The LEANWIND suite of logistics optimisation & full lifecycle simulation models for offshore wind farms

Presenter: Fiona Devoy McAuliffe

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Presentation overview

- Introduction
- Methodology
- Logistics optimisation models
- Financial simulation model
- Combined use
- Potential end-users
Introduction

**Significant cost reductions to date:**
Vattenfall’s 2016 offshore wind price bid of €49.9/MWh for the Kriegers Flak project set a record LCOE forecast of €40/MWh

**Current and future challenges to maintain & surpass savings:**
- Increased industry competition to find cost reductions
- New markets yet to achieve LCOE forecasts
- Sites further from shore in deeper waters and harsher conditions
- Larger turbines and farms with new equipment and logistical requirements
- Facing the unknown – the decommissioning phase
Introduction

What progress needs to be made?

<table>
<thead>
<tr>
<th>Turbine</th>
<th>Foundation &amp; tower</th>
<th>Transmission</th>
<th>Installation</th>
<th>OMS</th>
<th>Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology contributions to reducing LCOE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10%</td>
<td>1.5%</td>
<td>3%</td>
<td>1.5%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Supply chain contributions to reducing LCOE</td>
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<td></td>
<td></td>
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<tr>
<td>2%</td>
<td>1.5%</td>
<td>2%</td>
<td>1.5%</td>
<td>1%</td>
<td>1%</td>
</tr>
</tbody>
</table>

Source: BVG Associates 2016 The supply-chain’s role in LCOE reduction, Belgo-British offshore wind farm supply-chain seminar Brussels
Logistic Efficiencies And Naval architecture for Wind Installations with Novel Developments

OBJECTIVE: to provide cost reductions across the offshore wind farm lifecycle and supply chain through the application of lean principles and the development of state of the art technologies and tools.

- UCC is coordinator
- 31 partner organisations
  - 52% industry partners
  - Representing 11 countries;
- €14.9m total funding;
- €10m EC funding;
- 4 year duration
  - December 2013-November 2017
Introduction

Modelling is a safe and cost-effective way to evaluate and optimise operations. However, there is a lack of comprehensive decision-support tools, detailed enough to provide insight into the effects of technological innovations and novel strategies.

They can reduce costs by identifying potential savings and fostering effective decision-making for a wide range of stakeholders.

LEANWIND developed a suite of logistics and financial tools, which can optimise the entire supply-chain and simulate the full wind farm lifecycle, providing in-depth cost and time analysis.
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Methodology

Port to site: Installation vessel fleet; O&M vessel fleet & on/offshore bases; recommended schedule of installation activities

Prior to Port: Supply-chain prior to port; production, transport & storage/port costs

Site to Port: Recommended schedule of decommissioning activities

Post-Port: Supply-chain post-port e.g. landfill/recycling centers
Methodology

Database
e.g. vessels, turbines, substructures

Inputs
Weather data
Supply chain & costs e.g. ports
Resources & costs e.g. vessels, technicians etc. – capabilities & availability
Strategy per phase e.g. operations, duration, resources required i.e. vessel etc., weather restrictions etc.
Reliability data
See D8.2 for detail

Installation

Operations & maintenance

Decommissioning

Outputs
Cost breakdowns
Costs per year
Annual energy production
Availability
LCOE
IRR
NPV
Duration
Methodology

Optimised selection

Inputs to financial model

Logistics options

- Set of vessels
- Set of Ports
- Set of recycling/landfill centers etc.

Database
- e.g. vessels, turbines, substructures

Inputs
- Weather data
- Supply chain & costs e.g. ports
- Resources & costs e.g. vessels, technicians etc., capabilities & availability

Strategy per phase
- e.g. operations, duration, resources required, i.e. vessels, weather restrictions etc.
- Reliability data
  - See D6.2 for detail

Installation
Operations & maintenance
Decommissioning

Outputs
- Cost breakdowns
- Costs per year
- Annual energy production
- Availability
- LCOE
- IRR
- NPV
- Duration

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Logistics optimisation models

<table>
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<th></th>
<th>Installation</th>
<th>O&amp;M</th>
<th>Decommissioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior to/post port</td>
<td>PTPIns</td>
<td>PTPOM</td>
<td>IntDis</td>
</tr>
<tr>
<td>At port</td>
<td>Portlay, PortIns</td>
<td>PortOM</td>
<td>PortDis</td>
</tr>
<tr>
<td>To/from offshore site</td>
<td>VMIns</td>
<td>VMOM</td>
<td>IntDis</td>
</tr>
</tbody>
</table>

- **Prior to/post port**: manufacturing, transportation, storage, and assembly.
- **At port**: selection of the port(s) for each lifecycle phase & optimal layout (installation phase).
- **Supply to/from offshore site**: transportation of parts to/from the port to the site.
Optimal arrangement of supply chain (suppliers, manufacturers/plants, and warehouses (ports)) and schedule from the production of turbine parts to delivery at port.
PortIns PortOM PortDis – port selection

Portlay - port layout

Inputs:
- Set of edges that make up a polygon (the port area)
- Set of subareas
- Set of possible rectangles for each subarea
- Set of predefined subareas
- Set of components
- The unit transportation cost of each component

Outputs:
- Port layout for offshore wind farm
- Total travel cost of components

Optimal layout of the port given the dimensions and travel costs
VMIns VMOM – port to site models

VMIns - optimal vessel fleet and schedule of installation activities i.e. the number of components to be installed per day.

