Enhancing Offshore Wind Farm Operations through Innovative Geospatial Planning and Metocean Data Integration

In port and harbour environments, the challenges of offshore wind farm operations have persisted for an extended period, necessitating the development of innovative and sustainable solutions. This paper introduces an integrated system designed to address the complex operational requirements of marine activities, focusing primarily on meteorological and oceanographic (metocean) data. This system encompasses various aspects, including vessel/asset management, wind turbine generator (WTG) design, positioning, site considerations, and seamless integration with engineering design and operational support.

The integrated system holds particular significance for the wind farm development sector, which increasingly relies on coastal and offshore locations. Accurate metocean data is essential in this industry, and this integrated system offers invaluable support to wind farm developers and operators. It provides critical environmental data necessary for safe and efficient project planning, construction, and maintenance.

This paper also proposes a Geo-data technical guidance framework tailored for Site Investigation and Asset Integrity. This framework serves as a comprehensive product-based solution for both traditional maritime activities and the growing demands of wind farm development. It addresses metocean measurement and survey preparedness, offering sustainable solutions to meet the diverse needs of mariners and wind energy stakeholders. It provides operational, commercial, and technical support with a primary focus on safety and efficiency standards, especially within challenging environments, through sensor-based, data-driven assistance.

The integration of metocean databases assumes paramount importance in constructing and validating baseline models. It enables real-time sensor data to facilitate asset maintenance and risk assessment, with a particular emphasis on the insights provided by mooring and flotation buoy sensors for wind farm development, especially concerning wind turbine floating foundations and mooring systems.

by Jagadish Vallarampara

oceanology international
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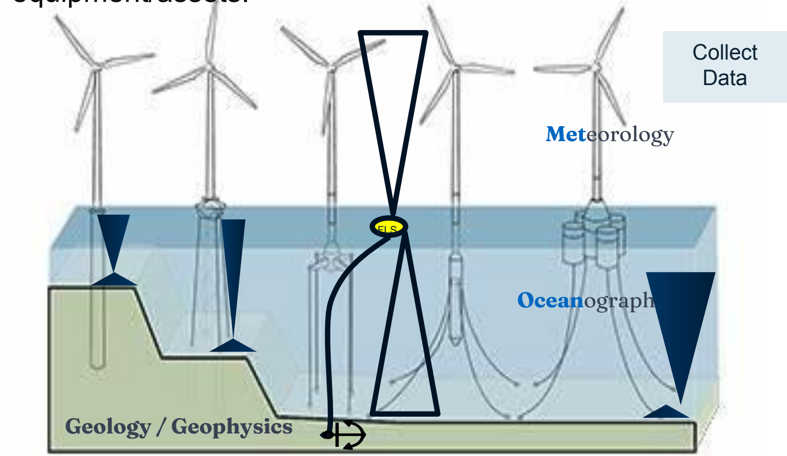
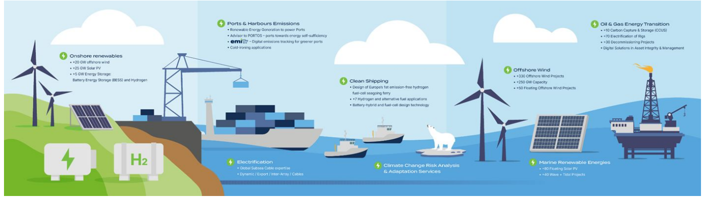
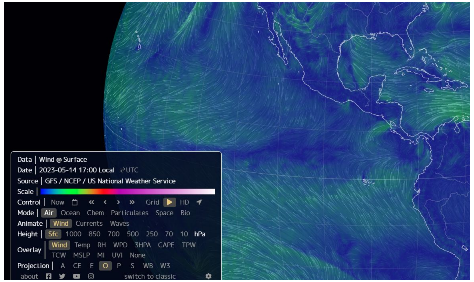
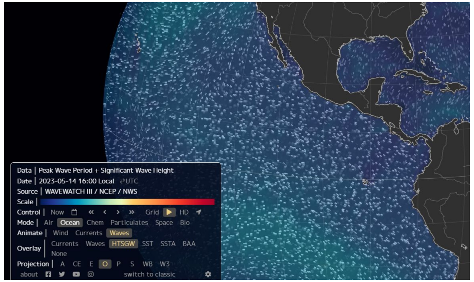
Geospatial Planning and Metocean Data

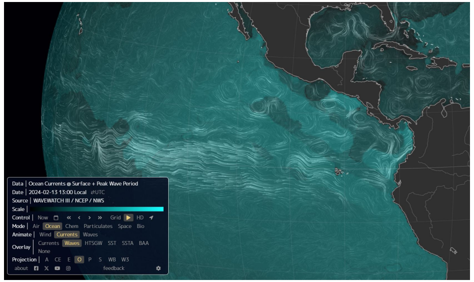
Understanding geodata conditions, including metocean (meteorology and physical oceanography), geology, and geophysics, is essential for planning and designing infrastructure and ensuring the safety of personnel and equipment/assets.











Earth :: a global map of wind, weather, and ocean conditions (nullschool.net)

Meteorology is the scientific study of the Earth's atmosphere, focusing on weather patterns, climate, and the processes that drive atmospheric phenomena including wind, temperature, humidity, Ice etc.

Oceanography is the scientific study of the Earth's oceans, encompassing various disciplines that examine multiple aspects of the marine environment. It involves exploring and understanding the physical, chemical, biological, and geological processes occurring in the oceans.

Physical Oceanography: Physical oceanographers study the physical properties of seawater, including temperature, salinity, density, currents, waves, and tides. They investigate ocean circulation patterns, the interaction of the ocean with the atmosphere, and the movement of heat, energy, and nutrients throughout the ocean.

