended delays for wind projects.

Source: GWEC Market Intelligence.

investment in communities, job opportunities and growth.

Elongated timeframes also lead to projects reaching the construction stage with outdated technology in their plans, including wind turbine models which may no longer be manufactured at optimal scale or cost-efficiency. Developers may need to modify the wind project design or layout by the time approvals are granted, triggering a permit extension and further delays. As noted by the Australian Energy Infrastructure Commissioner, it is therefore ''feasible that a period spanning 20 years or more can occur between the original prospecting at the wind farm site, permitting approvals and the wind farm being constructed.''[14]

This bottleneck has already garnered wide attention and prompted government action. In China, largely due to strong central steering, regulated timelines for permitting and consents (12-24 months for onshore wind and 24-36 months for offshore wind) are generally followed, and the attrition rate for wind projects is low. In the Philippines, an executive order in 2021 prompted the creation of a task group to implement the Energy Virtual One-Stop Shop (EVOSS), an online platform to coordinate data and information for energy project applications. The task group was directed to work with the Anti-Red Tape Authority government office, and report annually to the Office of the President.

The European Commission launched a public consultation on renewables permitting in January 2022, with the aim of accelerating progress towards the 40% renewable energy target by 2030. This consultation will include an examination of the rules around spatial planning, viability of ''one-stop shop'' models, intervening bodies for extensive legal challenges, as well as human and digital resource requirements for permitting bodies. The 2018 EU-wide Renewable Energy Directive already introduced guidelines for permitting including single contact points and maximum durations for the project approval process.[15] But this has not yet been successfully implemented at the country level.

While Europe is generally viewed as a climate leader, many countries in the region demonstrate how administrative procedures can become significant bottlenecks to the phaseout of fossil fuels. For instance, onshore wind construction permits in Italy take five years on average, rather than the six months required by law. These delays have dragged deployment rates down to roughly 200 MW per year – a far cry from the levels needed to deliver Italy's 70 GW renewable energy capacity target by 2030.[16] The impact on investment is brutally clear: Italy's recent renewable energy tender went undersubscribed, awarding only 975 MW of utility-scale projects out of a total 3,300 MW on offer.

The US goal for carbon-free electricity by 2035 is also threatened by permitting challenges, where wind projects are required to undergo an extensive inventory of reviews and authorisations. At the federal level, these include reviews or approvals under the Business Resource Lease, Clean Water Act, Bald and Golden Eagle Protection Act, Military Mission Impact Process, Endangered Species Act, Fish and Wildlife Coordination Act, Floodplain Assessment, Native American Graves Protection and Repatriation Act and more.[17] Federal agencies take an average of 4.5 years to complete environmental impact statements under the National Environmental Policy Act alone. [18]

Transmission projects which would widen renewable energy supply are also burdened by slow bureaucratic procedures. The $2.5 billion Clean Line Energy project which would have transferred wind energy from Oklahoma to the southeast of the US received a green light from the Department of Energy in 2015, but was stymied by legal challenges and community opposition until a crucial

14. https://www.aeic.gov.au/observations-and-recommendations/chapter-4-planning-permits
15. https://ec.europa.eu/info/sites/default/files/amendment-renewable-energy-directive-2030-climate-target-with-annexes_en.pdf
16. GWEC Market Intelligence reflects 192 MW of onshore wind installed in Italy in 2020 and 201 MW in 2021. Additional information: https://www.xm.com/research/markets/allNews/reuters/italy-promises-quotbrutalquot-cuts-to-red-tape-delaying-renewable-energy-projects-42462524.
17. https://www.permits.performance.gov/sites/permits.dot.gov/files/2020-03/Environmental%20Review%20and%20Authorization%20Inventory%20%281.17.20%20Update%29.pdf
18. Average of 4 years for Department of Energy and 2 years for the Bureau of Ocean Energy Management, measured over the period 2010-2018. See: https://ceq.doe.gov/docs/nepa-practice/CEQ_EIS_Timeline_Report_2020-6-12.pdf.

Case study: Making wind energy growth a political priority in Germany

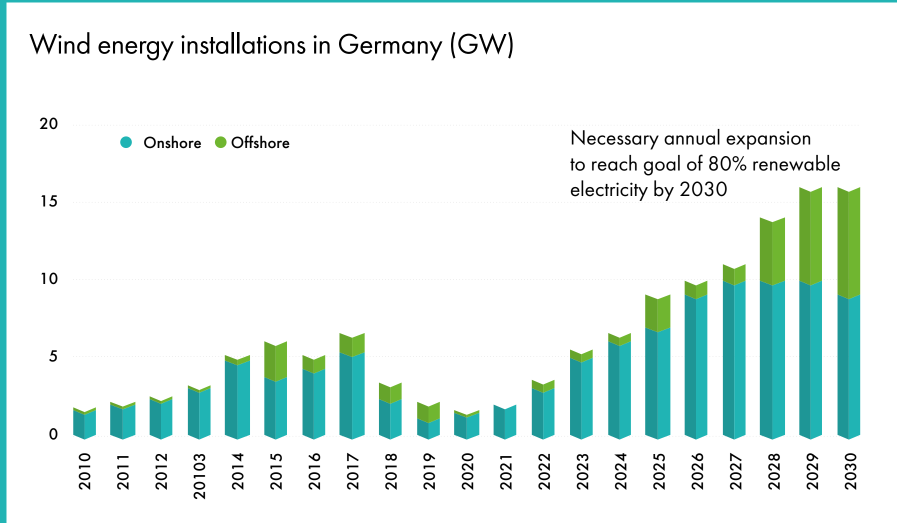
In recent years, the expansion rate of wind energy in Germany has severely declined. After a historic low in 2019, numbers are increasing slowly, but far stronger expansion rates are crucial to meet Germany's climate goals.

Tackling climate change and accelerating wind energy deployment are now becoming priorities of Germany's new coalition government. In 2021, after 16 years of Angela Merkel's chancellorship, a new government led by Social Democrat Olaf Scholz came into office.

The coalition agreement between the Social Democratic Party, the Greens and the Liberal Democratic Party emphasises the need for a rapid and massive expansion of renewables and commits to a 1.5°C pathway for climate neutrality by 2045. To reach this goal, 80% of the power mix must come from renewable sources by 2030 – this would require annual installations of more than 10 GW of wind energy from 2026 onward. Therefore, the coalition intends to reform the Climate Change Act and initiate all necessary policy reforms within the first half of 2022.

The new Federal Minister for Economic Affairs and Climate Action announced two major policy packages in January 2022:

- The reform of the Renewable Energy Sources Act will be at the core of the first package, which also includes proposals for reform of citizen energy projects, regulations regarding pilot project facilities and community profit-sharing schemes with wind projects. A cabinet decision on this set of legislation is expected in April 2022.
- The second package, to be presented in mid-2022, will address some of the core issues that have constrained expansion of wind energy in Germany: reform of the highly bureaucratic permitting process for wind projects, as well as a mandatory allocation of 2% of each federal state for wind farms. Reforms in the field of environmental protection and biodiversity conservation are expected to pre-emptively address challenges around conservation and the urgency of the energy transition.



Simplifying and speeding up the repowering prospects for existing wind energy sites is also a major focal area to reach the 2% allocation goal and improve the energy yield of already existing farms.

Taken altogether, these measures should streamline the permitting process, which currently takes six years for onshore wind, and lead to significant reduction of costs. However, these measures are not likely to take effect until at least 2023 and require strong federal-state alignment. Once in place, the growing share of wind and renewable energy, combined with a market framework that works for renewables, is the optimal remedy to the current power pricing crisis and to achieve Germany's climate goals.

With input from: Bundesverband WindEnergie e.V. (BWE)

Note: While this case study was written in early 2022, energy policy in Germany continues to evolve following European efforts to reduce reliance on Russian natural gas after Russia's invasion of Ukraine in February 2022.

interconnection agreement expired in 2018.[19]

Finally, permitting for repowering of older wind projects should be accelerated. Repowering offers an efficient pathway for more mature wind markets to maximise productivity and socioeconomic benefits from sites already permitted for wind power production. Around 4,700 wind turbines in Europe could be decommissioned by 2023, and nearly one-quarter of the onshore wind in North America will reach end of lifetime by 2030 – these turbines could be replaced with fewer and larger models in accordance with the most advanced technology, unlocking increased energy yield and cost reduction for offtakers, consumers and asset owners and operators.[20]

The benefits of repowering go beyond extending the operating lifetimes of wind projects. The first generation of projects developed in countries often benefit from allocation of sites with best-class wind resource. Repowering with full or partially upgraded turbine system components allows the project to obtain the maximum value of energy productivity from these sites with newer and more efficient technologies. In aggregation, this greater yield can help to enhance wind generation profiles in the wider energy system, increasing the installed capacity base and contributing to grid balancing and improved system stability.

Streamlined and sensible permitting schemes for renewable energy projects are needed to accelerate deployment and minimise project attrition. The following measures should be considered, among others:

- **Mandated maximum lead times** to permit wind energy plants, such as 2 years for greenfield onshore wind projects, 3 years for offshore wind projects and 1 year for repowering projects, with additional discretionary time allowance under extraordinary circumstances.
- **Repowering should be enabled via regulatory fast tracks** which allow streamlined permits and EIA procedures and extensions for site licensing and use, as upgraded turbine technology can bring modifications in physical structure and farm design. Simplified permitting should also include expansion of grid connections to integrate larger turbines with higher power ratings.
- **Digitised, searchable and up-to-date databases** for land registrations and siting of renewable energy projects, including an inventory of local ordinances and records of where energy projects have met community resistance, which can support local authorities with zoning for projects.
- **Dedicated centralised authorities** and single focal points who can work with renewable project developers to streamline the siting and permitting process.
- **More staff and digital resources** for the various authorities which make decisions during the permitting process of a wind project.
- **Transparent land and ocean use guidance,** aligned at national and sub-national level, which prioritises DNSH, green economy and nature-positive initiatives, and even identifies areas suitable for wind projects where planning could be fast-tracked.
- **Active dialogue between communities and industry** throughout the lifecycle of a wind project, particularly in developing economies where energy justice and energy sovereignty are emerging narratives.
- Where local opposition and NIMBYism is particularly challenging, policymakers can consider encouraging **community benefit schemes** attached to renewables projects to improve public support.
- **A clearing house mechanism for legal disputes** to prevent extended delays to critical infrastructure projects, and a structured and time-limited process for developers to provide evidence.

The energy transition calls for system-wide transformation, powered by renewable energy. Policymakers must ensure that regulation is set up to enable a

19. https://talkbusiness.net/2018/01/controversial-2-5-billion-clean-line-project-stalled-will-evaluate-options-officials-say/
20. https://windeurope.org/wp-content/uploads/files/about-wind/reports/WindEurope-Accelerating-wind-turbine-blade-circularity.pdf; GWEC Market Intelligence.

Case Study: Permitting – the make-or-break of Europe's decarbonisation ambitions

The EU wants to be climate neutral by 2050. Renewables-based electrification across the economy will be key to this ambition. Electricity covers only 24% of Europe's energy demand today. But the EU decarbonisation scenarios foresee it is set to cover directly 57% of final energy uses and 18% indirectly through renewable hydrogen. Wind will play the biggest role in providing clean and competitive power: it is set to generate 50% of Europe's electricity by 2050.

This all means that the EU is now calling for 1,000 GW onshore and 300 GW offshore wind in 2050, up from 173 GW and 16 GW today respectively. This is doable: the technology and finance are available, and costs have come down.

But the key challenge is permitting. Permitting procedures across the EU are long and cumbersome. Europe is not permitting enough new wind farms to meet the huge demand in renewables, nor is it permitting them fast enough. The EU-27 is building only half the wind volumes it needs to reach climate neutrality. It needs 32 GW of new wind capacity each year until 2030 already. The region built only 11 GW in 2021 and is set to build 18 GW a year over the next five years. Permitting delays lead to uncertainty over project pipelines and undermine the health of the European wind supply chain.

2022 will mark a make-or-break moment with regards to permitting in the EU. The EU Member States should have already implemented shorter permitting procedures as mandated by the EU Renewable Energy Directive. EU law says new renewable energy installations should be permitted within 2 years and repowered ones within 1 year. The majority of Member States fall behind these deadlines. So the European Commission is set to present a new Permitting Guidance in summer 2022 to support Member States with best practice in simplifying permitting.

To address the permitting situation, the EU has launched the RES-Simplify project to which the European wind industry is partnering up. The project looks at permitting barriers for all renewable energy sources in all EU Member States. It aims to provide an overview of permitting bottlenecks and to make recommendations for simplifying procedures. The full results of the project are expected by the end of 2022.

So far the preliminary conclusions show a fragmented picture for wind energy deployment. 75% of total wind installations happened in only six markets in the past 10 years. Buildout has been particularly weak for onshore wind. And administrative and grid barriers presented more than half of all barriers linked to permitting for wind installations.

In the meantime the European wind industry is making its recommendations for improving the permitting situation in Europe. These include the clarification of responsibilities in the permit granting process between the many administrative authorities involved at national, regional, local level, with clear decision deadlines to oversee. It's also about EU countries establishing a single contact point to expedite the process. Permitting authorities also need to ramp up human and/or digital resources to handle the increasing number of renewable permits and here the EU Recovery Plan could support Member States with funding.

EU countries could also apply best practice and common sense rules on spatial planning such as minimum distance to housing, tip/hub height restrictions, exclusion zones around military/aviation radars. This will allow Europe not to lock itself down in old wind turbine technology and will give a boost to repowering in major wind markets such as Germany, Spain, Italy. And Europe needs to develop rules on the simplified permitting and grid connection for co-located renewable energy projects (e.g. wind/solar/storage) and offshore hybrid power plants.

With input from: WindEurope

renewables-based system, and that bureaucracy and red tape are not obstructions to achieving our climate goals.

Disinformation: A growing threat to a just energy transition

Enduring political will among governments and policymakers is required to push forward consistent and sustained policies and enable a shift to renewables-based energy systems. This long-term political will must be based upon a wide-ranging social consensus around the actions necessary to decarbonise and carry out the energy transition.

In short, while we cannot expect public opinion and political debate to be without fluctuations, society will require a shared understanding based on rational decisions around social priorities and their implications for the energy sector. Radically overhauling our entire energy system will require hard choices in many cases. That being said, we cannot afford for disinformation to disrupt decision-making processes or mislead dialogues around the relative cost and benefits, discrediting viable solutions and creating false polarisations and zero-sum choices.

In recent years, governments have struggled to deal with a political animus that is both populist and sceptical – much of it fuelled by disinformation. Some policymakers have struggled to win over public opinion on previously uncontroversial scientific arguments, while others have been swayed by populist campaigns due to expectations of short-term political benefit. These opportunistic stances often have little political cost to politicians – but they can lead to serious hiatuses and disruptions to the energy policy environment.

For this reason, GWEC considers hostile disinformation as a growing and perhaps critical threat to the energy transition.

From climate disinformation to solution disinformation

The history of climate change denial has been well documented. Since the early to mid-1970s, increasing consensus around the basic tenets of climate change and, in particular, the causal link between human activity and climate change was met by systematic attempts to question and throw doubt upon climate science, much of this funded by incumbent fossil fuel interests.

In the internet age, a key moment was the release of hacked correspondence between climate scientists in November 2009. The incident, which became known as "Climategate," falsely purported to show a conspiracy by scientists to distort evidence and mislead the public to exaggerate certainty around the human-made nature of

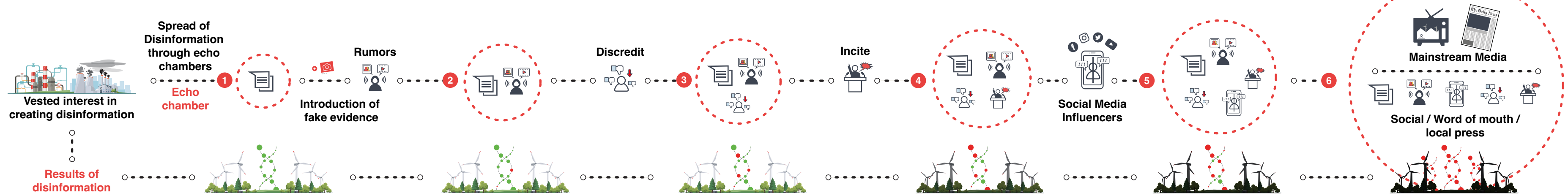
What is disinformation?

Disinformation is the intentional and organised diffusion of false information. It is often created and spread by extreme and ideologically driven groups, such as groups working to defend a particular economic interest from which they directly benefit, and by bad actor governments and bureaucracies which see a strategic advantage in disrupting change.

Disinformation can take a relatively small scale and spontaneous form, such as false claims repeated in an email chain or a single social media page. It can also take the form of large-scale "lie machines": well-funded operations that involve the systematic creation, distribution and marketing of false information.

Lie Machines, Phillip N. Howard, 2020.

Stages of Disinformation



climate change.[21] Fragments of thousands of hacked emails stolen from a UK academic server were selectively pieced together to form a narrative that suggested climate change was an elaborate hoax. These email extracts were then released and distributed in a highly organised fashion, with the storyline being reported enthusiastically by sympathetic media around the world, led by outlets in Rupert Murdoch's media empire such as Fox News and the Wall Street Journal.

Following two years of extensive investigations in the US and UK, the "revelations" turned out to be entirely baseless, with the scientists exonerated and no evidence of data manipulation or misleading the public; the only wrongdoing established was the theft of emails itself, purportedly carried out by a hacker based in Russia. However, the affair caused significant damage by undermining trust and focus at the crucial Copenhagen COP15 summit, where the story was cited by delegates of countries actively opposing proposed agreements. The summit ended in failure in December 2009.

Despite incidents such as this, consensus around climate change and the need to urgently act on mitigation has grown steadily since 2009 – backed by increasingly clear, comprehensive and undeniable scientific research.

Large-scale public opinion polling on a global scale shows increasing concern and prioritisation of climate change across all geographies, with public understanding and urgency particularly strong among younger people. A 2017 survey by Ørsted and Edelman Intelligence, which covered 26,000 people in 13 countries in North America, Europe and Asia, found that more than four-fifths of people believe it is important to create a world fully powered by renewable energy, with consistency across age, education level and stated political ideology.[22] A YouGov poll in Indonesia, Pakistan, the Philippines, South Africa, Turkey and Vietnam in 2019, found that the majority of citizens felt their country should invest in renewable energy to support long-term development.[23]

Accompanying this has been much stronger political consensus, which reached a key moment with the signing of the Paris Agreement by 196 Parties, accounting for 98% of anthropogenic emissions in 2015.

This has also led to a decline in disinformation campaigns around "classic" climate denialism and a shift in narratives towards discrediting climate solutions such as wind power. A recent paper reflects a study of machine-learning to identify growing disinformation narratives, and demonstrates this decisive shift from "climate denial to solution denial."[24] One of the academics has noted, "We fed 21 years of climate change denial blog posts from the UK into a machine-learning programme. We found that science denialism misinformation is gradually going down – and solution misinformation [targeting climate policy and renewable energy] is on the rise."[25]

Given the increased sophistication and capacity of "lie machines" to spread disinformation through social media and messaging platforms, and an increasing propensity in some countries to accept irrational and misleading ideas in opposition to established science, these "solution denial" narratives have a significant capacity to disrupt and delay climate action and the energy transition.

Identifying the narratives

Fundamentally, solution denial works in two main areas: arguing that policies aimed at addressing climate change do not work or make the situation worse; and arguing that key decarbonisation technologies (wind or solar energy, for instance) do not work.

21. The New Climate War, Michael E. Mann, 2021.
22. https://www.vox.com/energy-and-environment/2017/11/20/16678350/global-support-clean-energy
23. https://www.e3g.org/news/polling-citizens-six-belt-and-road-countries-want-clean-energy-not-coal/
24. Computer-assisted detection and classification of misinformation about climate change, Coan, Boussalis, Cook and Nanko, 2021.
25. We found that science denialism misinformation is gradually going down – and solution misinformation

In the latter area, and particularly regarding narratives discrediting wind energy, there is widespread organised disinformation based on false, antiquated or unsubstantiated data. Common arguments include claims that: wind turbines do not work or are inefficient; wind turbines use more energy than they produce; wind energy is more expensive than fossil fuel; wind energy capacity needs an equivalent amount of fossil energy as ''backup'' thereby involving large ''hidden costs''; and so on. These can be rebutted using widely available LCOE numbers, market data which reflects the impact of wind energy on power prices and analyses of the impact of wind energy production on power systems. However, the wide availability of such information has so far not curtailed such arguments from circulating.

Significantly, in a trait common to much disinformation, the concerns around cost often intersect with conspiracy-type theories based on the idea that renewable energy is a ''scam'' aimed at enriching an elite group, rather than a genuine response to the climate emergency.

More sophisticated campaigns have emerged around the exaggerated or false environmental impacts of wind turbines, which seek to engage people who would generally be supportive of decarbonisation initiatives. These are centred around a series of claims regarding wind turbines: having a negative effect on biodiversity, both onshore and offshore (a key claim of anti-wind advocates in the recent French election campaigns); wind turbines being a major source of bird deaths; using large amounts of fossil fuels to keep spinning; creating more emissions in the supply chain than they remove from energy systems; creating large amounts of waste; and creating massive environmental damage due to mining of minerals used in wind turbines.

These arguments are often presented without context and without comparative analysis against other energy technologies. They are aimed at confusing stakeholders – some of whom can be mobilised against wind energy, slowing the deployment of wind by creating public opposition to new projects – and creating justifications for vested interests that feel threatened by wind energy.

Texas Disinformation Trail in 2021

15 February

AM, 15 February
Disinformation first appears
Luke Legate's tweet first links a photo of a Swedish turbine from 2014, with Fox Business soon sharing similar messages to a wider audience

PM, 15 February
Disinformation echoed to new audiences
The message is spread to diverse audiences by other voices, on the fringes and in the mainstream

16 February
AM

AM, 16 February
Disinformation reaches thought leaders
Mainstream thought leaders carry the message into the centre of the news agenda

AM, 16 February
Disinformation reaches elected officials
A nationally elected Senator shares the original tweet, while a local official declares 'green energy' is 'killing people'

16 February
PM

PM, 16 February
Disinformation emerges as blame by Texas Governor
Texas Governor Greg Abbott names wind energy as a key issue, despite having named oil and gas in a previous tweet

"Our wind and our solar, they got shut down and they were collectively more than 10% of our power grid, and that thrust Texas into a situation where it was lacking power in a statewide basis"
Texas Governor Greg Abbott

Providing stakeholders and the public with facts and education about wind energy is, of course, important to rebutting disinformation. But the fundamental risk is that these narratives are based on organised and deliberate falsifications or distortions of facts.

In order to defend against and disarm the pernicious spread of disinformation, there are a number of actions which governments, communities and industry can undertake. On a general level, it is more important than ever that political leaders behave responsibly, act according to a shared understanding of scientific evidence and avoid embracing forms of populist discourse based on irrational distrust and suspicion. This means taking a principled position based on the long-term societal challenges and opportunities of the energy transition in the face of short-term challenges.

There are also a number of practical steps that can be taken by both public and private actors:

- Monitor the creation, distribution and marketing of false information, mapping and understanding its spread and emerging false narratives.
- Identify the bad actors that are creating and maintaining lie machines and exposing these to public scrutiny, thus allowing people to understand attempts at manipulation and make rational choices.
- Engage with platforms to ensure that false content is identified, flagged and removed.
- Educate through media literacy campaigns so that the public is prepared to recognise false information, scrutinise sources and check against facts.

Over the coming months, GWEC will be working with a number of partners to create a systematic framework that maps disinformation in the wind industry. The purpose is to understand how disinformation is being created and distributed, so that the industry can respond to it more effectively.


PART THREE: SUPPLY CHAIN

Part Three: Supply Chain

The global wind turbine supply chain is diverse and includes the participation of full turbine OEMs and key component suppliers for nacelles, blades, generators and converters, gearboxes, bearings and control equipment. The supply chain is further divided into sub-contracting for engineering and construction, providers of raw materials and heavy machinery, assembly, operations and maintenance (O&M) and other services. Manufacturers have sought to strike the most sustainable and competitive balance between vertical integration of component supply and full component outsourcing to fit their turbine designs.[1]

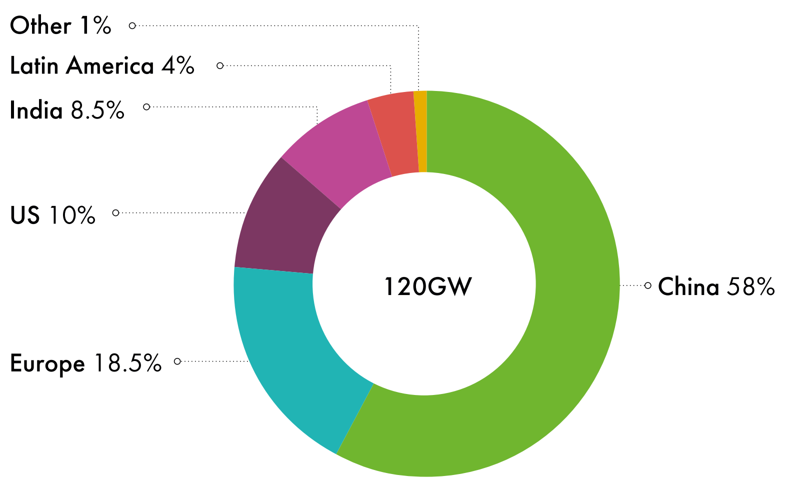
GWEC Market Intelligence shows that out of 35 global wind turbine suppliers, 23 are based in the Asia-Pacific (APAC) region, mainly China and India. The top three western turbine OEMs – Vestas, Siemens Gamesa Renewable Energy and GE Renewable Energy – are fairly globalised with local partners. China is the primary base for wind turbine components manufacturing and also a global export hub for generators, blades and gearboxes. Europe is the second-largest provider of generators and blades globally, followed by the US. Latin America, primarily Brazil, serves as a blade export hub to North America and other markets.

This increasingly global supply chain has excelled in technological innovation over the last decade. Global average rotor diameters have from 82 metres in 2010 to nearly 120 metres in 2020, while average hub heights have sprouted from 81 metres to 103 metres over the same period.[2] Turbine sizes have increased by more than 100% in Sweden, Brazil and Canada. Altogether, these developments have led to a nearly one-third rise in global weighted-average capacity factors for onshore wind to 36% in 2020, and driven down wind LCOE across the world.

In the offshore wind supply chain, rotor diameters have increased by nearly 50% to 163 metres by 2020, while turbine sizes have ballooned by 138% to an average 8 MW over the last decade. These have similarly allowed offshore wind capacity factors to reach new heights, as much as 44% in Europe in 2020. The advancement and technical standardisation of floating wind technology over the next decade will usher in similar achievements in performance and utilisation.

Still, technological advancements and best-in-class innovation have not sheltered the global wind supply chain from recent headwinds. From competitive tenders to geopolitics to circularity, forces of change are compelling the industry to react with greater consolidation and coordination.

Global wind turbine manufacturing capacity, 2020



Source: GWEC Market Intelligence, November 2021. Note: Wind turbine manufacturing capacity refers to wind turbine nacelle assembly capacity and does not represent actual nacelle production in 2020.

https://www.wind-energy-the-facts.org/supply-chain-key-to-delivery.html
Renewable technology innovation indicators: Mapping progress in costs, patents and standards, IRENA, 2022.

Consolidation as a response to global pressures

Over the last few years, revenue pressure, pandemic-related challenges to logistics and workforce availability, the ongoing US-China trade conflict and a rise in prices for raw materials and commodities have impacted pricing and procurement of wind turbine components. As price pressure on supply chains increases (see Industry Sustainability), consolidation and vertical integration are reshaping the way the global supply chain operates.

Around 40% of global generator demand and 45% of global wind blade demand can be supplied by the in-house production of 15 OEMs today, according to GWEC Market Intelligence. The global number of OEMs has almost halved from 63 in 2013 to 35 in 2020. This consolidation has helped achieve economies of scale and lower LCOE, by housing manufacturing of several components (such as turbines, gearboxes and other equipment) within a single company or network of local partners.

Production is shifting to markets with relevant domestic demand, ease of doing business, relatively lower production and labour costs, availability of local wind engineering skills, suitable infrastructure and seaways. India is now taking off as the second-largest export hub within APAC for wind turbine assembly and key components such as gearboxes, supplying Southeast Asian, European and the US markets. Moreover, top offshore wind turbine suppliers are gradually strengthening the role of Europe and China as export hubs, and giving rise to new localised partners and independent component suppliers in East Asia and Southeast Asia, such as in Taiwan and Vietnam.

Where wind manufacturing and export hubs have emerged (the top five globally are China, Europe, India, the US and Brazil), extensive local value creation has followed in the development of highly qualified workforces with skills in wind turbine technology design and engineering, wind resource estimation, business development and research, manufacturing, transportation, installation and O&M.

The global wind supply chain has consolidated for efficiency but is still exposed to headwinds, from competition for critical minerals to local content requirements to unexpected geopolitical events. The need for long-term and adequately ambitious policy frameworks, as well as remuneration mechanisms for stable cost reductions, will be increasingly important for mitigating supply chain risks (see System Design). In addition, maintaining and regulating free and open international trade for wind turbine components will support healthy price competition and a more efficient global supply chain.

The new geopolitics of the wind supply chain

A wind turbine is a substantial piece of construction and technology, with advanced machinery and high-strength materials. The amount of steel used in one wind farm is in the range of 107-132 t/MW, accounting for 24% of total materials in an onshore wind farm and 90% of total materials in an offshore wind farm, while concrete, in the range of 243-413 t/MW, accounts for roughly 72% of an onshore wind farm.[3]

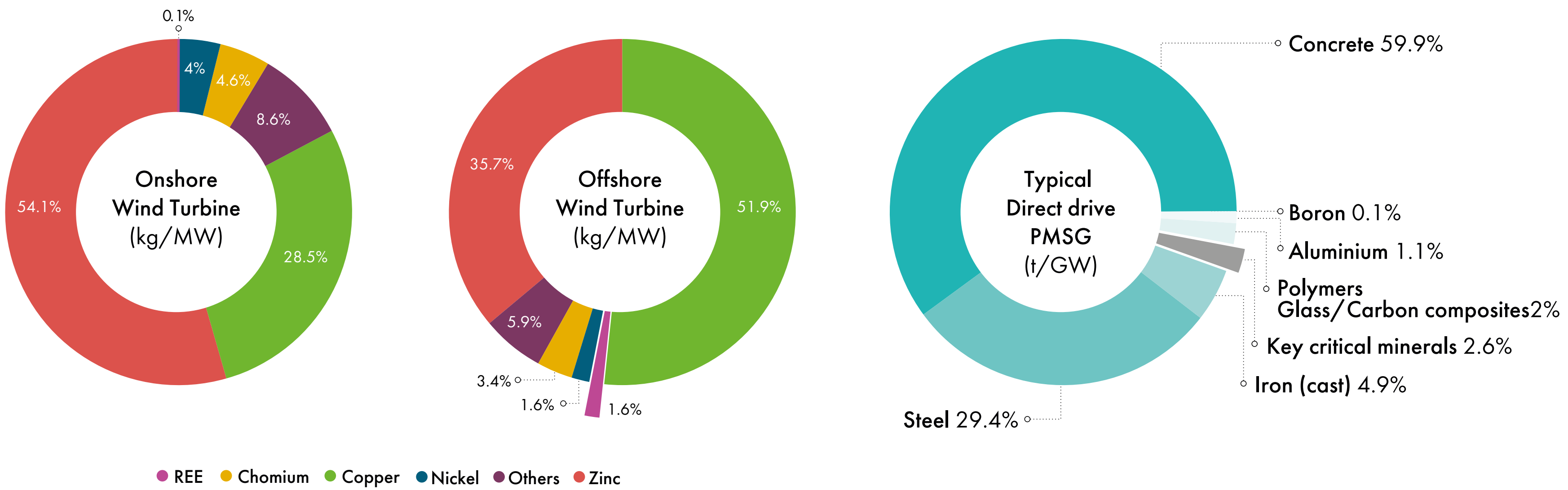
Other electric, electronic and magnetic wind turbine components (such as nacelles, rotors, generators, gearboxes and cables) demand a decent mass of critical minerals including copper, nickel, zinc, REEs like neodymium and dysprosium for permanent magnet generators, chromium and cobalt. The primary materials used for blades are balsa wood, glass fibres and epoxy resins, as well as more sustainable alternatives such as polyethylene terephthalate (PET) and pultruded carbon fibres.

While steel, iron, aluminium and concrete have fairly global production supply chains, the mining and processing of critical minerals for wind turbines are concentrated in certain geographies.[4] This means that global supply depends on a limited number of primary producers, presenting potential logistics and security risks. For the REE neodymium and dysprosium, the primary supply markets are China, the US and Myanmar. For nickel, the main

3. In a 221 t/MW offshore wind and 640 t/MW onshore wind farm, according to BloombergNEF.

4. China dominates crude steel production, with 57% of the market, according to the World Steel Association in 2021. The remainder of the market is fairly diversified across India, Japan, the EU, CIS countries, NAFTA countries and other countries.

Material breakdown of onshore and offshore wind turbines



Sources: IEA, Carrara et al. (2020); Elia et al (2020); GWEC Market Intelligence. Note: PMSG = Permanent Magnet Synchronous Generator.

markets are Indonesia, the Philippines and China, while for copper the main markets are China, Chile and Peru.

China dominates the processing of many of the minerals and REEs required to deliver the energy transition. This applies not only to the copper, nickel and REEs required for wind turbines, but also the lithium, nickel and copper required for battery storage and EVs, the REEs needed for EV motors and the nickel and zirconium used in electrolysers for green hydrogen.

According to GWEC Market Intelligence, nearly 30% of the wind turbines installed in 2020 used direct and hybrid drive generators which required neodymium and dysprosium for permanent magnets. That share is expected to increase to nearly 50% of installed turbines globally by 2025, given that most offshore wind turbine models use permanent magnet generators.[5] By 2030, demand for REEs in the wind industry is likely to double from today's number.

The IEA forecasts that clean energy technologies will become the primary source of demand for most minerals, driving up global demand for copper and REEs by as much as 40% by 2040, nickel and cobalt by as much as 60-70% and lithium by nearly 90%, in a sustainable development scenario.[6]

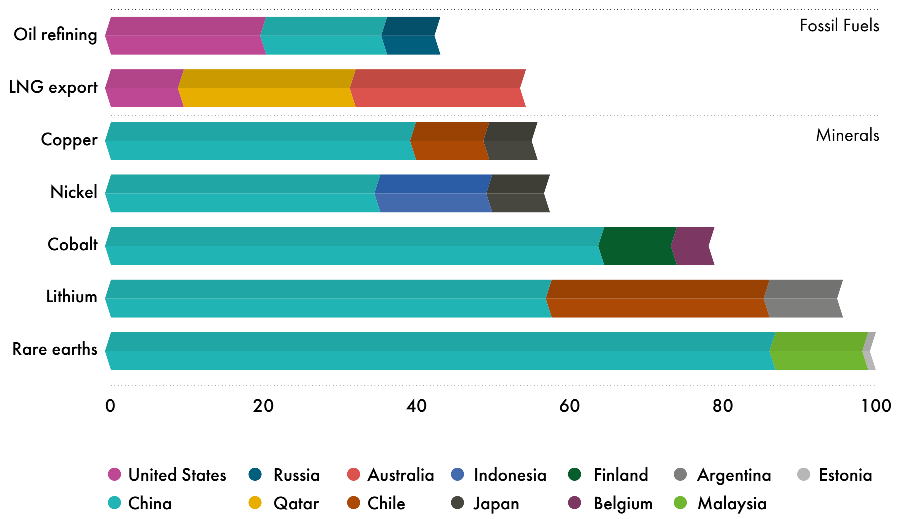
Along the supply chain, China dominates the processing and refining operations of key wind turbine minerals, with a majority share of the global market for copper (40%), nickel (35%) and REEs (87%).[7] There are several implications of increased reliance on a wind supply chain which is heavily concentrated in a small number of geographies:

- **New geopolitical considerations come into play,** where security of supply and open trade could be impacted by international conflict, trade disputes, political instability or administration change.

