



Satellite Imagery:

Remote Sensing to Enhance Offshore Wind Cost-Effectiveness

EO Commercialization Forum

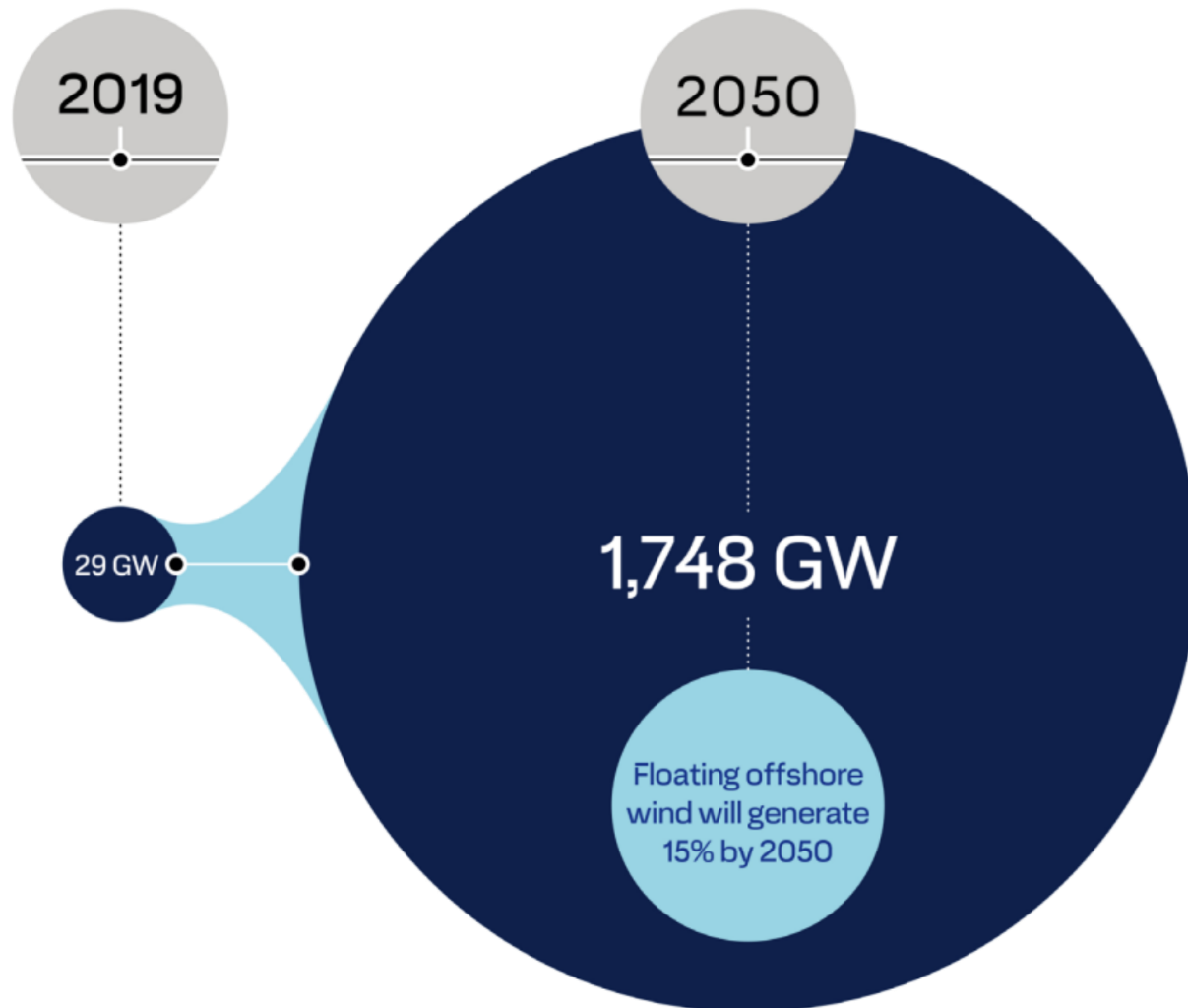
Green and Sustainable Future opportunities for the EO Industry

September 27th, 2024

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WavEC Offshore Renewables

Why Using Remote Sensing?



Floating Offshore Wind Outlook:

- i. **Extremely high wind energy potential**, predominantly in deep waters
- ii. **High level of social acceptance...**
- iii. **Forecast for 2050**
260 GW of offshore floating wind capacity by 2050 according to DNV-GL

Why Using Remote Sensing?

