

A photograph of an offshore wind turbine platform. The foreground shows a yellow safety door with a metal mesh and a yellow handrail on a metal grating deck. In the background, several wind turbines are visible on the horizon under a blue sky with light clouds.

TenneT offshore

Driving the European energy transition from the North Sea



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Changing the heart of European energy

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Secure supply from offshore

TenneT is the leading offshore transmission system operator (TSO) in the European Union and strongly positioned in the Dutch and German North Sea. With our vast experience in offshore grid development and innovative solutions in that field, we help to secure a stable supply of green energy for European households and industry alike – in an efficient, safe and sustainable way. That is our obligation. That is our expertise. That is the responsibility we shoulder.

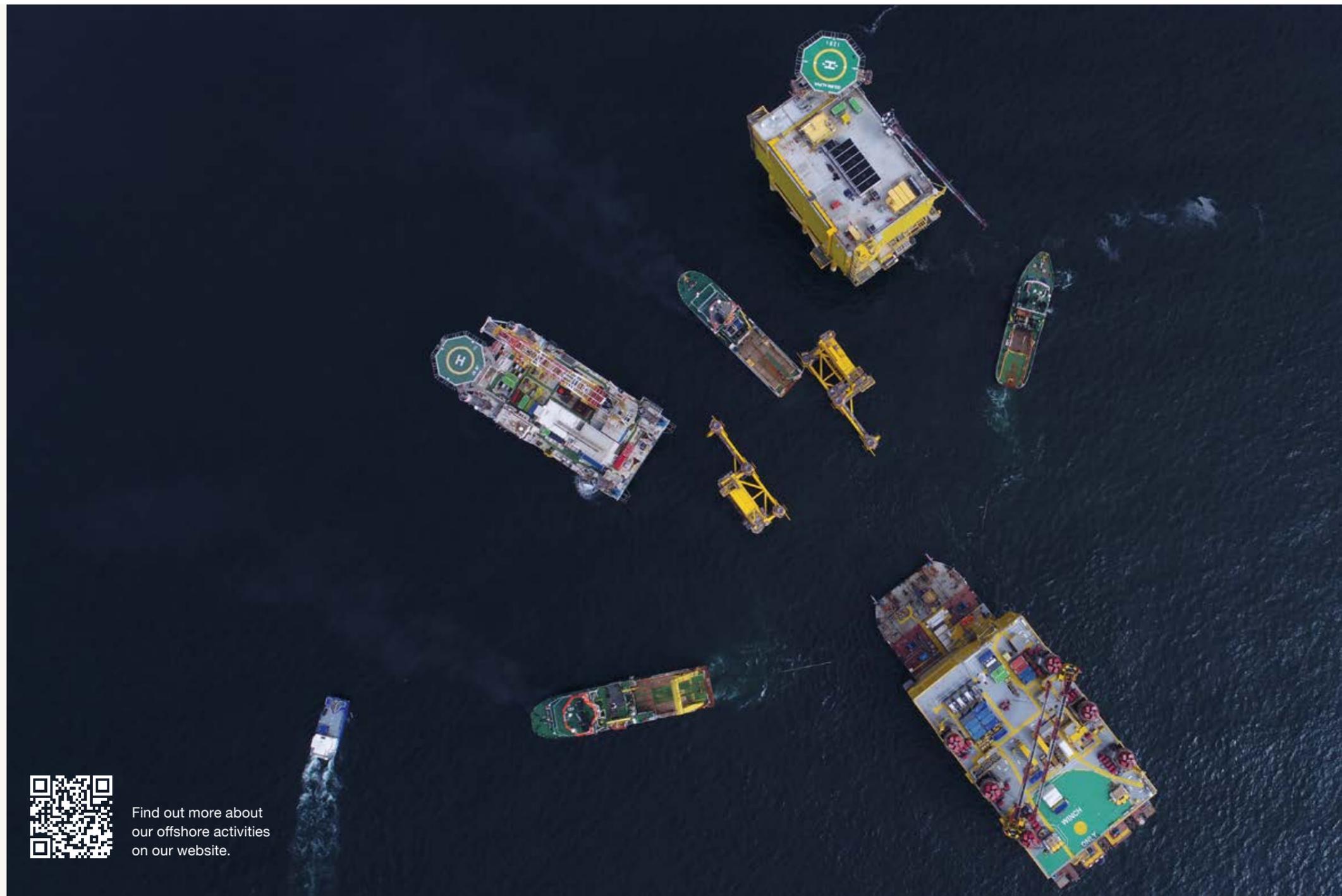
With our current offshore grid connection systems, we safely transmit more than half of the EU's entire offshore wind capacity from sea to land. To satisfy rising demand for green energy in Europe, we are working hard and systematically to expand our offshore energy grid – at an increasing pace. TenneT aims to deliver another 22 offshore grid connection systems in Germany and the Netherlands by 2031. 14 of these will be built according to our new innovative standard.

Investing in a green energy future

Over the next decade, TenneT will invest more than €40 billion in offshore grid expansion for its latest projects, making us one of the largest investors in Europe's path to a green energy future. With this commitment, we will change the very heart of European energy, shifting it away from fossil fuels towards an independent supply with domestic green energy.

There are, however, tremendous challenges ahead of us – a strong need for acceleration of offshore grid expansion, global supply chain issues and tight market capacities, just to name a few. More than ever, it will require long-term time and investment planning – nationally and internationally – to make the energy transition a success story. As a reliable transnational TSO with decades of experience in the development, installation and operation of offshore grid connection systems, TenneT is uniquely positioned to get the job done. We can draw on the knowledge gained from implementing 17 offshore grid connection systems and four interconnectors in both our operating countries – with many more in the making.

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Find out more about our offshore activities on our website.

Harnessing the North Sea's full potential

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Clean energy from our green powerhouse

Europe is determined to become the first climate-neutral continent by 2050. Germany even aims to achieve net zero by 2045. Meanwhile, compared to 1990 levels, the Netherlands plans to reduce its greenhouse gas emissions by 49% by 2030 and by 95% by 2050. As a green TSO, TenneT embraces these goals and supports both countries and the EU on their individual and collective journeys.

These journeys will entail a major increase in electrification. In the EU, the share of electricity in the energy system is expected to grow from around 20% today to more than 50% in 2050. Without a doubt, to meet rising demand and achieve net zero, member states must quickly ramp up their renewable energy supplies. Part of the solution to this, however, is right on our doorstep.

