Dear Reader,

Offshore wind is one of the most fascinating industries in the renewable energy sector and is experiencing a remarkable growth. By the end of 2010, around 3,000 MW of installed offshore wind capacity was operating in Europe. By 2020 around 40,000 MW should be installed, a 13-fold increase.

E.ON is committed to being a leading player in the offshore wind industry. In 2010, we commissioned 46% of all new offshore wind installations in Europe. E.ON has already invested around €2 billion into our offshore wind farms. This includes five operational offshore wind farms across the North and Baltic Sea, and the construction, with partners Dong and Masdar, of the London Array which will be the world’s largest offshore wind project when fully completed.

This unique experience enables us to move our offshore wind activities from a project-by-project basis to a portfolio approach, thereby leveraging E.ON’s skills and procurement capabilities. Using our extensive and diversified project pipeline, we will commission an offshore wind farm every 18 months while significantly reducing costs by 40% by 2015.

By 2015, E.ON will invest another €2 billion in three further offshore wind farms in Germany, UK and Sweden. In total these projects will have an installed capacity of around 550 MW. Our long-term lease of a specialist construction vessel will support the construction of these projects.

In this Factbook we would like to give you some insights into the offshore wind industry, its challenges, growth prospects, and our own projects. We hope that you find it useful, and we would welcome your comments and feedback.

Kind regards,

Mike Winkel, CEO E.ON Climate & Renewables GmbH
Picture taken at E.ON Offshore Project Robin Rigg (United Kingdom, 2009)
1. Offshore Wind – The Industry
2. Offshore Wind – The Challenges
3. Offshore Wind – Technical Solutions
4. Offshore Wind – The E.ON Approach
5. Offshore Wind – The E.ON Project Factsheets
6. Offshore Wind – The Key Learnings
Offshore Wind Development and Milestones in the EU

- After a slow and pilot-project driven development before 2001, offshore wind energy has developed into one of the key renewable energy industries in the EU.
- In 2010, with almost 3,000 MW installed offshore wind capacity, the EU is a world leader in offshore wind.

Source: European Wind Energy Association **JV of E.ON 26.25%), EWE (47.5%) and Vattenfall (26.25%)
Snapshot of the EU Offshore Wind Industry

Over 96% of global operational offshore wind installations are located in European waters.

More than 80% of the total offshore wind installed capacity in the EU is located in the United Kingdom, Denmark and the Netherlands.

In 2010 a total of 883 MW of offshore wind capacity was brought online in five European countries (UK, Denmark, Belgium, Germany and Finland).

Utilities have realized about 90% of EU offshore wind projects.

E.ON commissioned 46% of new installed European offshore wind capacity in 2010.

The first offshore wind farms outside Europe were commissioned in 2010 in China and Japan.

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**European Installed Offshore Wind Capacity**

<table>
<thead>
<tr>
<th>Country</th>
<th>Capacity Share</th>
<th>Installed Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>United Kingdom</td>
<td>45.5%</td>
<td>1,341 MW</td>
</tr>
<tr>
<td>Denmark</td>
<td>29.0%</td>
<td>854 MW</td>
</tr>
<tr>
<td>Netherlands</td>
<td>8.4%</td>
<td>247 MW</td>
</tr>
<tr>
<td>Belgium</td>
<td>6.6%</td>
<td>195 MW</td>
</tr>
<tr>
<td>Sweden</td>
<td>5.5%</td>
<td>163 MW</td>
</tr>
<tr>
<td>Germany</td>
<td>3.1%</td>
<td>92 MW</td>
</tr>
<tr>
<td>Finland</td>
<td>0.9%</td>
<td>26 MW</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.8%</td>
<td>25 MW</td>
</tr>
<tr>
<td>Norway</td>
<td>0.2%</td>
<td>2 MW</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
<td><strong>2,945 MW</strong></td>
</tr>
</tbody>
</table>

Sources: European Wind Energy Association, Emerging Energy Research
Following a rather slow growth until 2010, offshore wind energy in Europe is supposed to grow strongly over the next decade:

- 3,000 MW in 2010
- About 21,500 MW in 2015
- About 40,000 MW in 2020

Offshore wind energy is on the renewable agenda of several countries, especially in the North Sea and Atlantic:

- UK (13,000 MW by 2020; 33,000 MW by 2030)
- Germany (10,000 MW by 2020; 25,000 MW by 2030)
- France (6,000 MW by 2020)
- Netherlands (5,000 MW by 2020)
- Denmark (1,300 MW by 2020)
Global Perspective of Offshore Wind Energy

Installed offshore wind capacity and targets worldwide

- So far, development of offshore wind energy has mainly taken place in Europe, with first offshore wind farms commissioned in Japan (25 MW) and China (100 MW) in 2010.
- Europe will remain the leading region with a target of about 40,000 MW of offshore wind by 2020.