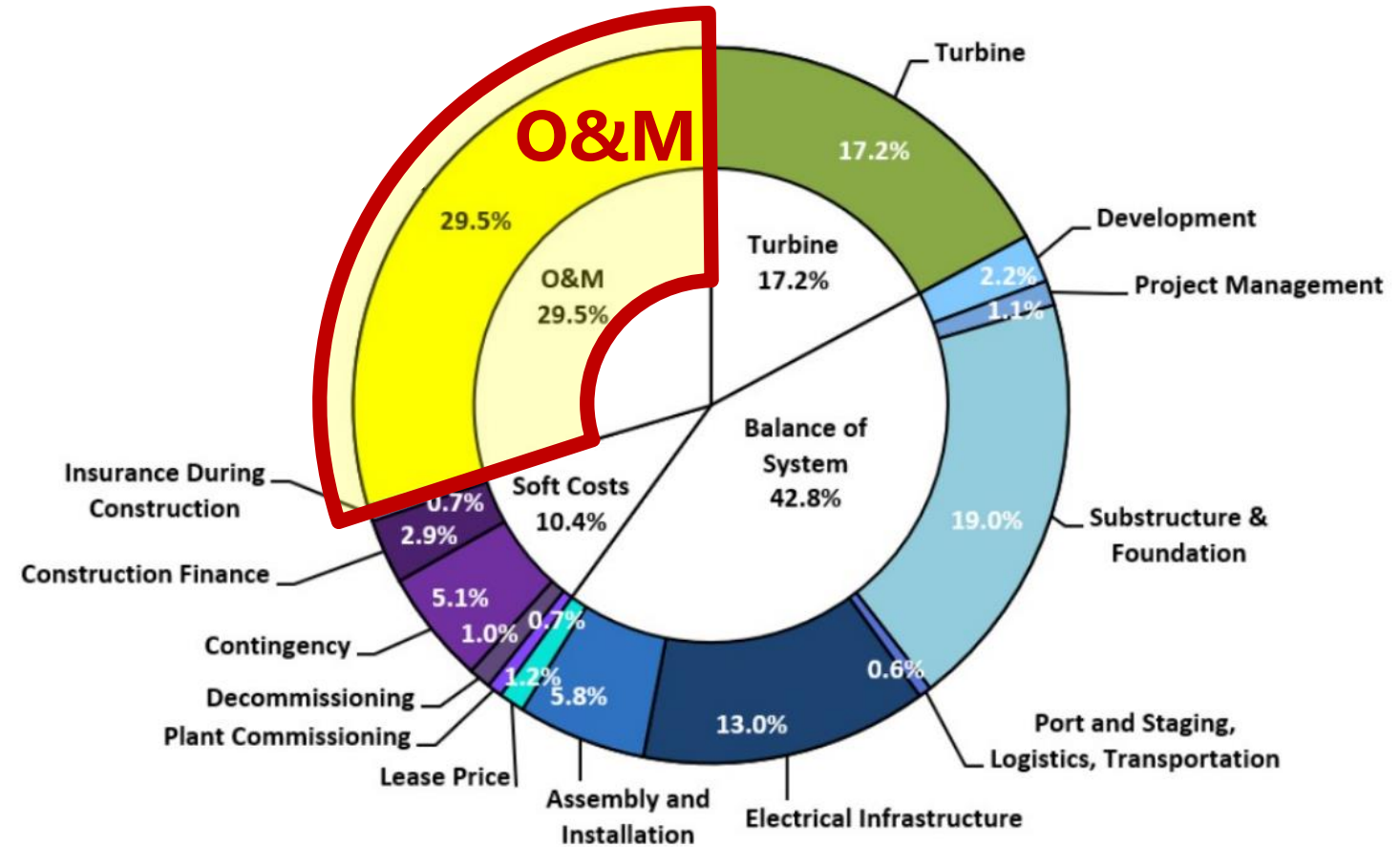
Floating Offshore Wind challenges:

i. Improve cost effectiveness - reduce LCOE-

30% of the LCOE is spent on O&M activities, according to NREL

ii. Improve inspection, monitoring and O&M

Farms of FWTs will be farther from the shore and thus access will be highly constricted



Why Using Remote Sensing?