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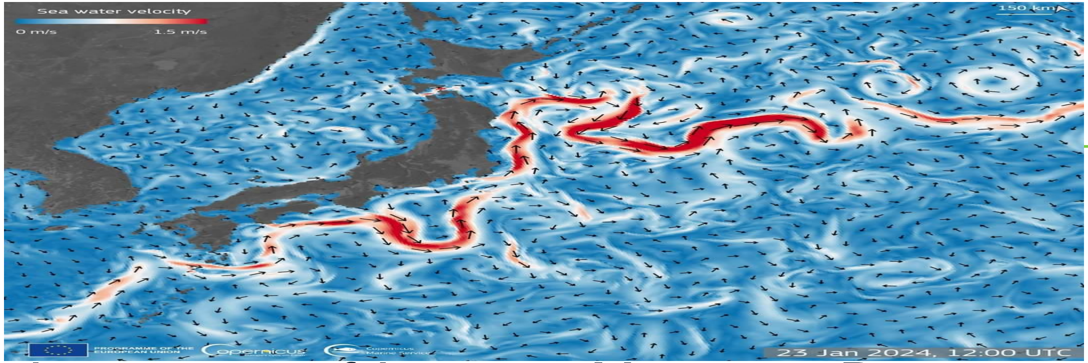
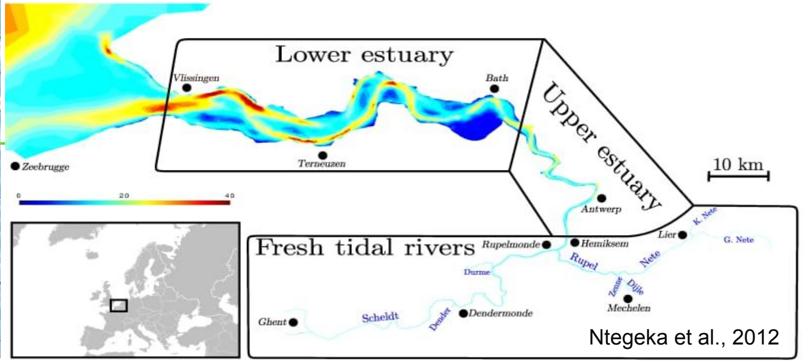




Ntegeka et al., 2012

Importance of Accurate Metocean Data

1 Safe Project Planning

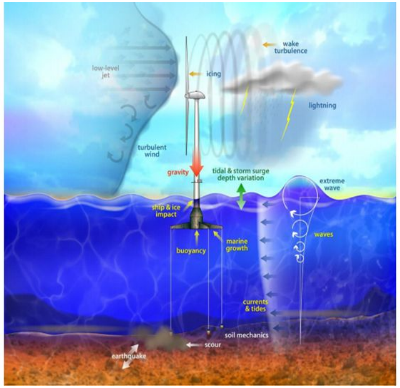
Accurate metocean data is indispensable for ensuring the safety and efficiency of project planning, construction, and maintenance in the offshore wind farm development sector.

2 Efficient Project Execution

The availability of critical environmental data assists wind farm developers and operators in making informed decisions for efficient project execution.

3 Supporting Coastal & Offshore Locations

The integrated system's support is particularly valuable as the industry increasingly relies on coastal and offshore locations for wind farm development and operations.



Loads on an offshore wind turbine (Jonkman, 2007)

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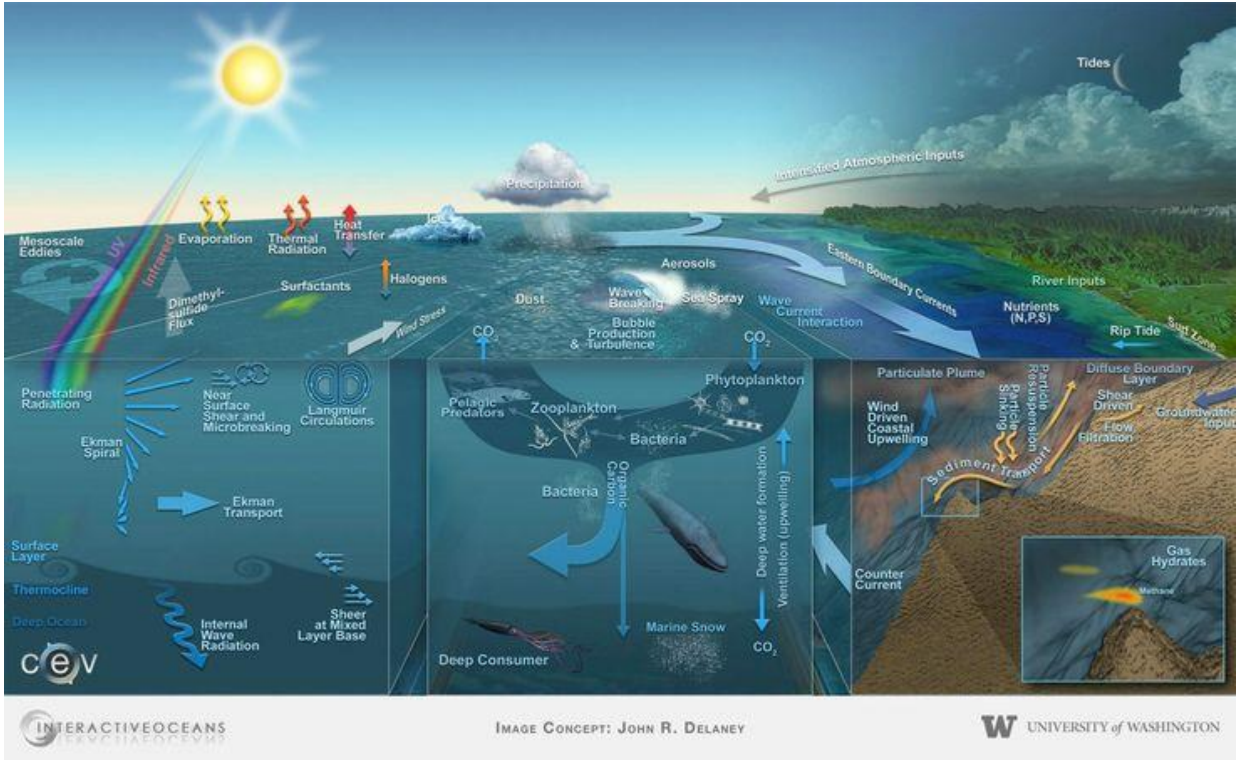
Metocean Process and Geospatial Understanding



Understanding of Metocean Process

- **Atmospheric** and **oceanographic** circulation systems act as the means for distributing thermal energy on the Earth's surface.
- This redistribution helps regulate global climate patterns, influencing regional weather conditions, oceanic productivity, and the overall climate system.
- The interaction between atmospheric and oceanographic circulation is essential for redistributing thermal energy.
- Warm ocean currents transfer heat to the atmosphere, influencing air temperature and moisture content.
- Conversely, atmospheric circulation affects ocean surface currents through wind stress, forming oceanic gyres and upwelling/downwelling regions.