Source: EWEA, Price Waterhouse Coopers, reNews
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"Offshore is more than onshore in the water”

Main differences between onshore and offshore wind energy projects

<table>
<thead>
<tr>
<th>Resources</th>
<th>Offshore Wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Wind potential for 4,000 full load hours</td>
<td>• Wind potential for 8,000 full load hours</td>
</tr>
<tr>
<td>• Limited sites available</td>
<td>• Large sites still available</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Offshore Wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 1 – 3 MW wind turbines</td>
<td>• 3 – 7 MW wind turbines</td>
</tr>
<tr>
<td>• Wind farms of 10 – 50 MW installed capacity</td>
<td>• Wind farms of 50 – 1,000 MW installed capacity</td>
</tr>
<tr>
<td>• Investment of €30 – €70 million per wind farm</td>
<td>• Investment of €1 – €3 billion per wind farm</td>
</tr>
<tr>
<td>• At full load, one wind turbine produces a household’s annual consumption* in 200 minutes</td>
<td>• At full load, one wind turbine produces a household’s annual consumption* in 40 minutes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Environment</th>
<th>Offshore Wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Land-based conditions</td>
<td>• Rough marine conditions</td>
</tr>
<tr>
<td>• Unrestricted access (24 hours / 7 days a week)</td>
<td>• Distance to shore 1 – 70 km</td>
</tr>
<tr>
<td></td>
<td>• Access limited by high waves and storms</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Foundations</th>
<th>Offshore Wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Built on solid ground</td>
<td>• Differing soil conditions (sand, clay, rock) and erosion</td>
</tr>
<tr>
<td>• Standard concrete foundations cast on site</td>
<td>• Foundation type depends on water depth and soil consistency (e.g. monopiles, gravity, tripod)</td>
</tr>
</tbody>
</table>

- Offshore wind energy has a greater energy potential but marine conditions pose great challenges to project delivery – weather, wind and waves are highly influencing the outcome.
- Thus, a whole new approach to wind power in terms of turbine technology and scale, foundation types, infrastructure, logistics and maintenance is needed.

*based on average annual electricity consumption of 3,500 KWh
“Offshore is not offshore”

- Each offshore wind energy project has its individual characteristics depending on factors such as wind conditions, the consistency of the seabed, water depth and the distance to shore:
  - Project developers choose their foundations and wind turbines considering the individual wind conditions, the consistency of the sea bed and the particular water depth
  - Logistics, Operations & Maintenance (O&M) concepts and the accessibility of the turbines are strongly influenced by the distance to the shore
  - Especially far-shore wind offshore farms with a greater water depth need larger wind turbines and a higher energy output in order to balance costs and revenue
Offshore projects require extensive long-term planning

1. Initial screening of potential sites
2. Preliminary evaluation of seabed and wind conditions
3. Securing of project and property rights
4. Application for permission

- Wind Assessment/ Ground Survey
- Environmental Impact Assessment (EIA)
- Technical planning
- Securing of grid connection
- Receiving of construction permit

- Component contracts signed
- Installation of foundations and wind turbines
- Connection to onshore grid
- Commissioning and start of operation

- Regular check of technical equipment and maintenance works
- Repairs, overhauls and upgrades
- At end of lifetime: decommissioning or repowering with new wind turbines

The realization time of an offshore wind park, from the first idea to the start of the project, might require up to 10 years of continuous work and requires a complex project management.
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Offshore Wind Foundations - Overview

Gravity Foundation
- Re-enforced concrete
- Max. water depth = 30m
- Suitable for 5 MW turbines
- Good experience

Monopile Foundation
- Steel structure
- Max. water depth = 25m
- Limited to 3.6 MW turbines
- Mostly used foundation

Tripod Foundation
- Heavy steel structure
- Max. water depth = 35m
- Suitable for 5 MW turbines
- Little experience

Jacket Foundation
- Laterace steel structure
- Max. water depth = 45m
- Suitable for 5 MW turbines
- Little experience

- Water depth and consistency of the seabed determine the choice of foundation. So far, there is no universal foundation type suitable for all kinds of seabed conditions.

- With a share of 67% in 2010, monopile foundations were the most commonly used foundation type, followed by gravity foundations with a share of 30%.

- Significant research and development are still necessary to develop a cost-efficient concept for production at industrial scale. New concepts, e.g. floating foundations, are being tested.

Source: European Wind Energy Association,
Gravity foundations are preferably used in waters with a maximum depth of 30 meters.

- Made of reinforced concrete, one gravity foundation can weigh up to 1,400 tons at a height of 15 meters.
- To increase weight and stability, gravity foundations are often filled with gravel and stones.
- From arrival at site the complete cycle of installation of a foundation takes less than 24 hours.
- E.ON has gained experience with gravity foundations in its Danish project Rødsand II.
- To date, E.ON has successfully installed 162 gravity foundations.