At TenneT, we believe that the North Sea holds one of the keys to achieving Europe's climate goals. No other place in Europe offers so much potential for a green, safe and independent energy supply. At present, installed capacities in the North Sea account for more than 75% of all offshore wind infrastructure in Europe. According to estimates, the North Sea offers a potential of up to 300 gigawatt (GW). This equals to more than 1,000 terrawatt-hours (TWh) per annum and could cover the yearly electricity demand in Germany, Denmark, the Netherlands and the UK – or in other words: almost a third of Europe's current total demand.

Offshore electricity from our green powerhouse is the natural choice to ...



... provide households with affordable green energy.



... facilitate the production of green hydrogen for energy-intensive sectors.



... fuel industry in the bordering countries with renewables.



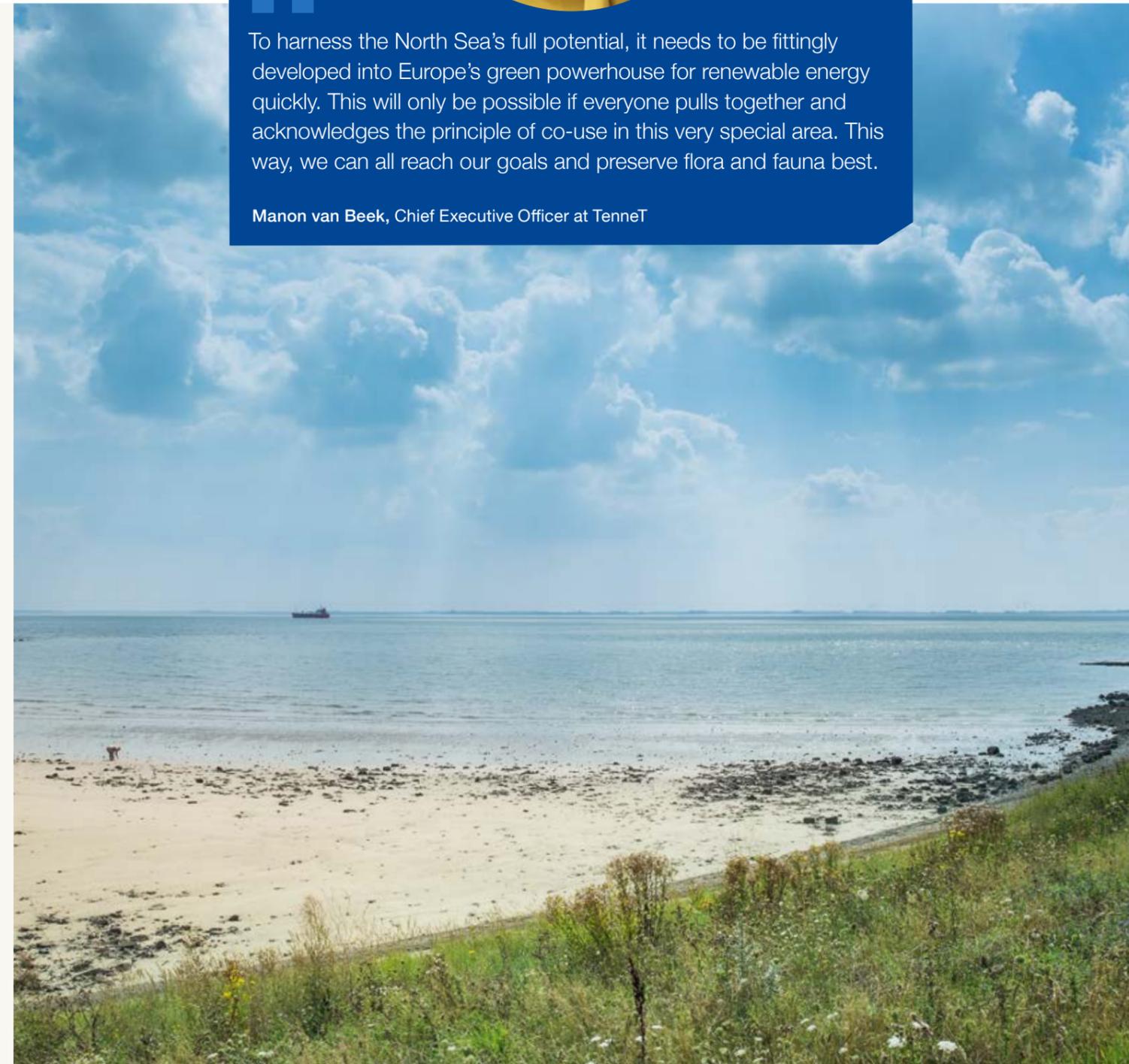
... offer the possibility of hedged prices.

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To harness the North Sea's full potential, it needs to be fittingly developed into Europe's green powerhouse for renewable energy quickly. This will only be possible if everyone pulls together and acknowledges the principle of co-use in this very special area. This way, we can all reach our goals and preserve flora and fauna best.

Manon van Beek, Chief Executive Officer at TenneT



Europe's offshore wind energy targets in comparison



The EU, Germany and the Netherlands have set ambitious offshore energy goals for 2030 and beyond. Together with Belgium and Denmark, Germany and the Netherlands have agreed on even more ambitious targets in the Esbjerg Declaration.

The ambitious offshore energy goals give strong political backing to the development of the North Sea. But they must now be followed by action. In addition to rapidly increasing capacities, we must also urgently expand our grid connection systems to safely bring the much-needed green energy from sea to land.

Tim Meyerjürgens
Chief Operating Officer at TenneT



Guiding through experience and know-how

The EU has emphasised the North Sea's potential in its 2020 offshore wind strategy and set ambitious offshore energy goals: it targets at least 60 GW of offshore wind capacities by 2030 and 300 GW by 2050. For 2030, Belgium, Denmark, Germany and the Netherlands have gone even further. In the Esbjerg Declaration, they agreed on a combined production of 65 GW of offshore wind energy from the North Sea. By 2050, the offshore output is to climb to 150 GW – more than a tenfold increase compared to today.