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Offshore Wind Market Growth

Technological Advancements

- The offshore wind sector has witnessed revolutionary technological advancements, leading to increased efficiency and substantial reductions in operational costs.
- Floating projects, albeit constituting a minority at present, hold potential for future prominence.
- Deploying large arrays of turbines along coastlines enables the capture of potent, steady offshore winds.
- Given that 40% of the global population resides within 60 miles of the ocean, offshore wind farms have the potential to significantly enhance worldwide efforts aimed at cleaning up the electricity supply.

Capacity Expansion

- **Resource Assessment:** - Metocean data helps in assessing the resource potential including wind, wave and tidal at the proposed expansion site. Data on wind speed, direction, and turbulence, which are essential for selecting the most suitable turbine technology and optimizing the layout of the expanded wind farm.
- **Environmental Impact Assessment:** Metocean data aids in conducting environmental impact assessments by providing information on ocean currents, water temperature, wave height, and other relevant parameters. This data helps in understanding the potential impacts of the expansion on marine ecosystems and coastal habitats.
- **Operational Planning:** Metocean data supports operational planning by providing forecasts of weather and ocean conditions. This includes forecasts of wind patterns, wave conditions, and storm events, which are essential for safe and efficient offshore operations during the construction, installation, and maintenance phases.
- **Risk Management:** Metocean data helps in assessing and mitigating risks associated with offshore wind farm operations. This includes identifying potential hazards such as extreme weather events, sea ice, and oceanographic phenomena, and developing contingency plans to minimize disruptions and ensure the safety of personnel and assets.
- **Grid Integration:** Geospatial and Metocean data supports grid integration by providing insights into the variability of wind and wave conditions, which impact the intermittency and predictability of offshore wind power generation. This information is essential for grid operators to manage the integration of renewable energy into the electricity grid effectively.

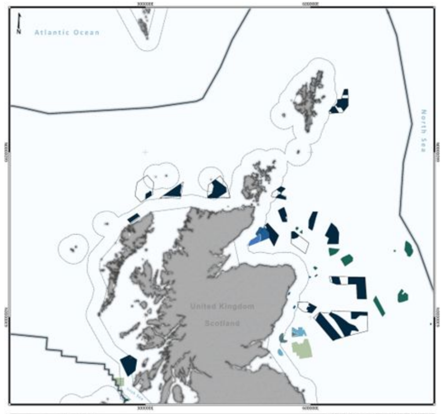
Global Uptake

- While European waters dominate installations, there is a burgeoning interest and increasing capacity noted in new markets across the globe.
- Despite growth, the industry faces challenges. Supply chain disruptions, rising interest rates, and high inflation have impacted project timelines
- Increased awareness of climate change and the need for clean energy sources have fuelled investment in offshore wind power

Environmental Impact and Sustainable Development

Positive Impacts

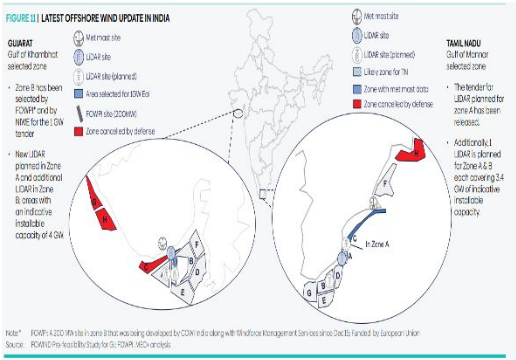
Offshore wind farms contribute significantly to carbon footprint reduction, bolstering the renewable energy sector's efforts towards battling climate change.



Source: Scotwind Crown Estate Scotland

Negative Impacts

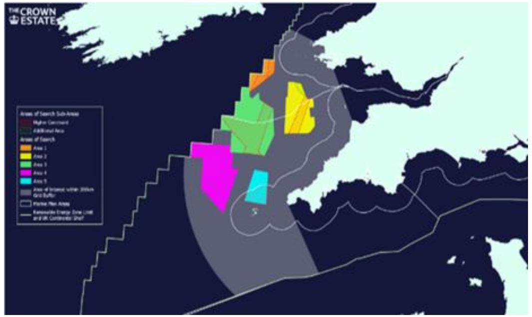
Challenges include potential disruptions to marine life and ecosystems, necessitating advanced geoscience solutions to mitigate potential harms.



Source: FOWIND, INDIA

Sustainable Practices

Despite growth, stringent practices in the wind industry aim to uphold sustainable development while minimizing environmental impact.



Source: Crown Estate (Celtic Sea)

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Challenges in Offshore Wind Farm Operations

In the offshore, port and harbour environments, the challenges of offshore wind farm operations have persisted for an extended period, necessitating the development of innovative and sustainable solutions. There is a need for accurate metocean data in the wind farm development sector, and the critical environmental data necessary for safe and efficient project planning, construction, and maintenance.

1 Integrated System Significance

The integrated system offers invaluable support to wind farm developers and operators by providing critical environmental data necessary for safe and efficient project planning, construction, and maintenance.

2 Geo-data Technical Guidance Framework

The proposed framework provides a comprehensive product-based solution for both traditional maritime activities and the growing demands of wind farm development, addressing metocean measurement and survey preparedness.

Integrated System for Marine Activities

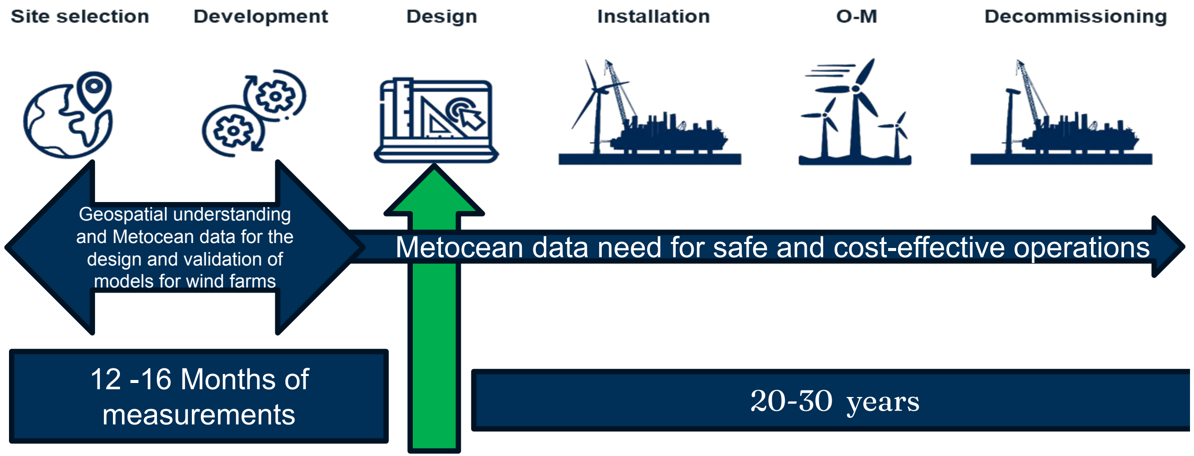
The integrated system encompasses various aspects, including vessel/asset management, wind turbine generator (WTG) design, positioning, site considerations, and seamless integration with engineering design and operational support. It offers invaluable support to wind farm developers and operators in coastal and offshore locations.