TAM

Total Addressable Market

Assumptions:

- OPEX* of Floating Wind ~ 80 k€/MW/Yr
- O&M Planning ~ 10% OPEX



SAM

Service Addressable Market

Assumptions:

- DNV GL: 60% of the global floating wind installed capacity will be in Europe*



SOM

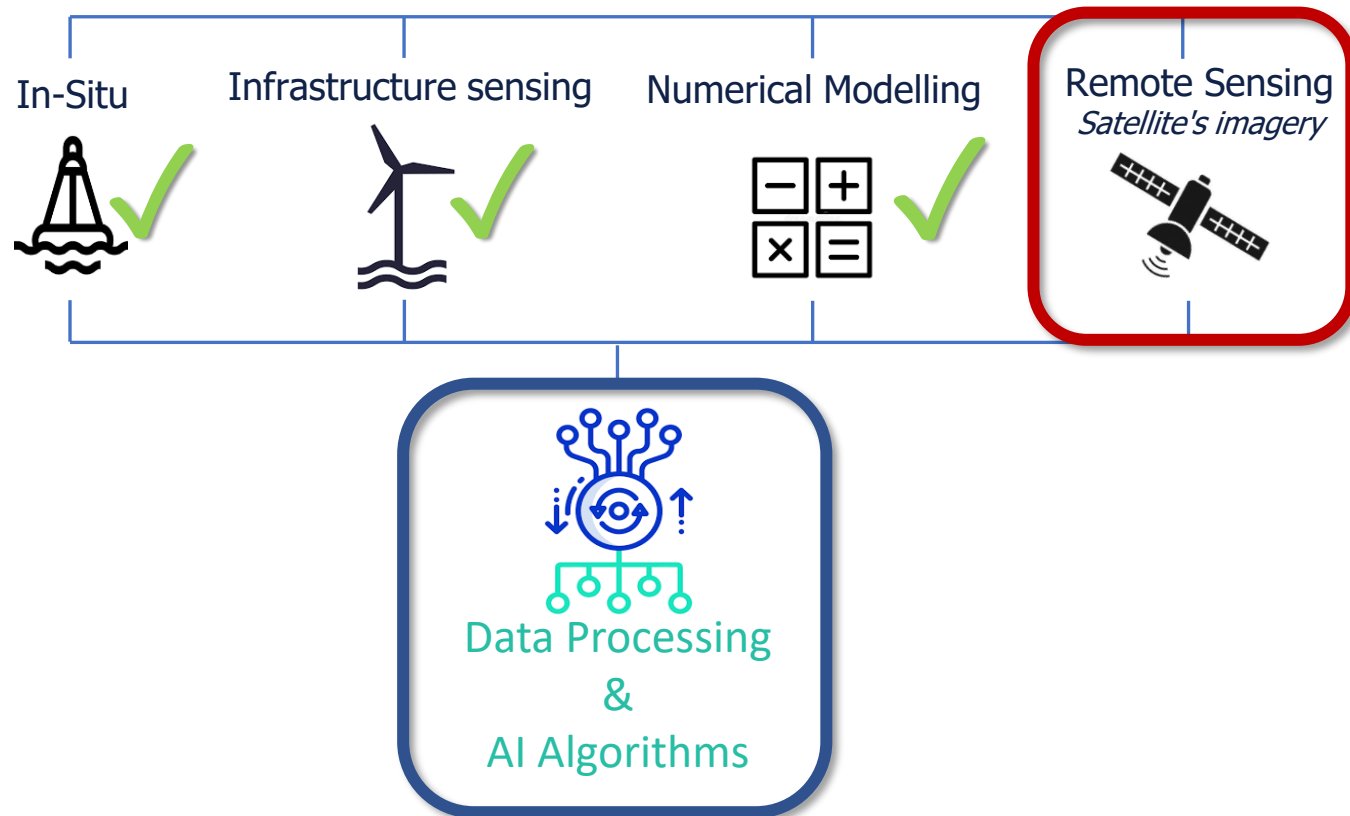
Serviceable Obtainable Market

Assumptions:

- SOM=5% SAM

Integrate Remote Sensing into a Holistic Approach

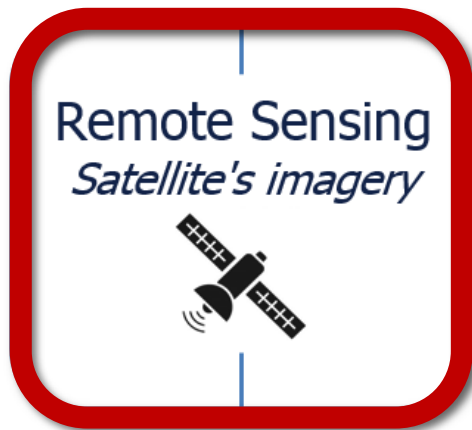
Combining data...