- **Regulatory frameworks less exposed to international standards,** where geographic concentration of production and processing in a few countries could give outsized influence to a few regulatory authorities on supply chain practices and legal frameworks which cover environmental, social, labour and human rights and economic dimensions.

- **Price exposure increases,** as the global supply chain must rely on a market with few suppliers, leaving actors worldwide vulnerable to price spikes caused by

Share of top three producing countries in total processing of selected minerals and fossil fuels, 2019 (%)



Sources: IEA (2020b), USGS (2021), World Bureau of Metal Statistics (2020); Adamas Intelligence (2020)

5. Global Wind Turbine Generators Supply Chain Update, GWEC Market Intelligence, December 2021.
6. https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/mineral-requirements-for-clean-energy-transitions. It is important to note that forecasts for commodity demand vary between different institutions.
7. The IEA notes that China's market share of nickel refining is even higher when accounting for Chinese companies operating in Indonesia, which makes up 15% of the global market. https://www.iea.org/data-and-statistics/charts/share-of-processing-volume-by-country-for-selected-minerals-2019

unforeseen externalities (e.g. COVID-19 pandemic) or a controlled tightening of supply. Mineral prices are already more volatile compared to commodities like crude oil. Some actors, including governments, may invest in strategic reserves, while others will be left to compete on the open market.[8]

- **Risk of a delayed energy transition,** as competition for procurement of critical minerals and REE increases, actors in the renewables supply chain may experience disruptions or delays in manufacturing.

- **End-of-life recycling plays a greater role,** as the scale up of mining and production of critical minerals will need to be accompanied by investment in material recovery and recycling. Currently, copper, nickel and aluminium benefit from high recycling rates, while there are no commercial recycling processes for REEs.

Policymakers can play a role in steering the timely and sufficient supply of materials to meet the demands of wind energy growth required for climate and energy targets. Governments can work with industry to establish reliable long-term price benchmarks, plan voluntary stockpiling of critical minerals to shore up security of supply, impose regular evaluation of ESG risks of importing and exporting entities, implement sustainability and recycling goals and invest in technology innovations, materials efficiency and materials alternatives. This work can also be steered by international energy authorities like IRENA and the IEA, which can convene governments around the common interests of the global energy transition. The European Commission's Action Plan on Critical Raw Materials published in 2020 offers an example of how governments can coordinate on foresight, analysis and strategic actions to strengthen the clean energy supply chain.[9]

It will be crucial for policymakers and actors in the critical minerals and REEs supply chain, including the wind industry to work together to ensure secure and sustainable supply. This includes prioritising the needs of clean energy technologies to send a clear signal about the volume of critical minerals and REE supply required over the next few decades, investing in recycling technologies and circuits and jointly calling for market transparency and open trade.

International coordination on resource and material sustainability

While the legacy energy industry is associated with a pattern of so-called "resource colonialism" which has transformed the geopolitical landscape today, the clean energy transition will usher in a shift in trade patterns and production hubs. As certain markets and export hubs emerge, it will be important to ensure that the dividends of supply chain activity are equitably distributed.

The wind industry must avoid the models of exploitation which have harmed the reputation of the legacy energy sector in communities around the world. This can be done by efforts such as intensifying ESG compliance across the value chain, raising public awareness of project benefits through community education and training programmes, as well as public campaigns for socioeconomic and

8. Japan has an official target for 80% self-sufficiency in mineral resources (base metals) by 2030 and 100% by 2050. This was prompted in part by a ban on export of certain REE from China to Japan in 2010. See: https://www.argusmedia.com/en/news/2201049-japan-targets-100pc-base-metal-selfsufficiency-by-2050.
9. https://ec.europa.eu/commission/presscorner/detail/en/IP_20_1542

environmental responsibility in the industry – particularly in countries with weaker governance and under-resourced public authorities.

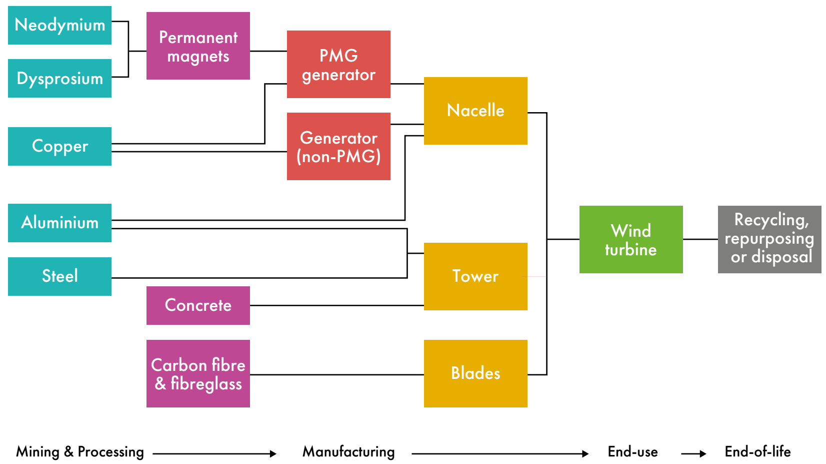
The intensifying focus on upstream materials in the wind supply chain highlights the need for international coordination for social and environmental sustainability. Supply chain risks are particularly high in the mining sector, which has been associated with issues such as human rights violations, land-grabbing, corruption, tax avoidance and adverse environmental impact.[10]

Global bodies such as the International Labour Organization (ILO), the United Nations High Commissioner for Refugees (UNHCR), the OECD Due Diligence Guidance for Responsible Business Conduct and the UN Guiding Principles on Business and Human Rights provide guidelines for international social criteria for the wind supply chain.[11] From OEMs to developers, the industry should be stringent in ensuring transparent and audited procurement processes, and supply of materials and components which complies with such international standards.

In addition to critical minerals and REEs, other components raise sustainability and recyclability issues in the supply chain, including balsa wood and epoxy resins for blade production. Balsa wood is one of the key components of the blade core for many turbine models, due to its flexibility, strength and lightweight nature. The vast majority of commercial balsa wood is supplied by Ecuador, although trade has been disrupted by the pandemic and changing climatic conditions. As a result of disruptions to supply and increased demand, the costs of balsa wood are also rising: Ecuador's balsa exports were worth $221 million in 2019 and jumped to $788 million in 2020.[12]

As with the extractive industries, the balsa wood trade is vulnerable to ethical and environmental concerns, including illegal deforestation practices and displacement of indigenous communities living in forest areas. This has raised public scrutiny of the wind industry's involvement in

A simplified materials breakdown of the wind value chain



Source: Carrara S., Alves Dias P., Plazzotta B. and Pavel C., Raw materials demand for wind and solar PV technologies in the transition towards a decarbonised energy system, EUR 30095 EN, Publication Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-16225-4, doi:10.2760/160859, JRC119941.

balsa wood forestry practices and export, as well as hastened R&D efforts for alternative materials, such as Aerovide's 2020 announcement of a balsa-free rotor blade.[13] Nonetheless, while balsa wood remains a core material for blade production, the industry is responsible for ensuring it procures from suppliers which adhere to environmentally and socially sustainable foresting practices.

Epoxy resins are used as a lightweight and resilient material which can widen the diameter of blades. These are fabricated using fibre-reinforced composites with a balsa wood or foam core. Epoxy is a combustible thermoset resin and not re-mouldable or currently recyclable using commercial recycling processes, although

10. https://www.somo.nl/wp-content/uploads/2018/01/Final-ActionAid_Report-Human-Rights-in-Wind-Turbine-Supply-Chains.pdf
11. International social criteria focus on promoting international labour standards and human rights, including combating forced labour, slavery, child labour and unfair discrimination.
12. https://english.elpais.com/usa/2021-11-26/how-the-wind-power-boom-is-driving-deforestation-in-the-amazon.html
13. Global Wind Blades Supply Chain Update, GWEC Market Intelligence, 2021.

there are many public-private initiatives underway to commercialise the value chain for recycling of blades (see Sustainability initiatives in the wind industry). For instance, a coalition of industry and academia are undertaking research in new technology to enable circularity for thermoset composites under the Circular Economy for Thermosets Epoxy Composites (CETEC) initiative, announced in 2021.[14]

Moving from renewable to sustainable energy

It is no longer enough for the wind industry to produce green electrons. As a pillar of the world's future energy mix, the wind industry bears greater responsibility for the environmental impact of its own industrial supply chain and activities. Simply put, renewable energy must now be a sustainable industry, accountable to increasing scrutiny on the emissions related to its entire value chain.

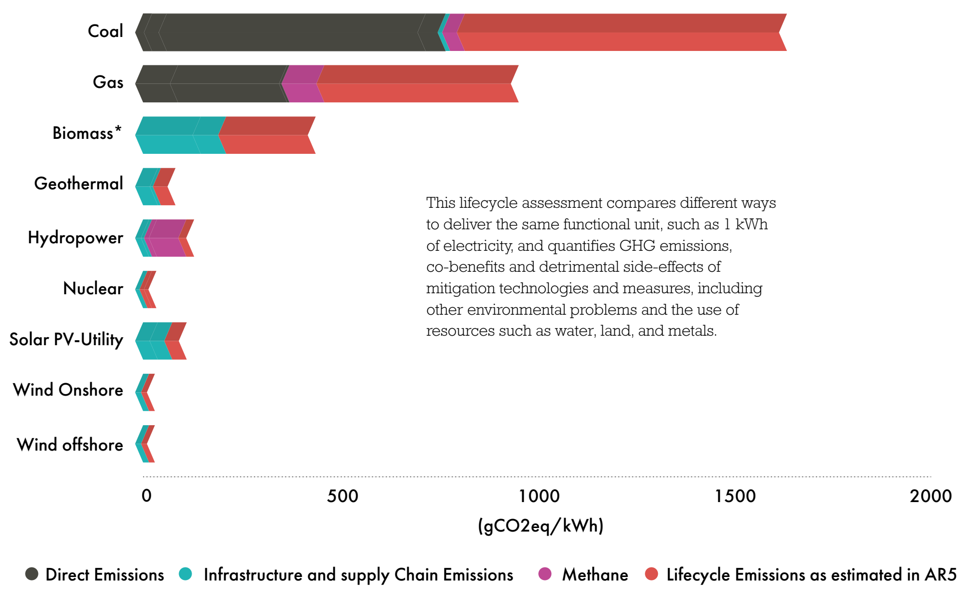
Building on the SOL addressed in the Society section of this report, the wind industry's licence to operate is being held to an increasingly high environmental standard by governments, wider industry and civil society. Accounting bodies such as the Science-Based Targets Initiative (SBTi) and campaigns such as Business Ambition for 1.5°C, SME Climate Hub and the Race to Zero are creating a global direction of travel for businesses in the green economy. The wind industry is already demonstrating proactive responses to this challenge, and it is vital that it continues to invest in innovation and circularity solutions to maintain its position at the forefront of the energy transition.

As a baseline, it is worth comparing wind energy's GHG emissions footprint with other electricity generation technologies. Full lifecycle GHG emissions assessments provide an important benchmarking exercise to understand the emissions attached to various electricity generation technologies. The IPCC's AR5 report, representing the global scientific consensus on energy systems and climate change, shows that **a range of technologies can provide electricity with less than 5% of the lifecycle GHG emissions of coal power, with the lowest emissions for wind power.**[15]

For wind and other renewable energy technologies, emissions are mainly associated with manufacturing and installation activities. Further reductions of lifecycle GHGs in these segments could be attained through cleaner production, raw materials alternatives and improvements in performance and efficiency.

The steel and concrete needed for wind turbines are largely

Comparative lifecycle GHG emissions by electricity technology



Sources: AR5- IPCC WG III Fifth Assessment Report, (Caduff et al., 2012; Dale and Benson, 2013), (Arvesen and Hertwich, 2011) ,Wind (Arvesen and Hertwich, 2012), PV (Kim et al., 2012; Hsu et al., 2012), geothermal power (Sathaye et al., 2011), hydropower (Sathaye et al., 2011; Hertwich, 2013), nuclear power (Warner and Heath, 2012), bioenergy (Cherubini et al., 2012). Annex II, Annex II.6.3 and Section A.II.9.3 for methodological issues and core literature. *Note: Lifecycle emissions from biomass are for dedicated energy crops and crop residues.

14. https://www.vestas.com/en/media/company-news/2021/new-coalition-of-industry-and-academia-to-commercialise-c3347473
15. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter7.pdf

produced from carbon-intensive processes. However, enhanced collaboration between these key upstream materials sectors and the wind industry is signalling demand for green steel and concrete, while introducing a role for wind energy to power the decarbonisation of upstream production processes. Despite wind energy's low full lifecycle emissions, sustainability challenges are being acted upon with new innovations to reach net zero and "waste zero" through a circular economy approach within this decade.

Sustainability initiatives in the wind industry

GWEC forecasts more than 550 GW of additional onshore and offshore wind capacity will be installed by 2026. Conversely, nearly 200 GW of onshore wind projects, mainly in Europe and the US, will reach their end of operating lifetime by 2030. Therefore, while reducing emissions throughout the wind supply chain is crucial, the management of decommissioned wind turbines must also be addressed.

Approximately 90% of the materials and components of a wind turbine's total mass can be recycled under current conditions. This proportion consists of the foundation, components of the nacelle and the tower, made from materials like steel, reinforced cement, copper wire and electronics, which can be commercially recycled. The remaining 10% of a wind turbine's mass consists of composite materials – glass or carbon fibres and a polymer matrix used in the production of wind turbine blades – which are more challenging to recycle. They are non-toxic and safe for landfills, but the industry is committed to a path of sustainable repurposing and recycling, rather than wasting resources.

The main challenge is not a lack of blade recycling technology, but the economics and scalability of the required composite recycling technologies. These are not yet commercially viable to factor into project lifetime and decommissioning costs – especially as the industry faces increased pricing pressures, both from downward pressure in markets and from sharp increases in raw material and logistics costs.

However, the industry is proactively changing its production processes to support the recyclability of blades and improve its circular economy. These include the company Modvion, which produces wooden turbine towers, as well as Siemens Gamesa Renewable Energy's launch of the first fully recyclable blade in 2021, with a new resin that can be more easily separated to recover materials.[16] Blade manufacturers are also moving away from materials such as balsa wood, which is harvested from forests in and around Ecuador, and replacing them with recyclable foams such as polyvinyl chloride (PVC) or polyethylene terephthalate (PET).

The three-year DecomBlades project established in 2021 brings together a consortium of 10 partners, including manufacturers Siemens Gamesa Renewable Energy, GE subsidiary LM Wind Power, Vestas, developer Ørsted and a number of technical and academic institutions.[17] It aims to commercialise the value chain for the recycling of wind turbines, in particular the shredding of blades and use of shredded blade

16. https://www.siemensgamesa.com/en-int/newsroom/2021/09/launch-world-first-recyclable-wind-turbine-blade
17. https://www.siemensgamesa.com/newsroom/2021/01/210125-siemens-gamsa-press-release-decomblades-launched

Case study: Global Alliance for Sustainable Energy

Established in 2021, the Global Alliance for Sustainable Energy is an independent global alliance open to all actors recognizing the urgency of tackling the climate emergency according to 'just transition' principles and the need to promote and embed sustainability and social responsibility in the renewable energy industry.

The Alliance brings together 17 founding members comprising utilities and global players in the solar PV and wind value chains, sector associations and innovation partners, including GWEC. The aim of the Alliance is to ensure the renewables sector is fully sustainable and respects human rights across the entire value chain. While wind and solar have distinct characteristics as renewable technologies, they are highly complementary and share both similar growth trajectories and similar challenges to their sustainable deployment. Closer alignment between wind and solar is therefore critical for accelerating the energy transition.

To achieve this, the Alliance will work to define sustainability standards and Key Performance Indicators (KPIs), achieving ambitious targets together and fostering collaboration. The Alliance's current membership spans NGOs, associations and civil society representatives, utility companies, material suppliers and equipment manufacturers, renewable project developers and plant builders, technical and technological partners, and, end-users, spanning industrial, commercial and domestic energy consumers.

material in cement production and advancing pyrolysis, or a process to separate composite materials under extremely high temperatures.

Increasing the commercial viability of composite materials recycling will require collaboration across sectors, including other industries dependent on composites such as construction, electronics, transport and shipping. A larger and more diversified waste stream across multiple sectors will strengthen the business case for investment in recycling technologies and innovations.

In addition to the industry's investments in circularity solutions, policymakers should also align their climate plans with public-private research and innovation programmes. These programmes can focus on scaling recycling technologies and identify high-performance sustainable materials, ensuring climate targets and circularity go hand-in-hand.

PART FOUR: SYSTEM TECHNOLOGY

Part Four: System Technology

2021 represented a year of gathering global momentum on decarbonisation. Ahead of and during COP26, the industry witnessed a slew of new announcements from countries committing to a net zero pathway (e.g. India, Vietnam), as well as a number of renewables and wind-specific targets.[1] With the technology and cost-competitiveness of wind and solar energy proven, it finally feels like the world is poised on the edge of a renewables revolution.

Such a revolution will see a rapid increase in the global installed capacity of wind power, which must scale up nearly 10-fold over the next three decades to meet growing demand for clean power. By 2050, 73% of the installed capacity and 63% of all electricity generation will come from wind and solar PV energy.[2]

But replacing coal and gas in the energy mix will necessitate new ways of ensuring system stability and flexibility. Integrating such high levels of renewables can no longer be seen through the prism of the power sector alone.

Electrification will be the primary decarbonisation pathway for the transport, heating and cooling sectors. Green hydrogen will enable the abatement of emissions in industrial sectors and long-range surface and marine transport. Delivering a stable and secure low-carbon power system necessitates a seismic shift in how we produce and manage energy writ large.

The world therefore needs to plan for a transition that touches every part of our energy system, from how we use cars and heat our homes to the interconnections with other countries and the decarbonisation of industrial processes. **The global wind industry is confident that with fit-for-purpose policies and regulatory frameworks which cover the whole energy system, an innovation-led approach to renewables integration can deliver a low-cost, stable and secure energy system that is better for people and communities.**

Technology innovation has been a driving factor in the dramatic cost reductions of renewables, allowing wind power to move from the margins of the energy sector to the mainstream. Innovation will once again play a critical role in the large-scale integration of wind, with technological solutions for flexibility, storage at varying durations and responsive management of demand and supply. Whole-systems thinking will be of paramount importance.

Many commentators such as BNEF, IRENA and the IEA have shown that the energy system of the future will not only be decarbonised but far more decentralised and digitised. Such a system will have important co-benefits in terms of job creation and health outcomes, as well as drastically increasing energy access in an increasingly distributed energy system.

Based on recent evidence from countries with significant renewables penetration (Costa Rica, Sweden, UK and Denmark), a

1. https://www.wri.org/insights/how-countries-net-zero-targets-stack-up-cop26; Net Zero Action Tracker
2. World Energy Transitions Outlook: 1.5°C Pathway, IRENA, 2021.

flexible, decentralised and renewables-led system will ultimately be the most cost-effective and resilient option for energy consumers.[3] This chapter sets out GWEC's view of the future energy system and explores how technology innovation will once again support the next phase of renewables growth.

A changing paradigm and the demise of baseload

In the conventional model of supplying electricity in centralised energy markets, large thermal or nuclear power stations were located near cities or industrial centres. These plants were always running to minimise start-up and O&M costs, giving rise to the "baseload" concept. The relationship between supply and demand was linear; if demand increased then supply increased by burning more fossil fuels.

The rapid rise of low marginal cost renewable generation is disrupting the established paradigm of the global energy system. We are beginning to witness the demise of this traditional transmission-scale arrangement and the breakdown of that linear relationship between supply and demand. This has led to the former CEO of prominent UK/US system operator, National Grid, declaring that the concept of baseload is outdated.[4]

First, electricity production from renewables is highly predictable, but output is variable. Renewables obviously produce most when the wind is blowing and the sun is shining, flooding power markets with a bountiful supply of cheap generation. However, there are periods where renewables generate less. Reliance on an ever-increasing supply margin to meet demand in this reality is inefficient, resulting in significant oversupply of capacity.

Second, as a decentralised source of power, wind farms are sited in areas of best available wind resources, often further away from urban or industrial demand centres. As EVs, microgrids and home power systems begin to play increasingly significant roles in the energy system, decentralisation further increases.

Future energy systems will have no need for large, inflexible power stations which run constantly. **In a renewables-led system, flexibility is the chief currency.** On the supply side, technologies which can dispatch power quickly will be rewarded for meeting demand spikes or plugging the gap in any under-supply of electricity. Generators with high unit start-up costs, such as traditional large-scale thermal and nuclear plants, will therefore be at a disadvantage. Instead, battery and hydrogen storage, accompanied by a small amount of highly efficient gas peaking plant with CCUS, can be utilised to respond to demand fluctuations.[5] On the demand side, dynamic demand management and demand-side response (DSR) will be integral to the global energy system.

System operators will need to develop the tools and regulatory frameworks to send accurate signals to the market, and to ensure that the right products and services exist to address system requirements such as grid frequency and inertia. In markets with high renewables penetration, we increasingly see wind projects themselves being able to offer these system services.[6]

Four key technology areas will be crucial enablers of a renewables-led system: digitalisation; hybrid projects; green hydrogen; and energy storage. These are reviewed below:[7]

Digitalisation

As the themes of digitalisation and decarbonisation converge, the renewables industry is undergoing rapid digital transformation. A range of digital technologies will enable the transformation of the energy system and reduce friction in the integration of renewables. Generators, system operators, and consumers will increasingly

3. This calculation includes the "system costs" of integrating renewable generation. See: https://nic.org.uk/studies-reports/smart-power/; https://ukerc.ac.uk/publications/cost-of-energy-review/.
4. https://energypost.eu/interview-steve-holliday-ceo-national-grid-idea-large-power-stations-baseload-power-outdated/
5. IRENA's World Energy Transitions Outlook (2021) acknowledges a limited role for CCUS to abate energy and process emissions in industrial processes, like the cement, steel, chemicals and plastics sectors. Around 6% of the total carbon emissions abatement required by 2050 under the 1.5°C Scenario are delivered by the CCUS industry, compared to 70% by renewables-based power generation, electrification of end-use sectors and energy conservation and efficiency measures.
6. https://www.nationalgrideso.com/future-energy/projects/pathfinders/stability/Phase-3 ;
7. The discussion on four technologies does not include other enablers, such as fostering hybrid offshore interconnections. Detailed overviews of innovative technologies which will enable a flexible renewables-led system are in IRENA's "Innovation landscape for a renewable-powered future" report (2019) and RenewableUK's "Powering the Future" report (2020).

Case study: Cooperative control of wind turbines can increase site-wide AEP by up to 5%

Provided by: WindESCo

In nature, many species have realised the evolutionary benefits of operating as a coordinated unit. Swarming is the collective motion of a large number of insects, birds, fish or animals. This is a topic of active scientific research and is even being used to develop AI algorithms.
At dusk, starlings swarm in the sky and fly in complex formations, avoiding collisions by communicating with their neighbors. Migratory birds fly in a V-formation which reduces their energy expenditure between 12-20% while flying long distances.

Is it time to learn from nature and make wind plants more "social" and efficient?

Combining wake steering and collaborative control to boost AEP

Wind plants lose anywhere between 5-20% of output to wakes caused by the turbines' upwind. Wake steering is one strategy for mitigating wake losses to increase the overall plant's annual energy production (AEP), but this is heavily site-dependent.

In wake steering, the yaw position of upwind turbines is modified so the yaw orientation is no longer aligned directly into the wind. As a result, the wind turbine wakes can be deflected or steered away from the inflow of neighboring downstream turbines. Yaw control improvements adjust the nacelle position of the turbine to maximise energy capture and minimise wear and tear on the yaw drive components.

WindESCo Swarm combines hardware and software as an integrated system to allow turbines to communicate with and learn from each other. The system was developed over three years with a multidisciplinary approach combining the fields of turbine loads, controls, meteorology, sensing and machine learning.

The system has been tested on 13 turbines across two wind plants. The first commercial implementation on three wind plants with over 300 MW of capacity is underway in North America. Assessments have found that the AEP gains from wake steering alone can range anywhere from sub 1% to greater than 2%:

	Site A	Site B	Site C	Site D
OEM	GE Renewable Energy	Multiple	Suzlon	Siemens Gamesa Renewable Energy
Capacity	145 MW	300 MW	32 MW	90 MW
Estimated Annual Benefits in AEP and NPV	2.0 % $684,000	2.5 % $820,000	0.7 % $22,535	0.9 % $99,959

When combining these improvements with additional applications that allow the wind turbines to be controlled collectively, the applications can predict wind direction from nearby turbines to help capture more energy and reduce extreme loading on other turbines.

The AEP benefit of wake steering will depend on the site layout, wind and atmospheric turbulence conditions and the turbine model. However, when paired with other cooperative control applications which allow the turbines to share information to optimise yaw among other factors like predicting wind direction shifts, the system can deliver a 3-5% improvement in site-wide AEP without negatively impacting the lifetime of assets.

For a 1 GW fleet, the Swarm retrofit solution would provide a five-year net present value (NPV) of up to $30 million. Through continuous 3-5% AEP improvements, owners and investors can accrue a substantial return on investment (ROI) from existing installations and enable them to compete more effectively with newer farms.

Find out more: https://www.windesco.com/swarm harness artificial intelligence (AI) to make better predictions and to improve operations. **The industry is already witnessing the use of data to manipulate demand, improve predictability in weather patterns and renewables output and enable consumers to become active "pro-sumers" in the market.**

IRENA has found that "accurate weather forecasts and very short-term to long-term forecasting are key for effectively integrating [variable renewable energy] generation into the grid."[8] Innovation in weather forecasting and modelling, such as through AI or machine learning, enables generators and system operators to more accurately predict weather patterns and wind/solar output.[9] Machine learning is also enabling system operators to increase grid stability; better short-term forecasting can result in increased dispatch efficiency, thereby improving reliability and reducing operating reserves needed.[10] Non-renewable plants can also be adjusted and ramped up or down based on this forecasting.

Grids need comprehensive upgrades not only in terms of physical infrastructure, but also intelligence. The grid in the future energy system is likely to be a data network grafted onto a physical network, enabling one-way flow of energy distribution that we currently have, allowing for a multi-directional flow of energy and information with effective and precise controls.

Digitalisation is also driving innovation in business models. Increasing decentralisation of the energy market will mean a much larger number of actors in the power sector. In markets with high renewables penetration, both commercial and household consumers are playing an increasing role in their energy use to lower emissions and maximise efficiencies. EV ownership is rising, and the Internet of Things (IoT), including smart appliances and heating/cooling systems, is gaining traction. Products and services which use AI to aggregate demand can shift and delay demand on the system to better match generation profiles. Business models and energy tariffs can incentivise consumers to modulate power usage at times of the day with more plentiful and cheaper generation.

Digitalisation and AI are also improving the performance of renewable assets themselves, reducing operating costs and bringing down LCOE. AI can optimise output and algorithmically detect potential equipment failures before they become problematic, i.e. predictive maintenance. Robotic solutions such as remotely operated vehicles (ROVs) and autonomous drones/vessels can monitor and rectify equipment failures in remote or challenging environments, such as at sea, improving onsite health and safety and project costs.[11]

Hybrid projects

Hybridisation, i.e. the combination of wind energy with another energy source and/or storage solution, is a key topic in the renewables industry. Hybridisation offers opportunities to increase the share of renewables in the grid while replacing fossil fuels in mature markets like Europe, the US and Australia, and high-growth markets like Southeast Asia. In EMDEs and remote areas like small islands, hybrid solutions can bring value and security by facilitating system integration, as well as enabling micro-grid/off-grid solutions.

A hybrid power project can, therefore, use complementary renewable technologies to create a stable supply of power at project level. For example, wind combined with solar PV can generate power during cloudy periods, less windy periods and darkness. Such systems can be provided at

8. Innovation landscape brief: Advanced forecasting of variable renewable power generation, IRENA, 2020.
9. https://www.nationalgrideso.com/news/former-deepmind-experts-ai-tool-could-help-boost-national-grid-esos-solar-forecasts; https://www.nature.com/articles/s41586-021-03854-z
10. https://www.ey.com/en_uk/power-utilities/why-artificial-intelligence-is-a-game-changer-for-renewable-energy
11. Making Renewables Smarter, DNV, 2017.

Case study: Boosting turbine performance with the help of AI

Provided by: Kavaken

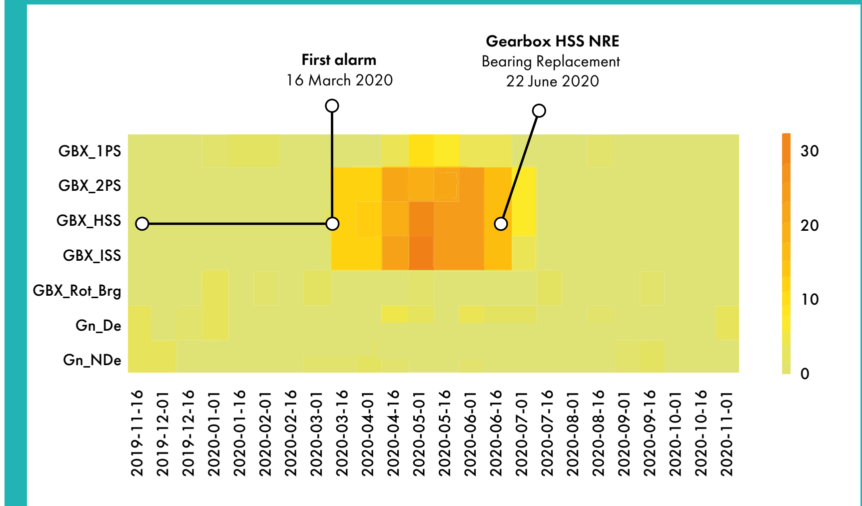
Forecasting and avoiding turbine component breakdowns play an important role in reducing costs and increasing value. Data-driven Software as a Service (SaaS) solutions can help turbine operators boost energy production and value. For instance, Kavaken's predictive maintenance module helps operators in determining the root causes of faults and also spare part and maintenance planning.

Kavaken has been engaged with an IPP with a large fleet of wind turbines to optimise wind farm operation and maintenance activities. The primary services include fault detection, diagnostics and prognostics, power curve analysis and production forecasting.

The predictive maintenance module employs an ensemble of tailored anomaly detection algorithms to determine each turbine component's health status and prognose remaining useful life before a failure occurs. Built-in algorithms sift through large volumes of vibration, SCADA and other accessible data, and evaluate hundreds of features to produce a smart condition indicator that triggers flags upon reaching certain thresholds.

One case study is in the automatic detection of a bearing fault in the high-speed shaft of a wind turbine gearbox. Starting from March 2020, the condition indicator of the gearbox subcomponent increased dramatically, which triggered the system to raise a fault flag on 16 March.

The heatmap graph below depicts condition indicators across time; the darker the cell, the more severe the condition. Kavaken's algorithm raised flags on 16 March for the 2nd planetary stage (GBX_2PS), high-speed stage (GBX_HSS) and intermediate speed stage (GBX_ISS) subcomponents as they exceeded the learned and optimised thresholds.



Following a gearbox endoscopy in June, maintenance personnel confirmed that the high-speed shaft non-rotor end bearing was faulty and required replacement, proving that the algorithms detected the fault three months before a costly failure occurred. Had the fault not been detected, it would have likely had adverse effects on adjacent components, causing costly repairs and financial losses.

Preventing costly equipment failures is only one of the ways digitalisation helps improve performance, reduce costs and risks. With vast amounts of data available at wind power plants, there is significant additional value to be created via other applications, such as power curve analyses, production forecasting and operations optimisation.

Find out more: https://www.kavaken.com/

grid-scale, regional scale or at micro-grid level as a feasible solution for rural electrification and community energy access.

Hybridisation as a solution combining several technologies is well underway in many markets. Currently Australia, the US, China and India are known key hybrid markets. According to GWEC Market Intelligence, developers in the US brought 2,238 MW of hybrid project capacity online in Q4 2021 alone – nearly half of the total hybrid installations in the US in 2021.[12] In China, 1,350 MW of hybrid projects were awarded in 2021; while in India, 2,800 MW and 1,950 MW of hybrid projects were awarded in 2020 and 2021 respectively.

Hybrid projects can be more economic due to efficient project design, including the size of the total project, as well as management and commercialisation of the project's power output. A suitable offtake agreement can optimise the capture of full output of the project at suitable times of supply. Hybrid projects are growing around the world as corporates and investors seek the benefits of stable supply, efficiencies in EPC, O&M and grid connection costs, as well as expanding revenue opportunities.

To help speed up the global energy transition, hybridisation has clear system value by providing cost-efficient electricity, improving flexibility for integrating more renewables into the grid and offering a better match of supply-demand profiles.

Although these enablers are recognised, political support, such as specific procurement frameworks, is still lacking in current market design. Hybrids also require technical enablers, such as more economical and efficient storage solutions to bring down the cost of storage as well as digital solutions/energy management systems (EMS) to manage generation and dispatch. With these enablers, the level of market penetration of hybrid solutions is expected to grow sharply, especially in developing economies.[13]

Green hydrogen

Last year, in the 2021 Global Wind Report, GWEC set out the roles for green hydrogen and Power-to-X applications in the deep decarbonisation of industrial sectors and the provision of long-duration storage. It is worth noting that in IRENA's 1.5°C scenario envisions one-quarter of global electricity generation by 2050 dedicated to green hydrogen production, requiring around 10,000 GW of wind and solar capacity.[14]

Over the last year, global interest in hydrogen has increased even further with more countries announcing national hydrogen roadmaps or strategies. As of late 2021, more than 30 countries from Paraguay to Morocco to New Zealand had a hydrogen strategy in development or already published.[15]

As an example, China issued a hydrogen roadmap for the transport sector in 2016, and has named hydrogen energy as one of its critical future industries in its current Five-Year Plan (2021-2025), alongside quantum information and aerospace development.[16] India launched its much-awaited National Hydrogen Mission in 2021, targeting a scale-up of domestic green hydrogen production and potential mandates for refineries and fertiliser companies to integrate green hydrogen and green ammonia into industrial processes. The EU has made green hydrogen a part of its European Green Deal, which was announced in 2020, marking hydrogen networks as vital for "a clean and circular economy."[17]

The wind industry is now partnering directly with a range of industrial sectors to drive decarbonisation via green hydrogen as a fuel. For instance, Vattenfall have collaborated with Swedish steel fabricator SSAB and mining company LKAB on a pilot plant to produce sponge iron with green hydrogen.[18] Ørsted and ITM

12. These figures include hybrid projects combining: wind and storage; solar and storage; wind and solar and storage; and wind and solar.
13. For example, see the Zhangjiakou Energy Transformation Strategy 2050 developed by municipal authorities for Zhangjiakou City, in co-operation with the China National Renewable Energy Centre and IRENA, in 2019: https://irena.org/publications/2019/Nov/Zhangjiakou-Energy-Transformation-Strategy-2050.
14. World Energy Transitions Outlook 2021, IRENA, 2021.
15. Geopolitics of the energy transformation: The hydrogen factor, IRENA, 2022.
16. https://cset.georgetown.edu/wp-content/uploads/t0284_14th_Five_Year_Plan_EN.pdf
17. https://www.fch.europa.eu/news/european-green-deal-hydrogen-priority-area-clean-and-circular-economy
18. https://group.vattenfall.com/uk/what-we-do/roadmap-to-fossil-freedom/industry-decarbonisation/hybrit

Case study: China calls for integrated energy solutions

In 2020, China upgraded its NDC by targeting peak CO2 emissions before 2030 and carbon neutrality by 2060. The government further proposed a new type of renewables-based power system as the mainstay, demonstrating variability and fluctuation, and resulting in more complex and effective system balancing. **Integrated energy solutions will play a large role in increasing power system efficiency and balanced energy supply in China.**

In March 2021, China's National Energy Administration (NEA) issued the Guiding Opinions on Promoting the Integration of Source, Grid, Load and Storage and Multi-Energy Complementarity.

To optimise the scale ratio of various power sources to maximise output and efficiency, two types of hybrid projects are promoted in China:

- In western rural regions, existing conventional power plants are used for large-scale hybrid energy bases combining: wind, solar, coal and storage; wind, solar, hydropower and storage; or wind, solar hydropower, coal and storage.
- For towns, industrial parks and large public facilities such as airports and hospitals, an integrated power supply combines conventional and renewable sources such as wind, solar, geothermal energy and biomass.