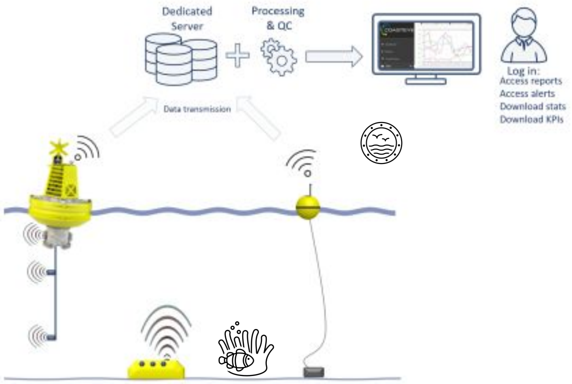
Key Aspects

Includes vessel/asset management, WTG design, positioning, and site considerations.

Seamless Integration

Integrates with engineering design and operational support for comprehensive functionality.





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Integrated Systems for Safe and Efficient Operations

Project Planning

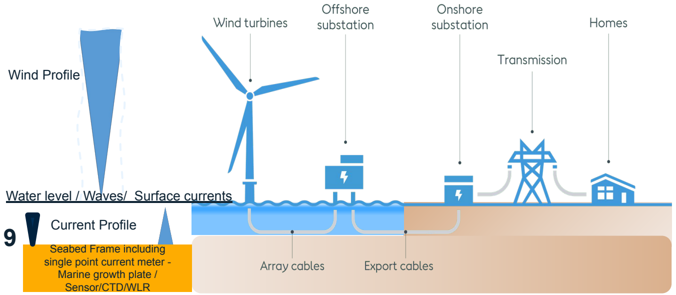
Geospatial planning and metocean data coalesce to determine prime locations for wind farm setup, optimizing layout to adapt to environmental constraints.

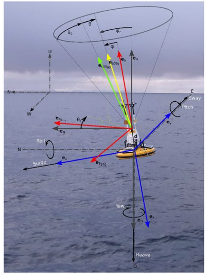
Construction

Integration of system data facilitates a construction process that prioritizes safety and minimal environmental disturbances.

Maintenance

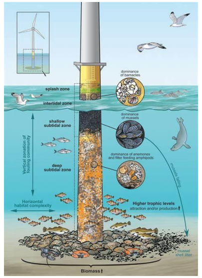
Regular monitoring and streamlined maintenance protocols are established, enabling prompt responses to operational issues.





F Kelberlau et al., 2020

Understands WTG Loads



Understand subsea conditions

Geo-Data Technical Guidance Framework

The Geo-data technical guidance framework provides sustainable solutions for site investigation and asset integrity within challenging environments. It addresses metocean measurement and survey preparedness, offering operational, commercial, and technical support with a primary focus on safety and efficiency standards.

Comprehensive Solution

Address Existing Data Gaps:

- Identify and prioritize key data gaps in wind and metocean datasets at a national scale.
- Develop methodologies to fill these gaps, leveraging innovative data collection techniques such as remote sensing, IoT (Internet of Things), and crowdsourcing.
- Establish protocols for data validation and quality assurance to ensure reliability and accuracy.

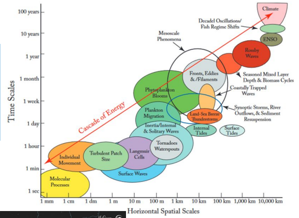
Facilitate Industry Development:

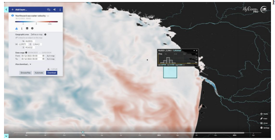
- Scope wind and metocean data needs to support marine development initiatives, particularly in the context of climate change.
- Identify emerging trends and technologies in geospatial data collection and analysis to de-risk marine development projects.
- Provide guidance on incorporating climate change projections into long-term planning and risk management strategies for marine renewables.

Drive Cost Reduction of Marine Renewables:

- Support greater access to relevant and high-quality wind and metocean data through open data initiatives, collaboration with governmental agencies, and industry partnerships.
- Develop standardized data formats and interoperability protocols to streamline data sharing and integration across stakeholders.
- Facilitate the development of predictive models and analytics tools using advanced data science techniques to optimize resource assessment, site selection, and project planning, ultimately driving cost reduction in marine renewables.

Each project site has specific metocean characteristics affected by large-scale, mesoscale, and fine-scale factors.





Survey Preparedness

Metocean and Marine Measurement Planning

- Develop standardised protocols for metocean data collection, considering factors such as data frequency, spatial resolution, and instrumentation requirements.
- Identify optimal measurement locations and deployment strategies to capture representative data across various marine environments.
- Integrate advanced technologies such as remote sensing, autonomous platforms, and satellite observations to enhance measurement capabilities.

Survey Readiness Assessment:

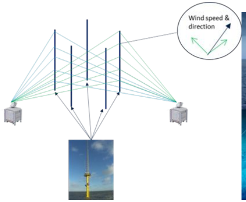
- Conduct comprehensive assessments of survey readiness, evaluating the availability and reliability of metocean data to support maritime operations and wind energy projects.
- Identify potential gaps in data coverage and quality, prioritizing areas for additional survey efforts or data collection initiatives.
- Establish contingency plans and response protocols to address unforeseen challenges or disruptions in data availability during survey operations.

