Connecting wind energy
THE OFFSHORE GRID IN THE NETHERLANDS
The Dutch offshore wind programme until 2023 will provide a total capacity of at least 3,500 megawatts (MW), on top of the 1,000 MW that is already operational. Bringing this much power from sea to land will make an important contribution to the Dutch government’s renewable energy targets, as set out in the National Energy Agreement.

As TenneT is the offshore grid developer for the Netherlands and also for the German part of the North Sea, we have built up significant experience in connecting offshore wind energy and integrating it into the electricity grid, connecting over 5,300 MW of offshore wind power and more than 2,800 MW under construction. And by 2025 TenneT will provide over 10 GW transmission capacity in the German North Sea.

When developing the Dutch offshore grid, we went through an intensive consultation process that brought together experts from TenneT and leading (inter)national players in the wind energy sector. Together, we explored the technology, planning, design and construction of the offshore grid and, using all of our combined expertise, devised the optimum solution for bringing this Dutch North Sea wind power to shore.

4,500 MW
Electricity from the offshore grid is enough to power nearly half of all Dutch households.

GRID OPERATOR
The Dutch government appointed TenneT as the offshore grid operator in 2016.

ASSURED OF ENERGY
TenneT safely and securely connects the energy from the offshore wind farms to the onshore high-voltage grid.

TenneT is developing five new offshore grid connections, connecting the offshore wind farms and transporting the electricity to the onshore electricity grid and consumers. These will be constructed in stages over the next few years.
The offshore grid concept consists of standardised grid connections to wind farms built in the three wind energy zones designated by the Dutch government. They will collect the energy generated offshore and transport this to the onshore electricity grid.

**Offshore grid CONCEPT**

The platform is one of the main parts of the offshore grid. The energy generated in the wind farms is transported to an offshore platform owned by TenneT and then, via the two 220 kV AC cables, to an onshore high-voltage station. The size of the platform is optimized at 700 MW. Multiple wind farms can be connected on a 700-MW platform, which helps reduce the social cost and environmental impact. The offshore grid is compact, reliable and future-proof.

The offshore grid helps to reduce the costs of offshore wind power and reduces the impact on the environment.

**66 kV CONNECTION VOLTAGE**
The platform of the offshore grid will be the first in the world to have a connection voltage of 66 kilovolt (kV) instead of 33 kV.

**OFFSHORE PLATFORM**
The platform is the heart of the grid connection. It transforms the voltage level from 66 kV to 220 kV. It consists of a steel topside and jacket that are built separately.

**220 kV CABLES**
The 220-kV offshore cable has a diameter of approximately 280 mm and consists of three single-phase conductors, and two (or three) optical fiber cables, bound together and covered with steel wires.

**TRANSFORMER STATION**
The onshore transformer station will raise the voltage level from 220 kV to 380 kV in order to directly connect the wind energy to the onshore high-voltage grid.
TenneT has applied a ‘lean and mean’ approach. This will ensure lower costs for development, construction and maintenance of the Dutch offshore grid concept.

The excavated trench carrying the four offshore cables is 1,600 metres wide: 200 meters between the cables, with a safety zone of 500 meters on either side.

Zone for the four onshore cable systems after being laid: 19.5 meters, including safety zones. Each onshore cable system consists of three separate single-phase cables. They can also be laid in a triangular shape.

Because electricity generated by the wind varies, the load of the cables that transport the electricity must also vary. The cable can handle more than 350 MW for a temporary period of time: if the temperature of the cable doesn’t get too high, the cable can, in certain circumstances, transport an additional and temporary 30 MW. TenneT will make this dynamic loading possible under certain conditions and will keep a close eye on the temperature of the cable. Thanks to this approach, the offshore wind farm developer will have the optionality to install an additional 30 MW of wind turbine capacity, i.e. overplanting.

The platforms do not have to be permanently staffed. As such, they can be fitted out in a simple manner with fewer facilities.

