Ørsted’s approach to data-driven operations

Owner’s and operator’s perspective

Keynote at Virtual Wind II by ORE Catapult & Fraunhofer IWES

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Our vision
Let’s create a world that runs entirely on green energy
Ørsted at a glance

74 %
Offshore-Wind
Global market leader in offshore wind
Develops, constructs, owns and operates offshore wind farms in Denmark, Germany, the Netherlands, UK, the US and Taiwan
Development projects in UK, Germany, Taiwan and the USA

11 %
Onshore-Wind
Develops, constructs, owns and operate onshore wind, solar and energy storage projects in the US
1 GW onshore operational capacity

15 %
Markets & Bioenergy
Generates and sells power and heat to customers in Denmark and Northwestern Europe
Energy solutions for B2B customers

Headquartered in Denmark
6,526 employees
Listed in the NASDAQ DMX, Ørsted

EBITDA in 2019 EUR 2.34bn
Revenue in 2019 EUR 9.1bn

Phase out the use of coal by 2023

* Share of the Ørsted Group’s capital employed, Annual Report 2019

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United Kingdom

- Burbo Bank
- Burbo Bank Extension
- Barrow
- Isle of Man
- Walney
- Walney 1 & 2
- West of Duddon Sands

The Netherlands

- Westermost Rough
- Hornsea 1
- Hornsea 2
- Hornsea 3
- Hornsea 4
- Lincs
- Race Bank
- Race Bank
- London Array 1

Germany

- Borkum Riffgrund 1
- Borkum Riffgrund 2
- Borkum Riffgrund 3
- Gode Wind 1
- Gode Wind 2
- Gode Wind 3

Denmark

- Anholt

Taiwan

- Ørsted Offshore Wind Power

USA

- Horns Rev 1
- Horns Rev 2

Status

- In operation
- Under construction
- Under development

25+ years of unparalleled experience and track record
26 Offshore wind farms in operation
3 Offshore wind farms under construction
6.8 GW constructed capacity
3.1 GW under construction
14 million Europeans with clean electricity
2.777 dedicated employees
23 partnerships
Ørsted’s integrated end-to-end business model for Offshore Wind –
Share of employees over offshore wind farm life cycle

Ørsted Wind Power core competencies

~2,700 Full-time employees

Ability to design and optimize projects with a ‘total life-cycle cost of wind farm’ mindset

Experience and expertise along the entire value chain allow for better understanding and management of risks

End-to-end model reduces LCoE through fast feedback and learning across the entire organization

Develop
Identify and mature projects

Build
Manage construction, sourcing and supply

Operate
Conduct life-cycle maintenance

Own
M&A, attract capital through partnerships, asset management

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Ørsted strategic transformation
Green share of power generation ~99% in 2025, approximating zero emissions

Carbon intensity of power and heat generation
gCO$_2$/kWh

Global energy sector emission target to stay below 2-degree global warming

Ørsted CO$_2$ emissions

Ørsted installed renewables capacity
GW

<table>
<thead>
<tr>
<th>Year</th>
<th>Offshore wind</th>
<th>Onshore wind</th>
<th>Bioenergy</th>
<th>Renewables$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>2 GW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>10 GW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td>+30 GW</td>
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Offshore wind  Onshore wind  Bioenergy  Renewables$^2$
We’re building more and larger wind turbines

**Factors of cost reduction**

- Larger wind farms and larger turbines
- Optimization of manufacturing processes
- Reduction of the construction period
- **Reduction of operating and maintenance costs**
- Competition among suppliers

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**Boeing 747-8**
Length: 76m

**Wind turbine no. 1**
- Vindeby, Denmark
- Year: 1991
- Diameter: 35m
- Capacity: 0.45MW

**Wind turbine no. 500**
- Walney, UK
- Year: 2012
- Diameter: 120m
- Capacity: 3.6MW

**Wind turbine no. 1,000**
- Gode Wind 1 & 2, Germany
- Year: 2016
- Diameter: 154m
- Capacity: 6MW

**Wind turbine no. 1,500**
- Borssele 1 & 2, The Netherlands
- Year: 2020
- Diameter: 167m
- Capacity: 8MW
Our story

Ørsted Lab established in 2016.

Built on data and experience from Ørsted’s global operations.

First product release available and creating significant value at Wind Farms after less than a month.