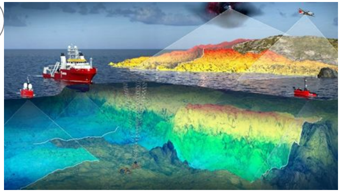
Stakeholder Collaboration and Coordination:

- Foster collaboration between mariners, wind energy developers, regulatory agencies, and research institutions to share data, expertise, and resources.
- Facilitate stakeholder engagement and consultation processes to ensure alignment of survey activities with industry standards, regulatory requirements, and environmental best practices.
- Promote knowledge exchange and capacity building initiatives to enhance survey preparedness and data literacy among relevant stakeholders.

Sustainable Solutions Implementation:

- Implement sustainable metocean measurement solutions that minimize environmental impact and promote long-term data reliability.
- Integrate renewable energy technologies such as solar-powered buoys, wave energy converters, and underwater gliders to support autonomous data collection efforts.
- Incorporate data management best practices to ensure secure storage, transmission, and accessibility of metocean datasets for ongoing monitoring and analysis.





Focus on Safety & Efficiency

Rigorous Safety Protocols:

- Implement stringent safety protocols and procedures to mitigate risks associated with marine operations and wind energy projects.
- Conduct comprehensive risk assessments and hazard analyses to identify potential safety hazards and develop proactive mitigation strategies.
- Provide ongoing safety training and education programs for personnel involved in offshore activities to ensure adherence to best practices and regulatory requirements.

Optimization of Operational Processes:

- Streamline operational processes and workflows to maximize efficiency and minimize downtime, especially in challenging environments.
- Utilize advanced technologies and data analytics to optimize resource allocation, scheduling, and logistics planning for marine and wind energy operations.
- Implement continuous improvement initiatives to identify and address inefficiencies, driving overall operational excellence and cost-effectiveness.

Commercial Viability Assessment:

- Conduct thorough assessments of commercial viability for wind energy projects, considering factors such as market demand, regulatory landscape, and financial feasibility.
- Evaluate potential risks and uncertainties associated with project economics, incorporating contingency plans to mitigate adverse impacts on profitability.
- Provide strategic guidance and decision support to optimize project financing, procurement, and contracting processes, ensuring long-term commercial success.

Technical Expertise and Innovation:

- Leverage technical expertise and innovation to overcome challenges posed by challenging environments, such as extreme weather conditions or complex geological features.
- Develop customized technical solutions and engineering designs tailored to the unique requirements of offshore installations and wind farm developments.
- Incorporate state-of-the-art technologies and industry best practices to enhance equipment reliability, performance, and safety standards.

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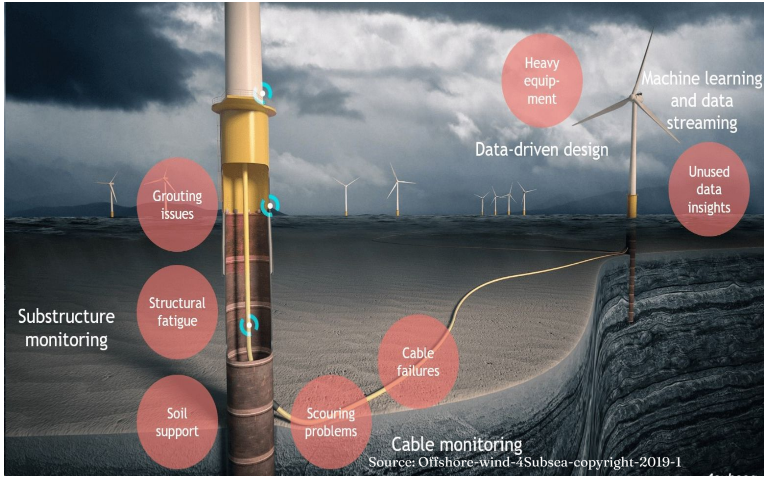
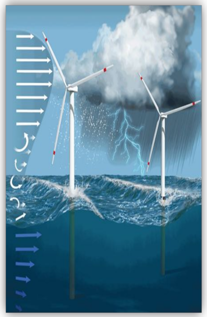
Geo-Data Technical Guidance for Site Investigation and Asset Integrity

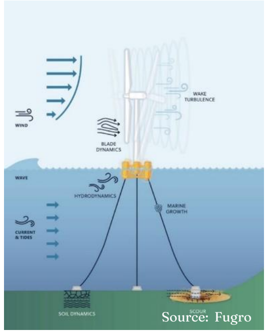
Establish Surface & Subsea IoT Technology

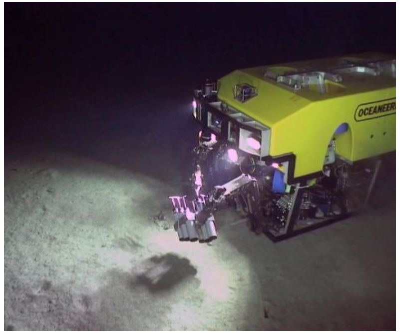
Establishing Surface & Subsea IoT Technology for geospatial and metocean data collection is paramount in modern maritime and offshore operations. By deploying cutting-edge sensors and communication devices both above and below the water's surface, this technology enables real-time monitoring of environmental conditions such as weather patterns, ocean currents, and seabed topography. Through seamless integration with existing infrastructure and data management systems, surface and subsea IoT solutions facilitate efficient data collection, analysis, and decision-making processes. This innovative approach not only enhances operational safety but also enables proactive risk management, resource optimization, and sustainable practices in marine industries.

Environmental management like underwater noise pollution, climate change-induced temperature change, seabed mobility, etc. is significantly constrained by a lack of baseline data. Measuring these parameters including noises and establishing the Subsea Internet of Things (SIoT) is becoming a more important requirement for any marine seabed operations. Subsea Internet of Things is a network of smart, wireless sensors and devices configured to provide actionable operational intelligence such as performance, condition and diagnostic information. SIoT will help the Subsea Baseline monitoring for geodata before, during and after any campaign.