To support a renewables-led revolution, the NEA is targeting a highly synchronised integration of source (supply), grid, load (demand) and storage through enabling technologies and power market reform.

Three provinces (Zhejiang and Fujian on the east coast and Qinghai inland on the Tibetan Plateau) have been selected as demonstration zones for this new power system. In January 2022, Zhejiang released the "Construction Plan for Building a Provincial Demonstration Zone for a New Power System with New Energy as the Mainstay". The guidelines for provincial integration of source, grid, load and storage are:

- Rely on regional power market and services, fully liberalise market-oriented transactions and guide all kinds of market entities to adjust and interact in multiple directions.
- Use modern information technologies such as 5G to strengthen unified dispatch and implement mechanisms for generation, power users, energy storage and virtual power plants to participate in the market.

At city level, China has also selected demonstration initiatives. Zhangjiakou in north-western Hebei province is home to the largest wind capacity in China. The city will give full play to the big data industry to deeply integrate energy resources, build virtual power plants and maximise local consumption of renewable energy.

In early 2022, China's State Council further issued a comprehensive work plan for energy conservation and emissions reduction as part of the 14th Five-Year Plan (2021-2025), encouraging industrial enterprises and parks to give priority to the use of renewable energy.

Power's Gigastack project for a 100 MW electrolyser system powered by offshore wind aims to decarbonise the Philipps 66 refinery processes in the UK by 2025.[19]

In 2021, Siemens Gamesa Renewable Energy announced that it had developed a project in Denmark, the first of its kind, capable of producing renewable hydrogen in "island mode," or connected to the grid, via an electrolyser connected to a wind turbine; it has also added a battery system to the site to store excess electricity.[20]

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, scalability, and for offshore wind projects, location. GW-scale wind projects paired with hydrogen highlight the opportunity for green hydrogen to achieve commercial viability by the end of the decade. Accordingly, in 2021 the US issued its first "Energy Earthshot" framework to reduce the cost of green hydrogen by 80% to $1/kg – foreseeing a potential five-fold increase in green hydrogen use if achieved.[21]

Analysis from WoodMac reported that renewable electricity would need to cost less than $0.03/kWh by 2030 for green hydrogen to be fully competitive with grey hydrogen in coal and gas-dependent markets like Australia, Germany and Japan.[22] Cost reduction in the price of electrolysers will further drive down green hydrogen costs and provide supply chain and export opportunities in some countries. Where strong renewable energy technical resources, lower LCOE, existing infrastructure and policy factors (such as government support, domestic demand for renewables, ease of doing business, etc) exist, green hydrogen production can take off.

Energy storage

Electricity storage will be a critical enabler of integration of large volumes of wind and solar energy into the power system. In the case of battery storage,

19. https://gigastack.co.uk/
20. https://www.siemensgamesa.com/en-int/newsroom/2021/11/211110-siemens-gamesa-green-hydrogen-to-vehicles; https://www.siemensgamesa.com/en-int/explore/journal/2021/03/siemens-gamesa-green-hydrogen
21. https://www.energy.gov/eere/fuelcells/hydrogen-shot
22. https://www.woodmac.com/press-releases/renewables-growth-may-close-green-hydrogen-cost-gap-by-2030/

Case study: Green hydrogen and ammonia production in Spain

Wind energy is being relied upon across the world to decarbonise the energy sector. This has led to opportunities to decarbonise other sectors, such as heavy industry and transport, through the production of green hydrogen or ammonia.

Hydrogen can already be produced at competitive prices in locations that have access to the richest renewable energy resources. New onshore and offshore wind farms producing energy at high capacity factors, equipped with the latest infrastructure technologies such as onboard electrolysers, are well-positioned for the renewable hydrogen production required to decarbonise 'hard to abate' industrial processes that require significant amounts of energy.

IRENA and the IEA have pointed out in 2019 that the high costs of renewable hydrogen production can be considerably lowered over the next 30 years with sufficient investment, which would also serve to facilitate a more rapid deployment of wind energy.

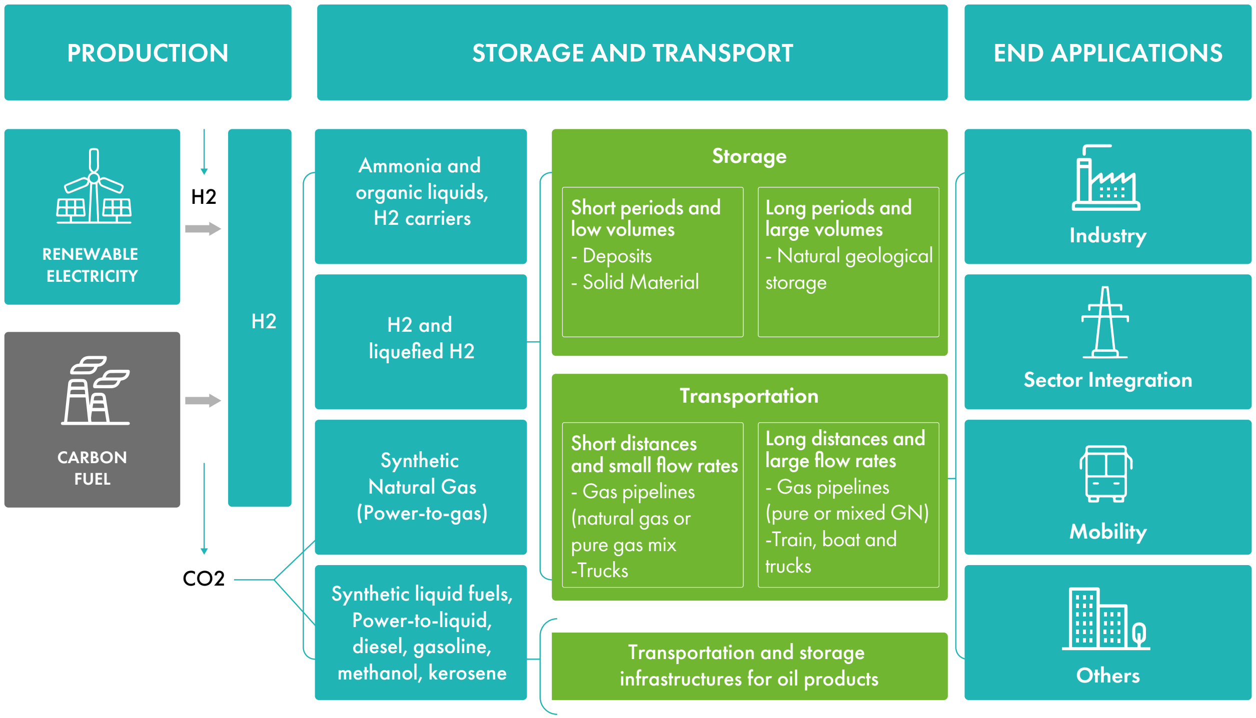
Countries such as Spain have committed to renewable hydrogen, setting a target of 4 GW of electrolysis installed capacity by 2030, and promoting the hydrogen value chain and its integration into different production processes. An example of this drive is the Catalina Project to produce green hydrogen and green ammonia, which will connect renewable resources with industrial consumption centres.

In the first phase, the Catalina Project will install 1.7 GW of wind and solar PV power, which will be connected to a 500 MW electrolyser to produce 40,000 tonnes of green hydrogen per year. This hydrogen will be transported through a "hydroduct" to a new ammonia plant, which will have the capacity to produce 200,000 tonnes per year. The green ammonia will be used to produce sustainable fertilisers, representing a technological breakthrough for the decarbonisation of the agricultural sector. The remaining green hydrogen will be transported via the natural gas grid and will be used to decarbonise other 'hard to abate' industrial processes.

The project, led by Vestas, Copenhagen Infrastructure Partners (CIP), Naturgy, Enagás and Fertiberia, will begin construction at the end of 2023, and in the second phase will reach 5 GW of wind and solar PV power to supply a 2 GW electrolyser, with the goal of meeting 30% of Spain's demand for green hydrogen.

With input from: Tomás Romagosa, Spanish Wind Energy Association (Asociación Empresarial Eólica, AEE)

Stages of the green hydrogen value chain



Source: Hydrogen Roadmap. A commitment to renewable hydrogen, Government of Spain, 2020.

lithium-ion battery pack prices have fallen dramatically, from $1,200/kWh in 2010 to $132/kWh in 2021.[23] These prices are taken as an average across different end-uses such as EVs and stationary storage projects but are even lower for battery EV packs in particular ($118/kWh in 2021).

The rapid cost reduction of battery storage has given rise to an increasing number of co-located generation and energy storage projects. Such projects have multiple uses and benefits. First, storage capability can alter the time of power dispatch or smooth renewable energy supply, allowing a renewable project to contribute a much greater level of flexibility to power grids through the provision of system services to power grid operators.

Storage co-location also allows generators to make the most of their assets by responding to market price signals. For example, on windy days when power prices are low due to significant supply, asset owners can store surplus power for dispatch when supply is lower, therefore avoiding curtailment and maximising asset revenues. Increasingly storage assets do not need to be located near renewable sites; a virtual power plant model can be utilised, whereby wind is sited in areas of optimal resource, and storage is sited closer to demand centres to improve price competitiveness.

In markets with high renewables penetration, system operators are increasingly procuring system (also known as ancillary) services, such as contracts to provide crucial technical functions to maintain frequency and inertia, as well as for emergency grid services such as "black start," or the synchronised process of restoring generation to parts of the grid after a blackout.[24] In renewables-led energy systems, it will be vital for transmission and distribution system operators to create an enabling framework for such services.

23. https://about.bnef.com/blog/battery-pack-prices-fall-to-an-average-of-132-kwh-but-rising-commodity-prices-start-to-bite/
24. https://www.nationalgrideso.com/balancing-services/system-security-services/black-start; https://www.nrel.gov/grid/black-start.html

Case study: The first carbon-neutral smart park in China

Provided by: Goldwind

Carbon neutrality initiatives can be extensive projects requiring long-term experience and practice.

Since 2010, Goldwind has transformed its headquarters park in Beijing into a "smart" park integrating modern micro-grid technology, distributed wind power, distributed solar energy systems, multiple energy storage modes, energy-saving and end-use scenarios. The park covers an area of 120,000 square metres.

In 2021, the park became the first carbon-neutral smart park in China by developing a renewable energy system and undertaking China Certified Emission Reduction (CCER).

Power system

The power system includes two wind turbines, respectively 2.5 MW and 2.3 MW, and a distributed solar energy system with a capacity of 1.3 MW, enabling generation and consumption of clean energy.

Three micro-gas turbines, one 600 kW and two 65 kW, consume natural gas to generate power that enables the combined supply of cooling, heating and power in the park. The power generated by the system is consumed locally. Meanwhile, the by-products of cooled and heated water can be used for the cooling and heating systems in the buildings. There is also another 500 kW diesel generator to simulate the operation of an island micro-grid project.

Energy storage devices, including all-vanadium flow batteries, lithium batteries and supercapacitors, are used for peak cutting and valley filling of the system and for regulating power fluctuations to improve power quality in the park.

Smart management

With energy-saving measures via buildings, air compressors, motors and precise aeration, the park saves 600,000 kWh/year of power and maximises efficiency by rationally utilising the price difference between consumption peaks and valleys. Using a chilled water thermal storage process, the air-conditioning system stores energy during power consumption valleys and releases it during power consumption peaks – saving 30-60% power. Sensors controlling all air conditioners and lighting devices enable additional energy saving.

Smart efficiency management has enabled digital and visual data on water, electricity and gas consumption in the park. Energy loss and consumption is displayed directly on platforms, allowing for targeted analysis reports and improvements.

The park also employs a smart operation system to improve operational efficiency and staff experience with digitalisation. For example, the smart meeting management system features online room reservation and enables improved energy consumption with automatic control of the air conditioning system and lighting devices based on the scenario and number of people present.

Project achievements

Through renewable resources and digitalisation, the park has achieved a power generation of over 7,500,000 kWh/year, with over 50% green power consumption and carbon emissions reduction of 4,950 tonnes/year. At present, Goldwind is promoting zero-carbon services and solutions to help others achieve a green transformation and smart upgrades of industrial parks.

Find out more here: https://www.goldwind.com/en/

There will also be a significant role for forms of long-duration storage (broadly defined as systems with a discharge range of anywhere from five to more than 1,000 hours), such as pumped hydro, ammonia and renewable hydrogen, to accompany high levels of renewables and achieve low emissions intensity.[25]

A whole systems approach to regulation is needed

The next stage of renewables growth will rest on the integration of wind power at scale to create low-cost and secure energy systems. To deliver this integration, policymakers, industry and the wider innovation community must work together to ensure:

- Systems based around renewables undertake a new approach to system design based around the principal concepts of innovation and flexibility.
- A fresh and holistic approach to policy and regulation across sectors which embraces technology innovation for a renewables-based grid, and invests in power grid operation, responsiveness and balancing.

Policymakers committing to renewables and net zero targets should also develop cross-sectoral net zero delivery plans. There is a now a growing catalogue of knowledge from system operators and grid engineering specialists on how to balance and maintain power grids with a high rate of renewables penetration. It is vital that this knowledge and best practice is shared globally.

25. https://www.energy-storage.news/longer-duration-storage-and-its-role-in-the-future-of-energy/

PART FIVE: INFRASTRUCTURE

Part Five: Infrastructure

The wind industry has already moved from the margins of the energy sector to the mainstream of energy production. But to reach a goal of exceeding 8,000 GW of installed wind capacity worldwide by 2050, wind energy deployment must rapidly accelerate within this decade.

Increasingly, a lack of facilitating infrastructure is seen as a major limiting factor in the wind industry's growth. In many countries, lack of infrastructure, such as grid and transmission networks, logistics highways and ports, is curtailing the expansion of wind power and stifling the very innovation needed to transform the energy system.

Industry, governments and financial institutions all have a role to play in creating the right conditions for investment in infrastructure to enable the next generation of wind projects, some of which are already in the planning pipeline today. Infrastructure developments must be aligned with long-term net zero strategies, including regional market integration and green industry development.

Much of the existing energy infrastructure in place globally was built for a fossil fuels-based power system, and is ill-equipped to respond to the modern era. **As the energy system becomes more decentralised and digitalised, there is a crucial need to upgrade and reinforce infrastructure, ensuring its resilience to climate change impacts.**

This need is a common thread running through many traditional forms of infrastructure such as ports, roads, transmission wires and distribution systems, grid connections and grid balancing. Many countries around the world experience a chronic lack of grid infrastructure, with limited transmission and distribution capability; it is estimated that 759 million people globally still live without access to energy or basic infrastructure (see Leapfrogging the legacy energy sector where electrification is low).

Whereas other challenges on the horizon may favour countries which host critical minerals or advanced manufacturing capacity for the wind supply chain, renewables infrastructure is a truly global challenge which touches all countries, from EMDEs to advanced economies. That said, infrastructure planning and investment needs will differ for advanced and developing economies; the latter may require combined investment in electrification and infrastructure to improve access to power grids, especially in countries where urbanisation is low and/or where remote communities and islands are prevalent.

As offshore wind projects expand and commercial-scale floating wind projects proliferate, port upgrades will be critical for the future success of the industry. Turbine sizes have increased dramatically in the last ten years, with 15 MW turbines now on the market. Experts now predict turbines with a 17 MW rating will be commonplace by 2035.

Floating offshore wind projects are being developed at huge volumes – the January 2022 ScotWind seabed leasing round auctioned off seabed for roughly 15 GW of floating wind capacity, for example. But floating projects require significant quayside storage and assembly, necessitating more spacious facilities, on-land connective transport links within port areas and deeper-water ports. Several governments have identified port upgrades as vital to progressing offshore wind, from Taiwan to New York State.

In addition to the necessary

Case study: How plug & play connectors can reduce transport and installation costs

Provided by: HARTING

The transportation of long and heavy wind turbine components has become a key issue for turbine technology scale-up. While blades and towers extend over 100 metres, the nacelle alone weighs 125 tonnes to 800 tonnes for mainstream 3.6 MW to 15 MW turbines.[1] Although they can be transported easily by railway or by ships, moving them by road is very challenging. Even specialised road transport companies can only handle loads of up to 125 tonnes or around 100 metres at a realistic freight rate.[2]

One solution to tackle this challenge is to split big components into smaller modules and then reassemble them, either before transportation by rail/ship or before final installation on the wind farms. For example, splitting the hub, nacelle housing, drive train and transformer into four modules for reassembly.

A modern wind turbine is 'an unattended power plant' with an autonomous operating system, where hundreds and thousands of electric, optic and hydraulic connections between various sub-systems transmit power, data and signal continuously and reliably.

Further modularisation due to transport limitations leads to exponential growth of interconnections and the need to reconnect modules via field assembly instead of in a factory hall. This means manufacturers must clearly define the interfaces between the modules and reduce the connection complexity.

HARTING's industrial Han® connectors have been widely used to achieve a range of modularisation in nacelles, blades, towers and foundations, as well as transition piece. For instance, modularised aviation lights with an IP69k HARTING connector of 24 poles substantially reduces the working hours and installation complexity for the installation engineer on a 100-metre high nacelle.

Find out more: https://www.harting.com/DE/en-gb/maerkte/windenergie

1. Installation of offshore wind turbines: A technical review, Zhiyu Jiang, Renewable and Sustainable Energy Reviews, 2020.
2. Transportation of Large Wind Components: A review of existing geospatial data, Meghan Mooney and Galen Maclaurin, NREL, 2016.

volumes of investment, innovation is a key factor in enabling the integration of large volumes of renewable energy. This innovation must facilitate a modern and flexible grid network, with a resilient transmission and distribution network at its core. In some regions the industry is already witnessing much greater decentralisation and a leapfrogging of traditional transmission infrastructure. Micro-grids and self-balancing regional systems are becoming more commonplace.

Crucially grid investment and infrastructure planning, especially of large transmission-scale grid infrastructure, must be conducted with careful stakeholder management and good communication to citizens. In many regions of the world, it will also require international coordination and shared spatial planning across a variety of government agencies, as in the case of offshore grid integration in the North Sea which involves 10 countries in a regional cooperation agreement.

Scaling up infrastructure to meet the needs of the energy transition can enhance the interconnectedness of communities, which will also support increased social and business exchanges. Ultimately, investment and innovation in the enabling infrastructure for renewables will benefit economies in both the short and long term, injecting capital into areas which need revitalisation, increasing access to clean power and improving balance of trade.

Connecting the dots with grid buildout

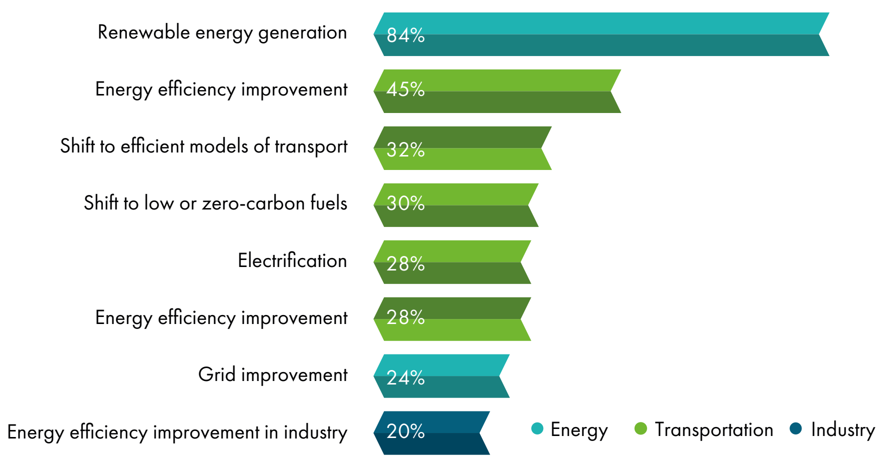
2021 was a dark year for grid infrastructure. Power blackouts and brownouts occurred across the US, Mexico, Central America, Puerto Rico, Pakistan, the Philippines and China, not to mention interconnection mismatches and near-misses affecting nearly every region in the world.

According to the Wall Street Journal, large and sustained outages are occurring with increasing frequency in the US, despite being among a handful of nations increasing investment in grid infrastructure in recent years. There were roughly 20 major disruptions in 2000, whereas in 2020 the number of major disruptions surpassed 180, with users experiencing longer interruptions of 8 hours on average.

While grid expansion will be crucial when it comes to expanding renewable energy, the topic was largely overlooked in the run-up to the COP26 climate conference in Glasgow. More than 80% of countries have indicated they plan to increase deployment of renewables, yet only 24% refer to grid improvements in their NDC.

Countries must catch up on their grid planning to meet their energy security and climate goals. In a Paris-compliant pathway to net zero by 2050, the IEA charts out annual global investment in smart transmission and distribution grids nearly trebling from current levels to $820 billion by 2030. This grid expansion responds to increased power demand and electrification, in addition to integration of renewables and replacement of aging infrastructure. By 2040, electricity network investment reaches $1 trillion on an annual

References to climate change mitigation options among NDCs of Parties to Paris Agreement, as of 2021



Sources: Energy Monitor, UNFCCC, 2021.

basis, before falling back to the $800 billion level in 2050 as the renewables growth rate begins to slow down.

This global challenge is also a global opportunity, offering potential for domestic job creation and local value added to national economies. Additional investment in power grids and energy flexibility measures in line with a 1.5°C scenario could generate tens of millions of additional jobs worldwide, compared to a BAU scenario.

Cross-border grid interconnections and power trading can support local and international goals such as improving grid flexibility and resilience, reaching renewable energy targets and increasing overall economic development, particularly for landlocked countries which lack solar and wind resources or available terrain for projects, such as Singapore.

Coordinating cross-border grid planning and operations can be a challenging and complex task, but highly beneficial in the new era of renewable energy growth. Some of the high-profile international grid visions include the Friends of the Offshore Supergrid (2002), European Supergrid (2010), Asian Supergrid (2011) and China's Global Energy Interconnection project (2015).

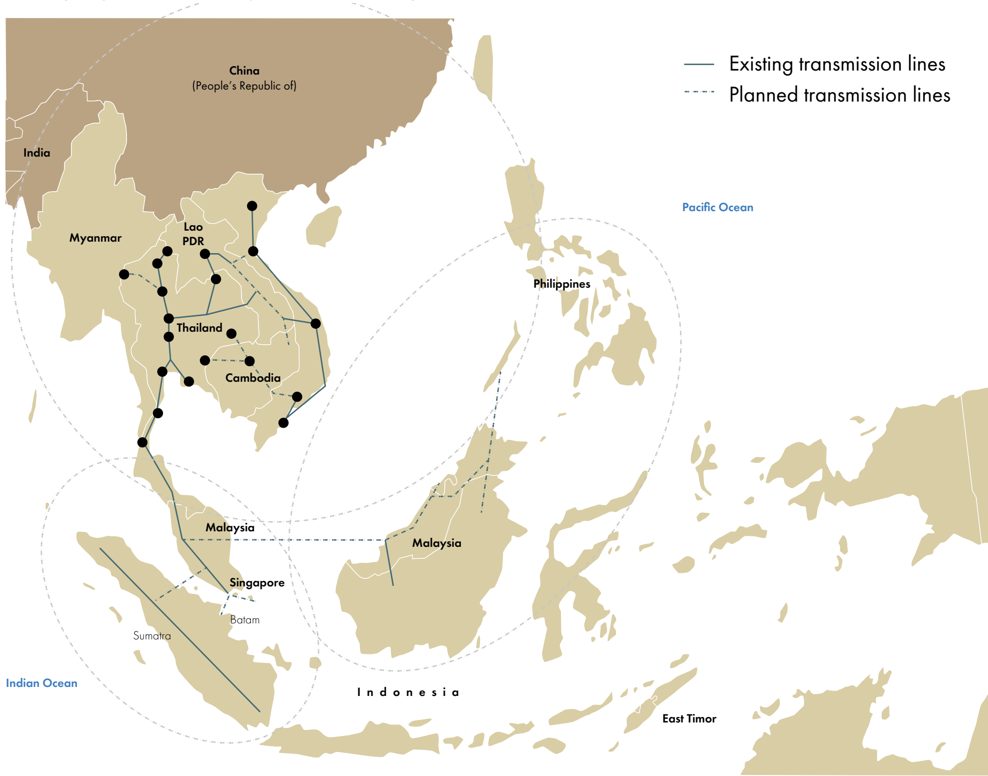
At COP26, India and the UK merged their One Sun, One World, One Grid and Green Grids Initiative, respectively. In the first phase, the Indian grid would be connected to the grids of Middle East, South Asia and Southeast Asia to develop a common grid. The second phase would expand to connect to the power pools in Africa and the third phase would look at transcontinental interconnection with Europe and the rest of the world, aiming for 2,600 GW of interconnection by 2050 and estimated power savings of $249 billion per year. About 83 nations have endorsed the initiative to date.

Improving grid technology

The energy transition is a transformational enabler of sustainable development and climate resilience, with technology at its heart. Improved wind turbine and solar PV panel technologies, and their rapid cost reductions, already provide the foundation needed for the next era of energy transition growth in many countries. However, achieving an all-encompassing smart, flexible and resilient electrical grid with underlying aging transmission and distribution infrastructure will require technology innovations at a pace never seen before.

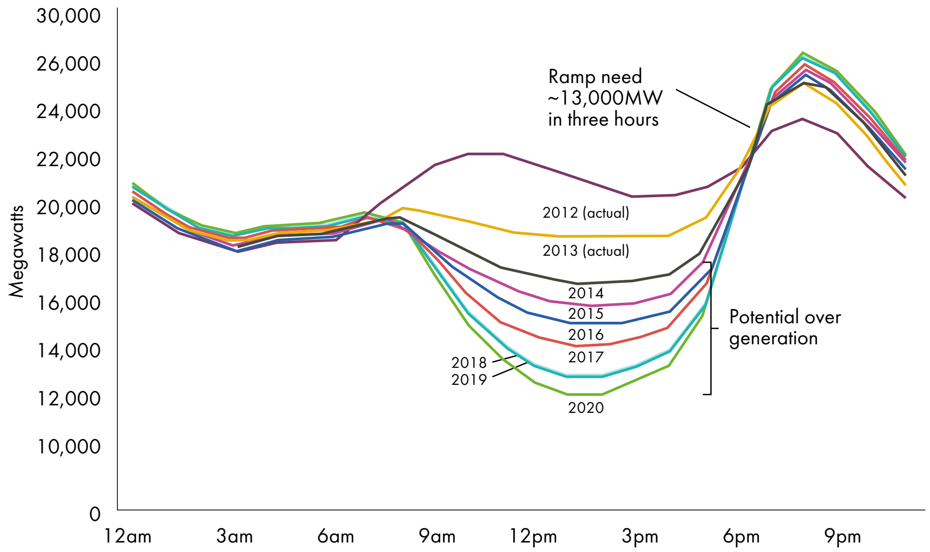
A smart grid as an electricity network that can efficiently integrate the behaviour and actions of all users in order to ensure economically efficient, sustainable power systems with low losses and high levels of quality and security of supply and safety. This may employ innovative products and services, together

Three proposed sub-regional electricity markets in Southeast Asia



Source: IEA, 2019

Duck curve" net load profile in California on 31 March, 2012-2020



Source: CAISO, 2020. The forecast was made in 2013.

with intelligent monitoring, control, communication and self-healing technologies. Grid flexibility expresses the extent to which a power system can modify electricity production or consumption in response to variability, expected or otherwise, and maintain reliable supply in the face of rapid and large imbalances, whatever the cause. Last, grid resilience is the ability to withstand and reduce the magnitude and duration of disruptive events, which includes the capability to anticipate, absorb, adapt to and rapidly recover from such events.

Thailand is a good example of a nationwide effort to implement a smart grid. In 2015, the Thai Government launched a $5.9 billion 20-year Smart Grid Master Plan to 2036 in support of the national goal to reduce GHG emissions by 20% from BAU levels by 2030. Since then, the Electricity Generating Authority of Thailand (EGAT), the Metropolitan Electricity Authority (MEA) and the Provincial Electricity Authority (PEA), have been conducting several pilot projects. EGAT is emphasizing grid modernisation, big data, grid connectivity and renewable energy forecasting, while MEA and PEA are focusing on distribution system management, smart metering and demand-side response. This year, Thailand kicks off the ultimate stage to 2026, aiming to enable nationwide automated electricity networks, large renewable energy resource integration, balance of energy production and utilisation and intelligent two-way power supply of electric vehicles. Thailand also recently announced a $7.1 billion 10-year programme to upgrade the national transmission network.

As far back as 2013, the California Independent System Operator (CAISO) forecast that increasing deployment of solar – which generates most during midday when the sun was strongest – would lead to a dip in net load or conventional generation, followed by a steep ramp-up of system demand into the evening hours. This demand profile means that CAISO would need resources with ramping and stop-start flexibility to adapt output levels to real-time grid conditions. CAISO's original prediction even underestimated the degree of the midday dip, according to analysis, though the operator has largely been able to maintain a stable grid.

Since then, California has committed to reach net zero by 2045, while its 2030 Climate Commitment targets at least half of its electricity supply to come from renewable energy sources by 2030. With these deadlines around the corner, California's grid operator is implementing a 10-year grid transmission plan with a view to boost grid flexibility and resilience, and prevent curtailment or over-generation. The CAISO plan includes 23 projects at a cost of $2.9 billion, based on a projection that around 2.7 GW of new renewable power generation (including offshore wind) will be integrated annually. In addition to mid-term and long-term grid reliability projects which can balance and stabilise the system, other flexibility measures are being implemented in demand-side response, interstate power flow and storage.

In Japan, the city of Higashi-

Matsushima rebuilt its energy infrastructure following the wake of Tohoku tsunami in 2011. Its restructuring involved microgrids and decentralised power systems to ensure that its localised grid could be more resilient to the eventuality of a natural disaster. Other cities in Japan are now following suit, while the Cabinet Office increased funding to the National Resilience Programme by around 24% in 2017.

In the offshore wind sector, high-voltage direct current (HVDC) technology is maturing. There have been many lessons learned and technology advancements since BorWin1, the first HVDC grid connection from an offshore wind farm, to Sunrise Wind, the first offshore wind project in the US to use HVDC transmission, and more recently Dogger Bank in the UK, announcing the world's first unmanned HVDC offshore substation, slashing topside weight by 70%. However, a key technology challenge remains in ensuring interoperability in complex HVDC grid structures, across multi-terminal, multi-vendor HVDC systems.

Future grid users

The future grid will be far more decentralised, decarbonised and digitised, with far greater consumer interaction than ever before. In the past, consumer interaction with the grid has been very limited and power has been provided without differentiation. However, rapid digitisation in our everyday lives, combined with greater concern about the climate crisis and falling costs, has seen consumers starting to play a more prominent role in power demand and supply.

In many regions, we are now seeing direct consumer interaction between consumers and the grid via smart appliances, electric vehicles and home heating, cooling and storage systems. At the same time, commercial and industrial (C&I) consumers of power are increasingly providing demand turn down services. We also see a much greater degree of decentralised battery storage active on the distribution grid.

In some regions there has been a proud history of community and consumer involvement in renewable projects. Blockchain technology is now making it possible for consumers to directly engage with how their power is produced in way fit for the digital era. Non-fungible tokens (NFTs) guaranteeing the units of power have been produced directly from renewables, and this is giving rise to new business models and ways of crowdsourcing funds for renewable projects.

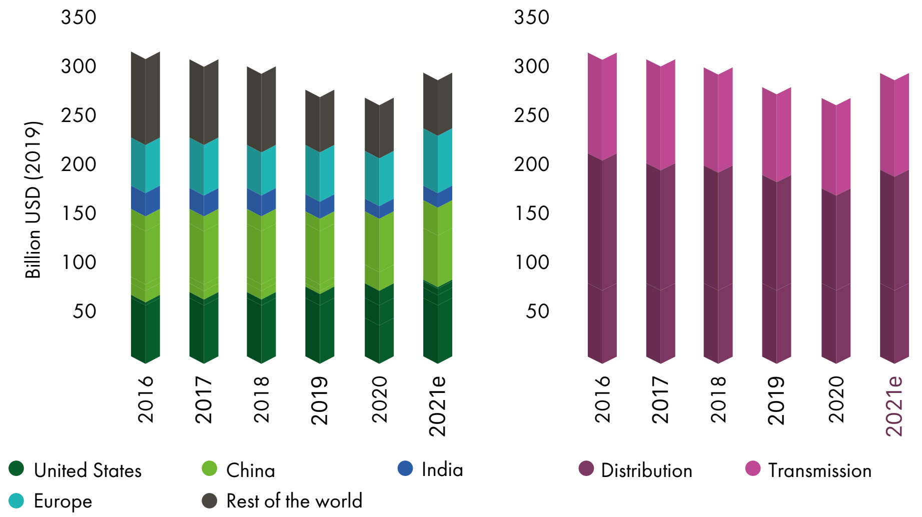
To maximise the opportunities brought about by these trends and technologies, a highly decentralised and flexible approach to transmission, and crucially, distribution grid management will be needed. In the modern grid of the future, interaction will go both ways in a dialogue between supply and demand. For the energy transition to truly benefit from these innovations, and be fair and equitable, a range of products and services will need to be integrated into grid systems, along with robust regulation and measures to protect physical and cybersecurity. This should include consumer tariffs that incentivise demand-shifting and behaviour change, such as time-of-use tariffs.

Planning for a renewables-based grid

Policymakers must urgently mobilise greater public and private investment in secure, smart and flexible grids which enable

ever-larger shares of renewable energy. Otherwise, availability of suitable grid connections, capacity and transmission lines can form a significant bottleneck to the growth of new utility-scale wind and solar projects.

A national grid infrastructure development plan of at least 10-15 years ahead, with broad stakeholder buy-in, will be needed to align with renewable energy development targets and unlock regulatory bottlenecks. This degree of long-term forward-planning will require a huge effort of coordination across different stakeholders, Investment in electricity networks by region and segment



Source: World Energy Investment 2021, IEA, 2021.

including ministries of energy and economy, in addition to system operators, regulators and utilities.

While this work needs to be steered by public authorities, it will require early and consistent engagement with sub-national and local government authorities and host communities to align priorities for transmission deployment and communicate the benefits of an expanded grid.

It will also require greater human, economic and digital resource to conduct comprehensive grid and transmission planning, including identification of areas of need for prioritisation, managing distributed system elements, running long-term scenarios and boosting grid security. In parallel, the public and private sectors should maintain active dialogues and R&D initiatives to advance digitalisation and scalability/cost of technologies which can optimise grid and transmission systems.

A more streamlined policy and regulatory framework must be implemented to motivate regional transmission organisations (RTOs) and independent system operators (ISOs) to perform integrated planning at regional and multinational level, so power grid investments can be de-risked and accelerated.

Finally, as with renewable energy projects themselves, an efficient and streamlined permitting process is urgently needed to enable grid and transmission buildout. This could include designation of priority corridors for electricity networks, based on forecast power needs and renewables deployment. It should also incorporate greater resource provided to consenting authorities to accelerate approval decisions for grid projects, which are often beset with delays. In the EU, for instance, around 30% of grid projects designated to be in the common interest are delayed due to permitting issues.

Scaling up infrastructure investment for the transition

Infrastructure needs in a net zero scenario go beyond electricity grids. They incorporate the mass dissemination of charging points for electric vehicles, ports and logistic highways, infrastructure for green hydrogen transport and marginal investment in carbon capture and storage infrastructure. Nonetheless, grids comprise the lion's share of infrastructure investment for the energy transition.

A great deal more volume of spending is needed, particularly as global investment in grid expansion in China, India and many other EMDEs declined from 2016 to 2020, leading to a 25% overall drop globally during this period. This occurred in China, for example, as rural power grid buildout targets were met and the focus shifted to less capital-intensive transmission reinforcement.