Data driven insights and advanced analytical models are used to mitigate the risk of wind farm operation and increase profits.
Our platform enables us to take optimal, data driven decisions across the value chain – and ensure execution throughout the line

<table>
<thead>
<tr>
<th>Input</th>
<th>The platform</th>
<th>Outcome</th>
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<tr>
<td><strong>Main types</strong></td>
<td><strong>Techniques</strong></td>
<td><strong>Results</strong></td>
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<tr>
<td>IT data</td>
<td>Digital twins</td>
<td>Optimal maintenance plans and activities</td>
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<td>OT data</td>
<td>Simulations</td>
<td>Reports and transparency</td>
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<td>Enterprise data</td>
<td>Predictive models</td>
<td><strong>Benefits</strong></td>
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<tr>
<td>External data</td>
<td>ML / AI</td>
<td>Availability increase</td>
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<tr>
<td><strong>Examples</strong></td>
<td>Data mining</td>
<td>Cost reductions</td>
</tr>
<tr>
<td>Turbine measurements</td>
<td>OR / Optimisation</td>
<td>Production increase</td>
</tr>
<tr>
<td>Service scope</td>
<td>Data capture and reporting</td>
<td>Lifetime extension</td>
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<td>Vessel measurements</td>
<td>Control &amp; Monitoring Centre</td>
<td>Safety improvements</td>
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<td>Tech observations</td>
<td>Operations Execution Tools</td>
<td>Risk reduction</td>
</tr>
<tr>
<td>Weather</td>
<td>Operations</td>
<td><strong>Results</strong></td>
</tr>
</tbody>
</table>

**Domains & applications**
- Data Driven Integrity Management
- Data driven condition monitoring and maintenance
- Data driven planning, scheduling, and logistics optimisation
- Data driven asset performance increase on top of availability
- Performance monitoring of after-market add-on services

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Actual product examples

**Predict failure and advice to replace** components before turbine stops

When a converter cabinet fan fails, the turbine stops

A data driven model detects fans about to fail, and **advice to replace** is issued

The site can schedule a visit to the turbine and avoid production losses between failure and repair

**Detect & classify underperformance** in after market add-ons and advice to reinstated agreed performance

A software update resulted in the turbines being curtailed in certain situations

A data driven model detects and classifies the underperformance, and **focussed dialogue** with add-on provider is initiated

Guaranteed performance reinstated. Loss recovered
Ørsted Lab_

We help make wind work_
What is Risk Based Inspections (RBI)?
Combining operational experience with advanced analytics to improve inspection plans

Risk = Likelihood of failure × Consequence of failure

RBI Process:
- Data and information collection
- Risk assessment process
- Risk ranking
- Reassessment (if any)
- Mitigation
- Inspection Plan

![RBI Diagram]
Ørsted’s ‘enablers’ for Risk Based Inspections and data driven operation

In-house core competencies, close collaboration with suppliers & existing operational base

Diagram:

- Project Development
- >1500 WTGs installed
- Foundation Design
- Asset Integrity Management
- O&M and inspections
- Supplier consultation

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Methodology of RBI vs. Prescriptive

**Prescriptive approach**
- Fix inspection intervals both for critical items (e.g. yearly) as well as non-critical items (e.g. once every 5 years = 20% annually)
- No systematic update based on new information
- Low confidence that most important areas are being looked at
- Large volumes of data

**Risk Based Approach**
- Inspection of a few representative structures in accordance with a risk based inspection plan
- Risk ranking created on all items based on likelihood of failure and the consequences of failure
  - Ranking continually updated based on current condition
  - High risk elements used to create inspection scope (Technical control of risks)
  - Clear identification of high risks allow management decision on acceptance of risks (Financial control of risks and inspection costs)
RBI Model Development and Risk Assessment Process

For each item, define its:
- Function
- Functional Failures
- Failure Modes
- Failure Mechanisms
- Consequence of Failure (CoF)

Adjust Probability of Failure (PoF) according to RBI Model

Evaluation of Observation Data

Trending of Failure Mechanisms

Initial Risk Level for each Item / Failure mode combination

New Risk Level for Item / Failure mode combination

Confidence Level for each Item / Failure mode combination

Estimated Remaining Life

Next Inspection Due Date

Risk Based Frequency Factor

Inspection Interval

Last Inspection Date
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Love your home