Pictures taken at E.ON Offshore Project Rødsand II (Denmark, 2009)
Gravity Foundation - Installation

Foundations shipped to site

Heavy lift vessel on site

Positioning of 1,300 ton foundation

Foundation lowered to seabed

Level checks on the foundation

Installation complete

Pictures taken at E.ON Offshore Project - Rødsand II (Denmark, 2009)
Monopile Foundation – Manufacturing and Delivery

- Monopile foundations can be used in waters with a maximum depth of 25 meters
- Made of steel, one monopile foundation weighs up to 600 tons
- About 30 meters of the monopile is driven into the seabed
- Monopiles are the most common foundations so far, especially for projects in the sandy North Sea seabed

Pictures taken at E.ON Offshore Project Scroby Sands (United Kingdom, 2003)
Monopile Foundation - Installation

- Pile gripper for exact pile positioning
- Pile hammer (300 t of force) driving monopile
- Installation complete

- From arrival at site, the complete installation of a foundation takes less than 24 hours
- E.ON has gained experience with monopile foundations in its United Kingdom projects at Blyth, Scroby Sands and Robin Rigg
- To date, E.ON has successfully installed more than 180 monopile foundations

Pictures taken at E.ON Offshore Project Scroby Sands (United Kingdom, 2003) and Robin Rigg (United Kingdom 2009)
Tripod Foundation - Manufacturing and Delivery

- Tripod foundations can be used in deeper waters with a maximum depth of 35 meters
- Made of steel, one tripod foundation weighs up to 700 tons with a total height of up to 50 meters
- In an extensive manufacturing process, all different pieces of the tripods have to be welded together
- Tripods are still in the development phase and are, until so far, rarely put to use in offshore wind installations

Pictures taken at E.ON Offshore Project Alpha Ventus (Germany, 2009, Source: DOTI)
Tripod Foundation - Installation

- For the installation of a tripod foundation three securing steel piles, each 30 meters long and weighing 100 tons, are needed to fix the tripod at the ground
- From arrival at site, the complete installation of a foundation takes 2-3 days but the installation process will benefit from larger capacity jack-up crane vessels
- E.ON has gained experience with the successful installation of six tripod foundations in the German offshore wind project Alpha Ventus
Jacket Foundation - Manufacturing and Delivery

- Jacket foundations can be used in water depths of more than 40 meters
- Made of steel, one jacket foundation weighs up to 500 tons with a total height of up to 45 meters
- In the manufacturing of the jackets, many single steel beams need to be welded together
- Next to monopile and gravity foundations, jacket foundations are the third most common type of foundation, quite often also used for transformer stations

Pictures taken at E.ON Offshore Project Alpha Ventus (Germany, 2009, Source: DOTI)
Jacket Foundation - Installation

- The installation of the jacket foundations at Alpha Ventus was done by the biggest crane ship in the world, „Thialf“, which has the size of two football fields and a lifting power of 14,000 tons.
- From arrival at site the complete installation of a foundation takes up to three days.
- E.ON has gained experience with the successful installation of six jacket foundations in the German offshore wind project Alpha Ventus and at the installation of the transformer station.

Pictures taken at E.ON Offshore Project Alpha Ventus (Germany, 2009, Source: DOTI)
Wind Turbines - Technology

Main components of a wind turbine

1. Tubular steel tower
2. Nacelle with main mechanical and electrical components
3. Hub with three rotor blades, rotating at slow speed
4. Main shaft transmitting rotation from hub to gearbox
5. Multistage gearbox with high gear transmission ratio
6. Fast turning generator, producing electricity

- Offshore wind turbines must be highly robust and reliable to avoid costly standstills, since they cannot be accessed at some times because of wind, wave and weather conditions.
- Most offshore wind turbines have a conventional design that is also used in onshore wind turbines, which includes gearbox and generator in the nacelle, while "gearless" turbines do not have a gearbox.
- In addition to normal "wear and tear" offshore wind turbines may suffer damage from:
  - Corrosion due to aggressive salty environment
  - High wear due to heavy mechanical loads and higher utilization
  - Failures may affect gearbox, generator, transformer, blades and transmission cables
Wind Turbines - Development

Size and capacity of wind turbines have significantly increased

- Size and capacity of offshore wind turbines have increased considerably. At the moment, wind turbines with a capacity of up to 7 MW are being tested.
- While at onshore sites the size of wind turbines is often limited by restrictions on height and rotor diameter, offshore wind turbines do not encounter these limits in the open sea.
- In 2010, the average capacity of offshore wind turbines was about 2.6 MW.

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**Project** | Scroby Sands | Rødsand II | Robin Rigg | Alpha Ventus
---|---|---|---|---
**Turbine Type** | Vestas V80 | Siemens 2.3-93 | Vestas V90 | REpower/Multibrid
**Hub Height** | 60 m | 68 m | 80 m | 90 m
**Rotor Diameter** | 80 m | 93 m | 90 m | 126 m / 116 m
**Capacity** | 2 MW | 2.3 MW | 3 MW | 5 MW
**Number of Turbines** | 30 | 90 | 60 | 12

Source: European Wind Energy Association
Wind Turbines - Pre-Assembly

- Wind turbine components need to be pre-assembled onshore to allow quick installation offshore. The most important pre-assembly works are the stacking of tower segments.
- Vessels with high cranes are needed to finally install the nacelle and the blades. This process needs a high level of precision and can only be fulfilled in good weather and with low wind speeds.
- From arrival at site the installation of a wind turbine takes a minimum of 24 hours.
- To date, E.ON is operating and installing more than 365 offshore wind turbines in three different countries.