The cables will go underground to the onshore transformer station and to the connection point at the high-voltage station.

The weight of the topside of the platform is purposely low so that it can be placed using standard heavy-lift ships.

TenneT is allowing the contractors to propose innovative technologies, where suitable. For instance, for building and laying the cable, TenneT will determine the installation requirements such as transport capacity, respective distances and excavation depth, while the contractor will determine the method of installation in the detailed design.

Measuring and communication equipment on the platform
The platforms will also be used as maritime information service points. This is of significant interest to various governmental and semi-governmental organisations that will benefit from a permanent measurement station in the North Sea.

A range of sensors will be installed to provide essential information, such as data on wind speed, waves, shipping, and the migration of birds and bats.

Availability of spare parts, thanks to a standardised approach. For instance, one spare transformer can boost the availability of all the offshore grid connections.

With this compact, reliable and future-proof concept, experts from the international wind energy sector, the Dutch government and TenneT will make an important contribution to cutting the costs of offshore wind power.

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**Offshore grid connections**

**IN THE NETHERLANDS AND GERMANY**

TenneT has been designing, planning, building and operating grid connections for offshore wind farms in Germany since 2006. In the Netherlands, we were formally appointed as offshore grid developer in 2016.

A few wind farms in Germany are located just off the coast. The majority of the wind farms are located further offshore and are therefore equipped with a direct current (DC) connection. Wind farms that will be built in the Netherlands before 2023, will be at a shorter distance and will therefore be equipped with an alternating current (AC) connection, which is then more efficient.

<table>
<thead>
<tr>
<th>#</th>
<th>Wind Farm</th>
<th>Connection Type</th>
<th>Distance (km)</th>
<th>Capacity (MW)</th>
<th>Location</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Borssele Alpha</td>
<td>AC</td>
<td>62</td>
<td>700</td>
<td>Borssele</td>
</tr>
<tr>
<td>2</td>
<td>Borssele Beta</td>
<td>AC</td>
<td>69</td>
<td>700</td>
<td>Borssele</td>
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<tr>
<td>3</td>
<td>Hollandse Kust (south) Alpha</td>
<td>AC</td>
<td>43</td>
<td>700</td>
<td>Maasvlakte</td>
</tr>
<tr>
<td>4</td>
<td>Hollandse Kust (south) Beta</td>
<td>AC</td>
<td>34</td>
<td>700</td>
<td>Maasvlakte</td>
</tr>
<tr>
<td>5</td>
<td>Hollandse Kust (north)</td>
<td>AC</td>
<td>-</td>
<td>700</td>
<td>Cable route and landing location being investigated</td>
</tr>
</tbody>
</table>

**Map**

[Map showing offshore wind farms and grid connections in the Netherlands and Germany]
The offshore project teams are accustomed to working in challenging circumstances, even right from the preparation phase. In this case, the practical conditions and technical requirements of the project can complicate the choice of cable track and platform location considerably.

For instance, the platforms should be easily accessible for maintenance ships, with no obstacles within a 500 m. radius and they should also be close to the wind farms, with cables kept as short as possible.

Meanwhile, the power cables should not cross pre-existing installations, such as data cables or pipelines (or at least keep this overlap to a minimum). They should also avoid areas that are important for nature, shipping, archaeology, fishing or recreation.

Unexploded ordnance on the seabed is another hazard: it is impossible to avoid all areas where there are explosives, so these obstacles need to be mapped out during the preparation process and removed if necessary.

Where possible, cables are laid in an open excavation. A trench for the cables is dug, and then buried in autochthonous material.

As TenneT explores possible routes for the grid connections, we consult with a wide range of stakeholders, including national and provincial governments, water boards, municipalities and NGOs. All stakeholders can have their say at different stages in the process. The final decision on the cable routes, landfalls and transformer stations will be made by the relevant Minister and laid down in a so-called ‘inpassingsplan’.