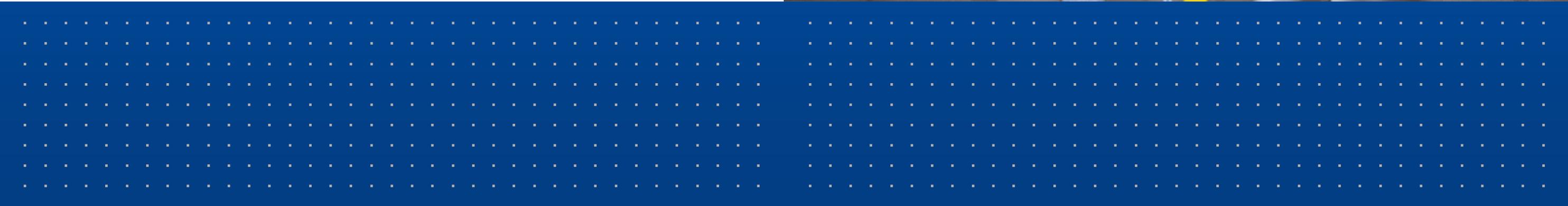
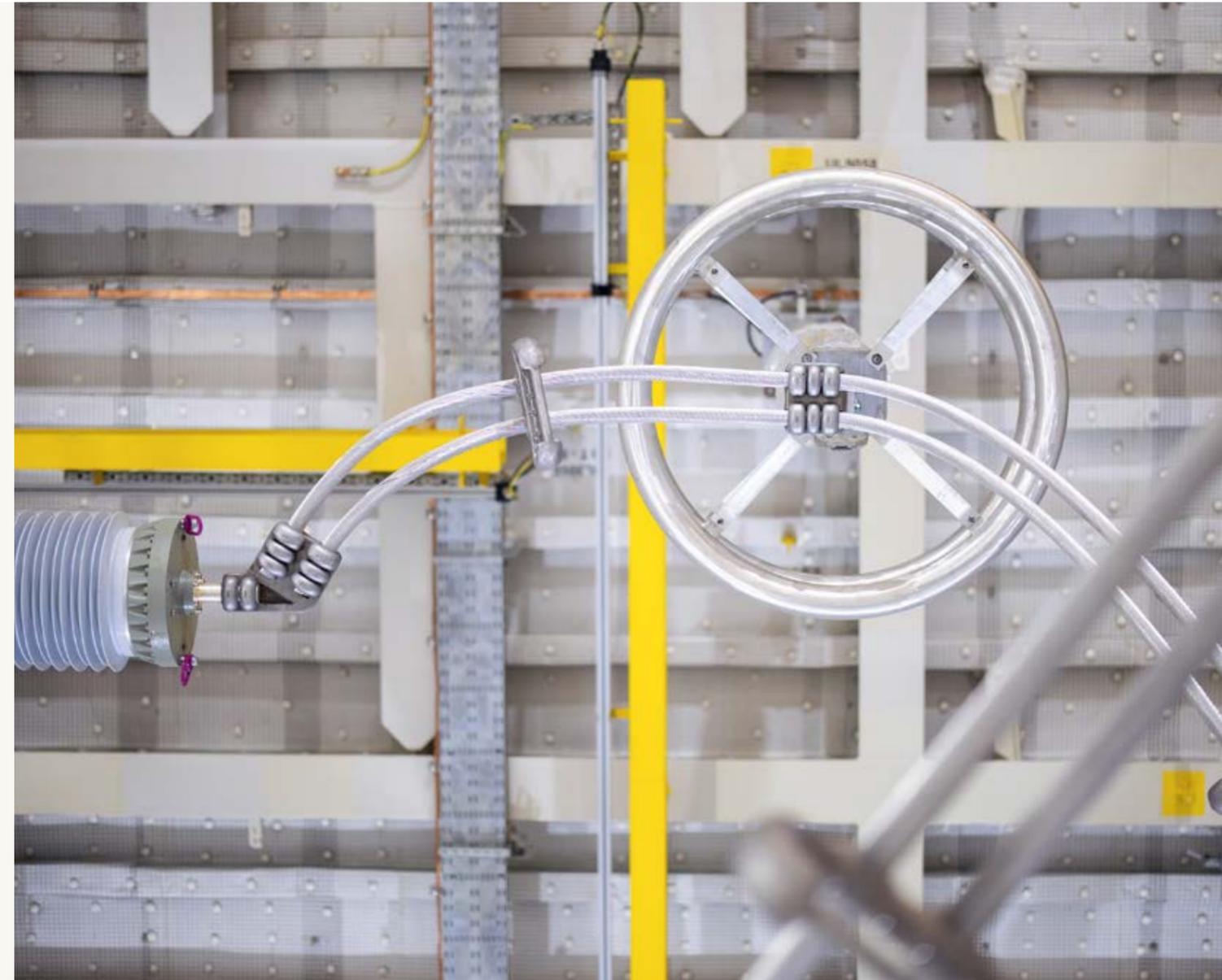
At TenneT, we can rely on decades of experience and know-how when it comes to connecting offshore wind farms to land. In 2009, we marked the beginning of a new era when we delivered alpha ventus, Germany's first offshore grid connection system, a 66-kilometre-long alternating current (AC) link. Only a year later, we put BorWin1 into operation, the world's first direct current (DC) offshore grid connection system, 200 kilometres (km) long and 400 megawatt (MW) strong. Since then, we have added another 15 offshore grid connection systems to our roster – providing roughly 10.6 GW, or enough to supply more than 13 million households with clean energy from the North Sea. With an additional capacity of 3.8 GW, our offshore interconnectors round off our portfolio.

However, we need to significantly increase our delivery capability. Since this cannot be achieved by linear growth alone, we have put our emphasis at an early stage on developing new standards for offshore grid connection systems. Through standardisation and harmonisation as well as technological innovations, we aim to make planning and implementing new offshore grid connections much easier, more efficient and wind energy from the North Sea scalable. This way, we can save time, resources and money – and help to deliver more and more power from sea to land. Ever since our first connection, we have continuously developed new

standards to transmit ever-larger capacities of energy from the North Sea: from 700 MW AC to 400 MW DC to 900 MW DC to, most recently, a whole new level: our new 2 GW high-voltage direct current (HVDC) standard for offshore grid connection systems. It has the capacity to handle an energy volume more than twice as large as previous systems. What's more, DC in general is much more suited for connecting wind farms that are more distant from the mainland, since this form of electricity can transmit large volumes of energy over long distances with less energy loss compared to AC.