- Site characteristics
- Weather conditions
- Components to install
- Potential activities
- Novel vessel concepts
- Existing vessels
- Installation ports
- Optimal vessel fleet
- Optimal port configuration
- Optimal activity schedule
- Estimated costs and time
VMOM - Based on the generated corrective & preventive maintenance patterns, the model chooses the *number and type of vessels* and the corresponding *infrastructure* (*bases, platform, mothership*) needed in the offshore transport system.

Source: Nonås L, Halvorsen-Weare E E and Stålhane M 2015 *Finding cost-optimal solutions for the maritime logistic challenges for maintenance operations at Offshore Wind Farms* (Denmark: Poster presentation at EWEA Offshore Wind Conference)
IntDis – integrated dismantling model

Vessel schedule and flow of components for decommissioning. The objective function is to minimise the total cost of activities.
Financial simulation model

**Financial model interface**

**Inputs**
- Farm details
- Strategy (installation, O&M, decommissioning)
- Vessel fleet….

**Outputs**
- Energy production & availability
- Time/activity
- Cost/activity
- Total cost breakdown
- Financial indicators…

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**Diagram**

- Financial model interface
  - Inputs
  - Outputs
- INST module
- O&M module
- DCM module
Financial simulation models

**Key Outputs**

- Full project timeline i.e. duration of activities across the lifecycle
- Energy yield and availability
- Detailed breakdown of
  - capital & installation costs (CAPEX)
  - operation & maintenance costs (OPEX)
  - decommissioning costs (DECEX)
- LCOE, NPV, IRR and payback period
- Cashflow with project profit and loss sheet
- Balance sheet to evaluate debt and equity
Scope: the turbine, foundation, substation, substation foundation, export and inter-array cabling. The user can specify or use a pre-defined selection of assets. Different operations are then associated with the installation of each asset e.g.

<table>
<thead>
<tr>
<th>Installation method</th>
<th>Lifts</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 tower parts, nacelle and hub pre-assembled</td>
<td>6</td>
</tr>
<tr>
<td>Tower parts and nacelle and hub pre-assembled</td>
<td>5</td>
</tr>
<tr>
<td>Blades and hub pre-assembled</td>
<td>4</td>
</tr>
<tr>
<td>Nacelle, hub and 2 blades (bunny ears) pre-assembled</td>
<td>4</td>
</tr>
<tr>
<td>Tower parts and nacelle, hub and 2 blades (bunny ears) pre-assembled</td>
<td>3</td>
</tr>
<tr>
<td>Pre-assembled</td>
<td>1</td>
</tr>
<tr>
<td>Pre-installed on substructure</td>
<td>0</td>
</tr>
</tbody>
</table>


Decommissioning cost estimate comparison

Source, capacity turbine/farm (year)

- Lincs, 3.6MW (2010)
- CCC, 240MW (2010)
- Gwynt Y Mor, 3.6MW (2011)
- Gwynt Y Mor, 3.6MW plus inflation & interest (2011)
- BVG, 4MW (2012)
- BVG, 6MW (2012)
- BVG, 8MW (2012)
- Ytre Stengrund, 2MW (2015)
- DNV GL estimate - low (2015)
- DNV GL estimate - high (2015)
DCM module

**Scope:** Turbine and foundation.

**Inputs:** The component (e.g. blades, nacelle, gearbox etc.) and order in which they are dismantled; component materials and weight; operation durations; up to three destination ports; landfill or recycling centre locations; number of technicians; vessels available etc.

**Outputs:** Costs; time and revenue e.g. salvage

**Validation:** Results for the C-Power OWF were €513,000 per MW within range estimated by DNV GL of €200,000-€600,000/MW (Source: Chamberlain K 2016 *Offshore Operators Act on Early Decommissioning* (http://newenergyupdate.com/wind-energy-update/offshore-operators-act-early-decommissioning-data-limit-costs: New Energy Update))
Combined use – the benefits

Different objectives and methodologies but complementary:
- Very time-consuming to optimise a scenario with simulation models & not humanly possible to consider all possible solutions.
- The optimisation models determine the key supply-chain configurations and the financial models examine the top ranking options in further detail.
- Simulation models can assess a scenario in detail and the Monte Carlo method considers the uncertainty of key risk factors e.g. failures and weather.
- Combined they can obtain the most economically viable and time efficient solutions to a wide range of logistical and strategic issues.
Potential end-users
Conclusion

1. Comprehensive and complementary set of logistics and financial models
2. Can foster significant cost-savings in the industry through effective decision-support.
3. Fill a significant gap in the current models available.
4. They can be used individually or together to optimise and simulate the full supply-chain and lifecycle of an OWF project.
5. Combined use can save considerable computational time.
6. Designed primarily for the project planning and design phase but also useful during operational period.
7. They can address current and future challenges faced by a wide range of stakeholders.
See you in Cork!
- WESC 2019 -
June 17th – 20th
Cork, Ireland
Thank you very much for your attention