Pictures taken at E.ON Offshore Project Robin Rigg (United Kingdom, 2009)
Wind Turbines - Installation

Special vessels to install wind turbines

A wind turbine is installed in several steps

Bunny ear method: Installation of the preassembled nacelle with two blades

Rotor star method: Installation of a preassembled hub with three blades

Once the tower is fully installed, the crane will pick up the nacelle and the blades

Installation complete

Pictures taken at E.ON Offshore Projects Robin Rigg (United Kingdom, 2009) and Rødsand 2 (Denmark, 2010)
Offshore Vessels - Requirements

- For the complex construction process of offshore wind farms, construction vessels need:
  - sufficient storage capacity for large components
  - sufficient height and lifting power
  - the ability to quickly position and jack-up at the installation site
  - the ability to operate year-round in a range of water depths, wave heights and currents

- Purpose-built vessels, which are especially equipped for the installation of foundations and offshore wind turbine installations, are key to successful offshore construction

Pictures taken at E.ON Offshore Project Robin Rigg (United Kingdom, 2009) and Alpha Ventus (Germany, 2009) Source: DOTI
Offshore Vessels - Characteristics

Heavy-lift crane ship
- Very limited storage capacity
- Strong lifting power, low height
- Slow, hauler needed
- Susceptible to waves

Jack-up barge
- Limited storage capacity
- Sufficient lifting power and height
- Slow, hauler needed
- Less susceptible to waves

Jack-up crane vessel
- Large storage capacity
- Sufficient lifting power and height
- Fast, flexible and independent
- Less susceptible to waves

- Jack-up crane vessels which are purpose-built for offshore wind energy installation represent the ideal solution, and a variety of designs have been presented to the market in recent years
- A new generation of jack-up crane vessels will be capable of installing turbines of the 5 - 6MW class and larger monopile and jacket foundations, with dynamic positioning systems for faster positioning at site
- E.ON has a six-year lease on a state-of-the-art jack-up crane vessel, the MPI Discovery for use in upcoming projects

Pictures taken at E.ON Offshore Projects - Robin Rigg (United Kingdom, 2009) and Alpha Ventus (Germany, 2009, Source: DOTI)
Grid Connection and Array Cabling

- Within the offshore wind farm, array cabling (AC) connects rows of wind turbines to the offshore transformer station.
- The offshore sea-cable (AC or DC) connects the offshore transformer station to the onshore grid.
- For larger distances from shore, HVDC\textsuperscript{e} transformer stations are used to transmit the electricity via DC cable to the shore.
- For safe operations, offshore cables are buried up to three meters deep into the seabed.

Pictures taken at E.ON Offshore Project Scroby Sands (United Kingdom, 2004)
Offshore Transformer Stations

- Transformer substations need to be assembled onshore and installed as a single unit offshore
- Heavy lift crane ships are required for the installation of both foundation and transformer station
- For long distance power transport e.g. at German projects, DC cables are used, which require an additional AC/DC transformer station offshore and at the grid connection onshore
- At Alpha Ventus, the transformer station has a height of 30 meters above sea level, and weighs together with the jacket foundation more than 1,300 tons

Pictures taken at E.ON Offshore Project - Alpha Ventus (Germany, 2009, Source: DOTI) and London Array (UK, 2011)
Offshore wind energy success comes from doing as much as possible onshore - every step completed onshore saves time and money during offshore installation and does not depend on offshore wind and wave conditions.

During the installation of offshore wind farms, port facilities have to allow for storage and pre-assembly of foundations and wind turbine components.

During the operation of offshore wind farms, the service parks have to allow quick loading of spare parts and 24/7 departure to offshore wind farms.
Operations and Maintenance (O&M)

- Quick O&M site access is crucial to avoid costly stand-stills
- Offshore access is constrained by weather and waves and can be impossible in winter or during storms
- Travel time is a big issue: small boat access to far-shore wind farms can take up to six hours
- New O&M concepts for far-shore projects need to be developed, including manned platforms and daily helicopter or speed boat transfer

Pictures taken at E.ON Offshore Projects Robin Rigg (United Kingdom, 2009)
Health and Safety: Safety is first Priority!

- Safety is the first priority for working offshore, since any minor accident may cause major harm with medical help being far away.
- Construction and maintenance work at offshore wind energy sites are very challenging and risky.
- The staff has to face tough environmental conditions and work in great heights and in a remote environment – dressed in special offshore suits all the time.

Pictures taken at E.ON Offshore Project Alpha Ventus (Germany, 2009, Source: DOTI)
Health and Safety: Ensuring a high Standard

• Every work and safety routine has to be planned and trained thoroughly to allow, safe, fast and efficient work
• A systematic HSSE (Health, Safety, Security and Environment) approach helps to minimize risks associated with working offshore
• E.ON has successfully established and audited an HSSE Management System and is engaging proactively to set global harmonized industry standards for offshore safety
Sustainable development of offshore wind energy

- E.ON is committed to a sustainable development and deployment of offshore wind energy by actively supporting research and development of suitable solutions to reduce the impacts on nature.

- As part of the permitting, an Environmental Impact Assessment (EIA) is carried out to evaluate possible impacts of the offshore project on marine ecology.