The evolution of transmission capacity

2 GW back then and now



Steering the way towards a meshed offshore grid

Energy landscape of the future

With its immense degree of harmonisation, our new 2 GW standard lays the urgently needed foundation for a much stronger form of European energy cooperation: a fully meshed European cross-border HVDC offshore grid system in which green wind energy can be allocated flexibly and used much more efficiently among the North Sea states. As an experienced cross-border TSO, TenneT can make a significant contribution to this vision.



Exemplary illustration

Thinking ahead through partnership

Facilitation of offshore grid expansion

Tackling Europe's green transition from offshore is a highly promising endeavour – and an enormous challenge. More and more wind farms as well as offshore grid connection systems must be built in less and less time. At the same time, fragile supply chains and sharply rising prices on the world market, such as for raw materials, make prompt and cost-efficient implementation increasingly difficult. We have to deal with these challenges together – in a collective feat of strength. Given these circumstances, we have made partnership a core value in our operations and fostered a fundamental change in values. Together with the market, we now form even stronger partnerships. We are committing to each other and will – as a team – facilitate expansion in a safe and sustainable way, manage costs and conserve resources. Forming the foundation for this will be mutual trust and transparency.

In close collaboration with the market and in accordance with the 2 GW standard of our offshore grid connection systems, we have launched an innovative market approach. Instead of tendering each offshore grid connection system individually, we now set up framework agreements for technological components for a whole series of systems with several partners at once.

With our framework agreements, we are addressing the big picture and providing a holistic and concrete action plan to further step up offshore grid development – and to deliver in scope and budget.

Our partnering approach

- brings together the right actors at the right time.
- pools know-how from leading offshore companies along the entire value chain and creates useful synergies.
- increases essential capacities in a progressively tight market in a timely fashion.

With a total investment of roughly €40 billion, we are providing both growth opportunities and maximum planning security for everyone involved. We will stimulate the entire market and set incentives for further investment, for creating and securing jobs, and for establishing new industries in the vicinity of our systems.





Greening our industry and safeguarding economic prosperity

Industry can particularly benefit from this forward looking partnering approach and our offshore grid expansion. After all, it faces the immense challenge – especially in energy-intensive sectors – of reducing its emissions to zero in the years ahead. This is an especially daunting task in Germany, where industry’s share in gross value lies at 20%, or almost twice as much as that of the United States. As the backbone of Germany’s economy, industry is responsible for over 40% of primary energy consumption. To ensure that the green transition in industry is widely accepted, there is a need for clever and cost-efficient solutions. With green wind energy from the North Sea, the key is right on our doorstep. Using our current radial offshore grid connection systems, we deliver clean wind power from the North Sea without detours to where it is needed most – namely, in large industrial centres, which can consequently take important steps towards decarbonisation by converting their energy supply to renewables. This way, our offshore connections are helping to safeguard prosperity in Germany and the Netherlands.

Pulling together towards the same goal

On a national basis, we work closely with other TSOs (in Germany, we are one of four) and authorities. Hence, cooperation and integration are the way forward. We will only be able to deliver well-thought-out development and grid planning together. And we can team up for beacon projects, such as Europe’s first multi-terminal hub in the Heide region of Schleswig-Holstein. We are also showing how large projects – such as the DC connections SuedLink and SuedOstLink – can be successfully implemented onshore together with other TSOs so that industry’s demands for green energy are also successfully met.

The same holds true on the international level. To achieve Europe’s climate targets and secure energy supplies, we need to link and, even more importantly, to integrate markets, grids and technologies in a smart and reliable way – with the ultimate goal of eventually having a fully meshed DC grid in the North Sea. In view of the current challenges, this is more important than ever. Hence, we are working closely with European TSOs as well as other relevant players and authorities to make our vision a reality. After all, when it comes to offshore, we – as TenneT – are pioneers by DNA.

There are several initiatives that illustrate our collaborative approach, such as:



The HVDC-WISE initiative, which is backed by the EU’s Horizon Europe programme and seeks to strengthen European system reliability and resilience through an integrated European HVDC grid.



Furthermore, we are member of the TSO association ENTSO-E as well as the Renewable Grid Initiative (RGI) and the European Commission’s Working Group on Offshore Renewable Energies, reporting to the Clean Energy Industrial Forum.



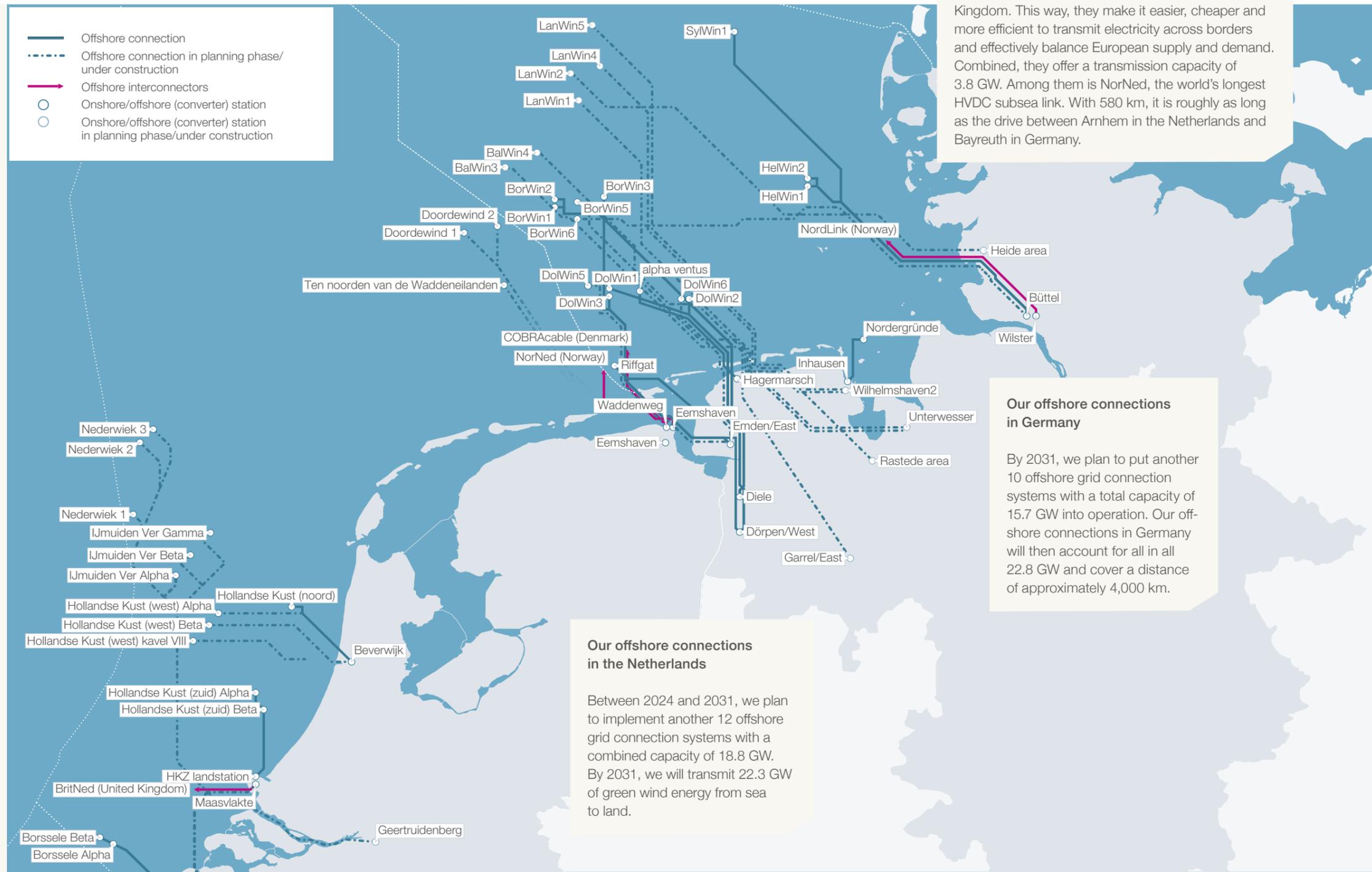
We are also actively participating in the InterOPERA initiative, where we help to make future HVDC systems mutually compatible and interoperable by design.