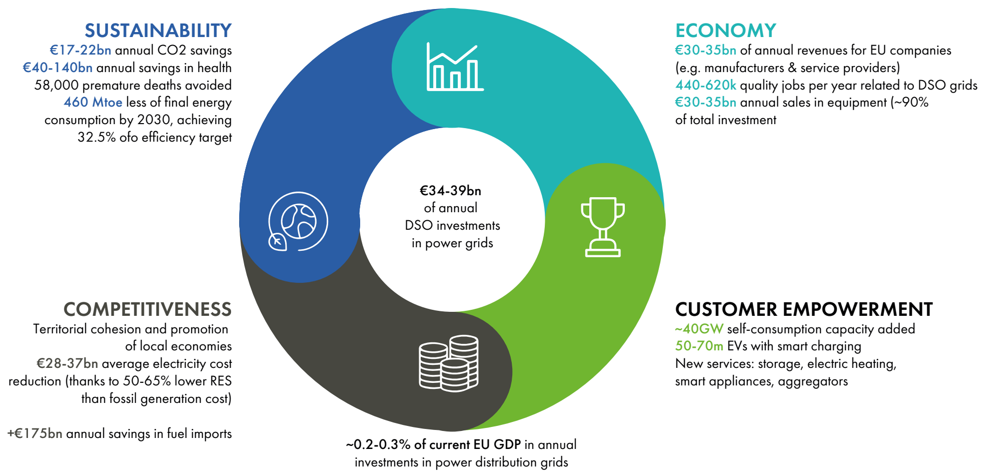
Grid investment rebounded in 2021, led by increased spending in China and Europe. However, the estimated figures for global grid spending last year are still below $300 billion, and less than what was spent in 2016 worldwide.

Grid investment needs to scale up in every region of the world. To reach a pathway well below 2°C by 2050, IRENA has called for at least $22 billion in annual investment in power grids and system flexibility in Southeast Asia, $105 billion annually in East Asia, $52 billion annually in the rest of Asia, $4 billion annually in Oceania, $15 billion annually in Latin America and the Caribbean, $23 billion annually in the MENA region, $65 billion annually in North America and $18 billion annually in sub-Saharan Africa.

The investment needs are significant, but studies show that countries would be more than recompensed by the savings in fossil fuel imports and subsidies. A 2021 study by Eurelectric and E.DSO found that the EU requires €375-425 billion ($413-468 billion) in distribution grid investments and modernisation by 2030, when half of the EU's grid will be more than 40 years old. The investment would be paid for several times over by the savings, which include €175 billion ($193 billion) annual savings in fuel imports and €27-37 billion ($30-41 billion) in long-term electricity cost reduction as renewable penetration increases. Grid investment also shepherds in significant socioeconomic benefits, including job creation for grid enhancements and capital investment in related economic sectors, such as construction and IT.

Enhanced or new mechanisms to mobilise investment in grid and transmission buildout is required, such as leveraging investment under a smart/green economy scheme, federal grant programmes and loan guarantee programmes. In EMDEs, concessional loans by multilaterals may be appropriate to finance grid transformation and buildout, especially blended with climate finance under mitigation and adaptation goals. As highlighted at COP26, this would require a model to estimate the emissions reduction potential of grid investments to make them eligible

Major social and economic benefits from power grid investment in Europe



Source: Connecting the dots: Distribution grid investment to power the energy transition, Eurelectric, E.DSO and Monitor Deloitte, 2021. Note: DSO stands for distribution system operator.

for climate finance, and incorporate grid considerations into investment criteria.

EMDEs may also seek out independent power transmission tenders to mobilise private financing to build, operate and maintain a transmission line and/or substation. Such tenders are common in Latin America – for example, Peru has organised 18 transmission tenders from 1998 to 2017, while Brazil organised 38 tenders from 1999 to 2015. India, Canada, the US and Australia have also leveraged tenders to attract private investment in transmission. Private capital may have an increasingly important role in distribution projects in EMDEs as well, such as through preferential loans to state-owned distribution entities.

Holistic planning for future system infrastructure

The increased integration of mature renewable energy sources on a smart and flexible grid will be vital to maintaining energy security and economic productivity, as the transition progresses. This includes integration of balancing technologies like hybrid projects, as well as batteries and green fuels for storage at shorter and longer durations (see A changing paradigm and the demise of baseload).

Policy, planning, regulatory guidelines and investment in grid and system infrastructure must accelerate in parallel with renewable energy deployment. Otherwise, we leave huge volumes of clean electricity without a route to market or access to grid connection – prolonging our reliance on fossil fuels, and further exposing us to the risks of a delayed and disorderly energy transition.

To achieve greater coordination and impact in grid and infrastructure planning, policymakers, system operators, regulators, utilities, the industry and the wider innovation community should:

- Ensure national development plans for grid infrastructure are in place, looking at least 10-15 years ahead, in alignment with renewable energy supply planning, fossil fuel phaseout schemes and sector electrification needs.

- Involve local communities hosting transmission and distribution infrastructure to ensure that grid enhancement and modernisation is seen in the common interest, and communicate the socioeconomic benefits brought by infrastructure projects.

- Mobilise public and private finance schemes for grid and transmission investments, including concessional loans, private sector transmission tenders and refinement of eligibility criteria for climate finance.

- Dedicate further human and digital resource to the permitting and consenting authorities for grid and transmission infrastructure projects, as well as to the research and innovation community which can continue advancing the pursuit of smart, modern and flexible grids.

PART SIX: WORKFORCE

Chapter Sponsor

LINCOLN ELECTRIC

Part Six: Workforce

As of 2020, 12 million jobs were attributed to the renewable energy sector, of which 1.25 million direct jobs were recorded in the wind industry.[1] Under a net zero by 2050 scenario, the renewable energy workforce could increase to 43 million jobs in the global economy, including jobs required for the power grid and flexibility services.[2]

Jobs in the wind energy sector will undoubtedly increase under this scenario. IRENA estimates that as wind energy installations grow 10-fold by 2050 to more than 8,000 GW of wind energy capacity worldwide, the wind energy sector could accommodate 5.5 million jobs. The share of wind energy jobs in the global renewables workforce may increase, as wind becomes a predominant electricity source and the value chain of the industry expands to include newer technologies and domains, such as floating offshore wind.

This scale up not only requires unprecedented public resources

1. Renewable Energy and Jobs – Annual Review 2021, IRENA, 2021.
2. World Energy Transitions Outlook: 1.5°C Pathway, IRENA, 2021.

Wind energy workforce requirements

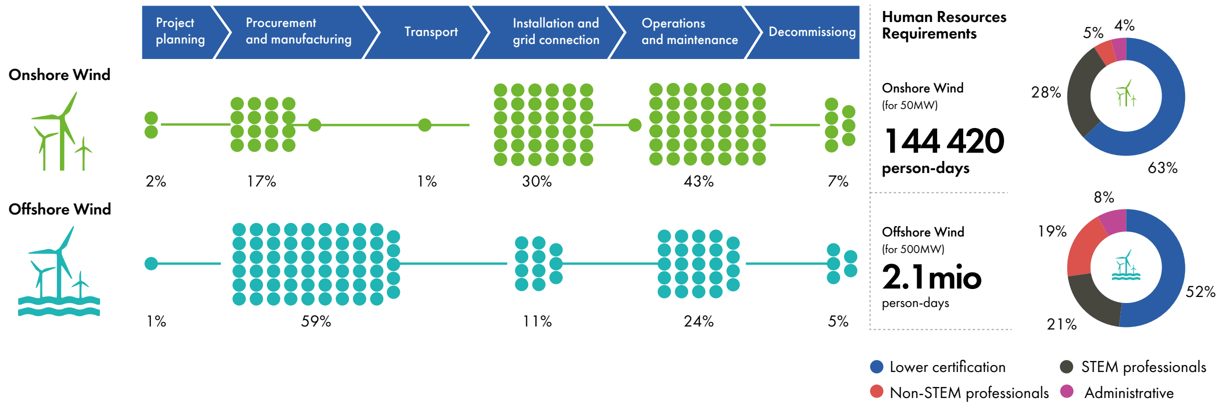
Renewable energy employs people across all trades and levels across the full value chain, from project planning to decommissioning. IRENA's analysis of the human resource requirements for the onshore and offshore wind industry shows the opportunities for employment in 50MW onshore and 500 MW fixed-bottom offshore facilities are for over 144 thousand person-days and around 2.1 million person-days, respectively.[4]

Regarding the skills required for the deployment of wind energy facilities, the analysis show that over 60% of the workforce in the onshore wind industry, and over half of the workforce of the offshore wind sector, requires minimal formal training. Individuals with degrees in fields such as science, technology, engineering and mathematics (STEM) are needed in smaller numbers (around 28% for onshore wind, and 21% for offshore sector).

Highly qualified non-STEM professionals (such as lawyers, logistics experts, marketing professionals or experts in regulation and standardisation) account for roughly 5% and 20% respectively, while administrative personnel make up the smallest share (4 and 8%, respectively).

4. Leveraging local capacity for onshore wind, IRENA, 2017; Leveraging local capacity for offshore wind, IRENA, 2018.

Human resources and occupational requirements for 50 MW onshore and 500 MW fixed-bottom offshore wind projects



Sources: Leveraging local capacity for onshore wind, IRENA, 2017; Leveraging local capacity for offshore wind, IRENA, 2018.

Case study: Attracting talent into the wind Industry

Provided by: NES Fircroft

The energy sector is in the middle of a major transformation. Governments around the globe have set goals to reach net zero by 2050, meaning companies need to ramp up their renewable energy strategies and attract specialist talent to get across the low-carbon future finish line.

Staffing specialist NES Fircroft recently released an "Energy Transition Outlook" report which offers unique insights into the current temperature of the talent landscape and how organisations should shape their recruitment strategy to attract engineers to the renewables sector.

Myths around transitioning from traditional energy to the wind power industry

The results from this report show that many candidates feel positive about the energy transition and the exciting projects it offers, but there are some common misconceptions surrounding moving from traditional energy to a renewables role.

Myth 1: The salaries are not competitive. Many workers stated they did not wish to make the move because they perceived salaries to be lower. However, this is not necessarily the case. More than 75% of respondents who have transitioned said their salary was higher or about the same.

Myth 2: Skills are not transferable. 71% of respondents said they needed further training to effectively transition skills. However, many skills are transferable, and the experience engineers can bring from traditional energy projects will be vital to the wind sector.

Myth 3: Newer industries may not offer the same stability. Big Oil and Gas have invested in renewable energy and wind energy is now "front and centre." Projects that will move the needle in sustainability can be ground-breaking and disruptive, but they are surely here to stay.

Myth 4: There are more interesting large projects in traditional sectors. Ambitious wind projects will provide several new jobs tapping into the latest and greatest technological advances. A good example is the soon-to-be world's largest wind farm, Gansu Wind Farm in western China; once expanded to 20 GW by 2025, it will be home to 7,000 turbines and produce enough energy to power a small country.

Myth 5: There just aren't as many job opportunities. There will be an abundance of new and exciting opportunities as companies try to meet their net zero goals. NES Fircroft is currently recruiting across the globe on wind projects from California to the UK, and has seen its renewables division grow exponentially to cope with the demand for talent.

The results from the Energy Transition Outlook report show that many candidates are considering working in the renewables sector, with wind energy at the forefront. Alignment with personal values is a key driver for many, but they still need reassurance to make the transition. Organisations should bear this in mind when they are considering their future recruitment strategies.

Find out more: https://www.nesfircroft.com/energy-transition-outlook-report

dedicated to mobilising a growing workforce for the wind and renewables sectors, but also a buildout of skills and an appropriate training infrastructure, as well as dissemination of the industry's health and safety standards in regions where wind energy is at an earlier stage. Studies show that one of the top challenges for the renewable energy transition is the difficulty of recruiting, training and retaining skilled workers with aligned skillsets.[3]

This means fostering diversity and inclusivity as the workforce expands in volume and geography.

Set for such large growth during the energy transition, the renewables sector is an ideal candidate to accommodate and absorb the displacement of workers from fossil fuels industries and carbon-intensive sectors. There will be a need for public-private planning and coordination, including support for workers who need re-certification in the transition phase.

Jobs generated from wind projects span the full value chain of the

3. Moving organizational energy use toward 100% renewables – aspiration or destination, Deloitte, 2019

Case Study: Just transition and building Scotland's supply chain

Provided by: SSE Renewables

SSE Renewables is investing in Nigg Offshore Wind (NOW), a new state-of-the-art offshore wind turbine tower factory in the Scottish Highlands that will help build the next generation of offshore wind farms in Scotland and beyond – creating hundreds of full-time green jobs.

NOW is the most significant localisation of offshore wind supply chain manufacturing ever seen in Scotland, boosting Scotland's renewable energy supply chain and helping reskill local workers.

The turbine factory will be built by Global Energy Group and Haizea Wind Group at the Port of Nigg at a total investment cost of over £110 million ($143.5 million), backed by £15 million ($19.6 million) in debt funding from SSE Renewables.

Once operational in 2023, NOW will employ 400 people on a full-time direct basis, manufacturing up to 135 towers each year for the next generation of fixed and floating offshore wind turbines. Its activities will support another 1,800 indirect jobs in the Scottish and UK supply chain – helping transform thousands of lives in the region and providing real opportunities for workers to transition from oil and gas to renewables. This is an integral part of the just transition in Scotland, in support of SSE's Just Transition strategy and drive for net zero.

The UK needs to be a world leader in offshore wind development, and to support this SSE Renewables intends to fulfil its role as a strategic backer for the facility by placing orders to meet its growing offshore wind pipeline in the future. A pipeline of offshore wind construction and development projects of scale, such as Dogger Bank and the super-sized Berwick Bank, can create a stronger, greener and more successful industry.

This collaboration can deliver a sustainable Scottish and UK supply chain that creates jobs, reskills our workforce for a low carbon future and maximises the economic benefits, both regionally and nationally.

Find out more: https://www.sserenewables.com/

sector, encompassing a variety of technical, professional and hard/soft skills. From project planning to manufacturing to operations and maintenance (O&M), the wind sector provides a range of jobs distributed along a diverse value chain.

Renewable energy employs people across all trades and levels across the full value chain, from project planning to decommissioning. IRENA's analysis of the human resource requirements for the onshore and offshore wind industry shows the opportunities for employment in 50MW onshore and 500 MW fixed-bottom offshore facilities are for over 144 thousand person-days and around 2.1 million person-days, respectively.

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Wind energy at the heart of a just and inclusive transition

There is an expanding body of evidence which shows that socially and environmentally responsible economic growth can reinforce workforce resilience, by encouraging workers to adapt to the low-carbon economy of the future.[5] The labour disruption and economic dislocation brought by the transition to clean energy could create hardships if not managed well. In addition, these hardships could translate into social tensions or the formation of marginalised communities – factors which could undermine public acceptance of the transition and thus interrupt the rise of renewable energy and displacement of fossil fuels.

Ensuring a just transition is therefore essential to sustaining the growth of the wind industry. The concept of a just transition is gaining ground, but is not a new phenomenon. There are many examples of national, regional and global efforts to drive a just transition adjacent to the energy transition, including recent reporting by the International Labour Organization.[6] IRENA's Collaborative Framework on Just and Inclusive Energy Transition, its Coalition for Action Working Group on Sustainable Energy Jobs and the IEA's Global Commission on People-Centred Clean Energy were all established in 2021.

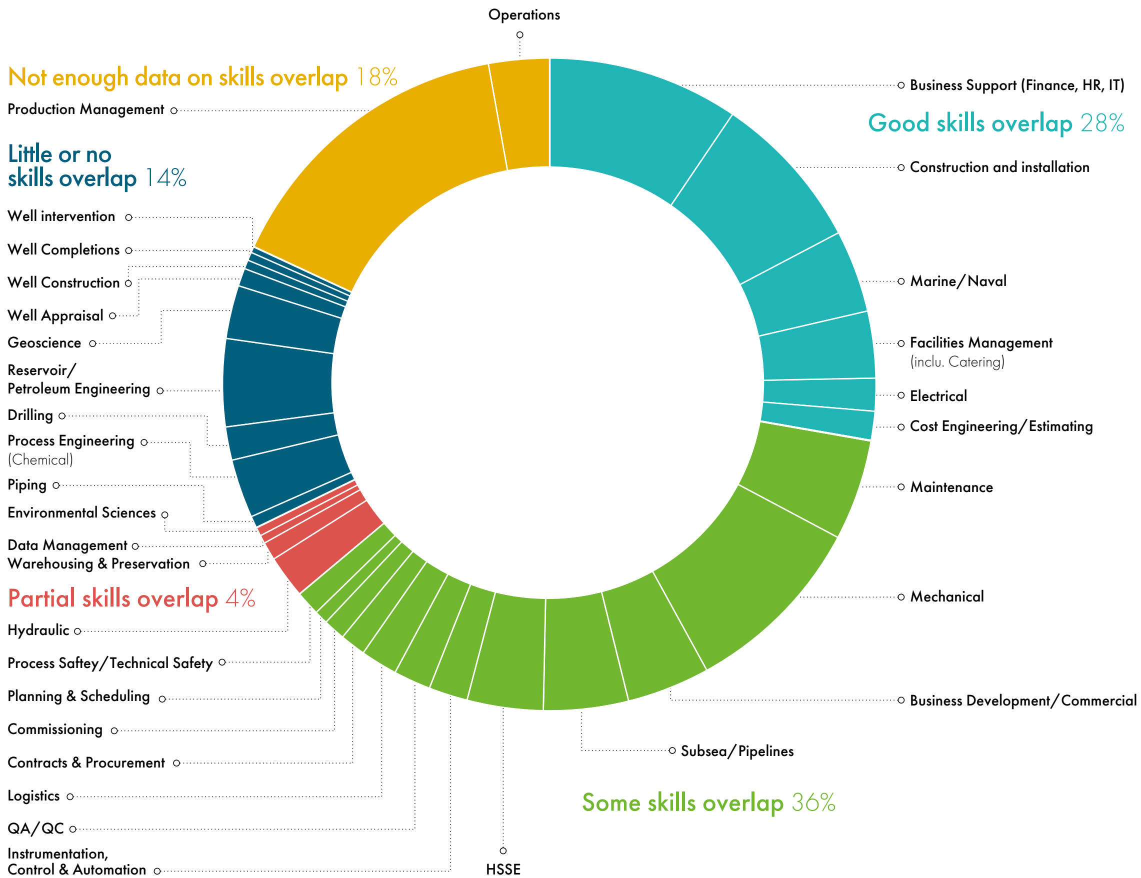
A just transition is characterised by its concern with the socioeconomic welfare of stakeholders involved in the energy transition, foremost those working in the energy sector.[7] Over the last few years, the concept has evolved and is often presented as the just and inclusive transition, as increasing importance is being placed on inclusivity of system transformation. There are many dimensions of inclusivity, but from the gender lens, the wind industry has a long way to go with women representing only 21% of the global workforce – even lower than the legacy energy sector, and far

lower than the 32% of women in the wider renewables workforce.[8]

The definition of the just transition is seemingly broad, as socioeconomic welfare covers a wide range of issues. Through a social lens, this includes the provision of human rights, worker safety and the inclusion of minority, marginalised or vulnerable categories of workers in some countries including women and disabled people. Through an economic lens, this includes geographic displacement of

5. https://gwec.net/green-recovery-policy-recommendations/#people
6. https://www.ilo.org/global/topics/green-jobs/publications/WCMS_432859
7. Glasgow Climate Pact, UNFCCC, 2021
8. Wine energy: A gender perspective, IRENA, 2020; Renewable energy: A gender perspective, IRENA, 2019.

Skills transferability from offshore oil and gas industry to offshore renewables



Source: Sea Change: Climate Emergency, Jobs and Managing the Phase-Out of UK Oil and Gas Extraction, Platform, Oil Change International and Friends of the Earth Scotland, 2019.

economic activity, jobs losses and security and costs of re-training. Although the energy transition is likely to generate far more new jobs then the number lost in fossil fuels, the transition may in the interim also generate discontinuities of a temporal, spatial, occupational and sectoral nature.

A just transition must also be highly contextualised to the conditions of the affected locality or community. As a result, frameworks in one country may look very different to those in another. For instance, in Brazil under the Just Transition Law, subsidies for coal plants are permitted until 2040 to ease the impacts of the shift to renewable energy on directly impacted stakeholders – although ongoing support to coal plants could prolong environmental, and ultimately social, harm.[9] In South Korea, the government's Green New Deal will invest $25 billion to create 387,000 jobs in the green economy, and encourage renewable energy growth.[10] Both approaches aim to protect the welfare of the workforce affected by the energy transition.

The just and inclusive energy transition is also a reflection of historic issues of inequity linked to economic transformation. Communities which have been marginalised or party to resource colonialism in the past may harbour sentiments of mistrust towards the harbingers of economic growth. A harmonious transition must respond to these concerns with participatory dialogue and clear policies that are appropriate for such communities.

9. https://www.reuters.com/markets/deals/brazil-extends-coal-use-2040-under-new-just-transition-law-2022-01-06/
10. https://www.iea.org/policies/11514-korean-new-deal-digital-new-deal-green-new-deal-and-stronger-safety-net

Uncertainty can be mitigated through targeted education and training programmes, investment schemes, industrial upgrades and promotion of public-private partnerships and joint ventures to integrate workers into the green economy.

Shifting workers from sunset industries to wind

Workers from carbon-intensive industries can be part of the solution in addressing the skills gap required to drive the energy transition. Skills and training obtained by workers in coal, oil and gas-related sectors can be repurposed and deployed to renewable energy sectors at a wide variety of points along the value chain. A shift to a renewables workforce then increases the need for labour mobility, as opposed to merely representing the loss of prevailing jobs in carbon-intensive sectors. There are three overarching factors to this shift:

- **Social dialogue** enables workers, communities, governments and a variety of stakeholders to understand the impacts of the energy transition and creates a platform for strategic and inclusive management of these impacts.
- **Increased investment** in community outreach, recruitment, training and reskilling programmes to close the skills gap and support job creation where required. Investment could also be required to provide interim social support payments where needed to the affected workforce.
- **Targeted education and skills transfer** in the form of tailored reskilling and training programmes addresses the skills gap that exists as a barrier to entry to the wind industry. This includes implementing practices and standards which recognise the relevance of transferable skills and existing qualifications possessed by those in carbon-intensive sectors, minimising the friction for a worker transition.

For instance, a 2019 assessment of skills transferability from the UK offshore oil and gas industry to the offshore renewables industry found that the disciplines covering nearly 70% of full-time equivalent (FTE) jobs in the offshore oil and gas industry had partial to good overlap with those required in offshore renewables.[11] These include good skills overlap in the areas of business support (finance, human resources, IT), business development, construction, installation, marine/naval services, facilities management, maintenance, mechanical engineering, subsea/pipeline construction and health, safety, security and environment (HSSE) expertise.

The skills and expertise of workers who have designed, managed, constructed, installed and maintained large-scale and complex offshore oil and gas projects are highly valuable for the offshore wind sector, which deploys projects in similarly harsh marine environments. This offers job transferability potential up and down the diverse offshore wind value chain, from steel manufacturing for foundations, substations and installation vessels, sub-sea cables to evacuate electricity and vessels for transport of equipment and workers.[12] Skills such as working offshore at heights or in deep water, HSSE training, offshore standards knowledge and engineering experience are all highly transferable.

Steering this workforce transition requires policymakers to make strategic choices on how existing capabilities and workers can be leveraged for high-growth areas. Where possible, reskilling offshore oil and gas workers should be leveraged to encourage competitiveness. Surveys have reflected that workers are open to career transitions as well – a 2020 survey among UK offshore oil and gas workers found that more than 80% would consider shifting to work outside the sector, and more than half preferred to shift to offshore wind.[13]

11. An FTE job is defined as a full-time job for one person in one calendar year. See: https://priceofoil.org/content/uploads/2019/05/SeaChange-final-r3.pdf
12. http://gwec.net/offshore-wind/; https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Biomass-Solar-Wind/Master-Plan/US-job-creation-in-offshore-wind.pdf
13. https://foe.scot/ wp-content/uploads/2020/09/Oil-Gas- Workers-Report-Final.pdf

Case study: Closing the skills gap in heavy fabrication as the wind industry expands

Provided by: Lincoln Electric

As the global wind industry expands its central role in meeting the world's energy transition targets by 2050, one point of increasing importance is how the global supply chain will adapt to the declining trend in available highly skilled trade workforce. This is particularly acute in the area of welders needed for metal fabrication of onshore and offshore wind projects.

In virtually every key region of the world, a shortage of skilled trade workers in welding and metal fabrication has been an ongoing trend for more than a decade. To combat this, new ways of engaging and closing the skills gap will only be possible with the help of individual companies, workforce development schools, colleges, unions and private entities to meet the industry's needs.

Lincoln Electric has been investing in new ways to reduce the training time necessary to provide highly skilled and effective new welders and welding operators to support industries like wind. Two areas that have achieved success are the Lincoln Electric "Train the Trainer" core curriculum and the development and integration of virtual reality welder training tools (VRTEX®). Together, these two pieces combine classroom time and practical hands-on education with a virtual reality experience. In the virtual training world, immediate feedback, positive reinforcement and visual acuity are critical to helping highly skilled welding workers develop fine motor skills with tremendous accuracy.

A recent study performed at WSU Tech in Kansas demonstrated that time to develop proper welding skills can be significantly reduced using this process. The study confirms that when programmes like virtual reality training (VRTEX®) are introduced to industry, the traditional learning curve is flipped. Students start to develop real-world skills immediately, and the study "concluded that those taught with the hybrid instruction methodology outperform those taught with only a live machine."

While this method has been successful, more work continues in the context of the rapidly expanding offshore wind developments around the world. A higher volume of skilled welders will be required to fabricate critical offshore components including towers and offshore foundations. To reach the 2050 installation targets called for in a net zero pathway, the industry must continue innovating and investing in a workforce with the skills needed for the global supply chain.

Find out more: https://www.lincolnelectric.com/en/Education/Training-Programs

The coal sector workforce is generally more challenging to transition directly into the wind sector, although there is scope to move between sub-sectors of the energy industry, such as legal or financial services.13 Along the value chain there will be other technical areas which could benefit from someone with prior experience in the energy sector. Targeted training and recruitment programmes which proactively address areas where labour disruption is expected will be important for protecting the welfare of displaced workers from the coal industry.

For instance, as South Africa has an overwhelming dependency on coal, coal phaseout will have a significant impact across the economy and communities. As a result, in 2013 the National Planning Commission dialogue process already included a just transition as part of the National Development Plan. Social dialogue is widely acknowledged as key to this process, reducing disinformation about the nature and consequences of the transition and creating a platform for understanding and collaboration between stakeholders. Dialogue has provided a forum to foster social consensus on the management of South Africa's energy transition.

In revitalising and repurposing a workforce to meet the demands of wind energy growth, policymakers must take responsibility for creating transparent guidance and proactive frameworks to support this process. In turn, the wind industry must support the shaping and implementation of these frameworks. Some of the good practices in a just and inclusive transition to wind include:

1. Encourage social dialogue and increased stakeholder engagement: Creating space for social dialogue and increasing stakeholder engagement helps to support social cohesion and a common understanding of the challenges and opportunities ahead. Stakeholders include displaced workers, residents of host communities of local projects and members of affected communities such as the fishing industry for offshore wind, among others.

2. Promote public-private collaboration to generate local value creation: As a leading energy solution, the wind industry should work with governments to facilitate local industrial activity and the creation of decent jobs for workers in areas where fossil fuels-based activity once thrived. The public sector must work together with the industry to identify viable projects and collectively support investment in training workers and repurposing sites. This includes the creation of a viable local supply chain, with schemes to incubate businesses and local capabilities for the wind sector, such as favourable loans and promotion of industrial clusters.

3. Tailored retraining and reskilling pathways for workers from carbon-intensive industries: Training and assistance to workers, including with re-certification for different wind industry occupations, could be designed under public-private collaboration to identify communities of need

Case study: Ardersier Port in Scotland

The Ardersier Port once employed roughly 4,500 oil and gas workers at one the largest oil rigs in the world, spanning over 400 acres off the Scottish coast of Inverness. Now undergoing a multi-million pound transformation to become Europe's first fully circular energy facility, the port's transition exemplifies how workers from the oil and gas industries can be mobilised to join the offshore wind and clean energy workforce at the same site as their previous employment. The value chain is anticipated to create 29,000 jobs by 2050 as a result of reviving the port.

This is a particularly positive example as geographic displacement is often a concern for workers whose opportunities may be constrained to specific localities. A shift of settled workers into alternative employment can feel more secure when these opportunities are local.

14. Skills and Occupational Needs in Renewable Energy, ILO, 2011.
15. "National Planning Commission - Department of Planning, Monitoring, and Evaluation: Republic of South Africa", Social Partner Dialogue for a Just Transition. 2019.

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Case study: Scaling up training infrastructure to meet workforce needs

A few months on from COP26, the wind industry's future is on an upward curve. For those concerned with workforce matters, systems of best practice are top of mind.

As a non-profit owned by the world's largest turbine manufacturers and owner operators, Global Wind Organisation's (GWO) mission is to ensure the adoption of best practice in the form of standardised safety training worldwide.

The growth in availability of the quality-assured GWO standard wind industry safety and technical training has taken huge leaps forward during recent years. Between 2012 and 2021, a workforce of 122,000 technicians carrying out various roles in construction, installation, operations and maintenance of wind turbines onshore and offshore has been certified to a global standard through training.

The Americas, Africa and Asia-Pacific regions saw their GWO-trained workforces increase by 50% in 2021, with markets such as Brazil, the United States and India establishing major new capacity off the back of industry efforts to communicate the value of safety standards. By the end of 2021, more than 21,000 people in these three countries had an industry standard safety training. In 2021, several new countries established GWO-certified training facilities for the first time, including Croatia, Ukraine, Egypt, Colombia and Russia, reflecting the heightened demand for wind workers in these markets.

The value to employers is clear – they define the standards and ensure training is appropriate to the risks and hazards in the workplace. They can rely on a market of quality-assured providers to deliver.

But what if the training infrastructure that is needed is not available? While the message about health and safety standards is getting through, it must be communicated with due attention to differing cultural and market dynamics. In some cases, establishing a global standard means encouraging existing workers to get into the scheme. In others, infrastructure is needed to accommodate a completely new workforce.

The US and China represent both cases. There is growing acceptance in these markets among existing (largely onshore) workforces and employers of safety certification on a resume.

A more common global challenge is the expansion of training infrastructure to keep pace with the pipeline of growth in the next five to ten years. GWEC forecasts upwards of 500GW of new wind energy capacity for installation up to and beyond 2025. The workforce demand to meet that challenge currently outstrips the availability of training.

For instance, Japan and Korea currently possess around 5-10% of the required GWO standard training capacity to meet their wind installation targets. As advanced industrial economies, they have alternatives available, such as safety training for the manufacturing, construction, oil and gas, telecommunications or maritime sectors, which could be adapted to meet the needs of a wind turbine technician. But this will likely be suboptimal owing to the domain-specific risks encountered in wind, where training for working at heights is one of many prerequisites.

Dialogue with policymakers, regulators and employers is a priority for meeting this challenge. There are also investments to be made. In the US, millions in federal and state funding have been allocated to workforce development programmes on the Eastern Seaboard. In some cases, this has resulted in impressive new training facilities for an anticipated workforce. GWO looks forward to working with parties across the world to explain the safety and business cases for adopting global training standards, and supports the efforts of GWEC in recommending these standards where the delta between capacity and need is greatest.

With input from: Ralph Savage, Director, Global Development & Stakeholder Relations, Global Wind Organisation (GWO)

and match these with anticipated workforce gaps. This should include a scheme of recognition of the relevant existing skills and qualifications of workers in carbon-intensive industries, to transfer them more efficiently into the wind sector. The public sector should clearly support the career progression pathways for fossil fuels workers into renewable energy to encourage labour mobility and upskilling.

4. Promote a diverse and inclusive workforce: Mainstreaming diversity and inclusion in the workforce requires commitment and action across company segments, from human resources to marketing to senior leadership. It is vital that the wind sector is publicly recognised as an attractive and welcoming place to work by those at different career stages, from graduates to executive talent. Youth outreach and education are also essential for ensuring that the diversified job opportunities offered by the industry are understood, particularly in countries where wind penetration is still at an early stage. Diversity should encompass different dimensions, including gender, ethnicity and physical ability.

The robustness and pace of the wind industry's growth will depend on the people who deliver it. Greater public and private collaboration on workforce planning for large-scale renewable energy deployment and a green economy should be an early policy priority.

Otherwise, a widening gap between skilled workers and wind capacity targets could delay countries from meeting their national climate and energy security goals, and further present missed opportunities for local value creation.

Finally, as the industry continues to expand around the world, it must also be aligned with the concept an practices of a just and inclusive transition, to ensure that wind energy retains sustainable development and social harmony as principles of growth.

MARKET STATUS 2021

Overview

93.6 GW of new wind power capacity was added worldwide in 2021, only 1.8% lower than the 2020 record, bringing the total installed wind capacity to 837 GW, a growth of 12.4% compared to last year.

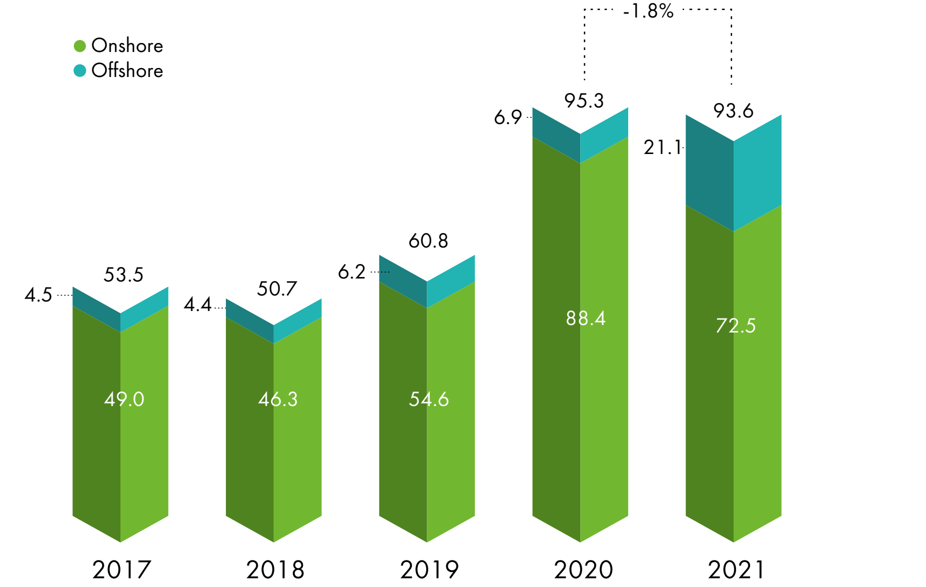
Although new installations in the onshore wind market dropped to 72.5 GW last year, it was still the second highest year in history. The offshore wind market had a record year with more than 21 GW grid connected, three times more than the previous year, making 2021 the highest year ever.

Thanks to the astounding growth of installations in China (offshore) and Vietnam, Asia Pacific continues to take the lead in global wind power development with its market share in 2021 almost the same as 2020. Driven by a record year of onshore wind installations, Europe (19%) recaptured the title of the second largest regional market for new installations from North America (14%) last year. Latin America and Africa & Middle East also had a record year in new installations in 2021 with their global market share reaching 6% and 2% respectively, but the two regions remain in the same positions as the previous year.

The world's top five markets in 2021 for new installations were China, the US, Brazil, Vietnam, and the UK. These five markets combined made up 75.1% of global installations last year, collectively 5.5% lower than 2020, primarily due to China and the US losing a combined 10% market share compared to 2020.

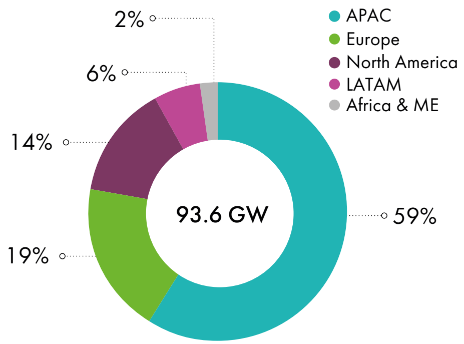
In terms of cumulative installations, the top five markets as of the end of 2021 remained unchanged. Those markets are China, the US, Germany, India and Spain, which together accounted for 72% of the world's total wind power installations, 1% lower than in 2020.