Measurements of the physical parameters for operational and Extreme conditions

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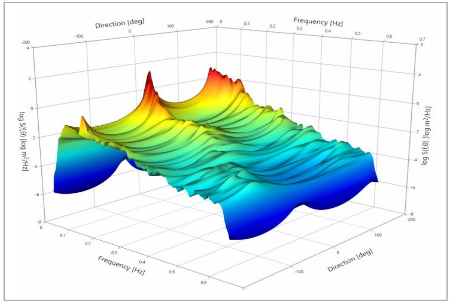
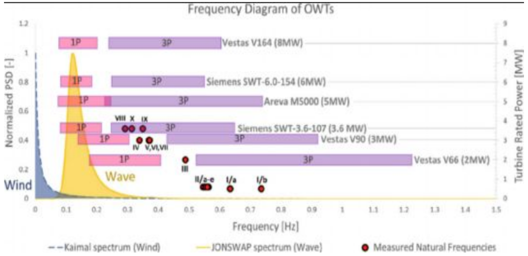
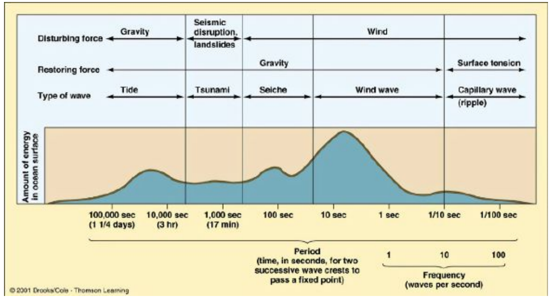
Metocean Measurement and Validation (Waves an example)



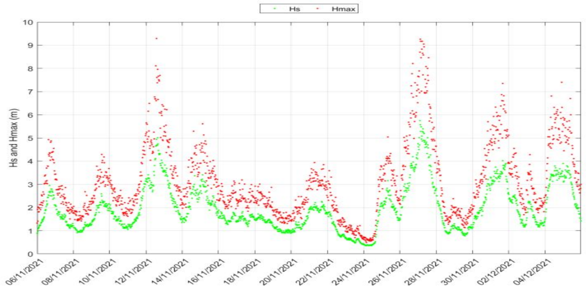
Wave data by Datawell Wave rider Buoys measures directional and non-directional – Zero up crossing (Z0)



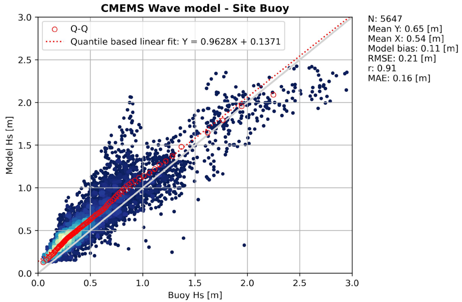
The plot shows the 1P and 3P frequency for rated wind speed for the WTG type.



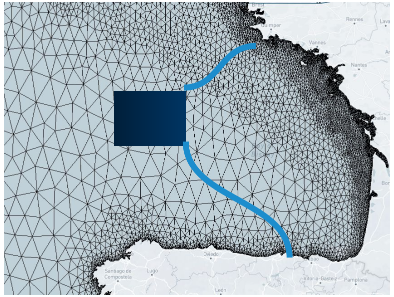
The required level of accuracy, and therefore cost of metocean data, evolves with the project.



Time series of Hs and Hmax (DD/MM/YYYY).



Wave Model Calibration and Validation



Wave model grid proposed OWF and cable route analysis locations and additional points for wave spectral data storage – full area

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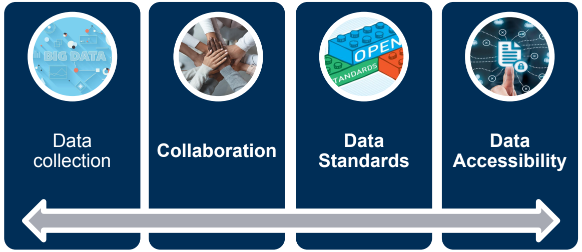
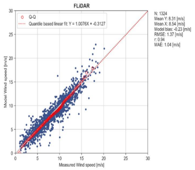
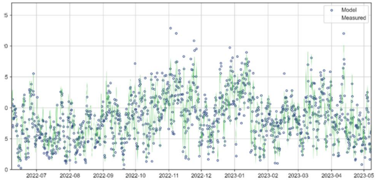
Improving Geodata Baseline Management in Port and Harbor Environments

Source : Associated British Ports (ABP)







In the realm of marine operations within port and harbour environments, navigating the complexities inherent to such domains requires a better understanding of metocean and geospatial dynamics. Enhancing geodata baseline management represents a pivotal step towards elevating the efficiency and safety standards within the Port and Harbor industry, extending to offshore sites.

Fundamental to this initiative is the recognition of the multifaceted challenges involved in designing and implementing offshore infrastructure, whether it be wind turbines (floating or fixed), offshore substations, subsea cables, or the required moorings to maintain components' station keeping at prescribed locations. These endeavours necessitate a comprehensive grasp of metocean conditions, geotechnical considerations, and seismic factors, all of which converge in the intricate engineering and operational facets of marine projects.

To address these challenges, we advocate for the deployment of an integrated system, seamlessly integrating technology and expertise to bolster both the Transportation and Installation (T&I) and Operations and Maintenance (O&M) phases of offshore endeavours. At the core of this system lies a robust framework that better understands the stakeholders' needs for the full lifecycle of any offshore operations, including wind farms, catering to the marine operational requirements of geodata. This framework encompasses vessel and asset positioning, metocean parameters, geotechnical assessments, and seismic analysis. By amalgamating these diverse datasets and insights, we empower stakeholders to make informed decisions at every stage of the project lifecycle.

Proposing a Geo-data technical guidance for Site Investigation and Asset Integrity, we envision a product-based solution tailored to offer operational, commercial, and technical assistance to mariners operating within the dynamic confines of ports and harbours. This guidance not only streamlines the acquisition and management of geospatial information but also serves as a beacon of reliability, augmenting the industry's collective capacity to navigate the ever-evolving marine landscape with confidence and precision

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Data Lake – Big Data

Ongoing Interest in Digitalisation incl. Port, Offshore sites

Utilising geospatial data intelligence has the potential to revolutionize global ports, enabling them to adopt a digital perspective. A comprehensive understanding of wind farm, port and harbour infrastructure, cable landfall locations, substations, and array sites is crucial for developing effective preparedness plans that prioritize safety and efficiency in maritime operations.