- To learn more about the impacts of offshore energy on the marine ecosystem, IUCN in cooperation with E.ON carried out the study “Greening Blue Energy” with essential findings:
  - Wind farms create safe habitats due to the exclusion of trawling and limitations to fishing.
  - These new habitats become potential breeding areas.
  - Wind farms, especially foundations, can provide artificial reefs which enhance biodiversity.
  - Piling noise is a major issue that requires further technical improvements.
  - Animals tend to avoid wind farms during pilling in the construction phase, but usually return afterwards.

Source: IUCN (International Union for Conservation of Nature)
Research on marine life and sustainable concepts

- E.ON’s first German offshore wind project alpha ventus* is accompanied by the comprehensive project “Research at Alpha Ventus” (RAVE) including a variety of projects on maritime environment which also revealed the creation of artificial reefs at the offshore foundations.

- In 2011 E.ON, together with other German Offshore wind operators, launched the German ESRA research project to test and further develop different technical concepts to reduce piling noise during construction, including bubble curtains, noise mitigation shields and sound dampers.

- Observations at E.ON’s offshore wind farms show a variety of wild life living around the offshore wind farm, from seals feeding on fish at the base of the wind turbines to various birds resting on the foundations and hunting at the offshore site.

Source: IUCN (International Union for Conservation of Nature), E.ON
Picture taken at E.ON Offshore Project Robin Rigg (United Kingdom, 2009)
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Picture taken at E.ON Offshore Project Robin Rigg (United Kingdom, 2009)
E.ON has a leading competence in offshore wind energy

E.ON’s offshore wind projects

- E.ON is a leading player in offshore wind industry
  - In 2010, E.ON commissioned about 46% of the European offshore wind farms
  - Around 470 MW of offshore wind farms in operation in UK, Denmark and Germany
  - Four projects with about 750 MW under construction
  - Project pipeline of more than 3,100 MW in European waters
- E.ON’s strategy for offshore wind energy foresees large investments into projects while simultaneously reducing costs
  - Realizing one offshore wind project every 18 months
  - Reducing installation costs by 40% by 2015

Joint Venture of E.ON (26.25%), EWE (47.5%) and Vattenfall Europe (26.25%), **Phase 1 (630 MW), Joint Venture of E.ON (30%), DONG (50%) and Masdar (20%)**
**E.ON will commission an offshore wind project every 18 months**

<table>
<thead>
<tr>
<th>Country</th>
<th>Project</th>
<th>Status</th>
<th>Start of Operation</th>
<th>Capacity</th>
<th>E.ON Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td>Blyth</td>
<td>Operational</td>
<td>2001</td>
<td>4 MW</td>
<td>100%</td>
</tr>
<tr>
<td>UK</td>
<td>Scroby Sands</td>
<td>Operational</td>
<td>2004</td>
<td>60 MW</td>
<td>100%</td>
</tr>
<tr>
<td>Germany</td>
<td>Alpha Ventus*</td>
<td>Operational</td>
<td>2009</td>
<td>60 MW</td>
<td>26.25%</td>
</tr>
<tr>
<td>UK</td>
<td>Robin Rigg</td>
<td>Operational</td>
<td>2010</td>
<td>180 MW</td>
<td>100%</td>
</tr>
<tr>
<td>Denmark</td>
<td>Rødsand II</td>
<td>Operational</td>
<td>2010</td>
<td>207 MW</td>
<td>100%</td>
</tr>
<tr>
<td>UK</td>
<td>London Array**</td>
<td>Construction</td>
<td>2013</td>
<td>630 MW (phase 1), 270 MW (phase 2)</td>
<td>30%</td>
</tr>
<tr>
<td>Sweden</td>
<td>Kårehamn</td>
<td>Construction</td>
<td>2013</td>
<td>48 MW</td>
<td>100%</td>
</tr>
<tr>
<td>Germany</td>
<td>Amrumbank West</td>
<td>Construction</td>
<td>2015</td>
<td>288 MW</td>
<td>100%</td>
</tr>
<tr>
<td>UK</td>
<td>Humber Gateway</td>
<td>Construction</td>
<td>2015</td>
<td>219 MW</td>
<td>100%</td>
</tr>
</tbody>
</table>

- Year to date, E.ON has already invested more than €2 billion into offshore wind projects, including London Array**, the world’s largest offshore wind project currently under construction.
- E.ON will invest around €2 billion into the offshore wind projects Amrumbank West, Humber Gateway and Karehamn, this represents the largest investment into offshore wind by a single company so far.
- E.ON’s offshore wind growth is supported by a six year long-term charter of a purpose-built specialist vessel for efficient and reliable installation at E.ON’s projects.

