GLOBAL WIND ENERGY SHIPPING AND LOGISTICS

LOGISTICS INNOVATION
COLLABORATION WITH PORT OF RØNNE
AND OFFSHORE CENTER BORNHOLM

JANUARY 27, 2016, RØNNE, DENMARK

Prepared for Denmark/Bornholm in focus
BACKGROUND & INTRODUCTION
Broad industry support

PhD objective is for the research to be useful to industry:

Reference Group
WIND MARKET SIZING AND OUTLOOK
Onshore and offshore distribution

Cumulative distribution ultimo 2013 (MW)

- Onshore: 6.832
- Offshore: 1.721

Installed distribution in 2013 (MW)

- Onshore: 36.134
- Offshore: 1.721

China onshore: 100 GW (October 15, 2015)
Source: NEA, China Wind Power 2015

372 GW end 2014
7.7 GW offshore wind
Source: Navigant Research (2015)
Number of offshore annual MW and wind farms installed up to and including 2013

Globally:
7,7 GW
(end of 2014)
Source: Navigant Research

2,3 GW offshore wind
installed in Europe
1st half, 2015
Source: EWEA (2016)

<table>
<thead>
<tr>
<th>Year</th>
<th>MW installed</th>
<th>Number of wind farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>1992</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>1993</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>1994</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>1995</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>1996</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td>1997</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>1998</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>1999</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>2000</td>
<td>55</td>
<td>3</td>
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<tr>
<td>2001</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>2002</td>
<td>183</td>
<td>2</td>
</tr>
<tr>
<td>2003</td>
<td>251</td>
<td>3</td>
</tr>
<tr>
<td>2004</td>
<td>60</td>
<td>1</td>
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<tr>
<td>2005</td>
<td>90</td>
<td>1</td>
</tr>
<tr>
<td>2006</td>
<td>198</td>
<td>2</td>
</tr>
<tr>
<td>2007</td>
<td>200</td>
<td>2</td>
</tr>
<tr>
<td>2008</td>
<td>344</td>
<td>4</td>
</tr>
<tr>
<td>2009</td>
<td>666</td>
<td>8</td>
</tr>
<tr>
<td>2010</td>
<td>1,428</td>
<td>9</td>
</tr>
<tr>
<td>2011</td>
<td>470</td>
<td>10</td>
</tr>
<tr>
<td>2012</td>
<td>1,131</td>
<td>9</td>
</tr>
<tr>
<td>2013</td>
<td>1,720</td>
<td>13</td>
</tr>
</tbody>
</table>

Source: BTM Consult a part of Navigant (2014a) and own construction
LOGISTICAL CHALLENGES
DIMENSIONS - ROAD

Source: Danish Shipowners’ Association, courtesy Siemens Wind Power
Innovation – what comes first?

Transport industry always caught back-footed – need to get in front of industry R+D trends…

Wind industry technology R+D leaps

First WTG serial production 1979
RACE FOR LARGER WTG OUTPUT
- AND IMPORTANCE OF SHIPPING/LOGISTICS/SCM

Source: Upwind Project (design limits and solutions for very large wind turbines) and Aalborg University Copenhagen photos
R+D - logistics

**Implications on:**
- Infrastructure (roads, bridges, tunnels, viaducts, storage facilities, ports)
- Logistics and shipping assets (trucks, trains, vessels, helicopters)
- Lifting equipment (land-based cranes, sea-borne cranes)
- Transport equipment (lifting equipment, transport frames, seafastening)
- Health, safety, security, environment, and quality (HSSEQ)

### Makers of wind turbines (OEMs):

**The pioneers**

- NEG Micon
- Vestas
- Bonus
- Siemens
- GE
- NASA

**Examples of the Asian “newcomers”**

- Enercon
- Nordex
- Gamesa
- Adwen
- Areva
- Hyundain
- Samsung
- Senvion
- Suzlon
- Envision

Source: AAU research, DHL Global Forwarding, Renewable Energy Solutions
And what about...?

Floating turbines...
• Installation?
• O&M?
How big is big enough?

<table>
<thead>
<tr>
<th>Weight &amp; Dimensions</th>
<th>Full nacelle weight (t)</th>
<th>Hub weight (t)</th>
<th>Total Hub Mass (t)</th>
<th>Blade Length (m)</th>
<th>Blade weight (t)</th>
<th>Tower weight (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siemens 2.3 MW</td>
<td>82</td>
<td></td>
<td></td>
<td>45</td>
<td></td>
<td></td>
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<tr>
<td>Repower 6.15 MW</td>
<td>325</td>
<td></td>
<td></td>
<td>61</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Siemens 6 (7) MW</td>
<td>364</td>
<td>96</td>
<td>360</td>
<td>75</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Samsung 7.5 MW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>83</td>
</tr>
<tr>
<td>Vestas 8 MW</td>
<td>390</td>
<td></td>
<td></td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NREL/DTU 10 MW</td>
<td>446</td>
<td>106-180</td>
<td>700</td>
<td>86-100</td>
<td>42-57</td>
<td>628</td>
</tr>
<tr>
<td>NREL 15 MW</td>
<td></td>
<td>303</td>
<td>1000</td>
<td>125</td>
<td>100</td>
<td>1000</td>
</tr>
<tr>
<td>DTU 20 MW</td>
<td>1061</td>
<td>299</td>
<td>125</td>
<td>118</td>
<td></td>
<td>1985</td>
</tr>
</tbody>
</table>