Planning O&M activities:

- i. Articulate data from different sources**
in-situ, monitoring, satellite imagery and numerical modelling/digital twins
- ii. Include farm operational data**
instead of relying only on turbine data
- iii. Advanced data processing algorithms**
to optimize maintenance procedures

Integrate Remote Sensing into a Holistic Approach



Remote sensing from satellite data can be used:

i. Estimate (*forecast*):

- Weather windows
- Electricity production
- Production losses due to downtime
- Planning for maintenance operations
- ...

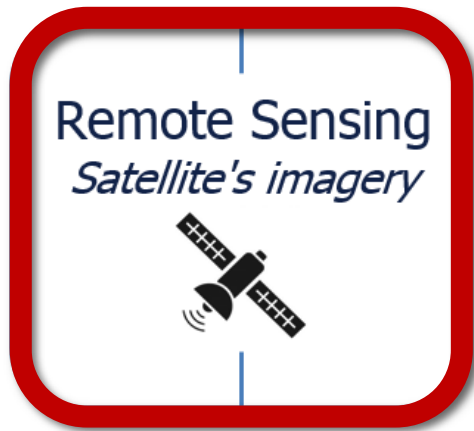
ii. Evaluate (*quasi-real-time imagery data*):

- Condition of the platforms and moorings
- Stoppage times of turbines
- Unexpected impacts on downstream turbines
both due to wake effects and turbulence from currents
- Support algorithms for maintenance decision
- ...

iii. Assess (*metocean historic data*):

- Remaining useful lives (RUL) based on accumulated damage
- Mapping of water depths and seabed dynamics
- Available resources (wind, waves, etc.)

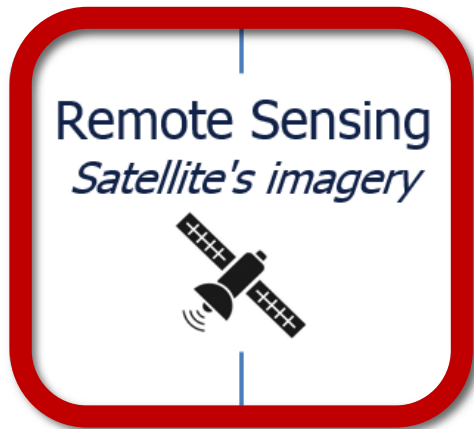
Integrate Remote Sensing into a Holistic Approach



ii. Quasi-real-time imagery data:

- Acquired from Optical Imager Satellites (such as the Sentinel, GEOSAT, etc.)
- Provide bottom-line information regarding the condition of the turbines, moorings and the entire farm as a whole

Integrate Remote Sensing into a Holistic Approach



ii. Quasi-real-time imagery data:

- Acquired from Optical Imager Satellites (such as the Sentinel, GEOSAT, etc.)
- Provide bottom-line information regarding the condition of the turbines, moorings and the entire farm as a whole...

State of Art Monitoring Systems

- ✓ Each turbine is monitored independently as a standalone device;
- ✓ Sometimes, using Captain-stewart strategies