New installations

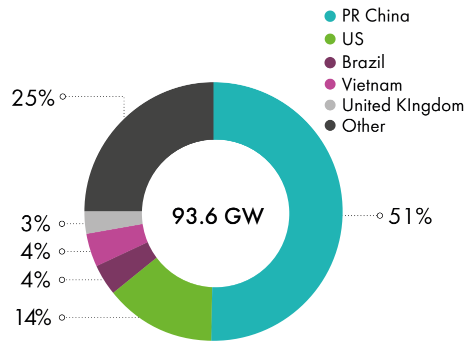


2020 new installations data has been adjusted based on the input GWEC received, For details see Appendix -Methodology and Terminology

New wind power capacity in 2021 by region
Per cent



New wind power capacity in 2021 and share of top five markets
Per cent



Onshore Wind Market – Status 2021

72.5 GW of new onshore wind capacity was recorded globally in 2021, bringing cumulative onshore wind capacity to 780 GW. The regions of Europe, Latin America and Africa & Middle East had a record year in new onshore installations, but total installations in 2021 is still 18% lower than the previous year. The decline was driven primarily by the slow-down of onshore wind growth in the world's two largest wind power markets, China and the US.

China had a record year in onshore wind installations in 2020 with more than 50 GW installed in a single year, chiefly driven by the new policy released by the National Development and Reform Commission (NDRC) that set the end of 2020 as the deadline for onshore wind to qualify the Feed-in Tariff (FiT). It was therefore no surprise that last year saw a 39% drop in new installations compared with 2020. The world's largest onshore wind market has entered the era of 'grid parity', meaning that from 1 January 2021 onshore wind was paid based on the regulated price for coal power in each province. GWEC expects the Chinese onshore market to reach new record levels of installations in the coming years, as China moves to fulfil its "30-60" targets and as wind adapts to the new market.

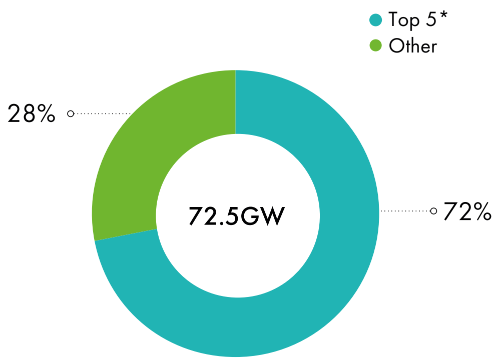
In the US, a robust onshore wind growth was predicted for 2021 after a record year in 2020 as the onshore wind installation rush driven by the planned Production Tax Credit (PTC) phase-down was expected to continue. Recognising the disruption of COVID-19 on supply chain and project construction execution, the Internal Revenues Service (IRS) in May 2020 extended the commissioning deadline for projects that started construction in 2016 and 2017 from four to five years, meaning project developers can still qualify the full PTC rate if their projects can reach the COD by end of 2021. ACP's quarterly installation data indicated that the US had a record onshore wind installations in the first and second quarters of 2021. However, growth slowed down in the second half, as some projects were delayed and postponed by supply chain issues and other disruptions caused by COVID-19. In June 2021, the IRS provided one more year extension for projects that started construction in 2016 or 2017, which eased the pressure on developers with projects underway that are seeking to preserve PTC eligibility based on start of construction during the highest available credit years. Those factors explain why new onshore wind additions in the US dropped by 25% in 2021 and why more than 5 GW of onshore wind projects with initial COD 2021 were delayed to 2022.

In addition to China (30.7 GW) and the US (12.7 GW), the top five onshore wind markets were Brazil (3.8 GW), Vietnam (2.7 GW) and Sweden (2.1 GW).

Structural changes in market support mechanisms for wind power continued to occur in 2021. FiT and PTC were two primary support schemes behind the new onshore wind capacity added in 2020, but China's grid parity scheme (42%) and auction/tenders (31%) replaced them as the two key support schemes last year. PTC (17.6%) became the third most important support scheme in driving new onshore wind growth in 2021, followed by FiT (4.8%) and Green Certificates (4.3%).

New wind power capacity in 2021 and share of top five onshore markets

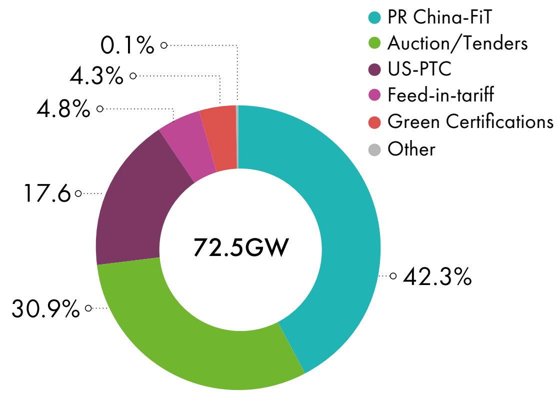
Per cent, onshore



*(PR China, the US, Brazil, Vietnam,Sweden)

New wind power capacity in 2021 by market support mechanism

Per cent, onshore



Despite the resurgence of COVID-19, the global onshore wind auction activities stayed on track overall in 2021. Last year was a record year with more than 69 GW onshore wind capacity awarded globally, twice the amount awarded in the previous year. China has played a leading role by allotting a total of 50.6 GW onshore wind capacity in 2021, followed by Spain, India, South Africa and Germany. China has committed to hit peak emissions by 2030 and to achieving carbon neutrality by 2060 (known as the "30-60" targets). To reach these targets, it will require average annual installation of 50 GW of wind power over the 14th five-year period (2021-2025). The allocated onshore wind capacity in 2021 shows that the country is on track to reach these ambitious targets. In Europe, wind, renewable energy and technology neutral auctions were resumed last year with more than 20 GW of onshore wind capacity floated for auction. Procurement was, however, undersubscribed in several key onshore wind markets, such as Germany, Italy and Poland, largely due to permitting related challenges. In the end, only 10.3 GW of onshore wind capacity was awarded in Europe in 2021.

Offshore wind market – Status 2021

2021 saw 21.1 GW offshore wind become grid connected worldwide, setting a record in global offshore wind history and bringing the total global offshore wind capacity to 57.2 GW by the end of 2021.

- China led the world in annual offshore wind installations for the fourth year in a row with nearly 17 GW of new capacity in 2021, bringing its cumulative offshore wind installations to 27.7 GW. This is an astounding level of growth, as it took three decades for Europe to bring its total offshore wind capacity to the same level. However, this was not a normal year, as the growth-rush was driven by the same policy shifts that created the same installation-rush in onshore wind in 2020. According to the NDRC regulation released in May 2019, projects approved before the end of 2018 would receive the 0.85RMB/kWh FiT, if fully grid-connected before the end of 2021. Starting from 1 January 2022, the subsidy for offshore wind from central government was terminated and projects would be paid based on the grid parity scheme. Two leading offshore wind provinces in China, Jiangsu and Guangdong, together approved more than 26 GW of offshore wind projects before 2019. According to GWEC Market Intelligence's Global Offshore Wind Project Database, 60 Chinese offshore wind projects, with combined capacity of more than 16 GW, were under construction at the beginning of 2021, of which more than half started construction before 2020.

- With 3.3 GW of offshore wind capacity added in 2021, Europe accounted for the majority of remaining new capacity. The UK had a slow year in 2020 due to the gap between the execution of projects in the Contracts for Difference (CfD) Round 1 and CfD Round2. However, with projects awarded in the CfD Round 2 in 2017 and one floating project coming online, the UK installed 2.3 GW of new offshore wind last year, making it the largest European offshore wind market in 2021, followed by Denmark (608 MW) and The Netherlands (392 MW).

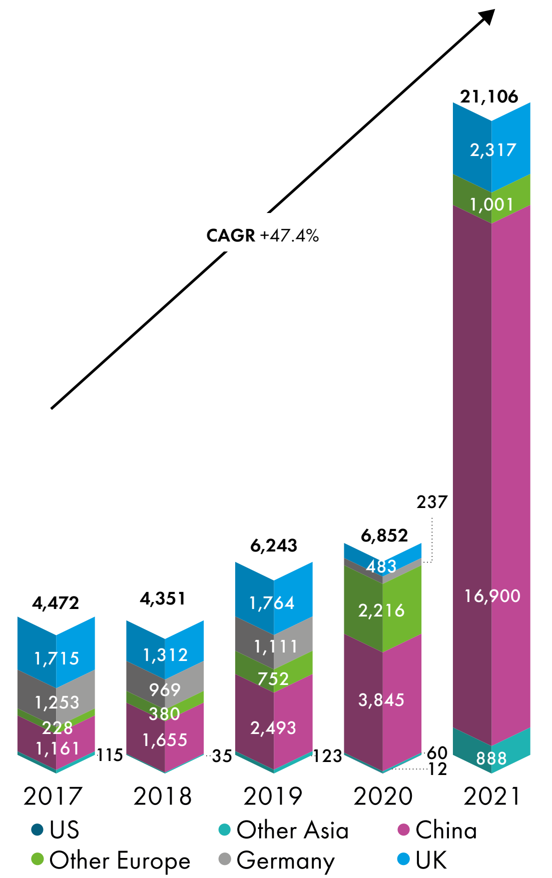
- There was only one small offshore wind project under construction in Germany during 2021, and no offshore wind turbines were installed. The slow-down was primarily caused by previously unfavourable market conditions and a low level of short-term offshore wind projects in the pipeline.

- 2021 also saw Norway commission the 3.6MW TetraSpar floating foundation demonstration project at the Metcenter Test site – the second floating offshore wind turbine in the country. Together with the five units of 9.5 MW floating wind turbines connected at the Kincardine floating wind farm in Scotland and the one 5.5 MW floating prototype unit installed at the Yangxi Shapa III offshore wind farm in China, a total of 57 MW floating wind capacity was commissioned in 2021.

- Outside of China and Europe, two other countries recorded new offshore wind installations in 2021: Vietnam (779 MW, intertidal only) and Taiwan (109 MW). Driven by the 1st of

New offshore installation

MW



The offshore wind market has grown from 4.5 GW in 2017 to 21.1 GW in 2021, bringing its market share in global new installations from 8.4% to 22.5%. This is three times higher than 2020 primarily due to the strong growth spurt of onshore wind in China. GWEC Market Intelligence expects the global offshore wind market to continue to grow at an accelerated pace (for details, see Market Outlook).

November FiT deadline, 20 intertidal projects in Vietnam reached the commercial operation date (COD) last year according to EVN, making it the third largest market in new installations in 2021. Taiwan should have commissioned more than 1 GW of offshore wind capacity from three projects last year based on the project COD plans, but only the 109 MW Changhua demonstration came online in the end. The delay is primarily caused by COVID-19 related disruption.

- United States is the only market with offshore wind in operation in America, but no offshore projects were built in 2021.

- In terms of cumulative installations, the top spot has been held by the UK since 2009, but as GWEC predicted, China took over the position by the end of 2021. The other markets in the global top-five are: Germany, The Netherlands and Denmark.

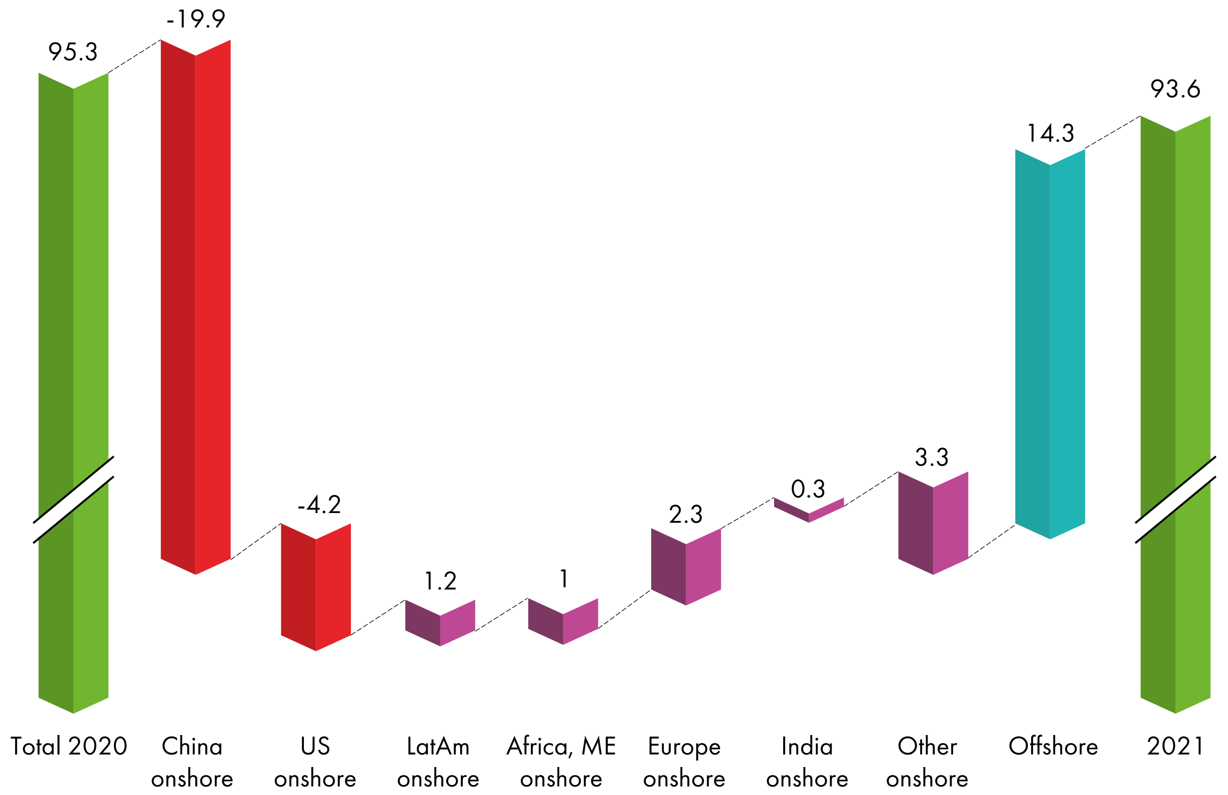
- Last year, a total of 19.4 GW offshore wind capacity was awarded worldwide through auctioning, of which 8.4 GW was in the United States (2.5 GW in New York, 2.7 GW in New Jersey, 1.6 GW in Maryland and 1.6 GW in Massachusetts), 7.8 GW in Europe (5.8 GW in Poland, 1 GW in Denmark and 0.96 GW in Germany), and 3.1 GW in Asia Pacific (1.7 GW in Japan and 1.4 GW in China). All three projects awarded in Germany last year were from so called ''zero-subsidy'' bids, meaning that the project will only receive the wholesale price of electricity and no further support/payment. In Denmark, the winner of the 1 GW Thor project was decided by a lottery draw as more than one bidder offered to build the Thor offshore wind farm at the minimum price of DKK 0.01/kWh.

- 2021 also saw the Crown Estate in the UK allocate areas for developing nearly 8 GW of capacity through its Round 4 seabed leasing. In addition, Crown Estate Scotland launched its first round of offshore wind leasing, ScotWind. The application window closed in July 2021.

All regions increased new installations, except Asia and North America

Changes in new installations 2020 to 2021

GW, onshore and offshore



Although the YoY growth rate was negative (-1.8%) in 2021, the annual wind market grew (with onshore and offshore combined) in all regions except Asia and North America. Looking at the onshore wind market, Europe, LATAM, Africa & Middle East and Pacific had a record year in 2021 with YoY growth rates at 19%, 27%, 120% and 58% respectively. However, new onshore wind capacity added in Asia and North America last year dropped by 33% (17.5 GW) and 21% (3.7 GW) compared with 2020. The decline in these two regions was primarily due to lower onshore installations in the world's two largest markets China and United States. In China, the transition from FiT support mechanism into the grid parity ("subsidy free") scheme for onshore wind from the beginning of 2021 slowed down growth. In the US, disruptions on account of the COVID-19 pandemic combined with supply chain constraints have caused delays in onshore wind project construction execution in 2H 2021. New offshore wind installations increased by 209% (14.3 GW) compared to 2020, which was mainly due to the policy-driven installation rush in both China and Vietnam.

Actual for 2021 vs the GWEC forecast

China onshore
Growth was expected to slow in 2021 as the Chinese onshore wind market has entered the ear of "grid parity". The country approved more than 27 GW of onshore grid parity projects after NDRC released the grid parity roadmap in the middle of 2019. Those projects were predicted to be the backbone of new installations in 2021.

USA onshore
Robust onshore wind growth was predicted for 2021, based on ISR in May 2020 extending the COD deadline for projects that started construction in 2016 from four to five years – this meant developers could still qualify for the full PTC if their projects can reach the COD by end of 2021. However, disruptions due to COVID-19 and supply chain issues slowed down project construction execution from the 3rd quarter of 2021 onwards.

India onshore
The onshore wind market in India was expected to recover in 2021 after the market was hit hard by the COVID-19 pandemic in 2020. Although its annual installation increased by 30% last year, the second surge of COVID-19 led to a renewed slowdown during the period of 1st April to 15th June, making 2021 another challenging year for India's onshore wind market.

Germany onshore
Germany had a low level of onshore wind installations in 2020 due to permitting issues and delays caused by COVID-19. Onshore installations rose to 1.9 GW in 2021, up from 1.4 GW in 2020, which was in line with our expectation and reflects a slight improvement in the permitting situation as well as the recovery of project construction execution.

Brazil onshore
Onshore wind power development in Brazil already demonstrated the strong resilience of the industry in 2020, shrugging off social and political turbulence in the context of the COVID-19 crisis. Nearly 4 GW of onshore wind installations in 2021 has set a new record for the country, representing strong growth of project development in the so-called "free market" (power contracted outside of regulated public auctions).

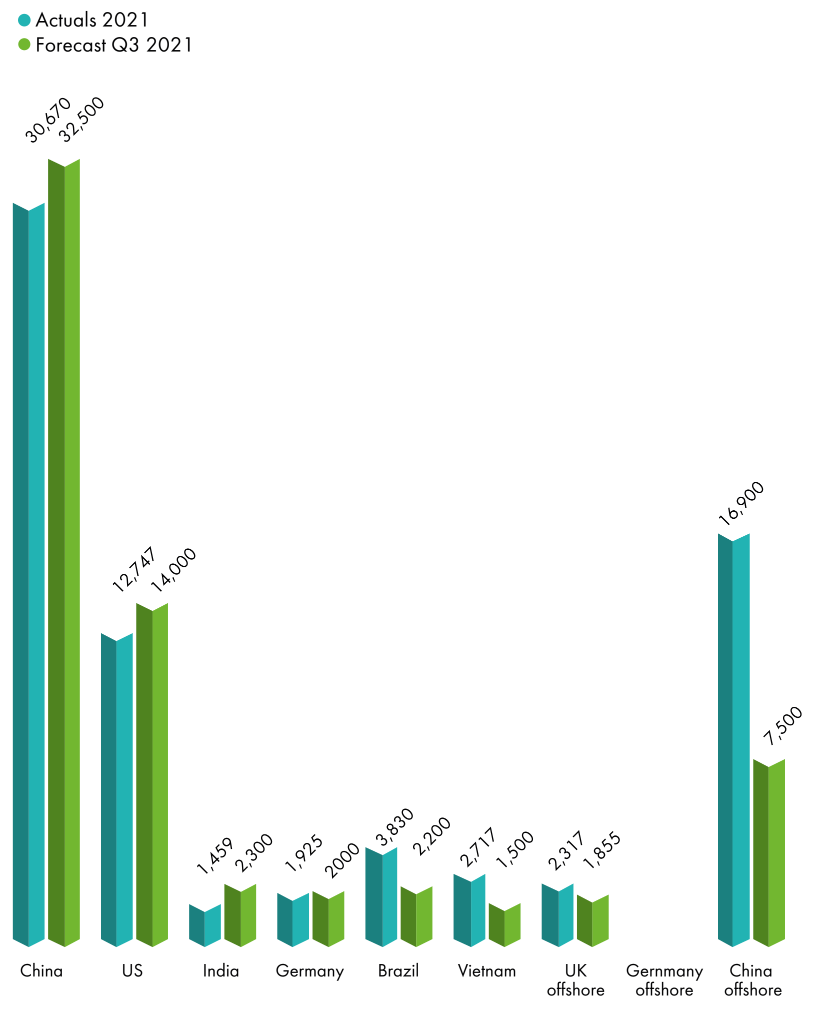
Vietnam onshore
Dramatic onshore wind growth was projected for 2021 as more than 100 wind projects, totalling 5.7 GW, already registered in August 2021 with national utility Electricity of Vietnam (EVN) rushing to begin commercial operations before the 1 November deadline, the cut-off date for projects to qualify the FiT in Vietnam. The local onshore wind industry outperformed in 2021 considering that the country was also impacted by the second wave of COVID-19.

UK offshore
In GWEC's Q3 2021 Market Outlook, two fixed-bottom projects and one floating wind project, totalling 1,855 MW, were predicted to come online in the UK in 2021. Statistics show that one third of turbines at the 1.4 GW Hornsea Two offshore wind project also came into operation in 2021 in addition to those three projects.

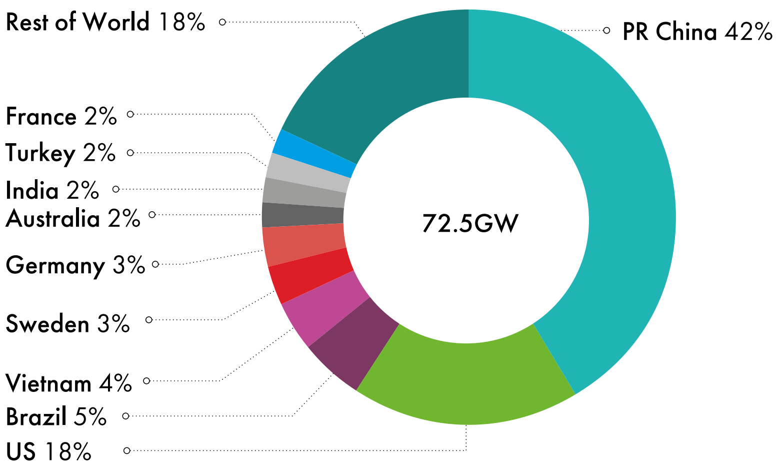
Germany offshore
Not a single offshore wind turbine was installed and commissioned in Germany during 2021, which was in line with GWEC's projection. This situation was primarily caused by unfavourable offshore wind conditions at the time and a lowe level of short-term offshore wind project pipeline. New capacity is expected to come online in 2022, but volume remains low.

China offshore
2021 was the third year of an offshore wind installation rush in China as projects approved before 2019 had to get fully grid connected before the end of 2021 to qualify for the 0.85RMB/kWh FiT. A big surge was expected for 2021 but connecting 16.9 GW in a single year surpassed all expectations.

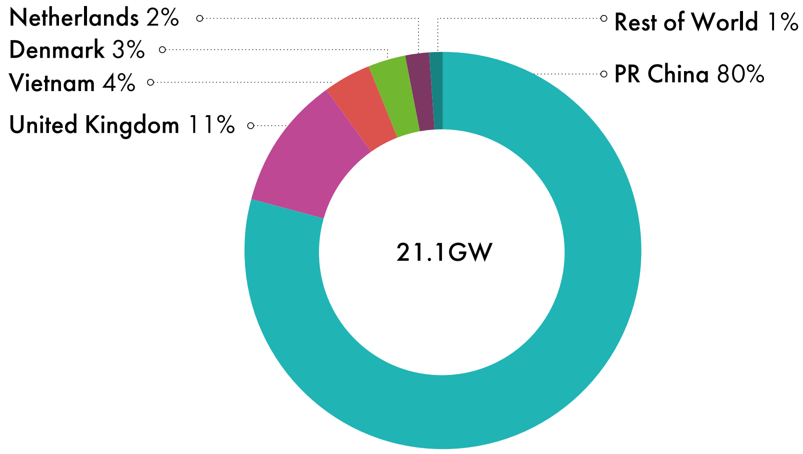
Actual for 2021 vs the GWEC forecast



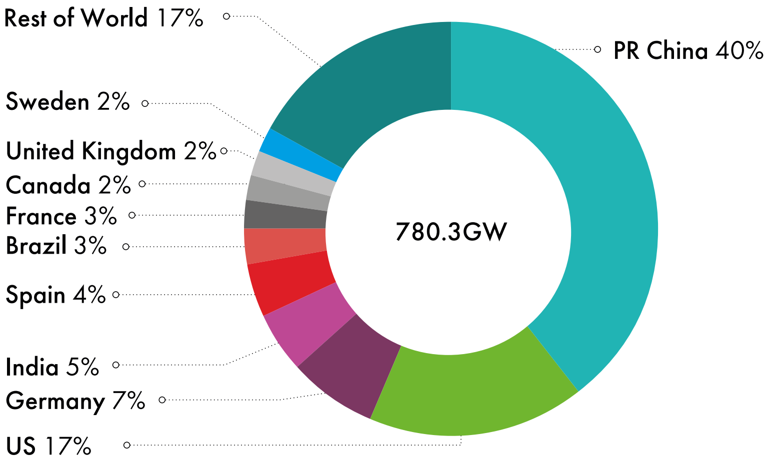
New installations onshore (%)



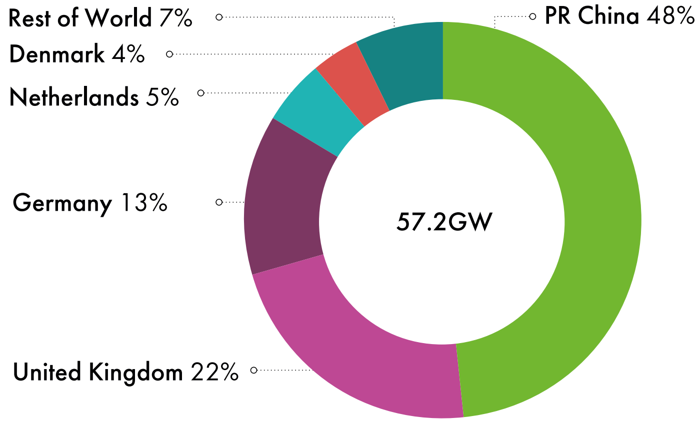
New installations offshore (%)



Total installations onshore (%)

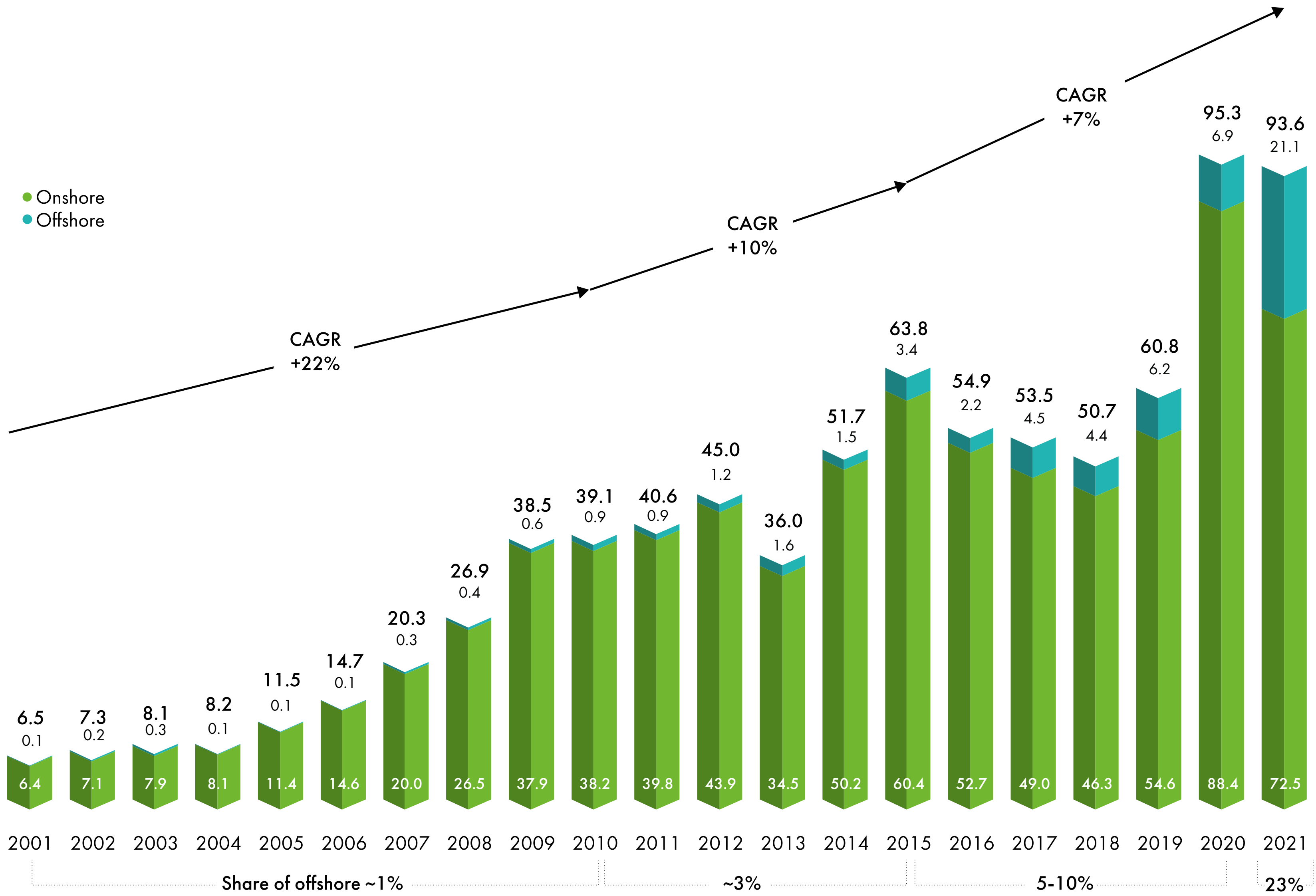


Total installations offshore (%)

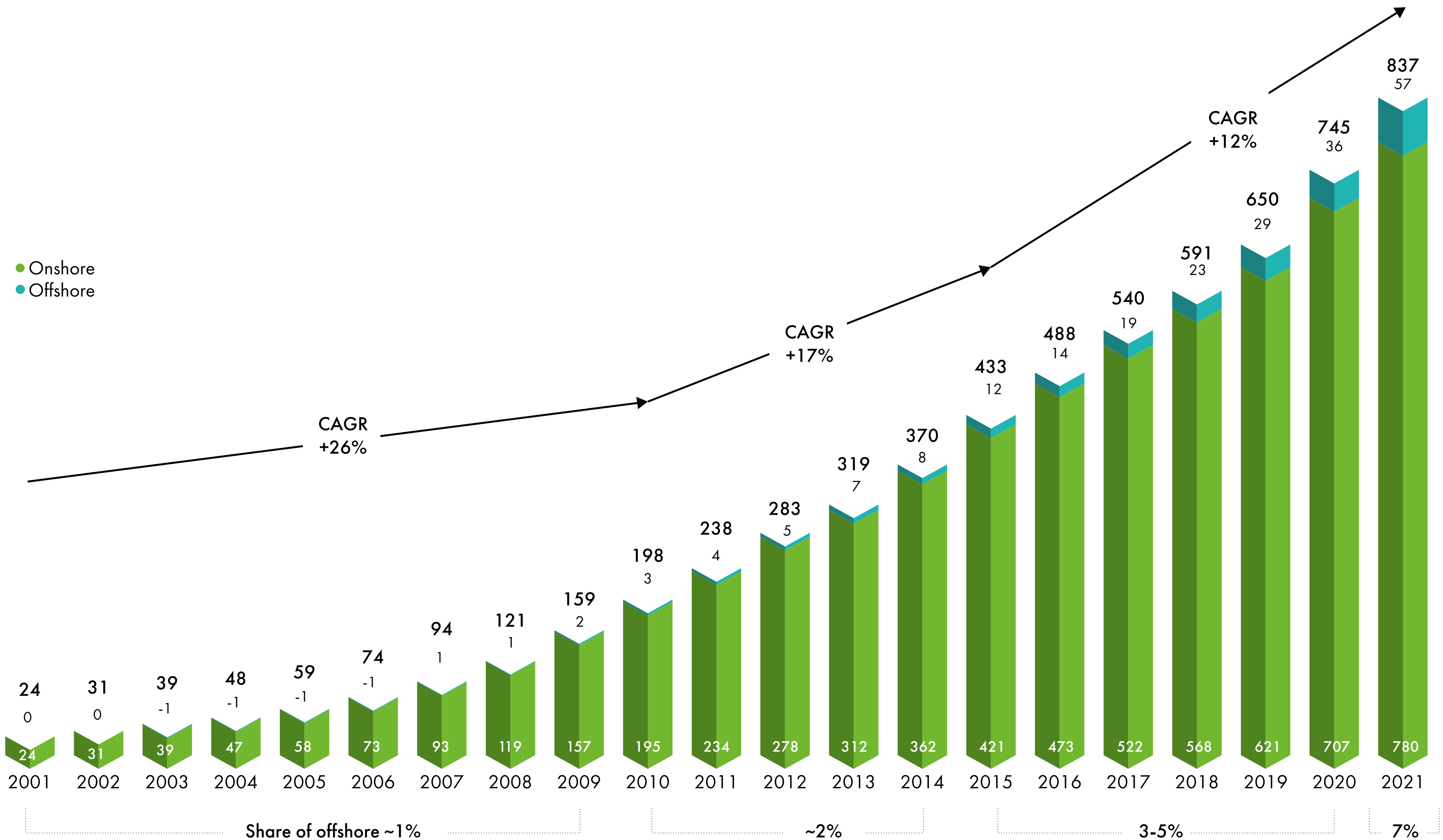


Detailed data sheet available in GWEC's member only area. For definition of region see Appendix - Methodology and Terminology

Historic development of new installations (GW)



Historic development of total installations (GW)



Historic development of new and total installations

MW, onshore	New installations 2020	Total installations 2020	New installations 2021	Total installations 2021
Total onshore	**88,437**	**708,901**	**72,499**	**780,275**
Americas	**21,650**	**169,658**	**19,243**	**188,233**
USA	16,913	122,275	12,747	134,354
Canada	165	13,578	677	14,255
Brazil	2,297	17,750	3,830	21,580
Mexico	574	6,789	473	7,262
Argentina	1,014	3,287	669	3,287
Chile	684	3,444	615	3,444
Other Americas	3	2,535	232	4,051
Africa, Middle East	**823**	**7,277**	**1,809**	**9,085**
Egypt	13	1,465	237	1,702
Kenya	0	338	102	440
South Africa	515	2,495	668	3,163
Other Africa	295	2,979	802	3,780
Asia-Pacific	**54,130**	**337,870**	**37,352**	**375,161**
China	50,576	279,959	30,670	310,629
India	1,119	38,625	1,459	40,084
Australia	1,097	7,296	1,746	9,041
Pakistan	48	1,287	229	1,516
Japan	551	4,373	211	4,523
South Korea	100	1,515	64	1,579
Vietnam	125	513	2,717	3,231
Philippines	0	427	0	427
Thailand	0	1538	16	1554
Other APAC	514	2,337	240	2,577
Europe	**11,834**	**194,097**	**14,095**	**207,796**
Germany	1,431	55,122	1,925	56,814
France	1,318	17,946	1,192	19,131
Sweden	1,007	9,811	2,104	10,002
United Kingdom	122	13,739	328	14,064
Turkey	1225	9,281	1,400	10,681
Other Europe	6,731	88,198	7,146	97,104

MW, offshore	New installations 2020	Total installations 2020	New installations 2021	Total installations 2021
Total offshore	**6,852**	**36,077**	**21,106**	**57,176**
Europe	**2,936**	**24,837**	**3,317**	**28,154**
United Kingdom	483	10,206	2,317	12,522
Germany	237	7,728	0	7,728
Belgium	706	2,262	0	2,262
Denmark	0	1,703	605	2,308
Netherlands	1493	2,611	392	3,003
Other Europe	17	327	4	331
Asia-Pacific	**3,905**	**11,199**	**17,788**	**28,980**
China	3,845	10,780	16,900	27,680
South Korea	60	133	0	133
Other APAC	0	285	888	1167
Americas	**12**	**42**	**0**	**42**
USA	12	42	0	42

GWEC made the adjustments to new installations and total installation in 2020 for China, Kazakhstan, Spain, United Kingdom, Italy, Poland, Ireland, Panama and Peru based on the updated statistics GWEC received.