Once the cable route has been decided and the permits are in order, we can begin installing the offshore grid. That’s when the offshore challenges start, not least dealing with weather conditions, which can have a major impact on the work.

If an open excavation is not an option, a horizontally powered drill could be a solution. The cable gradually arrives at the desired depth through the entry point.

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Preparing for and actually building an offshore grid is an intensive process. Being ready to start installing the platforms and cables, we may also face major challenges from the weather.”
Electricity has to travel far and wide to reach households and businesses. While making this possible, TenneT takes measures to minimise the impact on nature and the environment, protecting the landscape and the biodiversity of the area.

**Considerate OF NATURE AND THE ENVIRONMENT**

As such, taking care of nature and the environment is an integral part of our work to develop the offshore grid. For instance, there is a detailed study of the environmental effects of the alternative routes. They are outlined in an environmental impact report (known as MER in Dutch) and help determine the final route choice.

Onshore work activities are done in such a way that breeding birds or other protected species of animal or plant are not disturbed. TenneT makes sure that any negative impact on the natural environment at sea is minimised.

Wind farms and platforms can, however, also have a positive effect on the environment. Studies have shown that the biodiversity on the seabed increases near such structures as platforms and wind turbines. Many species of underwater animals were found, including fish such as cod, mackerel and ocean pout.

"TenneT takes measures to minimise the impact on nature and the environment."
Generating more offshore wind power is one of the most important pillars of energy transition in Europe. The Dutch and German governments are not alone in wanting to increase the amount of offshore wind power over the coming years. What’s more, other sources of renewable energy are also on the rise.

**OFFSHORE GRID IN THE FUTURE**

**MIDTERM PLANS UNTIL 2030**

In the mid-term until 2030, the Dutch government wants to be able to generate 7-10 GW more wind power than planned until 2023, also in wind energy zones located further offshore. TenneT will connect these offshore wind farms and link them to the onshore electricity grid.

Efficiently connecting the wind energy zones further out in the North Sea, for example IJmuiden Ver, will require a different technical approach, using a direct current (DC) connection instead of an alternating current (AC).

Although complex and challenging, TenneT is devoting its time and expertise into developing connections for this zone at the lowest possible cost for society and the environment. One of the options we are exploring is combining some of these connections with an interconnector, i.e. an international electricity connection between countries.

**2030**

**2050**

**COOPERATION ON THE NORTH SEA**

**LONG TERM PLANS UNTIL 2050**

To be able to access the required amount of generated energy in the mid and long term until 2050, it is important that we are able to exchange electricity with our neighbouring countries. Besides the named exchange of electricity via interconnectors, Europe also requires a coordinated joint effort by national governments, regulators, the offshore (wind) industry, national grid operators, and nature and environmental organisations.

TenneT has taken the initiative to come up with a shared European approach until 2050. This concept has the potential to provide renewable energy to 70-100 million European consumers by 2050.

The concept utilizes the North Sea as an important source and “distribution centre” of generated wind power that can be exchanged between the various neighbouring countries. These countries exchange the electricity via man-made islands connected to the mainland. In turn, new wind farms built near the islands can be connected to it.

“Sun and wind form the basis for a sustainable and stable energy system. More sun is available from springtime, and more wind from the autumn. TenneT ensures that there is electricity for all users throughout the year, also at moments or places where the wind doesn’t blow or the sun doesn’t shine.”
TenneT is a leading European electricity transmission system operator (TSO) with its main activities in the Netherlands and Germany. With over 22,000 kilometres of high-voltage connections, we ensure a secure supply of electricity to 41 million end-users. We employ approximately 3,000 people, have a turnover of EUR 3.2 billion and an asset value totalling EUR 19 billion. TenneT is one of the biggest investors in national and international electricity grids on land and at sea. Our focus is on developing an integrated Northwest European energy market and enabling the energy transition. TenneT makes every effort to meet the needs of society by being responsible, engaged and connected.

Taking power further

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