The Business Case for Structural Health Monitoring for Floating Wind

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Organized by

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### Site Investigation
- Geophysical site investigation
- Geotechnical site investigation
- Engineering & consultancy

### Engineering
- Concept design
- Foundation engineering
- Dynamic analysis
- Client engineer

### Installation
- Pile hammers
- Pile drilling
- Pile cleaning
- Piling templates
- Grouting
- Lifting & handling
- Survey & positioning
- Tow-out & mooring

### Operations
- Subsea Inspection
- Seabed & Cable Survey
- Structural monitoring
- Asset integrity management
- Digital Twins

### Late Life
- Cathodic Protection remediation
- Cable repair
- Jacket remediation
Agenda

- FOW Challenges / Drivers of LCOE
- What is Monitoring
- How to Monitor
- Data Management and Insight
- OPEX Optimization
- Summary and Take Away
Challenges of FOW

- Novel
- Increasing Turbine Capacities
- Ever Increasing Structures (Taller)
- Complex Dynamic Response
- Harsh Marine Environment
- Service life >25 years
Drivers of LOCE (Levelized Cost of Energy)

• CAPEX
• Financing
• Energy Production
• Operations

Source: Catapult
# High Level Economics of Fixed Offshore Wind

## Fixed Offshore Windfarm Key Parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind farm rating (MW)</td>
<td>1000</td>
</tr>
<tr>
<td>Wind turbine rating (MW)</td>
<td>10</td>
</tr>
<tr>
<td>Water depth at site (m)</td>
<td>30</td>
</tr>
<tr>
<td>Annual mean wind speed at 100m height (m/s)</td>
<td>10</td>
</tr>
<tr>
<td>Distance to shore, grid, port (km)</td>
<td>60</td>
</tr>
<tr>
<td>Efficiency Factor Average</td>
<td>37%</td>
</tr>
<tr>
<td>Efficiency Factor MAX</td>
<td>51%</td>
</tr>
<tr>
<td>Efficiency Factor MIN</td>
<td>29%</td>
</tr>
<tr>
<td>Offtake price MWh US-$</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Catapult

## Fixed Offshore Windfarm Cost@20 Years Service

<table>
<thead>
<tr>
<th>Category</th>
<th>Cost Estimate Mill-US$/MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development and project management</td>
<td>$163</td>
</tr>
<tr>
<td>WTG - Assembly</td>
<td>$1,364</td>
</tr>
<tr>
<td>Balance of plant</td>
<td>$820</td>
</tr>
<tr>
<td>Installation and commissioning</td>
<td>$888</td>
</tr>
<tr>
<td>SHM</td>
<td>$3</td>
</tr>
<tr>
<td>Decom</td>
<td>$442</td>
</tr>
<tr>
<td>OPEX</td>
<td>$2,067</td>
</tr>
<tr>
<td><strong>Sub Total</strong></td>
<td><strong>$5,748</strong></td>
</tr>
</tbody>
</table>

Source: Catapult

Average Fixed Offshore Wind Development and Operating Cost – INDICATIVE ONLY
CAPEX and Leverage Opportunities

Leverage

- Technology Maturity
- Standardization
- Production to Scale
- Optimize Supply Chain
- Reduce Project Risk

Source: Catapult
Select Leverage, Impact and Sensitivity

Efficiency Factor is the Ratio of actual electrical energy output over the maximum energy output.

### Scenario Efficiency Factor - US-$/MW

<table>
<thead>
<tr>
<th>Item</th>
<th>Average EF</th>
<th>MAX EF</th>
<th>MIN EF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capex</td>
<td>$ (3,235,440)</td>
<td>$ (3,235,440)</td>
<td>$ (3,235,440)</td>
</tr>
<tr>
<td>Opex</td>
<td>$ (2,067,200)</td>
<td>$ (2,067,200)</td>
<td>$ (1,717,802)</td>
</tr>
<tr>
<td>Decom</td>
<td>$ (442,000)</td>
<td>$ (442,000)</td>
<td>$ (442,000)</td>
</tr>
<tr>
<td>Revenue</td>
<td>$ 6,482,400</td>
<td>$ 8,935,200</td>
<td>$ 5,080,800</td>
</tr>
<tr>
<td><strong>Sub-Total</strong></td>
<td><strong>$ 737,760</strong></td>
<td><strong>$ 3,190,560</strong></td>
<td><strong>$ (663,840)</strong></td>
</tr>
</tbody>
</table>