Satellite data for Monitoring purposes

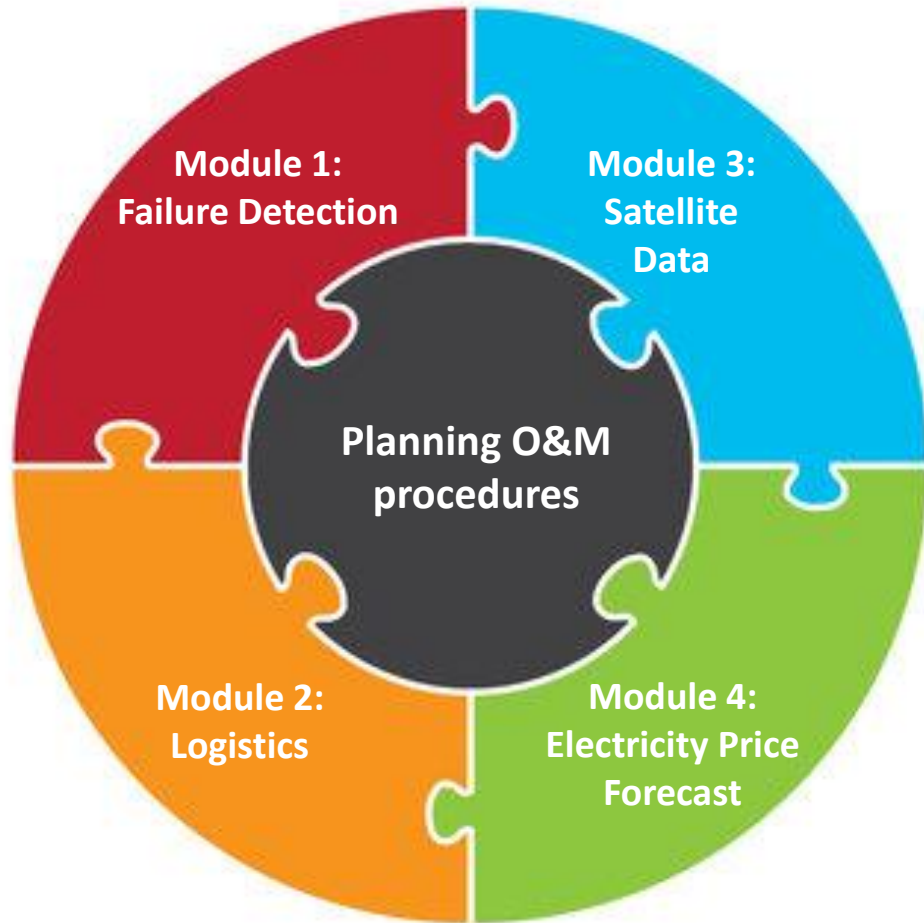
- ✓ Complement SCADA systems with data not available previously
- ✓ Detect trends on the overall farm, rather than on each independent turbine



looking at the forest, instead of just the tree ...

Proposed Approach

Support Decision Tool:



Using satellite data to support O&M planning:

i. Module 1

- Early failures detection based on data from SCADA system, satellite and digital twins
- Estimates of the remaining useful life (RUL) of subsystems

ii. Module 2

- Evaluates the type of failure which has occurred or is expected to occur
- Assess the availability of resources (e.g., vessels, spare parts, human resources)

iii. Module 3

- Forecast weather conditions to:
 - *estimate short-term electricity production*
 - *Identify weather windows*
 - *support selection of vessels for O&M activities*
- Detect failures on *blades, towers, foundations and seakeeping system...*

iv. Module 4

- Expected electricity production and revenue level

Proposed Approach

Module 3: Satellite Data



Sentinel 2 Image – 2022-02-05 (10-m resolution, 2.5 days revisiting period)

Remote Sensing: What we can measure ...

- i. **Relative distances** between the platforms and offsets from average positions (L1, L2)
- ii. **Relative rotations** of the platforms amongst each other or against time (a1, a2, a3)
- iii. **Orientations** of the three turbines (d1, d2, d3)
- iv. **Turbines stoppage** - One turbine is stopped, as the turbine orientation and position of the blades reveal...
- v. ...

Proposed Approach

Module 3: Satellite Data



Sentinel 2 Image – 2022-07-08

Remote Sensing: What we can measure ...

- i. **Surveillance and Supervision of activities** – Identification of proximity of vessels, boats, etc.
- ii. ...

Proposed Approach

Module 3: Satellite Data



Sentinel 2 Image – 2022-05-09

Remote Sensing: What we can measure ...

- i. **Impact on Currents** - Effect of the platforms on the ocean currents is identified...
- ii. **Wake Effects** – Impact of the turbine's wake is identified in the surrounding clouds
- iii. ...



Optical and radar (SAR) satellites can provide very detailed imagery down to 25-30 cm with no HSE risks associated. Satellite images are very cost-efficient in getting updated intel on specific OWF sites, allowing monitoring of specific maintenance activities

Core Message

Satellite Remote Sensing will be Pivotal
to Advancing the Emerging FOW Industry
and Boosting Its Competitiveness!

Going forward...

- Use these projects as test-cases to develop post-processing AI/ML tools
- Develop relevant proprietary technology/software and make it market-ready for when farms scale in size / generate collaborations with other entities that support commercial developments
- Other satellites with much better resolution (such as the GEOSAT, with 35-cm resolution, 2.5 days revisiting period) could be used, but require paying for images (1400\$ per 100 km²(min))
- The Atlantic Constellation expects to implement 16 satellites up to 2025, which will provide high resolution images of the Atlantic with a revisiting period of 2-3 hours

Thank you for your attention 😊



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