*Joint Venture of E.ON (26.25%), EWE (47.5%) and Vattenfall Europe (26.25%), **Phase 1 (630 MW), Joint Venture of E.ON (30%), DONG (50%) and Masdar (20%)
E.ON target: 40% reduction of installation costs by 2015

Drivers to reduce costs of offshore wind projects

<table>
<thead>
<tr>
<th>Wind turbines</th>
<th>Foundations</th>
<th>Logistics</th>
<th>Grid connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Examples</td>
<td>Examples</td>
<td>Examples</td>
<td>Examples</td>
</tr>
</tbody>
</table>

- Wider choice of concepts
- Larger wind turbines
- Special design for offshore installation, operations and maintenance
- New, industrial-scale foundation concepts
- Lower material costs
- Shorter installation time and lower installation costs
- Purpose-built vessels
- Suitable ports
- Optimized processes allowing shorter installations times and better access to offshore sites
- Foresighted planning
- Building up of offshore grid infrastructure
- Efficient bundling of grid connections of offshore wind farms

- Offshore wind is still at the beginning of its development, with more providers of wind turbines, foundations, logistics and offshore vessels stepping into the market and new innovative concepts

- E.ON’s offshore wind strategy targets at a significant reduction of costs of 40% by 2015 by realizing major saving potential in hardware costs, a standardized, integrated design approach to wind turbine generators and the optimization of installation and operations
Picture taken at E.ON Offshore Project Robin Rigg (United Kingdom, 2009)
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Blyth (United Kingdom, North Sea)

Picture taken at E.ON Offshore Project Blyth (United Kingdom, 2004)
Blyth (United Kingdom, North Sea)

<table>
<thead>
<tr>
<th>Wind Farm</th>
<th>Foundations</th>
<th>Wind Turbines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>Type</td>
<td>Type</td>
</tr>
<tr>
<td>4 MW</td>
<td>Monopile</td>
<td>Vestas V66</td>
</tr>
<tr>
<td>Status</td>
<td>Material</td>
<td>Capacity</td>
</tr>
<tr>
<td>Operational</td>
<td>Steel</td>
<td>2 MW</td>
</tr>
<tr>
<td>Start of Operation</td>
<td>Weight 110 t</td>
<td>No. of Turbines 2</td>
</tr>
<tr>
<td>2001</td>
<td>Height 25 m</td>
<td>Hub Height 60 m</td>
</tr>
<tr>
<td>Distance to Shore 1 km</td>
<td>Diameter 4 m</td>
<td>Rotor Diameter 66 m</td>
</tr>
<tr>
<td>Max. Water Depth 8 m</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Good to know

- Built in 2001, Blyth marked the start of E.ON’s activities in the offshore wind sector
- Blyth was a prototype build and the first offshore wind project in United Kingdom waters
- Monopiles at Blyth were drilled 10 meters deep into a rock seabed
- The total investment in Blyth amount to about €6 million
Scroby Sands (United Kingdom, North Sea)

Picture taken at E.ON Offshore Project Scroby Sands (United Kingdom, 2005)
Scroby Sands (United Kingdom, North Sea)

<table>
<thead>
<tr>
<th>Wind Farm</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>60 MW</td>
</tr>
<tr>
<td>Status</td>
<td>Operational</td>
</tr>
<tr>
<td>Start of Operation</td>
<td>2004</td>
</tr>
<tr>
<td>Distance to Shore</td>
<td>3 km</td>
</tr>
<tr>
<td>Max. Water Depth</td>
<td>15 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Foundations</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Monopile</td>
</tr>
<tr>
<td>Material</td>
<td>Steel</td>
</tr>
<tr>
<td>Weight</td>
<td>200 t</td>
</tr>
<tr>
<td>Height</td>
<td>50 m</td>
</tr>
<tr>
<td>Diameter</td>
<td>4.2 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wind Turbines</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Vestas V80</td>
</tr>
<tr>
<td>Capacity</td>
<td>2 MW</td>
</tr>
<tr>
<td>No. of Turbines</td>
<td>30</td>
</tr>
<tr>
<td>Hub Height</td>
<td>60 m</td>
</tr>
<tr>
<td>Rotor Diameter</td>
<td>80 m</td>
</tr>
</tbody>
</table>

*Up to 8m above sea level, buried up to 30m into ground

Good to know

- Scroby Sands was E.ON’s first commercial offshore wind farm
- Through the project E.ON gained valuable experience in installing a large series of offshore wind turbines with monopile foundations, even in the unfavourable winter season
- Operational improvements have led to a continuously high generation performance
- With an annual production of 171 GWh the farm is capable of supplying around 41,000 homes with electricity each year
- The total investment for the completion of Scroby Sands amount to €109 million
Robin Rigg (United Kingdom, Irish Sea)
The project built on the experience gained at Scroby Sands, employing similar monopile foundations and wind turbines. Realization of Robin Rigg benefited from the use of jack-up crane vessels that allowed to install foundations all year-round. With an annual production of 550 GWh the farm is capable of supplying around 155,000 homes with electricity each year. The total investment for the completion of Robin Rigg amount to around €420 million.
London Array (United Kingdom, Thames Estuary)
London Array (United Kingdom, Thames Estuary)

**Wind Farm**

<table>
<thead>
<tr>
<th>Capacity</th>
<th>1,000 MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Status</td>
<td>Construction</td>
</tr>
<tr>
<td>Start of Operation</td>
<td>2013*</td>
</tr>
<tr>
<td>Distance to Shore</td>
<td>22* km</td>
</tr>
<tr>
<td>Max. Water Depth</td>
<td>25* m</td>
</tr>
</tbody>
</table>