And we have already shown that we can successfully carry out lighthouse projects in international cooperations, as can be seen with the important European interconnectors NordLink and COBRACable, for example.

Connecting Europe every day

Clean energy for roughly 18 million households

With our offshore solutions and initiatives, we are supporting the European energy transition and helping to make Europe's energy supply safe and independent. We draw on the knowledge gained from implementing 17 offshore grid connections and four offshore interconnectors that transmit green energy across European borders in the North Sea region. Combined with our interconnectors, our offshore connections cover more than 3,600 km and account for 14.4 GW, enough to supply roughly 18 million households with clean energy. And there's much more in the making. We are planning to implement another 22 offshore grid connection systems with a total capacity of 34.5 GW in the North Sea region by 2031 – 10 in Germany and 12 in the Netherlands. In doing so, we will more than triple our current transmission capacity. This will be a mammoth task. And one that we will only be able to successfully accomplish if all of us – industry, politics and society as a whole – pull together.



- Offshore connection
- - - Offshore connection in planning phase/under construction
- Offshore interconnectors
- Onshore/offshore (converter) station
- Onshore/offshore (converter) station in planning phase/under construction

Balancing European demand and supply

Our four offshore interconnectors are beacons of European energy cooperation. They link Denmark, Germany, the Netherlands, Norway and the United Kingdom. This way, they make it easier, cheaper and more efficient to transmit electricity across borders and effectively balance European supply and demand. Combined, they offer a transmission capacity of 3.8 GW. Among them is NorNed, the world's longest HVDC subsea link. With 580 km, it is roughly as long as the drive between Arnhem in the Netherlands and Bayreuth in Germany.

Our offshore connections in Germany

By 2031, we plan to put another 10 offshore grid connection systems with a total capacity of 15.7 GW into operation. Our offshore connections in Germany will then account for all in all 22.8 GW and cover a distance of approximately 4,000 km.

Our offshore connections in the Netherlands

Between 2024 and 2031, we plan to implement another 12 offshore grid connection systems with a combined capacity of 18.8 GW. By 2031, we will transmit 22.3 GW of green wind energy from sea to land.



Find out more about our offshore projects and interconnectors.



Delivering wind energy safely from sea to land

Due to different connectivity concepts, our grid connection systems vary in design and scope. The choice of concept depends on several factors, such as the distance of transmission or the form of electric current used. In Germany, the scope of the latest standard for offshore grid connection systems is regulated by various planning tools, such as the area development plan (FEP). The FEP 2023 states that future wind farms will be connected directly to the offshore converter at sea via 66 kilovolt (kV) cables and 132 kV for DC systems commissioned in and after 2032. This means that the electricity generated at sea is fed directly to TenneT's offshore platform. The actual conversion from AC to DC takes place at the station itself. The electricity is then transported by sea cable to the mainland and, subsequently, by underground land cable to the onshore converter station. There, it is converted back to AC and fed into the extra-high-voltage grid.

In the past, other connectivity concepts have been used, too. Wind farms in the proximity of the coast are connected via AC, which is technically and economically efficient. Here, electricity from the wind farm is collected at a substation at sea. From here, the electricity is transmitted to a substation on land. In Germany, the energy

is now fed into the onshore grid. In the Netherlands, the energy passes a second substation before being fed into the onshore grid.