Government/Private Authorities' Investments

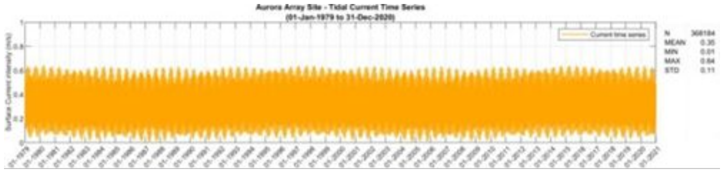
Government and private authorities have initiated investments in port digitalization, with a focus on enhancing overall development, client assistance, and alignment with the value-driven global transformation toward wind energy and the transition to sustainable energy sources.

Geo-Data for Risk Reduction

Geospatial data plays a crucial role in mitigating risks associated with monitoring assets and ensuring the safety of personnel and users at facilities. A comprehensive understanding of geospatial and metocean factors is essential for effective risk reduction measures

Real-Time Sensor Data

The integration of real-time sensor measurements, 2D-3D models, vessel and navigation buoy positioning, hydrographic surveys, and inland infrastructure details can generate significant interest among multiple clients. High-quality oceanographic, navigational, and geospatial data are essential for ensuring the accuracy and reliability of these datasets



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Baseline Model Construction and Validation

The integration of metocean databases assumes paramount importance in constructing and validating baseline models. It enables real-time sensor data to facilitate asset maintenance and risk assessment, with a particular emphasis on the insights provided by mooring and flotation buoy sensors for wind farm development.

Integration of Metocean Databases

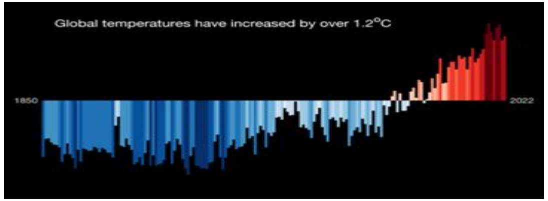
The integration of metocean databases is of paramount importance in constructing and validating baseline models for offshore wind farm operations.

Real-Time Sensor Data

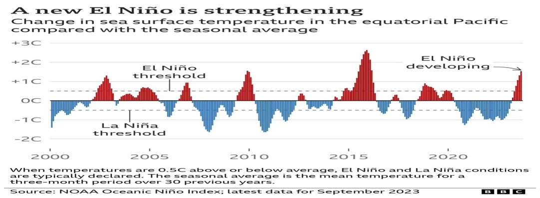
It enables real-time sensor data to facilitate asset maintenance and risk assessment, emphasizing the insights provided by mooring and flotation buoy sensors for wind farm development.

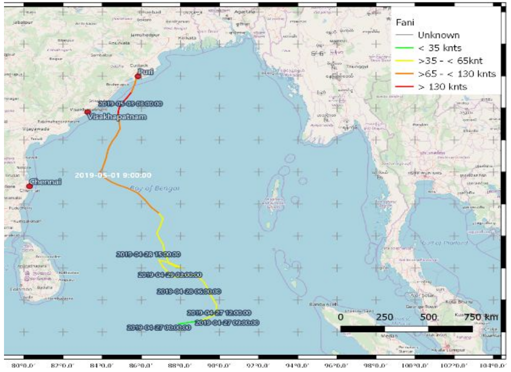
Climate Model Validation

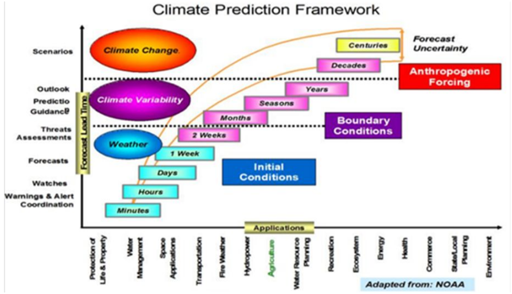
Observed data comparison is essential in validating climate models and ensuring accurate projections.

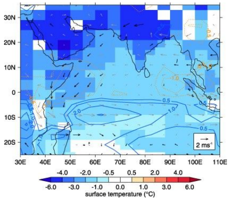


GLOBE Date Range1850-2022, Data Source UK Met Office, Creator University of Reading









Composite difference of boreal winter (DJF) conditions between the seven coldest and seven warmest CMIP3 models based on the index of northern Arabian Sea SST (50–70◦E, 20–25◦N). The figure shows differences in surface air temperature over land, ocean surface temperature

Deepthi et al 2013

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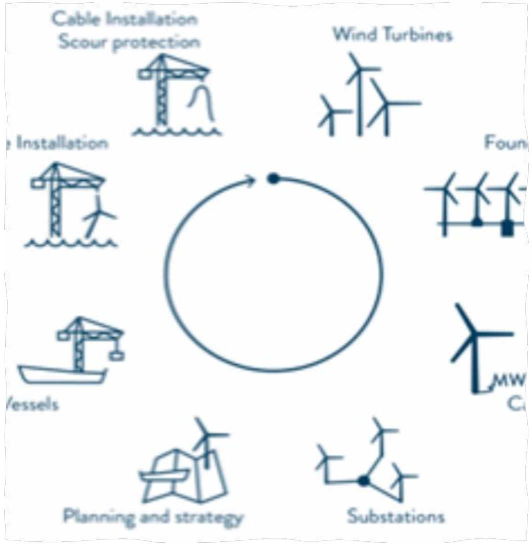
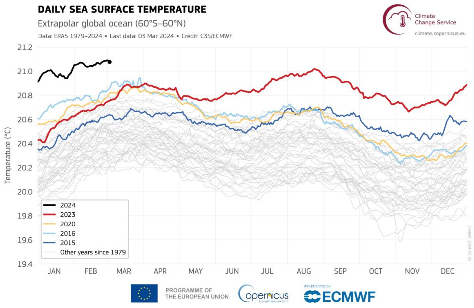
Harnessing Energy: Sustainable Wind Farm Development through Integrated Systems and Environmental Stewardship

Implement advanced geospatial planning techniques to identify optimal locations for wind farm setup, considering factors such as wind patterns, proximity to infrastructure, and environmental impact assessments.