* Phase 1 (630 MW)

**Foundations**

<table>
<thead>
<tr>
<th>Type</th>
<th>Monopile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Steel</td>
</tr>
<tr>
<td>Weight</td>
<td>600* t</td>
</tr>
<tr>
<td>Height</td>
<td>60* m</td>
</tr>
<tr>
<td>Diameter</td>
<td>4.7-5.7* m</td>
</tr>
</tbody>
</table>

**Wind Turbines**

<table>
<thead>
<tr>
<th>Type</th>
<th>Siemens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>3.6* MW</td>
</tr>
<tr>
<td>No. of Turbines</td>
<td>175*</td>
</tr>
<tr>
<td>Hub Height</td>
<td>87* m</td>
</tr>
<tr>
<td>Rotor Diameter</td>
<td>120* m</td>
</tr>
</tbody>
</table>

* Phase 1 (630 MW)

**Good to know**

- London Array will be built in two phases (phase 1 = 630 MW; phase 2 up to 370 MW) and will, upon completion, be the world’s largest offshore wind farm.
- The project is being developed jointly by Dong Energy (50%), E.ON (30%) and Masdar (20%).
- After full completion**, London Array will provide enough power for up to 750,000 homes.
- The total investment cost of Phase 1 of London Array amount to around €2.2 billion.
- Good progress is being made on the construction of the wind farm: in November 2011, 90 of 177 foundations and two offshore substations had been installed.

**Phase 1 (630 MW) **Including phase 1 and phase 2 of the project

**Phase 1 (630 MW) without the transitional piece
Humber Gateway (United Kingdom, North Sea)
**Humber Gateway** (United Kingdom, North Sea)

<table>
<thead>
<tr>
<th>Wind Farm</th>
<th>Foundations</th>
<th>Wind Turbines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>219 MW</td>
<td>Type</td>
</tr>
<tr>
<td>Status</td>
<td>Construction</td>
<td>Material</td>
</tr>
<tr>
<td>Start of Operation</td>
<td>2015</td>
<td>Weight</td>
</tr>
<tr>
<td>Distance to Shore</td>
<td>8 km</td>
<td>Height</td>
</tr>
<tr>
<td>Max. Water Depth</td>
<td>17 m</td>
<td>Diameter</td>
</tr>
</tbody>
</table>

**Good to know**

- Humber Gateway will be E.ON’s fifth offshore wind farm operating in the UK
- Humber Gateway is one of three E.ON offshore wind projects which will be built in a coordinated way, using state of the art installation vessels shared across the projects
- When commissioned in 2015, Humber Gateway will provide enough power for up to 150,000 homes each year
- The total investment for Humber Gateway is around €830 million
Rødsand II (Denmark, Baltic Sea)
Rødsand II (Denmark, Baltic Sea)

<table>
<thead>
<tr>
<th>Wind Farm</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>207 MW</td>
<td></td>
</tr>
<tr>
<td>Status</td>
<td>Operational</td>
<td></td>
</tr>
<tr>
<td>Start of Operation</td>
<td>2010</td>
<td></td>
</tr>
<tr>
<td>Distance to Shore</td>
<td>4 km</td>
<td></td>
</tr>
<tr>
<td>Max. Water Depth</td>
<td>10 m</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Foundations</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Gravity</td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td>Concrete</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>1,300 t</td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td>15 m</td>
<td></td>
</tr>
<tr>
<td>Diameter</td>
<td>15 m</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wind Turbines</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Siemens 2.3-93</td>
<td></td>
</tr>
<tr>
<td>Capacity</td>
<td>2.3 MW</td>
<td></td>
</tr>
<tr>
<td>No. of Turbines</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Hub Height</td>
<td>68 m</td>
<td></td>
</tr>
<tr>
<td>Rotor Diameter</td>
<td>93 m</td>
<td></td>
</tr>
</tbody>
</table>

Good to know

• E.ON’s offshore project Rødsand II builds upon established technology and installation contractors and has been realized 3 months ahead of schedule

• The project benefits from a perfect offshore combination: good wind yield, closeness to shore, shallow waters with low tides and good soil conditions in the Baltic Sea

• With an annual production of 800 GWh the farm supplies 229,000 homes with electricity each year

• The total investment in Rødsand II amount to about €400 million
Kårehamn (Sweden, Baltic Sea)
Kårehamn (Sweden, Baltic Sea)

<table>
<thead>
<tr>
<th>Wind Farm</th>
<th>Foundations</th>
<th>Wind Turbines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>48 MW</td>
<td>Vestas V112</td>
</tr>
<tr>
<td>Status</td>
<td>Construction</td>
<td>Type</td>
</tr>
<tr>
<td>Start of Operation</td>
<td>2013</td>
<td>Material Concrete</td>
</tr>
<tr>
<td>Distance to Shore</td>
<td>5 km</td>
<td>Weight 1,800 t</td>
</tr>
<tr>
<td>Max. Water Depth</td>
<td>21 m</td>
<td>Height 14 - 24 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diameter 18 m</td>
</tr>
</tbody>
</table>