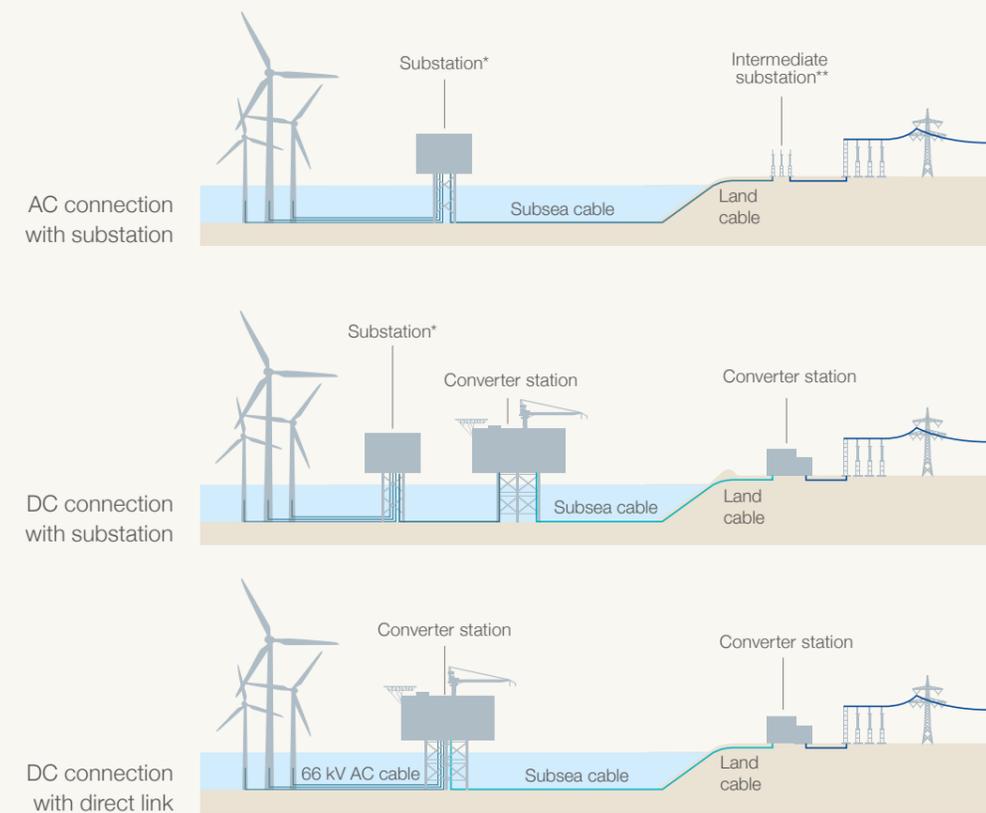
For longer distances and higher transmission capacities, HVDC is the best way to keep losses to a minimum. Here, electricity generated at sea is collected in the wind farm's own substation. From there, it is fed to TenneT's offshore converter station via a 155 kV AC cable. The conversion from AC to DC takes place in the converter station at sea. The electricity is then transported by sea cable to the mainland and, after landing ashore, by underground land cable to a converter station. Here, the electricity is converted back into AC and then – via a substation – fed into the extra-high-voltage grid.

Regardless of the connectivity concept applied, we take our responsibility and obligations very seriously. When planning and implementing our offshore grid connection systems in the sensitive North Sea region, safe operations and the protection of the environment are our top priorities. We limit interventions to a minimum. This applies both to planning and approval processes as well as to the construction and operation of our facilities.

In addition to developing and building offshore grid connection systems, TSOs also need the stamina to maintain them for decades. We are on it, as we attend to the safe and sustainable operation of our offshore connections to keep them up and running – in all weathers, 24 hours a day, and with the greatest care for our people and the environment. Our experts in the field and our control centres bear witness to this.

How we connect wind farms off the coast to the onshore grid

Our connectivity concepts in comparison



* In Germany, wind park operator's responsibility
 ** Applicable only in the Netherlands

We care

People. Planet. Financial well-being.

As a leading offshore TSO, we also aim to take a corresponding role in terms of how responsibly we conduct our business. And even though we quickly need to ramp up our capacities in power transmission in the North Sea to satisfy growing demand for renewables, this can only happen in a sustainable way – with regards to the environment and people alike. For us, this means being responsible when it comes to the materials we use to create our assets and their long-term value for society. It means there are limits to the spaces available for us to build and operate our assets in the natural environment. And it also means we have to guarantee a safe work-place for our people. To protect nature and people, we have formulated a Code of Conduct featuring clear guidelines on how we carry out construction, operations

and maintenance – always in accordance with safety rules and nature conservation laws, and therefore in a way that protects society as well as flora and fauna. We have also translated our ambitious sustainability goals into guidelines in all our tendering procedures in order to achieve an integrated technical, ecological and social design. Every day, we challenge our partners to follow our mindset regarding four overarching themes: climate impact, circularity, nature-inclusive design and safety.

We also accept our responsibility as a player in the European financial market. As a company, we are the largest issuer of so-called “green bonds” in Europe. These are bonds to finance sustainable projects.

“At TenneT, we care about the people who drive the energy transition – no matter if they work for us or our partners. We strive to ensure a fair, inclusive and safe working environment along the whole value chain.

Akshaya Prabakar
CSR Program Manager at TenneT



Climate impact

Be it in construction, the transport of materials, or the travel behaviour of project staff and other parties, everything counts when it comes to environmental impact. Hence, we require every contractor to demonstrably reduce CO₂ emissions according to the Environmental Cost Indicator methodology when carrying out operations for us. Furthermore, we only carry out our operations in sensitive habitats, such as the Wadden Sea, when regulations and time allows.



Circularity

Since raw materials are scarce, circularity is not a luxury but a necessity. When tendering, we encourage all our partners to choose materials that can be used longer, are environmentally-friendly and can be reused after use. To this end, we ask contract partners to investigate where materials come from as well as how they are processed, transported and subsequently reused. In tenders for cables, for example, we now ask for a minimum of 25% recycled copper. By actively asking for it, we are seeing increased application.



Nature-inclusive design

All our assets affect nature simply because of their location – both at sea and on land. Given this fact, we explicitly ask contractors to critically look for opportunities to integrate nature into our technical designs. We are looking for ways to increase biodiversity and the quality of life for animals and plants. We expect our contractors to think proactively about which nature-enhancing measures are suitable to apply. And we have done so with success, as numerous new measures have become standards and are now being monitored for their ecological success. Some of our measures are already applied during installation. For example, with bubble curtains around our offshore platforms, we protect animals in the vicinity of the construction works.



Safety

In addition to having an eye for technology, we also look out for people – our own and those of our suppliers and contractors, as defined in our Code of Conduct. Our safety vision is Zero Harm. To reach this, we have stepped up our commitment to safety and initiated the Safety Strategy 2025. Our goal is to improve our safety performance by making it even more central to our culture and everyday operations. For this to happen, we have translated our strategy into a Safety Roadmap, which contains specific measures that we will pursue to realise our Zero Harm vision.





Making visions reality

Next chapters after a technological evolution

To achieve the ambitious offshore wind energy targets in Germany, the Netherlands and Europe, a vast number of offshore grid connection systems must be installed in the North Sea in a timely fashion. The acceleration in grid expansion needed for this will be supported by increasing the individual transmission capacity per system while introducing comprehensive standardisation at the same time.