Average-37% Min-29% Max-51%

### Scenario OPEX Variation - US-$/MW

<table>
<thead>
<tr>
<th>Item</th>
<th>Average OPEX</th>
<th>OPEX Increase (2%/year)</th>
<th>OPEX Reduction (2%/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capex</td>
<td>$ (3,235,440)</td>
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<td>$ (2,067,200)</td>
<td>$ (2,511,376)</td>
<td>$ (1,717,802)</td>
</tr>
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<td>Decom</td>
<td>$ (442,000)</td>
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<td>Revenue</td>
<td>$ 6,482,400</td>
<td>$ 6,482,400</td>
<td>$ 6,482,400</td>
</tr>
<tr>
<td><strong>Sub-Total</strong></td>
<td><strong>$ 737,760</strong></td>
<td><strong>$ 293,584</strong></td>
<td><strong>$ 1,087,158</strong></td>
</tr>
</tbody>
</table>

Potential Revenue Range Mill US-$4,000

Potential Cost Savings Range Mill US-$800

Lifecycle Savings
Digital Transformation - What is Monitoring?
Creating a Workforce for the Machine Age

Transition to a Sustainable World

Building Trust in the Digital Economy

8.4 Trillion US-$ Select Industry Value

12.7 Trillion US-$ Societal Value

100 Trillion US-$ Combined Estimate for all Industries

Source: World Economic Forum Digital Transformation
What Is Monitoring?

My Personal Digital Transformation Journey
Peak Performance using Structured Monitored Training
Getting Dropped – A lot!

Trained  Bought Expensive Kit  Surveyed Good Riders
Performance Improvement using Structured Monitored Training Equipment

- Aerodynamics
- Fitness, Fatigue and Form
- Tactics
- Bike Handling Skills

Aerodynamics

Fitness, Fatigue and Form

Tactics

Bike Handling Skills
How To Monitor?
Structural Thread to Floating Offshore Wind

**Threads**
- In service environment and soil strength worse than design
- Vessel motions greater than design predictions
- Dynamic blade thrust loads on tower and platform higher than design
- Excessive corrosion
- Manufacturing defects
- Collision/Impact

**Degradation Mechanism**
- Overstress
- Fracture
- Fatigue
- Corrosion
- Wear
- Loss of Soil Support

**Risk Consequences**
- Loss of mooring line
- Power Cable Failure
- Excessive Tilt / heel
- Reduced Operability
- Reduced Power Output
- Damage to Tower
- Loss of Platform Stability and Position

- Low probability but high consequence events
- Probability of risks increase with age
- Need to be managed through inspection and monitoring

Floating Wind Solutions
Typical Structural Health Monitoring Systems

- Position & Heading
- Mooring and Cable Monitoring
- Metocean Wind, Wave
- Motion - IMU
- Foundation Load Monitoring
- Corrosion and CP Potential
## Monitoring Systems Distribution Recommendation

<table>
<thead>
<tr>
<th>Platform</th>
<th>Position and Heading</th>
<th>Mooring and Cable</th>
<th>Corrosion and CP</th>
<th>Metocean</th>
<th>Load Monitoring</th>
<th>Motion</th>
<th>Data Infrastructure and Insight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>2</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>4-100</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Weighed for Cost and Benefit
Data Infrastructure and Management

Platform - Edge

- Platform Operations SCADA
- Nacelle CMS
- Structural Health Monitoring
- Cable Health Monitoring

Platform Data Acquisition Server and Visualization
- Data gathering
- QA/QC Algorithm
- Trending
- Data Storage

Beach/ Cloud
- System Health and Status
- Statistics, Trending and KPI
- Service History
- Alarm Generation
- Advanced Analytics (AI and Machine Learning)
Data Management Insight and Reporting

Value Generation

- Data Aggregation
- Data Visualization
- Insight Generation
  - Algorithms
  - Local Fatigue
  - Corrosion Rates
  - Digital Twin
  - Storm Safe
- Action
  - Optimize Inspection Regime
  - Targeted Subsea Survey
  - Data Driven IMR

Value Add

- $$ saving

Company Representative
OPEX Optimization through Monitoring

Reduce Downtime Post Storm

Optimize P&U Maintenance

Reduce Inspection and Survey

Optimize Spare, Redundancy and Replacement Inventory

Reduce/Eliminate Repair and Component Replacement

Reduce/Eliminate Repair and Component Replacement

$
SHM – Value Summary

• Detection of Anomalies
• Optimize Inspection Maintenance and Repair Activity
• Increase Uptime
• Fundamental for Asset Life Extension
• Decrease Carbon Footprint
• Improve Long-Term Bankability
Thank You