**Good to know**

- Kårehamn represents E.ON’s first offshore wind project in Sweden
- The location near to shore reduces costs, logistic efforts and allows direct connection to the onshore electricity grid
- Kårehamn is one of three E.ON offshore wind projects which will be built in a coordinated way, using state of the art installation vessels shared across the projects
- The total investment in Kårehamn amount to around €120 million
- With an annual production of over 175 GWh Kårehamn will supply over 50,000 households with electricity*[^1]

*based on average annual consumption of 3,500 KWh
Alpha Ventus (Germany, North Sea)
**Alpha Ventus** (Germany, North Sea)

<table>
<thead>
<tr>
<th>Wind Farm</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>60 MW</td>
</tr>
<tr>
<td>Status</td>
<td>Operational</td>
</tr>
<tr>
<td>Start of Operation</td>
<td>2009</td>
</tr>
<tr>
<td>Distance to Shore</td>
<td>45 km</td>
</tr>
<tr>
<td>Max. Water Depth</td>
<td>33 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Foundations</th>
<th>Tripod/Jackets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Steel</td>
</tr>
<tr>
<td>Material</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>700/500 t</td>
</tr>
<tr>
<td>Height</td>
<td>45 m</td>
</tr>
<tr>
<td>Diameter</td>
<td>30 m</td>
</tr>
</tbody>
</table>

* plus 300 tons for securing-piles

<table>
<thead>
<tr>
<th>Wind Turbines</th>
<th>Multibrid M5000 Repower 5M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>5 MW</td>
</tr>
<tr>
<td>Capacity</td>
<td>6</td>
</tr>
<tr>
<td>No. of Turbines</td>
<td>6</td>
</tr>
<tr>
<td>Hub Height</td>
<td>90 m</td>
</tr>
<tr>
<td>Rotor Diameter</td>
<td>116 m, 126 m</td>
</tr>
</tbody>
</table>

**Good to know**

- 45 kilometers off the coast in waters more than 30 meters deep, Alpha Ventus is Germany’s first far-shore project and represents a further step-change in offshore wind.
- Alpha Ventus has been developed by a consortium of E.ON (26.25%), EWE (47.5%) and Vattenfall (26.25%) as a non-commercial pilot project.
- The deep-water pilot project yields important experience for the development of future far-shore wind projects.
- The total investment in Alpha Ventus amount to at least €250 million.
- In the time period between 2010 and early 2011 the overall generated electricity lay already 5% above the estimates.
Amrumbank West (Germany, North Sea)
Amrumbank West (Germany, North Sea)

**Wind Farm**
- **Capacity**: 288 MW
- **Status**: Construction
- **Start of Operation**: 2015
- **Distance to Shore**: 35 km
- **Max. Water Depth**: 25 m

**Foundations**
- **Type**: Monopile
- **Material**: Steel
- **Weight**: 800 t
- **Height**: 70 m
- **Diameter**: 6 m

**Wind Turbines**
- **Type**: Siemens
- **Capacity**: 3.6 MW
- **No. of Turbines**: 80
- **Hub Height**: 90 m
- **Rotor Diameter**: 120 m

**Good to know**

- Amrumbank West represents E.ON´s first commercial offshore wind project in Germany building on the pioneering experience of the pilot far-shore project alpha ventus.
- Amrumbank West is one of three E.ON offshore wind projects which will be built in a coordinated way, using state of the art installation vessels shared across the projects.
- After full completion, Amrumbank West will provide enough power for up to 300,000 homes each year*.
- The total investment in Amrumbank West amount to about €1 billion.

*based on average annual consumption of 3,500 KWh
1. Offshore Wind – The Industry
2. Offshore Wind – The Challenges
3. Offshore Wind – Technical Solutions
4. Offshore Wind – The E.ON Approach
5. Offshore Wind – The E.ON Project Factsheets
6. Offshore Wind – The Key Learnings
Offshore - Key Learnings

“Offshore wind energy is more than onshore in the water”
Offshore wind energy requires substantially different technologies and processes compared to onshore wind energy

“Offshore is not offshore”
Every offshore site has its own specifications and requirements, especially when moving from near-shore to far-shore

“WWW” - weather, wind and waves are the dominating factors in offshore wind
Access to offshore sites is strongly restricted or even impossible in times of bad weather, strong winds and high waves

“Using the right tool for the right job”
Experience shows that installation times can be shortened by the right combination of purpose-built vessels, skilled crews and installation tools

Offshore wind energy success comes from doing as much as possible onshore
Every step carried out on land saves time and money in the offshore installation process

E.ON has a leading competence in offshore wind energy
Around 700 MW of offshore projects in operation or under construction, give E.ON an outstanding expertise in offshore wind energy.

Offshore wind energy plays a key role in E.ON’s Renewables strategy
E.ON has already invested €2 billion in offshore wind projects and will invest another €2 billion into three projects by 2015, commissioning one offshore wind project every 18 months

E.ON is targeting at a significant growth and cost reductions for future offshore wind projects
E.ON has an extensive offshore wind project pipeline of 3,000 MW for further development and is aiming to drive costs of projects down by 40% until 2015
E.ON Offshore Factbook

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