MARKETS TO WATCH

Vietnam

Vietnam is leading Southeast Asia's energy transition. Having installed more than 20 GW of renewable energy in a short span of three years from 2019 to 2021, Vietnam now has nearly 4 GW of wind power and 16 GW of solar power.[1]

In 2021 alone, Vietnam surprised the world with an impressive boom in wind despite severe supply chain disruption brought by the COVID-19 pandemic. More than 3,360 MW of new wind capacity was built by the end of 2021 as the industry rushed to meet the wind Feed-in Tariff (FiT) deadline, making Vietnam the largest wind energy market in Southeast Asia.[2]

Despite the growth in renewable energy, with forecast 6.5% GDP growth and 11% increase in power consumption in 2022 estimated by the ADB, Vietnam is struggling to meet its energy demand with domestic fossil fuel production and is heavily reliant on imported fuels.[3] Coupled with the 2050 net zero target made at COP26 and the finalisation of the draft Power Development Plan VIII (PDP8), Vietnam is poised to usher in an era of renewable energy growth to meet its energy security and climate commitments. The wind industry is also waiting for further policy clarity on the replacement for the expired FiT mechanism, which has played a crucial role in driving renewables investment since its introduction in 2013.

These developments and strategic commitments will shape Vietnam's energy transition pathway in the next decade. Furthermore, recent coal and gas price volatility has led the Indonesian government to institute a temporary ban on coal exports and pushed up power prices across Europe and Asia. Coal projects are facing difficulties in securing project finance, and Vietnam has not had any new coal PPAs since 2017. These market forces should further encourage Vietnam to decrease its dependence on fossil fuels and raise its renewable energy ambitions.

1. Southeast Asia: 10 Things to Watch in 2022, BloombergNEF; GWEC Market Intelligence.
2. https://en.evn.com.vn/d6/news/The-status-of-commercial-operation-acceptance-COD-of-wind-power-plants-as-of-31-October2021-66-142-2562.aspx; GWEC Market Intelligence.
3. https://www.adb.org/countries/viet-nam/economy

Ambitious PDP8 and a bold net zero target by 2050

The draft PDP8 has undergone 4-5 rounds of revisions since its launch in March 2021. According to the Ministry of Industry and Trade (MOIT), as of March 2022, the PDP8 is due to be submitted for finalisation by the Prime Minister at the end of Q1 2022. It has not yet been finalised at the time of writing. The latest draft released by the Office of Government in March 2022 factors in Vietnam's 2050 net zero target, lower coal capacity targets and increased renewable energy targets.

As compared to the March 2021 draft of PDP8, the latest draft published one year later reflects an increase in offshore planned capacity by 2030 and 2045, and an increase in overall onshore planned capacity by 2045. Under Scenario 1, which implies a more basic energy transition, onshore wind and solar growth is restrained through 2030 considering grid and transmission challenges, and LNG takes a greater role in the energy mix by 2045. The more robust transition in Scenario 2 shows steeper cuts to coal and LNG targets, and more aggressive medium- and long-term growth for onshore wind, offshore wind and solar PV.

While the PDP8 has not been finalised at the time of writing, Vietnam will require accelerated and ambitious wind energy deployment to reach its targets under either scenario. The latest updates could be increased even further to reflect Vietnam's wind potential; for example, according to the World Bank Group, Vietnam has the capability to develop as much as 10 GW of offshore wind by 2030.[4]

Keeping onshore wind blowing through a transition mechanism

In recent years, policymakers in Vietnam have sought to encourage the onshore wind sector via several supportive policies. This includes Decision 39/2018 which provided a clear route to market and generated a response of more than 140 wind projects signing PPAs with the state-owned utility EVN.

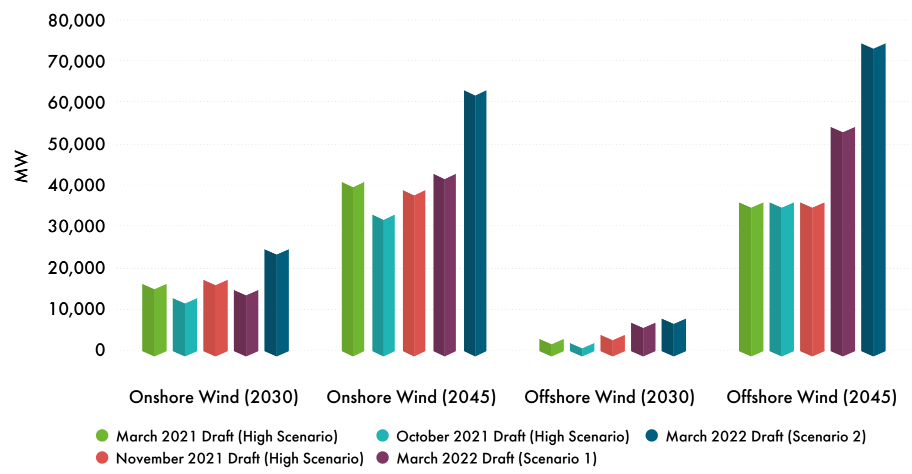
However, due to the logistic, workforce and supply chain challenges posed by the ongoing pandemic, project delays have led to only 106 wind projects (roughly 5,800 MW) successfully submitting the required paperwork for connection plans. Of these, only 84 projects (roughly 3,900 MW) have been accepted for COD or partial COD, leaving around 4,200 MW of onshore and nearshore wind projects at risk of becoming stranded assets without clarity on procurement or grid connection.

While the industry has advocated for a wind FiT extension to account for COVID-19-related delays, MOIT has instead proposed that project developers negotiate a price framework and connection agreement directly with EVN. As of today, the government has yet to finalise any supportive framework to replace the expired FiT scheme, which poses a major risk to onshore wind capacity additions in 2022.

Setting the path for offshore wind

It is important to ensure that Vietnam's offshore wind policy is designed for steady and sustainable long-term growth, providing sufficient time for the offshore wind industry to mature. With the influx of investor interest in the offshore wind market and a

Vietnam's wind energy targets in the draft PDP8



Sources: Unofficial updates announced by MOIT from March 2021 to March 2022.

4-5 GW target by 2030, the next step will be for policymakers to define a clear offshore wind regulatory framework, including the procurement mechanism and permitting and consenting requirements.

The old offshore wind FiT ($0.098/kWh), which applied to nearshore or intertidal projects, expired on 31 October 2021. An initial procurement mechanism for true offshore wind can be in the form of a transitional FiT to support the first batch of projects before moving to a competitive auction mechanism.[5]

A transitional FiT to cover a portion or all of the first 7-8 GW of offshore wind targeted by 2030 will not only give the government enough budgetary and planning control over offshore wind development, but also provide a smoother runway to competitive tenders.

The existing wind PPA provided in Circular No. 32/2012T must also be updated, as it is often deemed to fall short from international standards for bankability. Given the risks presented in the current PPA, including challenges on the terms for dispute resolution and

4. Offshore Wind Roadmap for Vietnam, World Bank, 2021.
5. Vietnam's Future Transition to Offshore Wind Auctions - International Best Practices and Lessons Learned, GWEC, 2021.

curtailment, it is even more important to have a clear and visible transitional support mechanism to support Vietnam's initial offshore wind development.

Renewable deployment and grid infrastructure go hand-in-hand
According to EVN, by the end of 2021 Vietnam's total installed power capacity reached 76.6 GW, a 7.5 GW increase from 2020, with renewable energy comprising 27% of the total capacity. The dramatic increase in renewable energy in the last three years has highlighted the need to upgrade existing electricity grid and transmission infrastructure to meet future energy demand and supply. If not properly managed, a bottleneck in renewable energy integration can deter the government from implementing the ambitious renewable energy targets in the draft PDP8.

As Vietnam continues to push for more wind and solar, it will require significant investment to upgrade and reinforce its grid system. Decree 35/2021/ND-CP from March 2021 provides details and guidance on the first-ever Law on Public-Private Partnership No.64/2020/QH14 – combined with the recent draft amendments to the country's Electricity Law, the government is considering allowing the private sector to build power transmission, with the exception of grid projects implemented by the state under the national electricity development plan. Vietnam's net zero commitment can also unlock various international financing channels to support grid initiatives to integrate larger shares of renewable energy.

5. Vietnam's Future Transition to Offshore Wind Auctions - International Best Practices and Lessons Learned, GWEC, 2021.

The Philippines

The Philippines is home to a rapidly growing population and steady urbanization, which translates into rising energy demand.[1] It is also endowed with natural advantages for the development of renewables, and benefits from a strong financing environment with public and private sector appetite for investing in clean energy.

Around four-fifths of electricity in the Philippines is drawn from imported fossil fuels commodities like coal, oil and natural gas. In the midst of an energy transition towards energy self-sufficiency, the government has introduced several pro-renewables policies such as the Renewable Energy Law, the targets set in its Philippine Energy Plan (PEP) 2020-2040 and a regulatory mandate of Renewables Portfolio Standards (RPS).

The PEP, last revised in 2021, targets a 35% renewable share of the power mix by 2030, rising to 50% by 2040. This will be a dramatic acceleration from the current one-fifth share held by hydropower, geothermal, solar and wind, requiring an additional 73.9 GW of renewable capacity over the next two decades. However, wind energy development has stalled in the last four years due to lack of ambitious targets or schemes and poor policy coordination, with around 442.9 MW installed as of the end of 2021.

Shifting away from coal, which provides more than 40% of the nation's electricity and is responsible for around 60% of energy outages in the Philippines, will be crucial to shoring up energy security through the large-scale deployment of renewables.[2] It will also be necessary to support the Philippines' NDC to reduce GHG emissions by 75% from 2020-2030, compared to a BAU scenario. Promising signs include a moratorium on new coal plants announced in late 2020, and the Philippines' partial endorsement of the COP26 Global Coal to Clean Power Transition Statement.[3]

The upcoming Green Energy Auction Program (GEAP) is an opportunity to reactivate the dormant wind and solar markets. Against this background is a series of topline news around the grant of a service license to several industry players in the offshore wind business, indicating the government's ambitions to kickstart the offshore wind sector.

Creating a supportive scheme for wind energy

With good wind conditions on the northern and central Batanes and Luzon areas, conservative assumptions by National Renewable Energy Laboratory (NREL) dating from 2020 concluded that these areas have an onshore wind technical potential of 76 GW.

However, development has not matched this potential. Most wind power to date was developed

1. https://data.worldbank.org/indicator/SP.URB.GROW?locations=PH
2. https://cleanenergynews.ihsmarkit.com/research-analysis/philippines-announces-moratorium-on-new-coalfired-power.html
3. The Philippines endorsed clause 1 and partially clauses 2 and 4, and reiterated "a call for climate justice given the Philippines is not a major emitter of greenhouse gases but bears the worsening impacts of climate change, and to emphasise that energy security is foremost as energy transition is a means to improve the lives of the Philippines' people and the country's economic development." See: https://ukcop26.org/global-coal-to-clean-power-transition-statement/.

under a FiT mechanism of $0.14-0.17/kWh, which was in place until the quota of wind was fulfilled in 2016. Activity has stalled since that time, although there is a total volume of 3,524 MW of wind projects which have secured Renewable Energy Service Contracts.[4] A lack of supportive mechanisms like a FiT is the main cause for the gap in project development. Although the RPS system was introduced in 2017 to incentivise renewable energy demand, the low requirement of a 1% threshold prevented it from being effective.

In addition, the Philippine Renewable Energy Market System (PREMS) for trading renewable energy certificates (RECs) was launched in December 2019 as an online platform. PREMS has not yet been in commercial operation and remains subject to some market readiness requirements to be issued by the government.

The National Renewable Energy Board is responsible for the National Renewable Energy Program (NREP), which includes technology-specific renewable energy targets and a renewables development roadmap. The NREP 2020-2040 is being updated to match with the PEP Clean Energy Scenario goals, and has introduced a wind energy target of 763 MW by 2030 and 11,387 MW by 2040. At the same time, the NREP maintained the 1% RPS level, instead of pushing for a higher threshold. Considering the volume of wind projects in the development pipeline and natural resource potential, the current NREP wind targets are deemed to be unambitious.

Guidelines governing the GEAP were introduced in 2020, aiming at providing additional market options through auctioning 2,000 MW of renewable capacity. Through the GEAP, the winner of the auction will secure PPAs and a 20-year FiT, providing optimism to actors in the dormant wind market. Due to the pandemic, implementation has been delayed to 2022. The Department of Energy (DOE) has announced a solicitation of qualified developers in February 2022. The Energy Regulatory Commission is in the process of determining the GEAP auction price cap, with 380 MW of wind capacity in Luzon and Visayas on offer in 2022.

More ambitious renewable energy targets, and a schedule of continuous and regular capacity procurement for specific renewable energy technologies, will help encourage local value chain investment and restore confidence in the wind sector's growth prospects.

Offshore wind development on the horizon

According to the World Bank Group, the Philippines' EEZ contains around 178 GW of technical resource potential for offshore wind, primarily in floating wind with around 18 GW for fixed-bottom offshore wind. This is more than seven times the total installed electricity generation capacity in the country – presenting an incredible opportunity to meet national energy security and decarbonization goals.

To date, the DOE has issued a large number of Offshore Wind Service Contracts (OWSC) to a number of players in the region. Recipients of OWSC will have five years to develop the projects. These include a few high-profile projects which are notable for their project size, such as Triconti's multiple OWSC totalling 3.5 GW, in partnership with international developer Iberdrola, as well as The Blue Circle's partnership with Cleantech Global Renewables to develop a 1.2 GW offshore wind farm off Bulalacao, Oriental Mindoro.

The DOE is also developing an offshore wind roadmap with the support of the World Bank Group's ESMAP-IFC Offshore Wind Development Program. The draft roadmap has identified 6 different zones suitable for offshore wind development, totalling 2.8 GW by 2030 and 58 GW of potential volume by 2050, across mainly floating offshore wind projects.

4. Power Development Plan 2020-2040, Philippine Department of Energy, page 84.
5. Power Development Plan 2020-2040, Philippine Department of Energy, Annex 13.
6. https://documents1.worldbank.org/curated/en/519311586986677638/pdf/Technical-Potential-for-Offshore-Wind-in-Philippines-Map.pdf

China

China has been the world's largest wind market by installed capacity since 2010. The continued growth of wind in China over the past decade is mainly due to ambitious policies from the central government.

2020 was a record year, with more than 54 GW of installations primarily driven by the expiration of the onshore wind FiT. Although onshore wind growth slowed down last year, China retained strong momentum in 2021. According to the National Energy Administration (NEA), 47.5 GW wind capacity was grid-connected in 2021, making it the second-best year in the country's history.

Of these new installations, 16.9 GW is offshore wind – a record in the global offshore wind industry, and nearly three times the volume of new offshore wind installed worldwide in 2020. This explosive growth was similarly driven by the deadline for projects to access an offshore wind FiT, under a policy released by the National Development and Reform Commission (NDRC) in 2019.

Notice of the on-grid onshore and offshore FiT in China

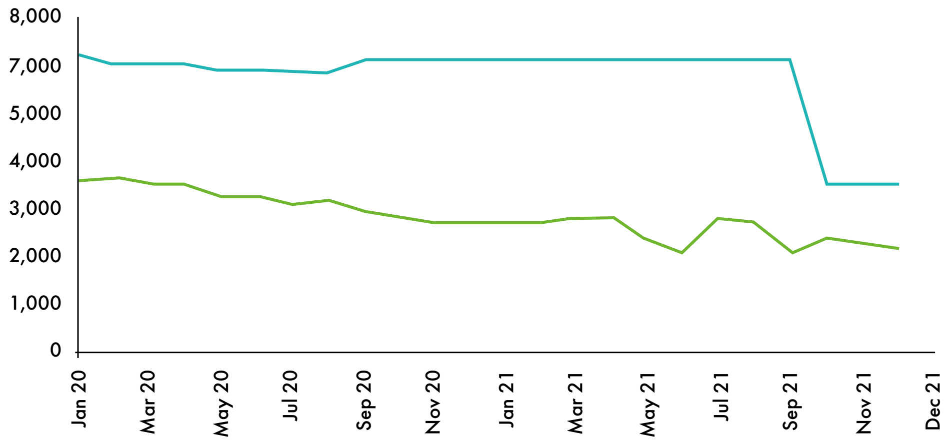
Type	Timeline	RMB/KWh	Requirement
Onshore	Approved before the end of 2018	FiT (2016-2017): Class I: 0.47, Class II: 0.50, Class III: 0.54, Class IV: 0.60 FiT (2018): Class I: 0.40, Class II: 0.45, Class III: 0.49, Class IV:0.57	Connected to grid before the end of 2020
	Approved in 2019	Auction ceiling price: Class I: 0.34, Class II: 0.39, Class III: 0.43, ClassI IV: 0.52	Connected to grid before the end of 2021
	Approved in 2020	Auction ceiling price: Class I: 0.29, Class II: 0.34, Class III: 0.38, ClassI IV: 0.52	Connected to grid before the end of 2021
	Since 2021	Subsidy-free	
Offshore	Approved before the end of 2018	FiT: 0.85	Connected to grid before the end of 2021
	Approved in 2019	Auction ceiling price: 0.80	
	Approved in 2020	Auction ceiling price: 0.75	

Source: NDRC, May 2019

A new era for the Chinese wind industry

After a decade of rapid growth, China's renewable market has entered a new stage. Support for renewables has shifted from a FiT model to a "grid parity" model, where renewable-generated electricity will receive the same remuneration as coal-fired power plants. Starting from 1 January 2021, all onshore wind projects shall reach grid parity. From 2022, the central government will cease subsidies for offshore wind, although a small portion of financial support will be offered by provinces like Guangdong and Zhejiang for the next 3-4 years to support offshore wind's journey to grid parity by 2025. In certain sea areas, the government is confident that grid parity can be achieved even before 2025.

Average tender prices for wind turbines in China, 2020-2021 (RMB/kW)



Note: Prices are ased on date of tender and include wind towers. If tender price was unavailable for a given month, price from previous month was used
Source: China Bidding Centre, December 2021

China is also the world's largest wind turbine manufacturing hub, accounting for 60-65% of global production of turbine nacelles and key components including gearboxes, generators and blades. There are still 20 turbine manufactures active in the Chinese wind market today. During the transition to the era of grid parity, manufacturing competition in China has become increasingly fierce, reflected in record-low bidding prices in 2021. At the start of 2022, price competition has become even more intensive with turbine prices including towers dropping to $316/kW for onshore wind and $632/kW for offshore wind.

Price pressure also drives technology innovation. Chinese wind turbine OEMs continue to launch new turbines with greater power ratings and bigger rotors for the domestic market. At China Wind Power 2021, co-organised by GWEC, local turbine OEMs released nearly 40 new models, with the majority of onshore products in the 5-7 MW size range and offshore turbines in the 12-16 MW range.

The 14th Five-Year Plan paving the road to "30-60" targets

To reach the "30-60" target (peak emissions by 2030 and carbon neutrality by 2060) on time, the Chinese government has made a comprehensive plan to accelerate the development of renewable energy. By the end of the 14th Five Year Plan period (2021-2025), the share of renewable energy in total power generation capacity is set to exceed 50%. The key measures outlined by the NEA to support wind power development in this period include:

- In northern China, development will focus on the Gobi and various other desert areas and efforts will be made to increase transmission capabilities and local consumption of renewable energy. Existing coal-fired power plants in the region will be upgraded to support balancing the grid system. Seven giant onshore wind/solar bases are planned. In 2021, the construction of the first phase of a renewables base, totalling 100 GW, kicked off, and applications for the second phase opened at the end of the year.

- In southwest China, combined with the development of hydropower, projects which integrate hydropower, wind and solar will be coordinated. Two giant energy bases will be constructed.

- In the eastern coastal areas, offshore wind clusters will be promoted with large-scale offshore bases (10 GW level). The five selected offshore bases are in Shandong Peninsula, Yangtze River Delta, Southern Fujian, Eastern Guangdong and Beibu Gulf.

- In the central and southeast regions, distributed wind projects will be promoted, especially in villages in the vast rural areas. It is estimated that 5,000 villages will be selected and 10,000 turbines, totalling 50 GW, will be installed by 2025.

- In areas with high-quality wind resources and existing installation, upgrading and repowering of aging wind farms will be implemented to increase efficiency and Annual Energy Production (AEP).

Case study: Challenges and opportunities facing China's wind industry

Provided by: Techstorm

In 2020, China announced the challenging "30-60" targets to reach peak CO2 emissions before 2030 and CO2 neutrality by 2060.

At the same time, China cut subsidies for onshore and offshore wind power. This has led to further cost-out pressure, as shown during the latest China Resources bidding round for 100 MW onshore wind in Inner Mongolia in February 2022, which saw a record-low price of RMB 1,889/kW ($297/kW), including the tower.

Often, challenge means opportunity. Techstorm has implemented a series of measures to achieve the carbon neutrality target. For instance, its new Shanghai plant uses solar energy and heat pump systems, as well as the "EnOS Ark" carbon management system to monitor and reduce CO2 emissions and energy consumption. It will also acquire green certificates to support carbon neutrality.

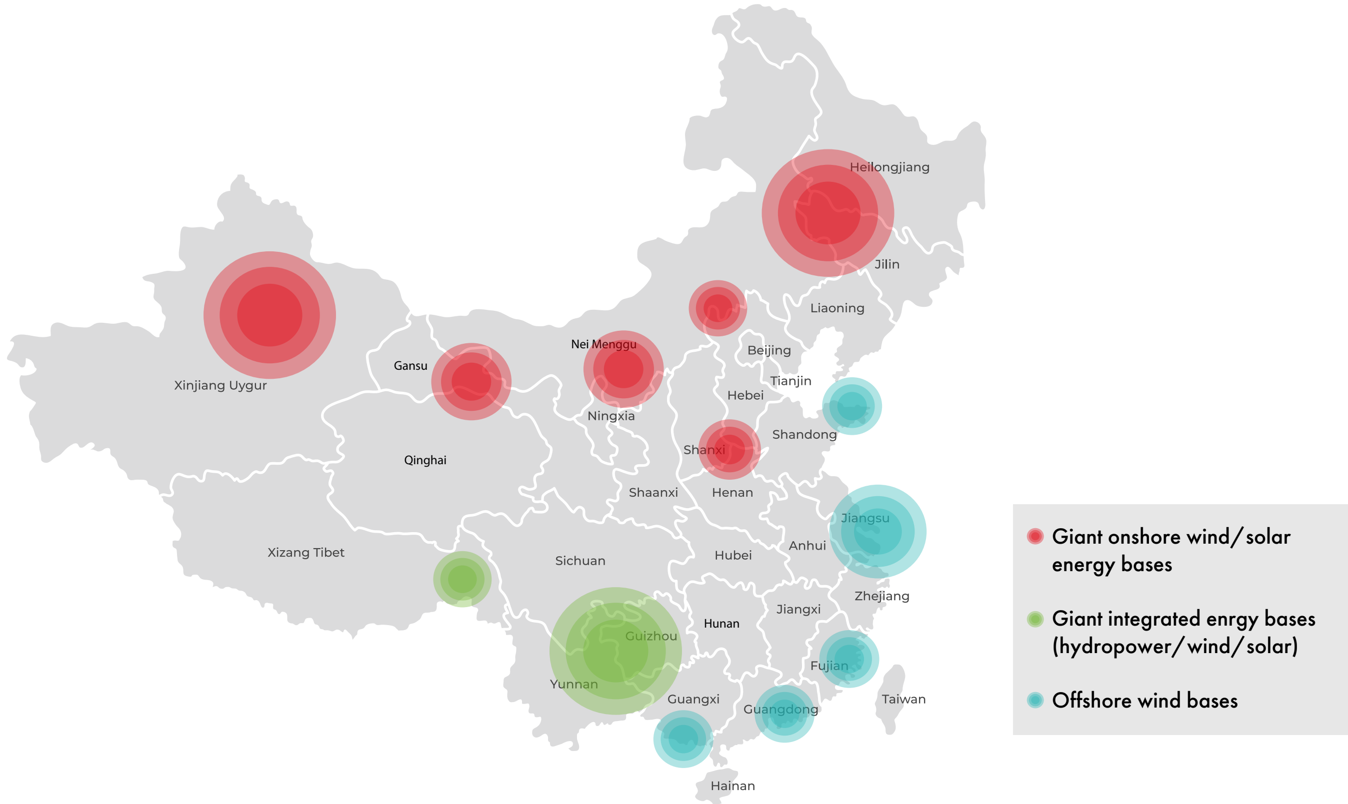
There are further measures needed to counter the cost-out pressure in China:

- **Supply chain improvement:** COVID-19 had a significant impact on the global supply chain stability, which can be improved by localisation measures, dual-sourcing and vertical integration.
- **Redesign existing formulations**: Reformulation towards better performance and lower cost is helping turbine manufacturers achieving LCOE reduction.
- **Longer blades:** These are needed for OEMs to continuously design new turbines with bigger rotors and greater power.
- **Bigger volumes:** Increased market share can help to establish long-term contracts with suppliers at lower prices. Larger platforms in factories to handle greater volumes optimise processes and reduce production costs.

With these measures, the industry can be confident to support China's targets of carbon neutrality and a sustainable future.

Find out more: https://techstorm.com/en/introduce.html

China's 14th Five-Year Period Renewable Development Plan



Source: NDRC, NEA, 2021

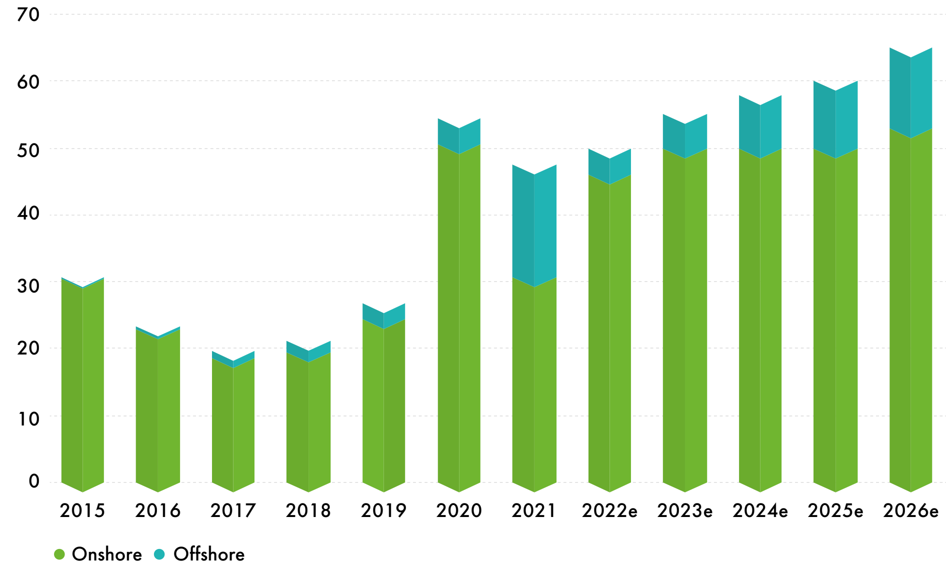
In addition, to promote technological innovation the government plans to support demonstration projects such as deepwater wind, high-efficiency solar cells, energy islands, large-scale renewable hydrogen, hybrid energy solutions and smart micro-grids.

Power market reform for a renewables-led revolution
To build a power system fit for the renewables-led energy transition, the government has recently launched plans for power market reform. In January 2022, the NDRC and NEA jointly released guidelines for accelerating the establishment of a unified national electricity market. This directive contains various short-term and long-term orders, including the initial build of a nationwide single power market to facilitate China's energy transition under its climate goals by 2025, and completion of the market development by 2030.

Efforts will be made to enhance the adaptability of the electricity market to a high proportion of new energy sources, according to the guidelines, which also urge the strict implementation of laws, regulations and policy measures to promote the participation of new energy in market transactions. Under the system, the national, provincial and regional markets will operate collaboratively, with significant improvements in cross-provincial and cross-regional market allocation of resources and green power trading. End-users will be able to directly purchase green electricity, and grid enterprises will prioritise the implementation of direct renewable power procurement.

China in pole position for global wind power growth
Following the "30-60" pledge made in September 2020, the Chinese government updated its NDC commitment to achieve 25%

Chinese wind market development, GW, 2015-2026



Source: GWEC Market Intelligence, CWEA, March 2022

non-fossil fuel generated energy in the primary energy mix and boost its solar and wind capacity to more than 1,200 GW by 2030. Following this example, China's major state-owned power companies have set goals of installing a total of 600 GW of additional solar and wind power during the 14th Five-Year Plan period. If fully implemented, China could hit its 1,200 GW solar and wind target by 2025, five years ahead of schedule.

The tremendous growth in 2020 and 2021 shows that the Chinese wind industry can deliver on its Beijing Declaration pledge of 50+ GW of annual wind power installations.[1] It also demonstrates that wind power would bolster the country's progress toward the goal of hitting peak emissions before 2030 and support a cost-efficient path to carbon neutrality by 2060. Based on China's latest renewable energy development plans as well as the directive on power market reform, GWEC Market Intelligence believes that China will continue to lead global wind power growth in the decades to come.

1. https://gwec.net/beijing-declaration-on-wind-energy/

India

India's announcements at COP26 in November 2021 strengthened confidence in the country's renewable energy commitments. Prime Minister Narendra Modi announced a multi-pronged approach to bolster climate action: 500 GW non-fossil fuels energy capacity by 2030; 50% renewables in the energy mix by 2030; reduction of total carbon emissions by 1 billion tonnes between 2021 and 2030; reduction of the emissions intensity of the economy by 45%; and achievement of net zero by 2070.

The current share of non-fossil fuels in overall generation capacity stands at 38.5%, out of a total 395 GW. While wind currently accounts for 10.2% of this, to further realise its 2030 climate commitments, the Ministry of New and Renewable Energy (MNRE) has estimated 140 GW wind energy capacity is needed by 2030.[1] Globally, India ranks fourth in installed wind capacity with 40.1 GW as of January 2022.[2]

Pandemic-related challenges receded by mid-2021

The second surge of COVID-19 from April to mid-June 2021 had a notable impact on India's wind industry. For instance, it slowed down production of wind towers as oxygen supply for industrial processes was diverted to medical requirements. Progress picked up again in the second half of the year.

More than 1.4 GW of wind was installed in 2021, exceeding the 1.1 GW of installations during the previous year. Auction activity also gained momentum in 2021, with nearly 2.7 GW of onshore wind and 1.95 GW of hybrid auctions awarded by state and central agencies. A 7.5-months blanket time extension has been granted to renewables projects on account of initial disruptions from COVID-19, but as supply chain challenges persist, GWEC Market Intelligence projects the market outlook for 2022 and 2023 as 3,200 MW and 4,100 MW of onshore wind installations respectively.

Policy measures helped to catalyse recovery and maintain investment interest in the wind market. These measures include: an extension of the waiver of interstate power transmission system (ISTS) charges for renewables projects commissioned by June 2025, with compliance of must-run status for all renewables projects; innovative auction models for round-the-clock and hybrid generation; and a clean energy trading system through the launch of the Real-Time-Market platform/Green Day Ahead Market and Green-Term Ahead Market.

Measures to accelerate wind sector growth

During the recent period of global wind supply chain crunches, India has been increasingly acknowledged as a prominent hub in Asia for turbine component manufacturing and exports. The keys to improving investors' sentiments for wind energy in India include prioritisation for timely attainment of targets, strengthening of the domestic supply chain, and ease of doing business with lower production and labour costs.

In 2021, GWEC India made representations to the MNRE and Ministry of Finance, requesting support for an enabling duty and concessions regime for wind energy.

1. http://164.100.47.193/lsscommittee/Energy/17_Energy_21.pdf
2. Central Electricity Authority of India

This would cover important aspects such as a surge in GST rates for wind components manufacturing from 5% to 12%, and the elimination or revision of Customised Custom Duty Concession benefits which have a direct implication on tariffs discovered through e-reverse auctions.

PPA sanctity and action to improve the financial health of distribution companies (DISCOMs) are also crucial for accommodating higher shares of wind into the transmission and distribution network.

To swiftly expand renewables capacity in India, policymakers can also encourage greater commitments from India's public sector undertakings (PSUs) to invest in renewables and participate in wind auctions. These PSUs are increasingly active in the sector:

- The largest state-owned utility NTPC has floated an Expression of Interest for shortlisting suitable land sites from seven windy states to set up wind projects.
- NTPC and coal mining company NLC India have begun bidding into SECI's ISTS wind and hybrid auctions during 2021.
- NTPC, oil and gas company ONGC, hydroelectric company SVJN and others are greening their energy portfolios through renewable energy targets and conversion of nonperforming fossil-fuel power generation assets into renewables assets.

The government is also working on grid integration of almost 44 GW of new renewable power generation through Green Energy Corridors (GEC). GEC Phase 1 is due to be completed in 2022, and the second phase, which will run through 2026, was recently approved by the Cabinet Committee on Economic Affairs.[3] For grid balancing, MNRE has asked the National Hydroelectric Power Corporation (NHPC) to exploit hydropower resources in the country.

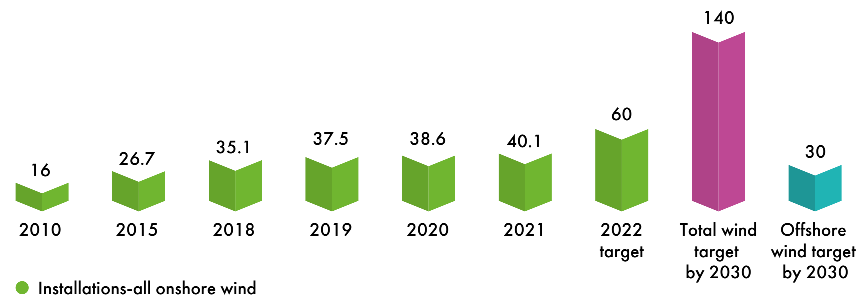
Finally, addressing land availability challenges for onshore wind is critical. Significant delays are experienced regarding the lack of proper strategy for inter-state Right of Way and attaining defence and forest clearances. Provisioning support for land can open up the wide spectrum for the wind market in this decade.

Exploiting untapped onshore and offshore wind potential to reach net zero

To meet the 2030 target of 140 GW installed wind capacity, policymakers should examine the vast, untapped onshore and offshore wind resource. Across the country, the National Institute of Wind Energy (NIWE) has assessed more than 300 GW of onshore wind potential at 100 meter hub height, as well as nearly 700 GW of onshore wind potential at 120 meter hub height.

Through repowering older kW-rated wind turbines through suitable repowering policy measures, India can add substantial wind capacity

Cumulative wind installations versus targets in India, GW



Source: GWEC Market Intelligence; NIWE

3. In seven states- Gujarat, Himachal Pradesh, Karnataka, Kerala, Rajasthan, Tamil Nadu and Uttar Pradesh. See: https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1788011

Through repowering, India can add substantial wind capacity while optimising the utilisation of existing wind-rich and consented sites.

while optimising the utilisation of existing wind-rich and consented sites. Similarly, development of less windy sites by advancing support for suitable wind turbine technology is likely to be beneficial.

Regarding offshore wind potential, World Bank-Group ESMAP has mapped 174 GW of fixed and floating offshore wind potential off India's coastline; the strongest resource is found off Tamil Nadu, while good resource is also available off Gujarat. In March 2022, the MNRE conducted a stakeholder consultation meeting and proposed the initiation of offshore wind leasing auctions from H2 2022. Learnings from countries in Europe point to the promising role of offshore wind in supporting India's National Green Hydrogen mission and the demand from large C&I entities.

Preparing a long-term non-solar RPO trajectory specific to offshore wind and offering schemes such as production-linked incentives for domestic offshore wind manufacturing could be considered. Apart from this, a growing pool of innovative financing mechanisms such as blended finance and Green/ Masala Bonds are likely to boost availability of finance for renewable energy projects, including offshore wind and onshore greenfield and brownfield projects.

4. https://documents1.worldbank.org/curated/en/116871586892855375/pdf/Technical-Potential-for-Offshore-Wind-in-India-Map.pdf

Brazil

2021 was a challenging year for the wind energy sector in Brazil, largely due to the COVID-19 pandemic, but it also brought relief with signs of economic recovery. According to the national statistics agency and Central Bank, Brazil's GDP grew 4.6% in 2021, with a direct impact on electricity consumption which increased 4.1% from the previous year.

Last year, wind energy reached a milestone of 20 GW of installed capacity in Brazil – equivalent to 70% of all wind power capacity in Latin America – after more than 3 GW was installed in 2021 alone. This record growth was due to a confluence of factors, including economic recovery, increase in demand for electricity and efficiencies from a more consolidated wind energy industry. The year also marked the arrival of new frontiers for wind energy in the country in the form of offshore wind, production of green hydrogen and regulation of hybrid projects.