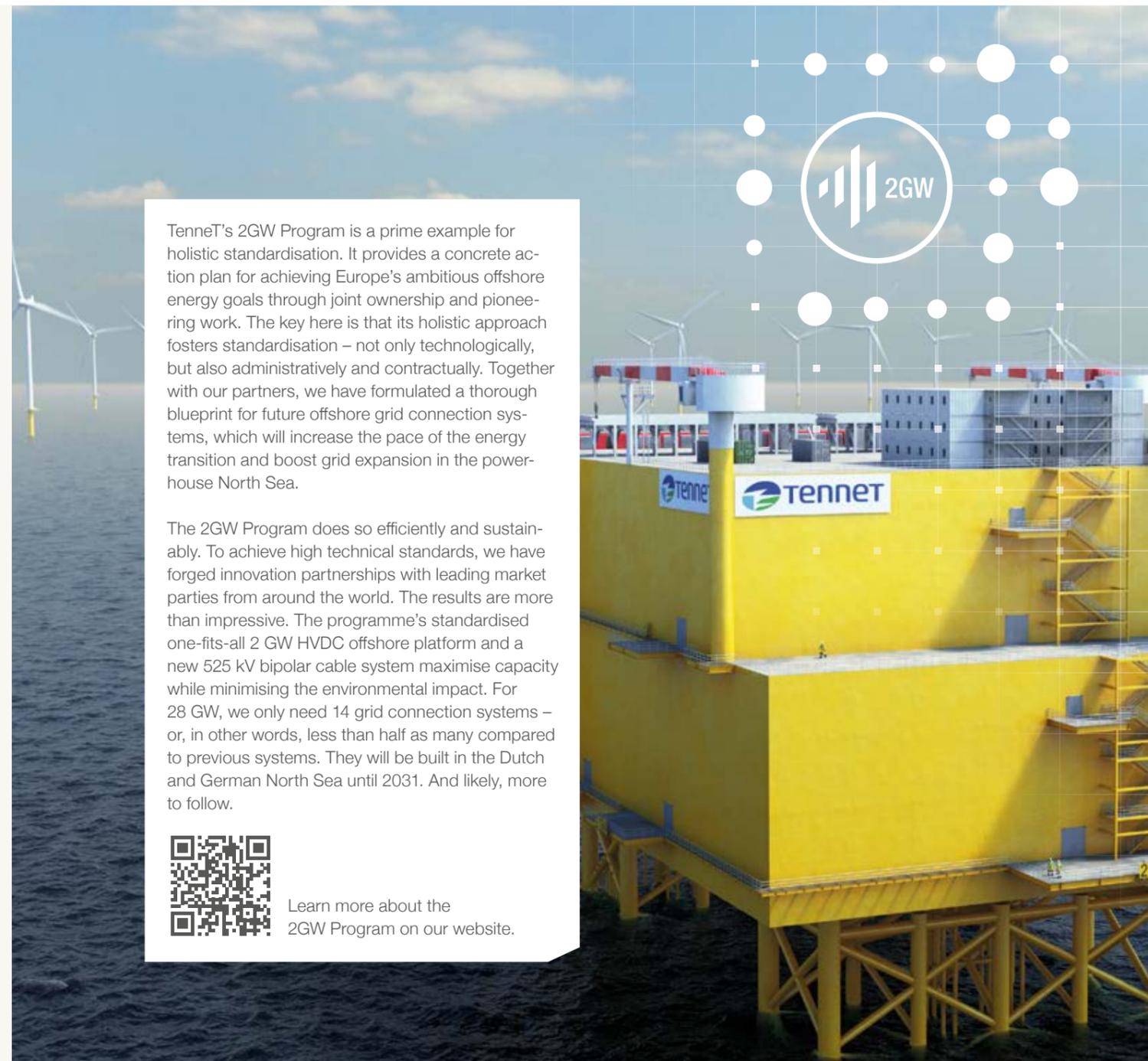
The foundation for a swift acceleration will be the standardisation and harmonisation of technological components.

This will ...

- enable a comprehensive transfer of knowledge between all parties involved.
- make cooperation much easier.
- simplify planning and implementing additional systems.
- make green wind energy from the North Sea scalable.
- allow us to get a step closer to an integrated, meshed DC offshore grid.

To deliver on the rapidly increased offshore wind targets, we aim for the full picture. First, we developed our approach into an innovative standard: the next generation of offshore grid connection systems. And now, we keep pushing as one team together with our partners. By accelerating innovations, we contribute to a fully meshed future grid in the North Sea. We want to make visions reality.

Marco Kuijpers
Director Large Projects Offshore at TenneT

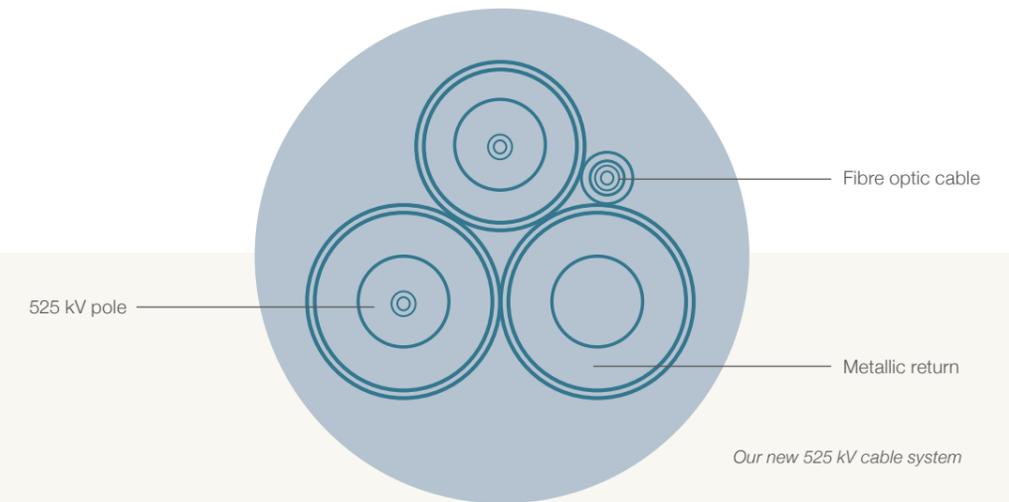


TenneT's 2GW Program is a prime example for holistic standardisation. It provides a concrete action plan for achieving Europe's ambitious offshore energy goals through joint ownership and pioneering work. The key here is that its holistic approach fosters standardisation – not only technologically, but also administratively and contractually. Together with our partners, we have formulated a thorough blueprint for future offshore grid connection systems, which will increase the pace of the energy transition and boost grid expansion in the powerhouse North Sea.