Source: AAU research, NREL, DTU Risø Wind, Siemens Wind Power, Renewable Energy Solutions
RESEARCH FINDINGS
Single project life-cycle E2E

Global supply chain

- Tier 4 suppliers
- Tier 3 suppliers
- Tier 2 suppliers
- Tier 1 suppliers
- Parts & components

Wind turbine generator modules

- Tower
- Nacelle
- Hub
- Blades

Balance of plant modules

- Foundation
- Cables
- Sub-station
- Accommodation

Offshore wind only

European supply chain

Two different flows: Onshore and Offshore

Development and consent phase
1 2-8 years

Installation & commissioning phase
2 2-5 years

Operations & maintenance phase
3 25 years

Decommissioning phase
4 1-3 years

Shipping & logistics

Source: LogMS conference paper, 2013, Singapore 2013, Poulsen et.al.
Each life-cycle phase have very different characteristics

- Different supply chains
- Different logistics and shipping needs
- Different supply chain constituencies and contract set-up

<table>
<thead>
<tr>
<th>Wind farm phase</th>
<th>Development &amp; Consent (D&amp;C)</th>
<th>Installation &amp; Commissioning (I&amp;C)</th>
<th>Operations &amp; Maintenance (O&amp;M)</th>
<th>De-commissioning (De-comm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply chains</td>
<td>D&amp;C chain</td>
<td>I&amp;C chain - Inbound</td>
<td>O&amp;M - Preventive</td>
<td>De-comm chain</td>
</tr>
<tr>
<td>Description</td>
<td>Site surveys, birds, wildlife, sea, seabed</td>
<td>Inbound assembly parts and components</td>
<td>Personnel, parts, and components</td>
<td>Restoration of site for new wind farm or to original condition</td>
</tr>
<tr>
<td>Characteristics</td>
<td>Specialized vehicles (onshore) and vessels (offshore)</td>
<td>Mainly a homogenous flow using ocean containers and air; some project cargo</td>
<td>Mainly service boats, crew transfer vessels and some larger vessels</td>
<td>Project cargo/break-bulk</td>
</tr>
</tbody>
</table>

Wind energy supply chains

Source: Brand new research to be published soon. Watch this space!
CASE STUDY:
ANHOLT OFFSHORE WIND FARM

Fact box

- Operator: DONG Energy
- Ownership: DONG Energy, PKA, and PensionDanmark in JV
- Construction cost: DKK 11.5B
- Number of positions: 111 WTG’s
- WTG type: 3.6 MW geared Siemens Wind Power
- Foundation type: MP/TP
- Total windfarm output: 400 MW
- Area covered: 88 km²
- Distance from installation / service port (Grenå): 15 km
- Water depth 15.5 – 18 meters

Source: DONG Energy, MTH, AAU research (meetings and site visits), EAWE conference paper, 2013 (Poulsen et.al.)
Case: O&M logistics cost reduction

18 interviews
- 14 F2F
- 4 phone
= 36 ideas

2 additional ideas
3 ideas selected

8 additional ideas

Grouping:
- Standard rules
- Optimize utilization of vessels
- Stand alone projects
- "Maybe"
- "No go"

24/7
Lean

2 groups Idea development

Concept Business case elements Calculations

Implementation planning
Risk analysis
Likelihood
Case: Logistics innovation

Project planning
- July, 2014 Kick-off
- October, 2014 Interview start
- February, 2015 Interview end

Exploratory interviews
- January, 2014 Student exam #1
- February 11, 2015 Reference Group kick-off

Follow-up surveys
- April, 2015 Pilot survey
- May, 2015 Main survey

Analysis
- June, 2015 Student exam #2
- End June Start
- End July Complete

Reference Group presentation
- September 7, 2015

Phase 1
- Exploratory interviews

Phase 2
- Follow-up surveys

Phase 3
- Analysis

Phase 4
- Project planning

Phase 5
- Reference Group kick-off

Phase 6
- Student exam #1

Phase 7
- End July Complete

Key tasks:
1. Planning
2. Exploratory interviews
3. Surveys
4. Interview transcription
5. Student exam analysis
6. Project analysis
7. Strategy hand-over to company
Case: Testing – logistics and shipping

1. Small scale test – DTU, Force
2. Shore turbines – Østerild
3. Other parts – LORC

Next up:
In the ocean?
CONCLUSION
KEY TAKE-AWAYS FROM TODAY

• Offshore wind market is growing rapidly
• Many projects in the pipeline, under construction, and already in operation
• End-to-end life-cycle view for logistics holds strong potential for cost savings
• Proactive logistics innovation is critical
• Live testing and training offshore is needed
THOMAS POULSEN – Q&A?

Aalborg University, Copenhagen Campus
Department of Mechanical and Manufacturing Engineering

CONTACT INFO
tp@m-tech.aau.dk
www.en.m-tech.aau.dk

RESEARCH INTERESTS
Global wind energy shipping and logistics

BACKGROUND
25 years of global shipping, logistics, and SCM experience having lived in 8 different countries working at practical, strategic, general management, and consulting level

DDMF grant 2012-097