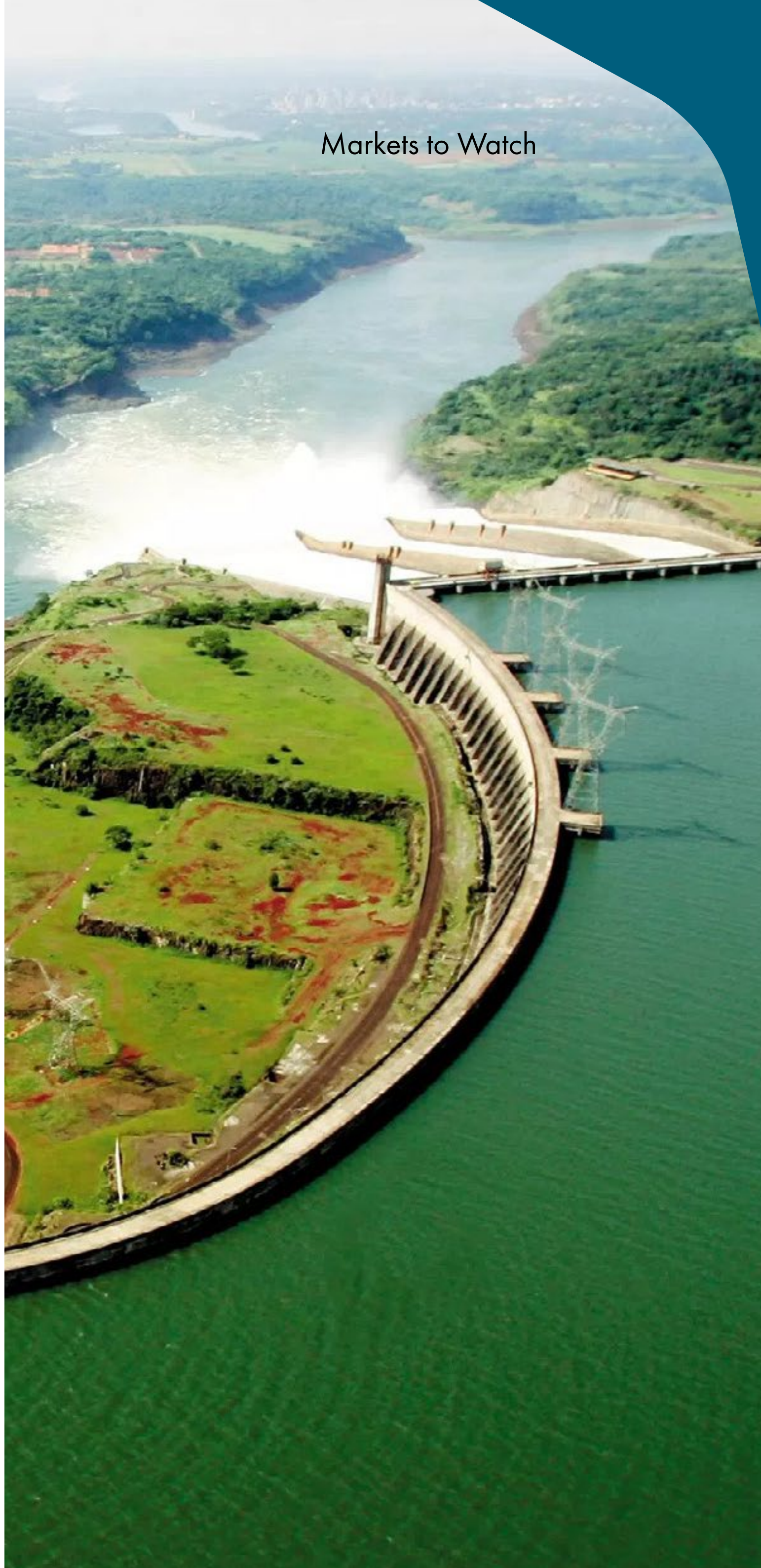
Wind energy in Brazil has been marked by virtuous growth over the last decade, jumping from 1 GW in 2011 to 21 GW by January 2022. Today, wind is the second-largest source of power generation in the country, making up 11% of the electricity matrix. Three factors were decisive for this growth: First, the regulatory framework for auctions facilitated procurement of wind energy at competitive prices; and second, financing design focused on national content provided Brazil with a solid wind industrial base, with capacity to produce enough turbines to install around 5 GW per year.

The third factor is external: Due to changing weather patterns and drops in reservoir levels for hydropower generation, there is increasing uncertainty around the role of hydropower in the electricity matrix. Last year, Brazil experienced the worst hydropower crisis in the last 91 years, making wind the locomotive of the expansion of the Brazilian electric system. Generation reports from last year reflect that wind even supplied 100% of the entire Brazilian Northeast's electricity demand and even had a surplus, according to the National System Operator (ONS).

The prospects for investments in the country remain positive, anchored by a regulatory apparatus and solid growth of the bilateral market for wind energy. According to the Brazilian Wind Energy Association (ABEEólica), sector investment is expected to reach $5.8 billion in 2022, with up to 5 GW in the pipeline for installation this year. EPE (the state Energy Research Office) estimates investments of around $59 billion in centralised power generation and another $20.2 billion in transmission and substations from 2020 to 2029.

The next frontier: Offshore wind

2021 was a milestone for the beginning of offshore wind implementation in Brazil, with GWEC acting with ABEEólica to support the development of a regulatory framework for the sector. By the start of 2022, the long-awaited Decree No. 10,946/2022 was published, providing for the transfer of physical spaces and the use of natural resources to generate electricity from offshore plants. The document, which comes into force in June 2022, sends a positive



signal to the market to begin getting the first offshore wind projects up and running.

Investors now have their eyes on Brazil, reflected in the licensing requests for more than 80 GW in offshore wind projects submitted to the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA). This is just a fraction of the technical resource potential in Brazil, which is more than 700 GW, according to EPE's roadmap. EPE further provides a conservative forecast that by 2050, Brazil will reach 16 GW of installed offshore wind capacity offshore, with a 20% CAPEX reduction.

The expectation is that the first offshore wind auction will be held in 2023. Until then, there is much work to be done, from upgrading port infrastructure, building out transmission, increasing public institutional resourcing and advancing the implementation of a "one stop shop" concept for permitting, among other regulations that will be dealt with through ordinances and resolutions.

Perspectives on future growth

For the next decade of wind energy growth to be as virtuous as the last, it is essential that wind energy plays a central part in the country's energy, economic and environmental planning. Strategic planning and public policies need to follow the move towards a clean, competitive and fair energy transition, with a view to diversifying the power matrix.

New business models are emerging that will continue to attract investor interest. Hybrid projects which co-locate wind and solar generation was the subject of the recent Normative Resolution 954/2021. There are also discussions about hybrid projects combining storage, offshore wind and hydrogen. The offshore wind decree already allows for the production of electricity via technological islands, giving space to projects where offshore wind directly produces green hydrogen.

Brazil's continued economic growth will also spur increased demand for clean electricity and a significant auction pipeline. In addition to the regulated environment, there is no doubt that wind energy is taking off in the bilateral market. From 2018, the free energy market has been contracting around 4 GW of wind energy per year. The future of demand in the bilateral market, however, will depend on the progress of market opening and purchases through auctions.

As indicated by EPE's Ten Year Energy Expansion Plan, wind energy in Brazil is set for considerable growth in this decade, and is on-track to become a central source for the expansion of the Brazilian electricity matrix alongside solar power.

Colombia

Colombia has received international recognition for its commitment to renewable energy, including from the UN and IRENA, among other bodies. The country has promoted a strong transformation of the energy sector in technical, regulatory, infrastructure and market dimensions, with a view to advancing renewable energy project development.

Security of supply has become a growing issue, as periods of low rainfall have impacted the role of hydropower in the electricity mix, which provides more than two-thirds of the country's electricity.1 This challenge has become more pertinent since 2018, reiterating the need for alternative energy sources including wind to ensure sustainable power supply.[1]

The announcement of a new energy transition law, progress on the development of the La Guajira wind farm and the prospect of a fourth renewable energy tender in mid-2022 have created a sense of promise for the Colombian wind industry. The public and private sector are working collaboratively to introduce Colombia into Latin American markets as a leader of wind. This year will see the development of wind projects procured from 2019 onwards making pace and contributing positively to the renewable energy mix.

During the COP26 conference, Colombia's president reiterated the country's commitment to reducing GHG emissions by 51% by the year 2030, compared to 2014 levels, and its pledge to reach net zero by 2050. Colombia houses large regions with untapped onshore and offshore wind potential which needs to be utilised in order to reach these goals.

2022: A growth year for the Colombian wind market

Considering the level of post-COVID-19 recovery called for under the clean growth pillar of the national 'Commitment to the Future of Colombia' plan, both public and private investment is needed to push growth of the renewables sector.[2] Of the $3.1 million assigned for electricity projects in this plan, more than one-third will provide funding for five wind power projects – the highest proportion of all electricity projects, followed by transmission projects.[3] The investment in those five wind projects will in turn generate around 4,300 local jobs to support Colombia's green recovery.[4]

The prioritisation of wind in Colombia's recovery scheme indicates the appetite for accelerating sector development, after more than 1 GW of wind capacity was awarded by the Mining and Energy Planning Unit (UPME) in 15-year PPAs under the renewables auction in 2019. By the end of 2022, it is anticipated that over 1.7 GW of installed wind capacity will be in

1. https://www.iea.org/countries/colombia
2. https://www.windpowermonthly.com/article/1720453/colombia-prepares-wind-power-boom
3. https://www.iea.org/policies/13979-commitment-to-the-future-of-colombia-clean-growth-mines-and-energy?Residential=&page=208
4. The five wind projects are: 50 Camelia; 202 Windpeshi; 44 Acacias 2; 209 Betha; and 210 Alpha. See: https://compromisoporcolombia.gov.co/#containerCompromisosArticle.

place as a result of auctions to date.[5]

In 2020 Vestas was commissioned for two big projects in Colombia, gaining a market position after multinational Elecnor and energy generator Isagen placed a 20 MW order for the La Guajira wind farm.[6] The wind farm was inaugurated in January 2022 – the first to reach this milestone in 17 years.[7] The Minister of Mines and Energy in Colombia has made optimistic remarks about the La Guajira wind farm being one of 14 projects to be developed in the coming three years.[8]

An order for an undisclosed project of 504 MW has also been reported, indicating that there is indeed growth on the horizon. Overall, last year saw record amounts of investment into Latin America, with Colombia having attracted around $800 million in renewable energy investment.[9]

Linking wider policy to the renewable sector

In mid-2021, President Iván Duque Márquez demonstrated leadership in driving the energy transition by making regulatory modifications to the legislation on power generation from non-conventional renewable energy sources (NCRS). The Energy Transition law classifies both blue and green hydrogen as NCRS.8 Green hydrogen is a key vector for the decarbonisation of so-called hard-to-abate sectors such as transport and heating.

Offshore wind's capability to produce green hydrogen can be beneficial for the wider agenda of decarbonisation. Colombia recently presented a public consultation for the draft Offshore Wind Development Roadmap, in which it builds up to 1 GW of offshore wind by 2030, 3 GW by 2040 and 9 GW by 2050 in a vest-case scenario. This roadmap is paving the way for embracing offshore wind, outlining the regulatory landscape of environmental and social assessments, seabed use, permitting and other licensing procedures. The proposed actions should be urgently initiated to enable the expected volumes by the end of this decade.

Onshore and offshore wind mixed with the other mature renewable energy technologies available in Colombia will allow for a diversified and reliable renewable energy mix. Parallel to scaling up the deployment of wind, the government must also steer the buildout and reinforcement of grid infrastructure to ensure grid access and evacuation capacity for large-scale renewables projects. This is especially the case in the northeastern region of La Guajira, where there is excellent wind resource and a hub of project activity.

5. https://www.windpowermonthly.com/article/1720453/colombia-prepares-wind-power-boom
6. https://www.vestas.com/en/media/company-news/2020/vestas-enters-new-market-with-an-order-in-colombia-c3196448
7. https://renews.biz/75085/colombia-to-inaugurate-first-wind-farm-for-17-years/
8. https://www.vestas.com/en/media/company-news/2020/vestas-wins-first-enventus-order-in-latin-america-for-a-c3263319
9. https://www.bnef.com/shorts/13469?query=recommendations
10. https://investmentpolicy.unctad.org/investment-policy-monitor/measures/3732/colombia-enacts-new-legislation-on-electricity-generation-activities-from-renewable-sources

South Africa

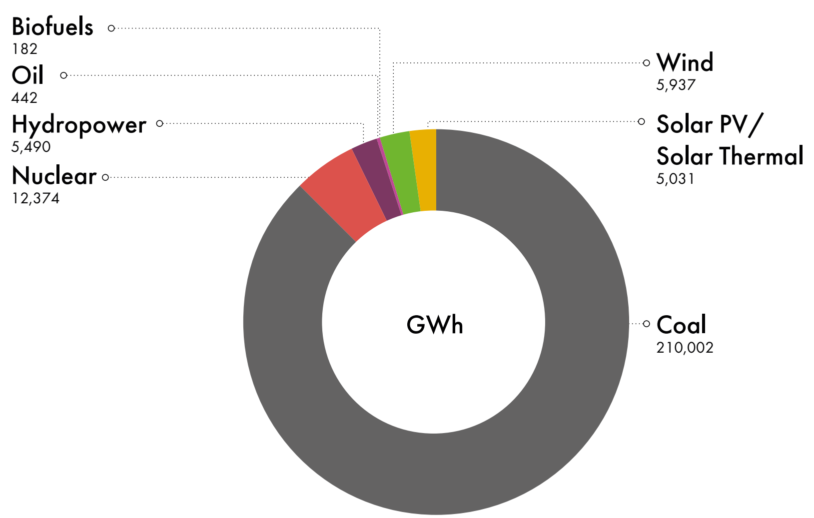
South Africa is the largest wind market in Sub-Saharan Africa in terms of installed capacity. As Africa's third-largest economy and one of the most populous nations on the continent, South Africa has around 3,024 MW of wind capacity connected to its grid. Despite great potential for wind and renewable resources, South Africa's energy mix is largely based on fossil fuels, with nearly 90% of its electricity generation derived from coal and peat, as of 2020. Wind is the largest source of clean power, providing 2.5% of electricity generation.

The country's push for universal electricity access (access is currently at around 85% of the population) and renewable energy ambitions are encouraging a shift towards clean electricity. In the master strategy Integrated Resource Plan (IRP 2019-2030), renewable energy takes on a primary role in the power mix. The Low Emission Development Strategy published in 2020 foresees 35-40% of renewable electricity share by 2030, requiring an additional 20.4 GW of renewable energy capacity in this decade.

Timely implementation of these strategies will be necessary to decarbonise the power system in South Africa, and will include addressing some of the financial and operational challenges of the state-owned utility Eskom as well as committing to regular procurement of large-scale renewable energy projects.

In September 2021, South Africa submitted an updated NDC to the UNFCCC, following the recommendations of the Presidential Climate Commission (PCC). The PCC was established as a multi-stakeholder group to

South Africa's electricity generation by technology, 2020 (GWh)



Source: IEA

1. https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=ZA; https://www.carbonbrief.org/the-carbon-brief-profile-south-africa

advise on South Africa's plans for mitigation and adaptation to climate change, the development of a low-carbon economy and a just and inclusive transition. The updated NDC pledges to limit GHG emissions to 350-420 $MtCO_2e$ by 2030 – a 12-31% reduction from its previous NDC in 2016 – and has been rated by Climate Action Tracker as "Almost Sufficient" for a 2°C global warming pathway.[2] The updated NDC also underscores South Africa's commitment to reach net zero by 2050, although this target is yet to be legislated.

Growing political support for the clean energy transition

South Africa's reliance on coal means around 80% of its GHG emissions come from the energy sector, making the phaseout of coal vital for climate action. Following a milestone agreement at COP26 in 2021, South Africa is set to receive $8.5 billion to decommission, repurpose or repower coal-fired power stations and invest in renewable energy within the decade in order to

2. https://climateactiontracker.org/countries/south-africa/targets/
3. https://ukcop26.org/political-declaration-on-the-just-energy-transition-in-south-africa/; https://www.theafricareport.com/143773/cop26-south-africa-to-receive-8-5bn-to-stop-using-coal/

achieve its carbon targets and NDC.[3]

In 2011, the South African government launched the Renewable Independent Power Producer Procurement Programme (REI4P) aimed at bringing additional megawatts onto the country's electricity system through private sector investment in wind, solar, biomass and small hydro. To date the REIPPP has resulted in 46 wind projects awarded to various developers. The latest Bid Window 5 in October 2021 attracted bids amounting to nearly four times the capacity awarded, resulting in a record 12 wind farms winning bids; the 12 projects are expected to reach COD within three years.

Accelerating deployment of wind power

Given South Africa's strengthened commitment to phase out coal and adopt larger shares of renewables into its electricity mix, it is no surprise that the latest REI4P round received 38% more bids compared to the previous one, despite the challenges associated with the COVID-19 pandemic. South Africa's vast wind resource is still largely untapped, presenting an attractive opportunity to IPPs, investors and community stakeholders.

Recent announced reforms include the unbundling of Eskom by the end of 2022, which will be critical for providing an adequately resourced and independent transmission entity, as well as a more reliable offtaker to power generators. There are also new rules in Schedule 2 of the Electricity Regulation Act which exempt developers from applying for any licensing with the National Energy Regulator of South Africa (NERSA) for embedded generation projects up to 100 MW, and will further incentivise renewable energy development.

But the South African energy market still has key challenges to overcome. Historically, regulation has favoured legacy systems based on fossil fuels. This means that regulatory changes will be necessary to support the transition to cleaner sources. Investors and financiers require as much policy certainty as possible, with supportive frameworks which allow for wheeling and the signing of direct PPAs with IPPs without ministerial approval.

Stable pipelines of wind projects can be created through continuous and regular capacity procurement, including a long-term and on-time auction schedule, as well as a more robust REI4P process which can minimise delays for selection and contract completion.[4]

In addition, grid constraints in three provinces including the Northern Cape have strongly curtailed the rollout of shovel-ready projects in these areas, affecting investment certainty in new renewable projects. An updated Generation Connection Capacity Assessment (GCCA) report is due to be released in Q1 2022 to provide more clarity on capacity planning and transmission connections. Meanwhile, new wind resource assessments in provinces like Mpumalanga, historically home to fossil fuel generation and energy-intensive industries, could unlock further deployment.[5]

The pipeline of wind power has created significant jobs owing to strong local manufacturing of components like towers and transformers. While this is a positive step for growth of the local economy, a lack of predictability for future renewables procurement has introduced some uncertainty to the local value chain. A more straightforward approach to local content requirements, accounting for existing and planned local manufacturing capacity as well as training and financial provisions for the local workforce, can help build a more sustainable local industry.

South Africa's leadership position in wind energy on the continent is set to continue for years to come. With strong local demand, shifting priorities to sustainable energy and promising policy signals, wind power is set to drive the phasing out of coal in South Africa and contribute to the creation of a low-carbon economy.

4. https://www.pv-magazine.com/2021/09/30/reippp-one-of-the-worlds-best-renewable-energy-tenders-but-theres-room-for-improvement/; https://coalition.irena.org/-/media/Files/IRENA/Coalition-for-Action/Coalition-for-Action-BusinessInvestors-GroupScalingRenewableEnergyInvestmentSouth-AfricaDec2021.pdf?la=en&hash=E73566B496FEF275568627C7F95968944ED789F9
5. https://www.engineeringnews.co.za/article/sawea-chair-sees-100-mw-reform-unlocking-wind-investments-in-mpumalanga-2022-01-28

Egypt

As the world prepares for COP27 in Sharm El Sheikh in November 2022, the summit marks an occasion to examine Egypt's ongoing energy transition. Governments will be looking closely at the host country's progress towards meeting its intended NDC submitted in 2017.

Egypt's NDC does not include a quantifiable GHG emissions reduction target, but does pledge "widespread diffusion of locally-appropriate low-carbon energy production technologies, with substantial reductions in energy intensity."[1] It also estimates the investment required for adaptation and mitigation goals by 2030 at $73 billion, with an expectation of financial contribution from developed countries.

The stakes are high for Egypt to demonstrate leadership on climate change mitigation and phasing out fossil fuels , precisely as global ambition on climate action needs to ramp up. With tremendous wind energy potential, the government has an opportunity to raise its renewable energy ambitions, align with international net zero pathways and make a clear statement about the urgency of the energy transition in the MENA region and worldwide.

Encouraging a shift to wind and renewable energy

Egypt has a long history as an oil and gas producing country, as the largest non-OPEC oil producer in Africa and one of the largest exporters of gas.[2] It also subsidises domestic fuel supplies and electricity prices, although electricity tariffs have been reformed in recent years to be more cost-reflective. While its known natural gas reserves are only a fraction of those in Iran, Qatar or Saudi Arabia, Egypt is the fastest-growing exporter of LNG in the MENA region, due largely to geographic proximity to the Mediterranean and Europe.[3]

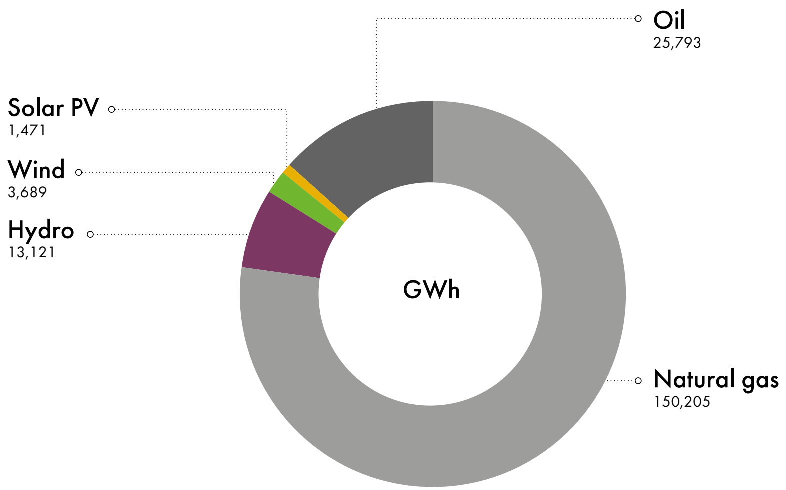
As of 2019, roughly 90% of Egypt's electricity generation is derived from natural gas and oil, followed by hydropower, wind and solar energy. But population growth, increased foreign direct investment (FDI) and economic liberalisation are spurring increased electricity demand. Meanwhile, there is growing national interest in diversifying the energy mix and capitalising on renewable energy potential in the country.

The government's current aim is to reach 42% of renewables in the power mix by 2035, which will include 14% wind, 21% solar PV, as well as hydropower and concentrated solar power (CSP). But it should be noted that Egypt has far more potential – a recent IRENA report found that the country could generate up to 53% of its electricity from cost-effective renewable sources by 2030 with a targeted long-term strategy.[5]

Egypt boasts impressive onshore wind potential which can be exploited to support national renewable energy ambitions.[6] Several locations in windier regions, in particular along the Gulf of Suez

1. https://www4.unfccc.int/sites/NDCStaging/pages/Party.aspx?party=EGY
2. https://theenergyyear.com/market/egypt/
3. https://www.mei.edu/publications/egypts-future-lng-market
4. https://www.trade.gov/country-commercial-guides/egypt-electricity-and-renewable-energy
5. https://www.irena.org/newsroom/pressreleases/2018/Oct/Egypt-Could-Meet-More-than-50-percent-of-its-Electricity-Demand-with-Renewable-Energy
6. "Renewable Energy Outlook Egypt", IRENA. 2018.

Electricity generation in Egypt by source, 2019 (GWh)



Source: IEA

coastline, feature wind speeds of between 5-11 m/s at 100-metre hub height. The National Wind Atlas assesses that the East and West Nile areas alone could host more than 31 GW of wind capacity.[7] Other promising terrestrial wind resource areas are located in more remote regions of the country, farther from demand centres. World Bank Group-ESMAP estimates technical offshore wind potential of 166 GW in Egypt's Exclusive Economic Zone (EEZ), including 27 GW of fixed-bottom offshore wind and 139 GW of floating offshore wind potential.[8]

The first phase of Egypt's commercial scale wind deployment involved a series of utility-scale turnkey wind projects totalling 545 MW near Zafarana, funded by soft loans to the state from Germany, Spain, Japan and Denmark between 2001-2010; these projects were then handed over to and operated by Egypt's New and Renewable Energy Authority (NREA). Between 2010 and 2021, installed wind capacity grew to 1,638 MW, primarily via turnkey EPC contracts commissioned by NREA, around a third of these comprising independent developer projects.[9]

Private sector driving onshore wind growth

The recent growth of onshore wind in Egypt has been driven by policy frameworks such as renewable energy tenders for build-own-operate (BOO) contracts. However, there is now a long-overdue shift towards implementation of a private IPP wind market.

In 2015, Egypt's Electricity Transmission Company (EETC) opened a tender for the development of a 250 MW wind power installation by the private sector in the West Nile region.[10] In 2019, an international consortium including France's ENGIE, Japan's Toyota Tsusho Corporation and Egypt's Orascom Construction was established to develop the first private wind farm in Egypt with a capacity of 262.5 MW. At the end of 2021, Lekela Power (a joint venture between Mainstream Renewable Power and Actis) commissioned the 250 MW West Bakr wind farm; NREA supported this by signing an usufruct agreement with Lekela Power to procure access to the land for the project. The two IPP wind projects include a 20-year PPA with the EETC to supply electricity to the national grid, with turbines from Siemens Gamesa Renewable Energy.

These two wind IPP projects taken together with the 1.4 GW Benban solar IPP complex near Aswan, demonstrate that Egypt can now benefit from international collaboration to expand its installed renewable energy capacity with a variety of stakeholders including developers, utility companies, industrial conglomerates, private investors and international financial institutions. The growth of the onshore wind sector will provide tremendous opportunity in creating clean energy jobs in and around communities hosting wind projects.

As a sign of further innovation, in mid-2021 Siemens Energy signed an MOU with the Egyptian Electricity Holding Company (EEHC), a state-owned entity which owns most power generation and distribution companies in Egypt. The cooperation will focus on developing a domestic green hydrogen ecosystem based on renewable energy, beginning with a 100-200 MW electrolyser pilot project and establishing an enabling regulatory

7. https://www.trade.gov/country-commercial-guides/egypt-renewable-energy
8. https://documents1.worldbank.org/curated/en/465001586847822299/pdf/Technical-Potential-for-Offshore-Wind-in-Egypt-Map.pdf
9. Assessment of Private Sector Participation in the Power Sector of Egypt, World Bank, 2014; https://www.iea.org/countries/egypt; NREAMeter, 10th Periodical, NREA, 2021.
10. https://www.iea.org/policies/5901-egypt-renewable-energy-tenders-build-own-operate-boo-contracts https://www.iea.org/policies/5901-egypt-renewable-energy-tenders-build-own-operate-boo-contracts

The growth of the onshore wind sector will provide tremendous opportunity in creating clean energy jobs in and around communities hosting wind projects.

and certification environment. [12]

If the Government of Egypt and its agencies, including the Ministry of Electricity and Renewable Energy, EETC and NREA, continue to meet their contractual obligations then we can anticipate that other developers, utilities and investors will also seek entry to the Egyptian wind market. Development finance institutions (DFI) may continue to play an important role in providing attractive financing terms that help to mitigate important risks, such as government liquidity, foreign exchange convertibility, political risk insurance and other areas.

The Egyptian government needs to attract sufficient private capital to meet its aggressive plans to expand the renewable energy share of its power mix. The success of these wind IPP projects as a result of collaborative private sector efforts will provide future investors with greater confidence in investing in wind projects to meet Egypt's burgeoning electricity demand growth.

11. https://dailynewsegypt.com/2019/03/13/nrea-lekela-sign-usufruct-agreement-to-establish-wind-farm/
12. https://press.siemens-energy.com/mea/en/pressrelease/siemens-energy-supports-egypt-develop-green-hydrogen-industry

Exploring new markets: Onshore Wind

GWEC Market Intelligence is monitoring activities in 46 countries on a regular basis to document the opportunities and progress of taking wind global, and supporting governments in developing appropriate policy frameworks.

The four selected countries – Algeria, Uzbekistan, Oman, and Peru – represent countries with high onshore wind potential but varying political support and targets to date. Still, in all four countries there is an increasing awareness that wind can provide a scalable, cost-competitive and efficient solution for renewable energy.

Algeria

Development stage
Since 2014, 10 MW installed wind capacity exists at Adrar in Algeria, as a pilot project funded by state utility Sonelgaz. Two 20 MW wind farms were expected to be constructed during 2014-2015. To meet earlier wind targets of 2016-2030, studies were supposed to be undertaken to identify suitable sites in 21 identified areas across Algeria by Sonelgaz's electricity generation subsidiary, Shariket Kahraba wa Taket Moutadjadida (SKTM).

Political support
In June 2021, the government refreshed targets to 15 GW renewable electricity generation by 2035, i.e. 1 GW installed per year. The earlier target from 2016, which aimed for 22 GW of renewables by 2030 (including around 5 GW of wind), was deemed unachievable. In 2021, the government created a national renewable energy company, SHAEMS, to conduct renewables tender activities and foster foreign investment in the sector, under the authority of the Ministry of Energy Transition and Renewable Energies (METRE).

Challenges
Algeria's economy is heavily dependent on fossil fuels and funded by oil and gas export revenues. Lack of precise wind resource mapping and absence of a local wind supply chain makes wind energy initially expensive, with limited investments and experience in the sector in the country to date.

Next milestone
Dedicate funding for precise wind resource mapping, procurement scheme, and wind workforce training programme to scale up market readiness. Raise foreign investments and market confidence with a clear policy and regulatory framework, grants and risk mitigation guarantees, as well as financial and tax incentives for supply chain development.

Uzbekistan

Development stage
Two potential areas have been identified for wind installations by central authority Uzbekenergo, in the Navoi region and southern Karakalpakstan. In 2021, the first PPA-based competitive wind tender awarded development of the 100 MW Nukus wind farm in the latter region. As of 2021, 4 GW of total wind project agreements are signed, including 1 GW in Bukhara and Navoi region and 1.5 GW in Karakalpakstan region, both by ACWA Power, and 1.5 GW Zarafshan wind farm by Masdar .

Political support
The country has devised a low carbon energy strategy to boost renewables for diversified energy mix. The Ministry of Energy has set a 3 GW wind target by 2026 and plans to raise it to 5 GW by 2030. The overall target is 25% renewables in the energy mix by the end of 2030. The country is developing a legal framework for renewables development, including adoption of the Law on the Use of Renewable Energy Sources and the Law on Public-Private Partnerships for foreign investment.

Challenges
There is a lack of utility-scale wind project procurement and a high cost of power generation. Inadequate economic support (such as provision of import duty waivers for wind components) or financial incentives are needed to stimulate growth.

Next milestone
Utility-scale wind procurement and local skill-building and public awareness is needed for economies of scale. Although Uzbekistan holds around 520 GW of moderate technical wind resource, detailed techno-economic studies of wind sites are required.

Oman

Development stage
The first 50 MW Dhofar wind farm, developed by Masdar and funded by Abu Dhabi Fund for Development, is in operation. A competitive tender for a 100 MW project in the southern part of Oman is due. Projects are planned in seven locations, under the delayed 'Wind 2023 IPPs' scheme to be now launched in 2025 under the rebranded 'Wind 2025 IPPs' for MW wind-based IPP procurement.

Political support
A National Energy Strategy encourages zero-carbon fuels and green hydrogen. Oman's '2040 Vision' aims for renewables to reach 39% of total energy supply, with an interim goal of 20% by 2030. Strategic energy partnerships outline large green hydrogen and ammonia production plans via wind and solar generation. The Wind Atlas Project is plans mapping of windy sites at 80m hub height to gather bankable data and encourage investments. An electricity spot market is liberalising power procurement.

Challenges
High capital costs and a lack of procurement timelines are holding the 'Wind 2025 IPPs' scheme back. There is an unavailability of advanced technologies in the country for wind measurements.

Next milestone
Set clear wind policy with targets and a robust regulatory framework. Provide initial subsidies and grants for the first generation of large-scale projects. Similarly start market exploration in light of huge offshore wind technical potential, which is around 61 GW fixed and 118 GW floating offshore wind.

Peru

Development stage
Around 20.5 GW of feasible onshore wind potential is available in Amazonas, Ancash, Arequipa, Cajamarca, Ica, La Libertad, Lambayeque, Lima and Piura regions. Around 7 wind projects are in progress: In 2021, Concessions were granted to a total of 528 MW of wind and solar power projects, while temporary concessions were granted to 1.9 GW of wind and solar capacity, as per the Ministry of Energy and Mines.

Political support
Peru has a commitment to reach 15% of renewables in its energy mix by 2030 and reduce emissions by up to 40% by 2030. A proposed bill provides investment incentives for renewable energy, including extending accelerated depreciation from 2025 to 2025. Alternative mechanisms such as green bonds are being explored to fund renewable projects. After the fourth renewables auction in 2016, the government plans to announce 2 GW of renewables auctions in 2022.

Challenges
Grid infrastructure expansion is needed to accommodate new renewables capacity. Regulatory measures to ensure system stability are also required, and there is a lack of clear policy for incentivising investment in renewables.

Next milestone
Set wind targets to harness the 20 GW of feasible onshore wind potential to meet Peru's rising energy demand. Formulate policy and regulatory frameworks, possibly with annual wind auction pipelines, and dedicate investment and resources for grid expansion.

Exploring new markets: Offshore Wind

GWEC Market Intelligence is monitoring activities in 46 countries on a regular basis to document the opportunities and progress of taking wind global, and supporting governments in developing appropriate policy frameworks.

The four selected countries – Sri Lanka, Azerbaijan, Australia and Turkey – represent markets with high offshore wind potential but varying political support and targets to date. Still, in all four countries there is an increasing awareness that offshore wind can provide a scalable, cost-competitive and efficient solution for renewable energy

Sri Lanka

Development stage
A total 92 GW (55 GW fixed and 37 GW floating) technical offshore wind potential exists in Sri Lanka, according to World Bank-ESMAP. There is a World Bank-driven offshore wind roadmap underway since late 2020, with a focus on the Gulf of Mannar, which will be open for consultation and commentary this year.

Political support
Sri Lanka updated its NDCs in July 2021, committing to achieve 70% renewable energy in the electricity generation mix by 2030, carbon neutrality in electricity generation by 2050 and no new coal power capacity. Offshore wind can play a role in the country's transition from coal and fossil fuels.

Challenges
There are no offshore wind framework or target in place currently. Bankability of projects may be a challenge due to currency risk, offtaker risk, legal risk and performance on debt-to-equity ratios. Projects may be of a smaller scale than other countries in the region, and transmission buildout will be required to enable offshore wind.

Next milestone
More detailed resource and zonal assessment is required, in addition to a high-level vision of offshore wind's place in Sri Lanka's energy mix. This should include a clear timeline for ambitions and capacity to be installed. Dedicated efforts for grid and port infrastructure development are also required.

Azerbaijan

Development stage
Consultation will begin soon for a draft roadmap to develop offshore wind energy, led by World Bank-IFC and focusing on a demonstration project followed by low/high growth scenarios. Saudi Arabian utility ACWA Power has signed an MoU to develop offshore wind in Azerbaijan. SOCAR and Technip Energies have signed a cooperation agreement to work on a joint floating offshore wind pilot project for powering upstream operations in Azerbaijan's sector of the Caspian Sea.

Political support
Plans are in place to generate 30% of electricity from renewables by 2030 and reach net zero emissions by 2060, with significant ambitions in developing hydrogen.

Challenges
Azerbaijan lacks offshore wind-related policy, including a legal and regulatory framework, enabling infrastructure and a support mechanism for procurement.

Next milestone
With an estimated 157 GW technical offshore wind potential and high corporate demand for electricity, offshore wind has great potential. Clear offshore wind vision and targets to initiate public and private investor interest is needed, including an alignment of offshore wind development with net zero goals. Greater technical know-how experience is also needed within government bodies.