The 2GW Program does so efficiently and sustainably. To achieve high technical standards, we have forged innovation partnerships with leading market parties from around the world. The results are more than impressive. The programme's standardised one-fits-all 2 GW HVDC offshore platform and a new 525 kV bipolar cable system maximise capacity while minimising the environmental impact. For 28 GW, we only need 14 grid connection systems – or, in other words, less than half as many compared to previous systems. They will be built in the Dutch and German North Sea until 2031. And likely, more to follow.



Learn more about the 2GW Program on our website.



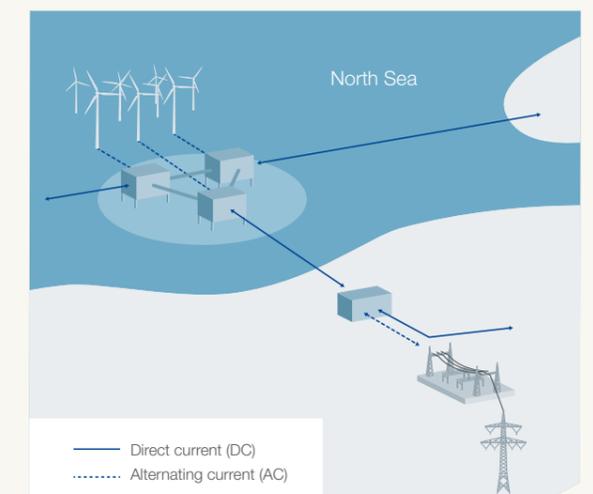
Increasing capacities through innovations

Together with leading companies from our sector, we have developed central components of our offshore grid connection systems. These are a standardised HVDC platform and a new 525 kV cable system. The new cable system is a bundle of four individual cables. It consists of a negative and a positive 525 kV pole, a metallic return and a fibre-optic cable. The system has a significantly higher capacity than its predecessors and enables a more cost-efficient transmission over long distances. It also reduces environmental impact because fewer cables are needed to transmit the same amount of energy. The metallic return built into the new cable system ensures that the system can continue to operate at 50% of its capacity even in the event of a cable fault.

We also joined forces with industry partners in an innovation partnership for our new HVDC platform standard. The goal was to establish a common language, so to speak, when it comes to technical design and to have a one-for-all model. As a result, an innovative and standardised multi-vendor HVDC platform model was developed featuring technology that will ultimately enable us to guarantee a transmission capacity of 2 GW.

Most importantly, our new platforms are planned to be multi-terminal ready. In other words, they have the technological prerequisite to allow point-to-point connections to be extended to different types of multi-purpose interconnectors (MPIs). In the future, they could

potentially link offshore converters and energy systems, even across borders. With this degree of technological innovation, TenneT paves the way and lays the foundation for a fully meshed European cross-border HVDC offshore grid system in which renewable energy can be allocated flexibly and efficiently across the North Sea region. Our new technologies are showcases for European cooperation, integration and standardisation – and will enhance security of supply across the continent.



Our offshore converter stations will be multi-terminal ready in the long run and can potentially connect different countries' energy systems to allocate renewable electricity even more efficiently while further stabilising our networks.

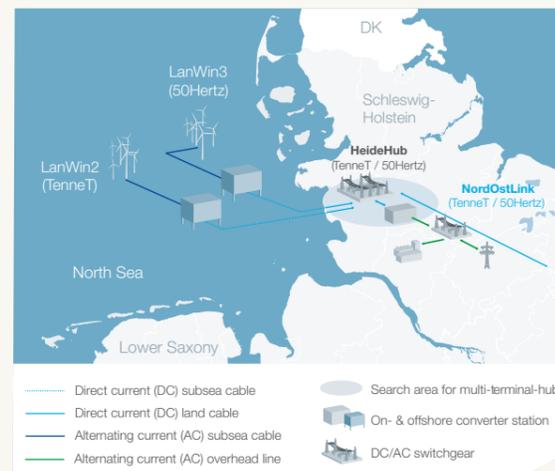
Steering the way

Interoperable hub technologies

To bring the vision of a meshed DC grid closer to reality, we are participating in several European research programmes aimed at further developing standardised MPI technologies so as to facilitate cross-border connectivity. Most notably, we are contributing to the InterOPERA project, which aims to make future HVDC systems mutually compatible and interoperable by design and is backed by the Horizon Europe programme. The project brings together more than 20 European partners from the industry to facilitate the integration of renewable energy in a European DC grid. Thanks to this project, offshore grid components based on different technologies and modules supplied by different manufacturers shall be able to integrate seamlessly and operate together in the future. Moreover, just like TenneT's 2GW Program, InterOPERA is not only about developing technological standards, as it also aims to facilitate agreement on the procurement, commercial, legal and regulatory frameworks – all with the goal of creating a truly European meshed DC offshore grid in the North Sea.

We are convinced that offshore hubs will also play a key role in this future and facilitate the smart use of wind energy. TenneT is currently working on planning the first offshore hubs in both the Netherlands and Germany. Here, we are drawing on our extensive knowledge and studies from the North Sea Wind Power Hub (NSWPH) programme. This programme has evolved from the

initial vision of a large international energy island into a modular concept of smaller, linkable hubs. Furthermore, we need hubs to connect off- and onshore grids. With the concept for a wind power booster, we presented a concrete and visionary idea in 2021 of how the expansion of offshore wind energy can be accelerated through the long-term meshing of the DC grid at sea and on land as well as through the clever integration of industry and electrolysis projects. In addition, together with TSO 50Hertz, TenneT will be building Europe's first multi-terminal hub in the Heide region of Schleswig-Holstein.



In the future, offshore wind will undoubtedly become an important source of green electricity and green hydrogen. And it will make a decisive contribution to the success of Europe's energy transition. With our concepts and technological designs, we are helping to make this vision a reality.



TenneT is a leading European grid operator. We are committed to providing a secure and reliable supply of electricity 24 hours a day, 365 days a year, while helping to drive the energy transition in our pursuit of a brighter energy future – more sustainable, reliable and affordable than ever before. In our role as the first cross-border Transmission System Operator (TSO) we design, build, maintain and operate 25,000 kilometres of high-voltage electricity grid in the Netherlands and large parts of Germany, and facilitate the European energy market through our 17 interconnectors to neighbouring countries. We are one of the largest investors in national and international onshore and offshore electricity grids, with a turnover of EUR 9.8 billion and a total asset value of EUR 41 billion. Every day our 7,400 employees take ownership, show courage and make and maintain connections to ensure that the supply and demand of electricity is balanced for over 43 million people.

Lighting the way ahead together

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