Australia

Development stage
With an estimated 4,963 GW (fixed 1.6 TW and floating 3.4 TW) offshore wind potential, the opportunity in Australia is huge. Work has begun on the environmental assessments for the 2.2 GW Star of the South wind farm. There are more than 10 projects proposed in the pipeline, with a combined capacity of over 25 GW; this includes Oceanex plans to develop >9 GW of floating wind and Copenhagen Energy's 3 GW project within Geographe Bay.

Political support
The Offshore Electricity Infrastructure Bill passed in 2021, with a complementing Offshore Electricity Infrastructure (Regulatory Levies) Bill 2021, designates offshore wind areas in Commonwealth waters and imposes duties on regulated entities to recover regulatory costs. State interest is high: Victoria plans to reach 2 GW of offshore wind by 2028 and 9 GW by 2040. The Energy Innovation Fund will fund the initial development of three offshore wind projects. The Victorian government has earmarked $1.08 billion for boosting decarbonisation via offshore wind and green hydrogen.

Challenges
Currently there are inadequate regulations and permitting guidelines for seabed leasing, port refurbishment and grid infrastructure development. Federal ambition in offshore wind is held back by support for incumbent fossil fuels.

Next milestone
Plans to harness offshore wind should be incorporated into national decarbonisation and energy planning goals, and not limited to state level. Grid expansion and social dialogue and benefit programmes are also needed. programs. A clear, transparent and streamlined leasing and permitting process will also provide confidence to investors.

Turkey

Development stage
In 2018, the 1.2 GW capacity YEKA tender was postponed due to immature tender conditions and dearth of site data. A roadmap for offshore wind is underway in Turkey, led by World Bank-ESMAP, with industry consultation scheduled for this year.

Political support
Turkey aims to add 20 GW of wind energy by 2030. A roadmap by the Izmir Development Agency to promote offshore wind development estimated Turkey's total offshore wind potential at 70 GW. An Offshore Wind Energy Association (DÜRED) has been established to bring the energy and maritime sector together and to drive investment in offshore wind.

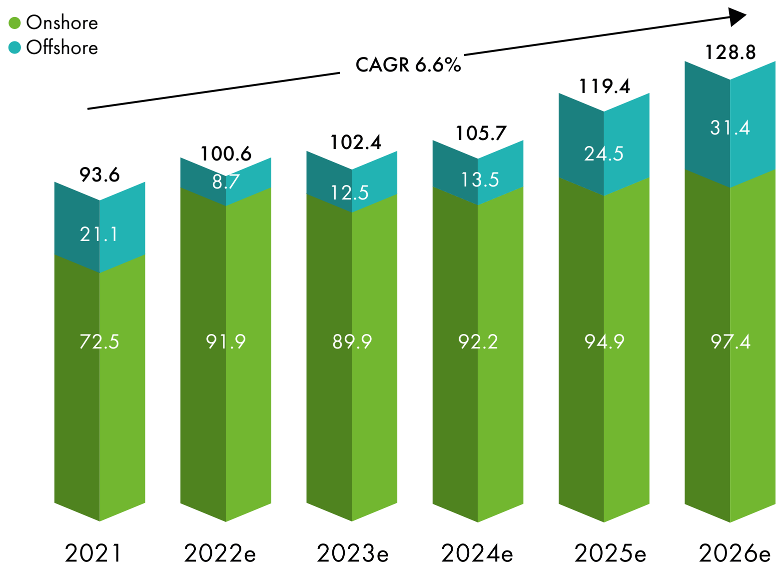
Challenges
Uncertainty regarding financing could mean longer lead times for offshore wind projects, while a preference for building more onshore wind could push back commercial scale projects to the 2030s.

Next milestone
Dedicated offshore wind targets within the wider energy transition strategy are needed, followed by concrete offshore wind legislation and policy formulation. A support mechanism for the initial set of offshore wind projects will also help to kickstart the sector.

MARKET OUTLOOK 2022-2026

Global wind energy market expected to grow by 6.6% per year on average

New wind power installations outlook 2022-2026 (GW)



GWEC's Market Outlook represents the industry perspective for expected installations of new capacity for the next five years. The outlook is based on input from regional wind associations, government targets, available project information and input from industry experts and GWEC members. An update will be released in Q3 2022. A detailed data sheet is available in the member only area of the GWEC Intelligence website.

Global outlook

- After a year in which net zero commitments gathered global momentum, coupled with renewed urgency for achieving energy security, the market outlook for the global wind industry looks even more positive. The CAGR for the next five years is 6.6%, even though the level of installed capacity for 2021 was the second highest in history.

- GWEC Market Intelligence expects that 557 GW of new capacity will be added in the next five years under current policies. That is more than 110 GW of new installations each year until 2026.

- Achieving eligibility for FiT and Green Certificates was the key growth driver in the past two years. But as the FiT support schemes have been terminated in markets such as China and Vietnam and the two Nordic countries Sweden and Norway also agreed to stop the Green Certificate system by the end of last year, from 2022 onwards the global wind power growth is expected to rely primarily on the following market support mechanisms: (1) grid-parity scheme (mainly in China, where wind generated electricity will receive the same remuneration as coal-fired power plants; (2) PTC and ITC (US onshore and offshore wind); and (3) wind-only, hybrid, renewable and technology-neutral auctions (Europe, Latin America, Africa & Middle East and South East Asia). Since auction/tender mechanisms have prevailed in markets excluding China and the US, challenges from previous auctions, including permitting and market design, need to be addressed to support growth in the next five years.

Global onshore outlook

- The CAGR for onshore wind in the next five years is 6.1%. The expected average annual installation is 93.3 GW. In total, 466 GW is likely to be built in 2022-2026.

- In our previous year's market outlook, we predicted that global onshore wind growth would slow down in 2021 followed by flat growth in 2022 and 2023. This was predominately in response to China's onshore wind market entering the new era of grid parity and our expectation that it might take another two years for the country to reach the same installation level as 2020. However, we upgraded our near-term forecast in this year's outlook due to the Chinese government's implementation plan to reach the "30-60" targets together with the renewable development plans for 2021-2025 released in 2021, as these are likely to accelerate growth from 2022 onward (for details, see the Market to Watch-China).

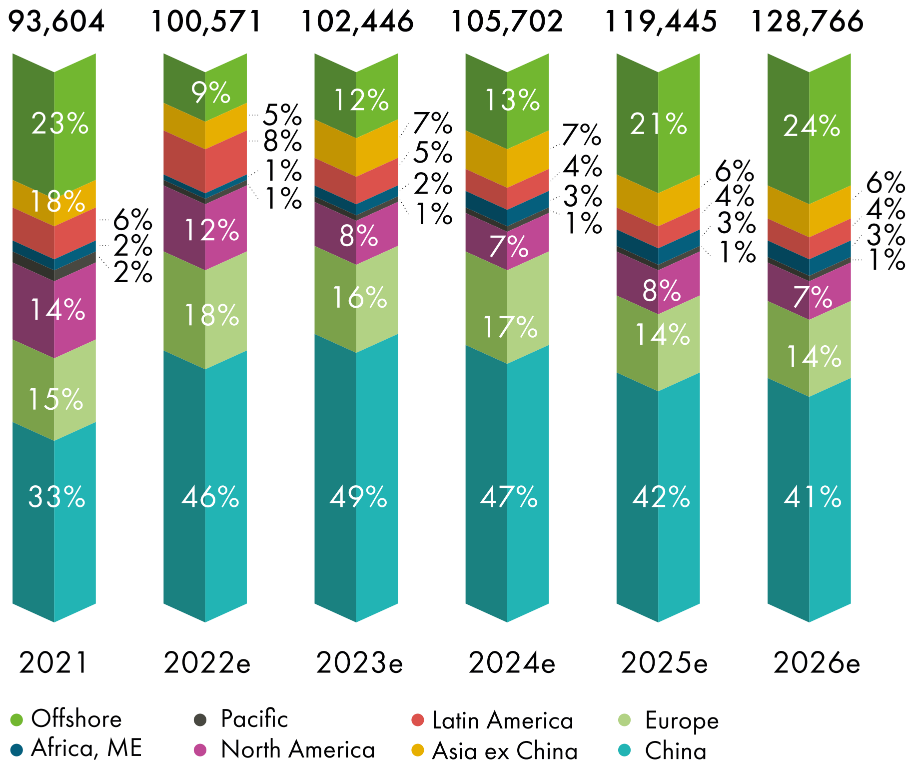
Global offshore outlook

- The CAGR for offshore wind in the next five years is 8.3%. Considering that more than 21 GW of offshore wind capacity was added last year, such a growth rate is extremely positive.

- Following an outstanding year, new offshore installations in 2022 are likely to return to the 2019/2020 level, primarily due to the reduction of installations in China. However, market growth is expected to regain momentum from 2023, eventually passing the 30 GW mark in 2026.

- In total, more than 90 GW of offshore is expected to be added worldwide in 2022-2026. The expected annual average offshore installations is 18.1 GW.

New wind power installations outlook 2022-2026 by region
MW and per cent, onshore and offshore



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APAC onshore markets and offshore likely to take bigger role to drive global growth

Offshore wind

The global offshore market is expected to grow from 21.1 GW in 2021 to 31.4 GW in 2026, bringing its share of new global installations from today's 22.5% to 24.4% by 2026. In Asia, China will remain the largest contributor with 39 GW to be added in the next five years, followed by Taiwan (6.6 GW), Vietnam (2.2 GW), South Korea (1.7 GW) and Japan (1 GW). In Europe, more than 28 GW of offshore wind capacity is expected to be built in 2022-2026, of which 41% is likely to be installed in the UK, primarily driven by the commissioning of CfD Round 3 projects, 15% in the Netherlands, 12% in France, 11% in Germany and 6% in Poland. In the US, thanks to the target of 30 GW by 2030 of offshore wind released by the Biden Administration, great progress has been made in 2021. With construction work already kicking off last November, the country's first utility scale offshore wind project is likely to be online in 2023. 11.5 GW of offshore wind capacity is expected to be built in the next five years, making it the largest offshore wind market after China and the UK in terms of new additions.

Africa and the Middle East

After a record year in new installations in 2021, growth in this region is likely to slow down in 2022 and 2023 mainly due to the delays of the first and second rounds of REIPPPP Bid Window 5 auction in South Africa. However, with projects awarded from those auctions coming online in South Africa, a new installation record is expected to be achieved in this region in 2023 and the growth momentum is likely to be maintained during the rest of the forecast period. In total, 14 GW of new capacity is expected to be added in Africa/Middle East in the next five years (2022-2026), which is primarily driven by growth from

South Africa (5.4 GW), Egypt (2.2 GW) and Morocco (1.8 GW) in Africa, and Saudi Arabia (1.3 GW) in the Middle East.

Asia excluding China

Driven by the FiT cut-off, Vietnam made up 57% of new onshore installations in this region in 2021, but this growth is expected to slow down in 2022 and the market is unlikely to recover until the new wind energy support mechanism and PDP8 wind targets are finalised by the government. India had another tough year in 2021. The second surge of COVID-19 prevented the region's largest wind market from making its expected recovery. With more than 20 GW capacity (wind and hybrid/RTC/peak power) awarded by the end of 2021, the situation was expected to improve in 2022 compared to 2021. However, increased turbine prices driven by the rise in commodity prices made investors hesitate to commission wind projects that were awarded previously with very low PPA prices. In total, less than 20 GW of wind capacity is predicted to be built in India in the next five years. Elsewhere in this region, growth is expected to come from Japan, Pakistan and emerging markets of southeast Asia (mainly the Philippines, Laos, Thailand and Indonesia), as well as in central Asia (Uzbekistan and Kazakhstan). Southeast Asia and central Asia are likely to make up 16% and 8% of the new capacity expected for this region in the next five years.

Pacific

150 MW of new wind capacity was commissioned in New Zealand in 2021, making it the second highest year in history. However after another three projects, totalling 436 MW, come online in the 2022-2023, there will be no more wind projects in the pipeline. Thus, 94% (or 7.3 GW) of projected new installations in this region in the next five years will come from Australia. With the planned EnergyConnect link between South Australia and New South Wales coming online in 2023 and strong renewable commitments from state-level government (renewable energy zones) and from local mining and iron ore giants (green hydrogen), Australia will continue to be a key onshore wind market in this decade.

Europe

Our forecast for the next five years is in line with WindEurope's Realistic Expectation Scenario, which is based on the current policy context,

2022 is likely to be another record year for European onshore wind, driven by the economic recovery from COVID-19 as well as the expected strong market growth in Germany, Sweden, Finland, France and Spain from the EU-27 and non-EU 27 markets such as Turkey.

the latest permitting status and auctions/tenders results. 2022 is likely to be another record year for European onshore wind, driven by the economic recovery from COVID-19 as well as the expected strong market growth in Germany, Sweden, Finland, France and Spain from the EU-27 and non-EU 27 markets such as Turkey. After this peak, the average annual installations in 2023-2026 will drop to the level of 17.4 GW but will remain stable. In total, 87.7 GW of onshore wind is expected to added in Europe in the next five years. Of this amount 19.7 GW (22%) will come from Germany – supported by the new German coalition government's spatial planning reforms that aim to boost onshore installation rates by streamlining the permitting process – followed by Spain (11%), France (10%), Sweden (9%) and Finland (7%). Russia's invasion of Ukraine has brought uncertainty not only for the existing project pipeline (>4 GW awarded), but also for new project development in both markets. As the invasion is still ongoing at the time of finalizing our market outlook, GWEC will monitor the situation closely and provide an updated outlook for this region in our Q3 Market Outlook.

Latin America

Latin America had a record year for

new installations in 2021 and new additions are expected to be even higher this year. This strong growth momentum is primarily driven by Brazil, where project development under the private PPA market continues to bring new "blood" into a market that had hitherto been driven by regulated public auctions. However, annual growth in LATAM is likely to drop to 4-5 GW in the period 2023-2026 following the slow-down of installations in key markets such as Mexico and Argentina as a result of an unhelpful policy environment and economic instability. Colombia is projected to be the largest onshore wind market in this region after Brazil, Chile and Mexico in total added capacity in the next five years.

North America

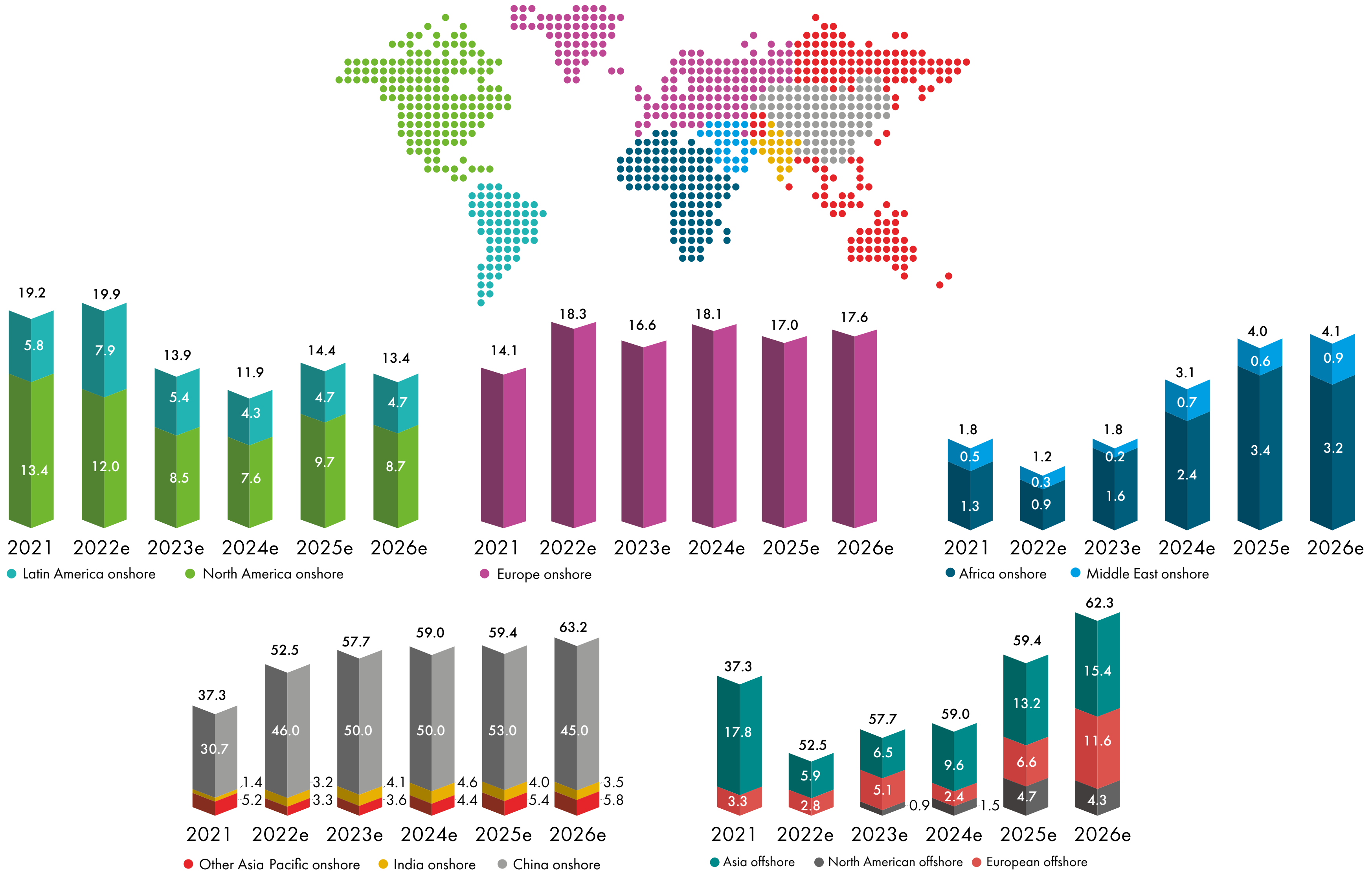
In the US, the PTC will continue to be the primary driver supporting US onshore wind growth in 2022-2025. 2022 is likely to be another strong year in new installations as multi-GW onshore wind projects that got pushed back from 2021 to 2022 and projects that started construction in 2016 are still eligible for the full PTC rate if they can reach the COD by end of 2022. Based on the current PTC phase-down plan, onshore wind installations in the U.S. are likely to decline in 2023 and 2024, but can be expected to bounce back in 2025, driven by the PTC extension enacted in both 2019 and 2020. Onshore market growth in the US after 2025 depends on whether the Biden administration's Build Back Better Bill can pass the Senate as well as the tax incentives unveiled in the president's 2022 State of Union address. In total, 46.5 GW of onshore wind capacity is expected to be added in the next five years in North America, of which 90% will be contributed by the US and the remaining will come from its neighbour Canada.

China

New onshore wind installations dropped by 39% in 2021 after the Chinese onshore wind market entered the "subsidy-free" era at the beginning of the year. Nevertheless, GWEC Market Intelligence upgraded its onshore wind installation forecast for the 14th five year period (2021-2025) by 16% compared with the Q1 2021 Outlook. This was mainly because the government's renewable development strategies included in the 14th five year plan have paved the way for reaching China's "30-60" targets and the recently launched power market reform is expected to support China's renewable-led revolution in the next decades.

Regional onshore wind and offshore wind outlook

New installations (GW)



APPENDIX

Global Wind Report 2022 - Methodology and Terminology

Data definitions and adjustments
GWEC reports installed and fully commissioned capacity additions and total installations. New installations are gross figures not deducting decommissioned capacity. Total installations are net figures, adjusted for decommissioned capacity.

Historic installation data has been adjusted based on the input GWEC received. GWEC made the adjustments to new installations in 2020 for China, Kazakhstan, Spain, United Kingdom, Italy, Poland, Ireland, Panama and Peru.

All currency figures in $ are given in US Dollars.

Definition of regions
GWEC adjusted its definition of regions for the 2018 Global Wind Report and maintains these in the 2022 edition, specifically for Latin America and Europe.

Latin America: South, Central America and Mexico

Europe: Geographic Europe including Norway, Russia, Switzerland, Turkey, Ukraine

Sources for the report
GWEC collects installation data from regional or country wind associations, alternatively from industry experts and wind turbine manufacturers.

Used terminology
GWEC uses terminology to the best knowledge. With the wind industry transitioning certain terminology is not yet fixed or can have several connotations. GWEC is continuously adapting and adjusting to these developments.

Acronyms

AEP Annual Energy Production
AI Artificial Intelligence
APAC Asia-Pacific
ASEAN Association of Southeast Asian Nations
BAU Business As Usual
BESS Battery Energy Storage Systems
BNEF Bloomberg New Energy Finance
BOEM Bureau of Ocean Energy Management (BOEM)
C&I Commercial And Industrial
CAGR Compound Annual Growth Rate
CAISO California Independent System Operator
CAPEX Capital Expenditures
CBAM Carbon Border Adjustment Mechanism
CCER China Certified Emission Reduction
CCGT Combined Cycle Gas Turbine
CCUS Carbon Capture, Utilisation, And Storage
CfD Contract for Difference
CO2/ CO2e Carbon Dioxide/ Equivalent
COD Commercial Operation Date
COP Conference Of the Parties
DFI Development Finance Institution
DNSH Do No Significant Harm
DSR Demand-Side Response
ECA Export Credit Agency
EGAT Electricity Generating Authority of Thailand
EEZ Exclusive Economic Zone
EIA Environmental Impact Assessment
EMDEs Emerging Markets and Developing Economies
EMS Energy Management System
EPC Engineering Procurement Construction
ESG Environmental, Social, and Corporate Governance
EU European Union
EV Electric Vehicle
EVOSS Energy Virtual One-Stop Shop
FDI Foreign Direct Investments
FID Final Investment Decision
FiT Feed-In Tariff
FTE Full-Time Equivalent
GDP Gross Domestic Product
GHG Greenhouse Gases
GST Goods and Services Tax
GW Gigawatt
HSSE Health, Safety, Security, And Environment
HVDC High-Voltage Direct Current
IEA International Energy Agency
IFC International Finance Corporation
IoT Internet of Things
IPCC Intergovernmental Panel on Climate Change
IPP Independent Power Producers
IRENA International Renewable Energy Agency
IRP Integrated Resource Plan
ISO Independent System Operator
kt Kilo Tonnes
kWh Kilowatt Hour
LCOE Levelised Cost of Energy
LNG Liquefied Natural Gas
MEA Metropolitan Electricity Authority of Thailand
MNRE Ministry Of New and Renewable Energy
MOIT Ministry of Industry and Trade of Vietnam
Mt Metric Tonnes
MW Megawatt
MWh Megawatt Hour
NDCs Nationally Determined Contributions
NFTs Non-Fungible Tokens
O&M Operation And Maintenance
OEMs Original Equipment Manufacturers
OWSC Offshore Wind Service Contracts
PDP Power Development Plan of Vietnam
PEA Provincial Electricity Authority of Thailand
PPA Power Purchase Agreement
PV Photovoltaic
PTC Production Tax Credit
R&D Research And Development
RECs Renewable Energy Certificates
REE Rare Earth Elements
ROI Return on Investment
RPS Renewables Portfolio Standards
RTO Regional Transmission Organisation
STEM Science, Technology, Engineering and Mathematics
TWh Terawatt Hour

About GWEC Market Intelligence

GWEC Market Intelligence provides a series of insights and data-based analysis on the development of the global wind industry. This includes a market outlook, country profiles, policy updates, deep-dives on the offshore market among many other exclusive insights.

GWEC Market Intelligence derives its insights from its own comprehensive databases, local knowledge and leading industry experts.

The market intelligence team consists of several strong experts with long-standing industry experience across the world.

GWEC Market Intelligence collaborates with regional and national wind associations as well as its corporate members.

How to access GWEC Market Intelligence Corporate GWEC Members

- Wind energy associations
- Market Intelligence subscription

Contact

Contact Feng Zhao feng.zhao@gwec.net

GWEC Market Intelligence Areas

Market Insights
Market statistics, market outlook, auction/tender updates

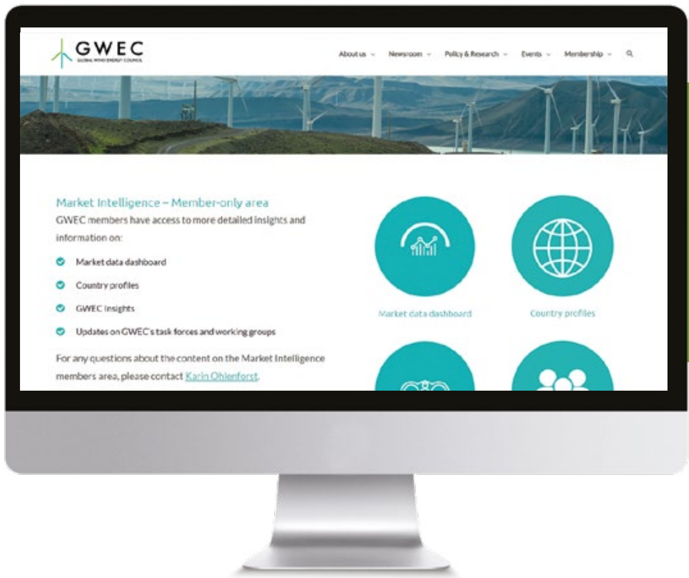
Policy and Regulations
Country profiles, policy updates, offshore updates

Asset Owners
Database of asset owners in key markets

Technology/ Supply Chain
Wind turbine data, technology trends, component assessment

Energy Transition
Shift to value-focused, new wind-based solutions

O&M
ISP - OEM - Self Perform database for key markets



GWEC Market Intelligence created a Member-only area to provide more in-depth market intelligence to GWEC's members and their employees.

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GWEC Market Intelligence Products in 2022

Product	Frequency
1. Wind Energy Stats/Market Data	
Wind Stats 2021 (historic annual, accumulative, decommision data)	Annual
Global Wind Report 2022	Annual
Wind Energy Statistics (wind energy penetration rate, jobs)	Annual
2. Country Profiles/Policy Updates	
Country Profiles Onshores/Country Profiles Offshore	Quarterly/Ad-hoc
Ad-hoc Policy Updates	Ad-hoc
3. Market Outlook	
Global Wind Market Outlook 2022-2026 (Q1 and Q3) Database + Report	Semi-Annual
India Market Outlook Report 2022-2026	Annual
Global Wind Workforce Outlook 2022-2026	Annual
4. Supply Side Data	
Global Wind Turbine Supply Side Data Report 2021 (by OEM, by technology, by turbine ratings, models and drive train, etc)	Annual
5. Auctions/Tenders	
Global Wind Auction Database Annual/Quarterly Auction Trends and Learnings	Quarterly
6. Offshore Wind Market	
Global Offshore Wind Report 2022 Annual Market Entry Opportunities Database	Annual/Quarterly
Global Offshore Project Pipeline (database, in operation and under construction)	Annual/Quarterly
Global Offshore Turbine Installation Vessel Database and Report	Annual/Quarterly
7. Components Assessment	
Gearbox (2019), Blade (2020), Generator (2021), Gearbox (Q4 2022), followed by other components	Special Report
8. Wind Asset Owners/Operators	
Asset Owners and Operators Database (Onshore & Offshore Ranking)	Annual
Asset Owners and Operators Status Report (including strategical trends)	Annual
9. O&M	
O&M Service Provider Database (ISP - OEM - Self-perform)	Annual
O&M Service Provider Status Report (including regional trends)	Annual
10. Energy transition, Digitalisation, New Technologies	
Position papers/ studies - permitting, Corporate PPAs Special Report New solutions, GWEC policy recommendations	Special Report

As the world recovered from the Covid-19 pandemic, we entered 2021 battle-hardened but ready to face the challenges of the "new normal." For the Women in Wind Global Leadership Program (WIW), 2021 was the year we remained resilient and responsive. We welcomed the third cohort of the program with 21 participants. WIW also hosted its first-ever virtual Study Tour designed to engage participants in an international learning and networking experience in addition to equipping them with practical skills and industry knowledge such as engaging participants in a 2-day PPA Academy hosted by Study Tour Partner Pexapark.

However, the pandemic deepened pre-existing inequalities and exposed the vulnerabilities of our social, economic and political systems. As the global community examines the path to green recovery and sustainable growth, diversity and inclusion must be mainstreamed as a priority. Gender equality is crucial to the design of effective climate policies, and national and international efforts to tackle climate change must address the need for shared empowerment and innovation to be successful.

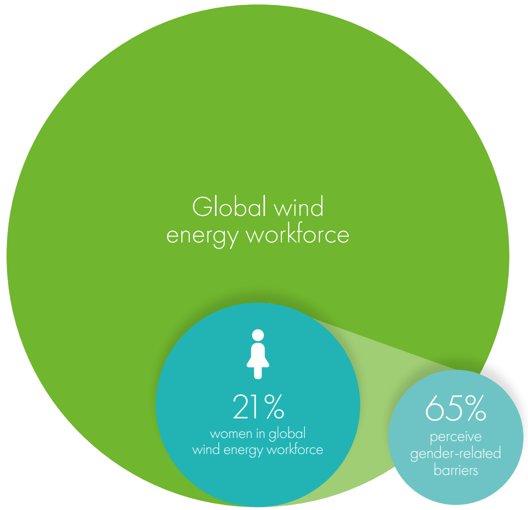
Women's contributions are critically important in supporting the growing wind industry during a momentous transition towards a more sustainable energy system benefiting all of humanity. However, a study by IRENA and Women in Wind published in 2020 found that women currently make up only 21% of the global wind workforce, and the majority owf women in the sector perceive gender-related barriers to their retention and/or advancement.

GWEC and GWNET call on stakeholders across the wind and renewables industries to recognise the importance of equal participation in the fight against climate change. In uplifting the next generation of stewards for a sustainable energy system, we affirm that our efforts are in alignment with UN Sustainable Development Goal 5 (achieve gender equality and empower all women and girls) and UN Sustainable Development Goal 7 (ensure access to affordable, reliable, sustainable and modern energy for all).

About the Program

Established in 2019, the Global Wind Energy Council (GWEC) and the Global Women's Network for the Energy Transition (GWNET) jointly launched the Women in Wind Global Leadership Program as a response to the call for more consideration of gender and climate policy, which has been growing in volume in recent years. The program is designed to accelerate the careers of women in the wind industry, support their pathway to leadership positions and foster a global network of mentorship, knowledge-sharing, and empowerment. Greater gender diversity brings valuable perspectives to social and economic development and – in the landscape of global issues requiring strong leadership and a skilled workforce – few areas are as critical as climate change and the transition to a sustainable, clean energy system.

Find out more and join us: https://gwec.net/women-in-wind/about-the-program/
Instagram: @WeAreWomenInWind



Women make up 21% of the global wind energy workforce, and 65% of them perceive gender-related barriers in the sector
Source: 2019 study by IRENA and Women in Wind, with nearly 1,000 respondents from 71 countries

Jointly organised by:

GWNET Global Women's Network for the Energy Transition | GWEC Global Wind Energy Council

GWEC Global Leaders

The Global Wind Energy Council's Global Leaders are an exclusive leadership group of decision-makers and top-tier members who form the basis of the Association's Executive Committee, which drives the work programme and plays a major role in shaping GWEC's priorities for its efforts in the short and long-term strategy.

Siemens Gamesa

Siemens Gamesa unlocks the power of wind. For more than 40 years, we have been a pioneer and leader of the wind industry, and today our team of more than 26,000 colleagues work at the center of the global energy revolution to tackle the most significant challenge of our generation – the climate crisis. With a leading position in onshore, offshore, and service, we engineer, build and deliver powerful and reliable wind energy solutions in strong partnership with our customers. A global business with local impact, we have installed more than 120 GW and provide access to clean, affordable and sustainable energy that keeps the lights on across the world, while supporting the communities where we operate.

Shell

Shell is building a global integrated power business spanning electricity generation, trading and supply. Shell entered the offshore wind business in 2000 as part of a consortium that installed the first offshore wind turbine in UK waters. Today, we have deployed, or are developing, over eight gigawatts (GW) of wind across North America, Europe, the UK, and Asia. We see offshore wind as a critical way of generating renewable electricity for our customers and moving Shell towards its target of being a net-zero emissions energy business by 2050 or sooner, in step with society.

Ørsted

The Ørsted vision is a world that runs entirely on green energy. Ørsted develops, constructs, and operates offshore and onshore wind farms, solar farms, energy storage facilities, renewable hydrogen and green fuels facilities, and bioenergy plants. Moreover, Ørsted provides energy products to its customers. Ørsted is the only energy company in the world with a science-based net-zero emissions target as validated by the Science Based Targets initiative (SBTi). Ørsted ranks as the world's most sustainable energy company in Corporate Knights' 2022 index of the Global 100 most sustainable corporations in the world and is recognised on the CDP Climate Change A List as a global leader on climate action.

Mainstream Renewable Power

Mainstream Renewable Power is a leading pure-play renewable energy company, with wind and solar assets across global markets, including in Latin America, Africa, and Asia-Pacific. Mainstream is one of the most successful developers of gigawatt-scale renewables platforms, across onshore wind, offshore wind, and solar power generation. It has successfully delivered 6.5 GW of wind and solar generation assets to financial close-ready. In May 2021, Aker Horizons acquired a 75% equity stake in the company, accelerating its plans to deliver its high-quality pipeline of over 16 gigawatts of clean energy. Mainstream has raised more than EUR3.0bn in project finance to date and employs more than 420 people across five continents.

GE Renewable Energy

GE Renewable Energy harnesses the earth's most abundant resources – the strength of the wind, the heat of the sun and the force of water; delivering green electrons to power the world's biggest economies and the most remote communities. With an innovative spirit and an entrepreneurial mindset, we engineer energy products, grid solutions and digital services that create industry-leading value for our customers around the world.

Iberdrola

With over 170 years of history behind us, Iberdrola is now a global energy leader, the number one producer of wind power, and one of the world's biggest electricity utilities in terms of market capitalisation. We have brought the energy transition forward two decades to combat climate change and provide a clean, reliable and smart business model, to continue building together each day a healthier, more accessible energy model, based on electricity

Vestas

Vestas is the energy industry's global partner on sustainable energy solutions. We design, manufacture, install, and service wind turbines across the globe, and with +151 GW of wind turbines in 86 countries, we have installed more wind power than anyone else.

Through our industry-leading smart data capabilities and +129 GW of wind turbines under service, we use data to interpret, forecast, and exploit wind resources and deliver best-in-class wind power solutions. Together with our customers, Vestas' more than 29,000 employees are bringing the world sustainable energy solutions to power a bright future.

Equinor

We are looking for new ways to utilise our expertise in the energy industry, exploring opportunities in new energy and driving innovation in oil and gas around the world. We know that the future has to be low carbon. Our ambition is to be the world's most carbon-efficient oil and gas producer, as well as driving innovation in offshore wind and renewables. We plan to reach an installed net capacity of 12-16 GW from renewables by 2030, two-thirds of this will be from offshore wind. With five decades of ocean engineering and project management expertise, focus on safe and efficient operations, in depth knowledge of the energy markets, skilled personnel and a network of competent partners and suppliers, Equinor is uniquely positioned to take a leading role in the offshore wind industry. From building the world's first floating wind farm to building the world's biggest offshore wind farm we are well underway to deliver profitable growth in renewables be a leading company in the energy transition.

Leading Sponsor

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Associate Sponsors

Iberdrola	s.ren@iberdrola.es	**Henkel**	Larissa Spilke (larissa.spilke@henkel.com)
Hamburg Messe (WindEnergy Hamburg)	info@windenergyhamburg.com	**Kavaken**	contact@kavaken.com
Lincoln Electric	Bryan O'Neil (Bryan_ONeil@lincolnelectric.com)	**NES Fircroft**	Vicki Codd (Vicki.Codd@nesfircroft.com)
Harting Electric	Guanghai Jin (Guanghai.Jin@harting.com)	**SSE**	Richard Holligan (Richard.Holligan@sse.com)
Goldwind	Corporate_Comms@goldwind.com	**Techstorm**	Martijn van Breugel (martijn@techstorm.com)
WindESCo	contact@windesco.com		

Global Wind Energy Council

Rue de Commerce 31
1000 Brussels, Belgium
T. +32 490 56 81 39
info@gwec.net

@GWECGlobalWind
@Global Wind Energy Council (GWEC)
@Global Wind Energy Council

www.gwec.net

GWEC
GLOBAL WIND ENERGY COUNCIL