Integrate real-time metocean data into construction operations to ensure safety and minimise environmental disturbances, such as coordinating construction activities during favorable weather conditions and avoiding sensitive ecological areas

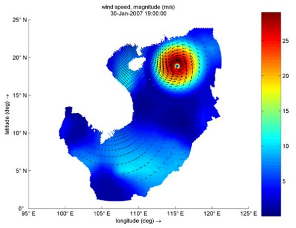


Establish comprehensive monitoring systems and streamlined maintenance protocols for ongoing wind farm operations, enabling rapid response to potential issues and ensuring maximum efficiency and safety throughout the project lifespan



The temperature fluctuations witnessed in early January/Feb 2024 extend beyond mere meteorological occurrences; they serve as profound lessons in the intricacies of climate modelling. Navigating and rectifying these shifts are pivotal elements, fortifying the dependability of overarching climate models. Ensuring precise representation affords the foresight necessary to adeptly adapt and mitigate the impacts of our continually evolving climates

Daily sea surface temperature (°C) averaged over the extra-polar global ocean (60°S–60°N) for 2015 (dark blue), 2016 (light blue), 2020 (yellow), 2023 (red), and 2024 (black line). All other years between 1979 and 2022 are shown with grey lines.
Data source: ERA5. Credit: Copernicus Climate Change Service/ECMWF.



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Integrated System Overview

Site Considerations

Site-specific conditions are meticulously analyzed using integrated systems, ensuring a thorough assessment of potential risks and benefits.

Wind Turbine Generator Design

WTG design considerations are incorporated into the integrated approach, aligning engineering aspirations with practical environmental data.

Vessel Management

Management systems for vessels and assets integrate with operational support, ensuring a seamless transposition of all marine activities in wind farm projects. Consider the vessel with low noise and zero-emission operation allow for a more sustainable approach to CTV, protecting marine life and preserving the ocean's delicate ecosystem.

Source: Navalt Solar & Electric Boats

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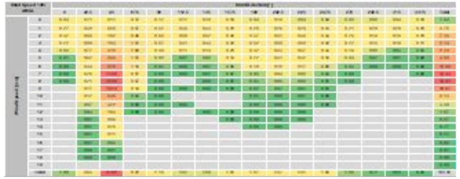
Vessel & Asset Management Integration

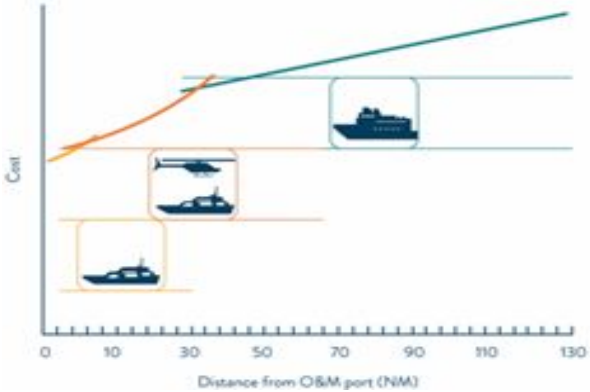
Enhanced Operational Oversight

The integrated system provides enhanced operational oversight and streamlined management of vessels and assets involved in offshore wind farm activities.

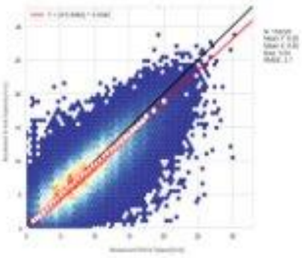
Efficiency & Safety

It prioritizes efficiency and safety by integrating sophisticated tracking and monitoring mechanisms for vessels and assets.

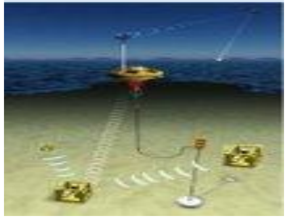


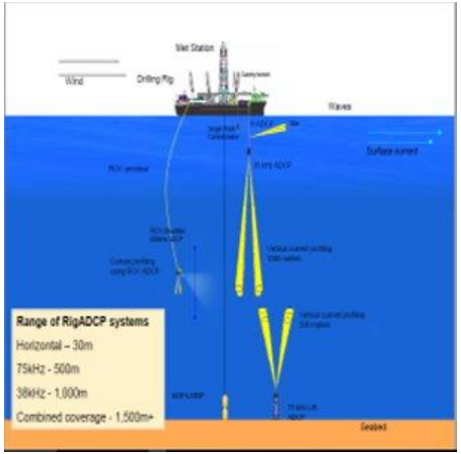


Source GL Garrad Hassan, 2013 "A Guide to UK Offshore wind operations and Maintenance",Scottish Enterprise and The Crown Estate

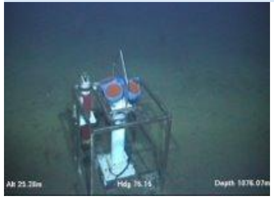


Real time metocean measurement





Seabed /Subsea measurement



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Marine Activities and Wind Farm Development

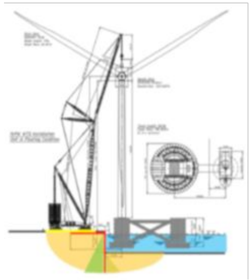
The proposed Geo-data technical guidance framework offers support for the diverse needs of mariners and wind energy stakeholders. It provides operational, commercial, and technical assistance, focusing on safety and efficiency standards, especially within challenging environments, ensuring sustainable and reliable solutions.

Mariners Support

Provides operational and technical assistance for mariners.

Wind Energy Stakeholders

Supports stakeholders in the wind energy sector.



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Wind Turbine Generator (WTG) Design and Positioning

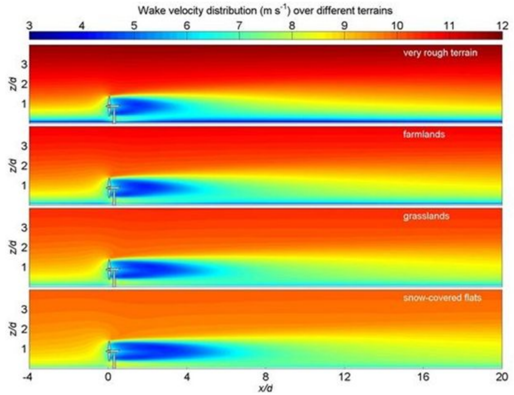
The integrated system encompasses various aspects, including vessel/asset management, wind turbine generator (WTG) design, and positioning, ensuring seamless integration with engineering design and operational support. This offers critical support for wind farm developers and operations in coastal and offshore locations.

Seamless Integration

- Integrates with engineering design and operational support for comprehensive functionality.
- Understanding of wind speed, direction and Turbulence plays an important role in the recovery of the wind turbine wake which affects power production from downstream turbines

WTG Design and Positioning

- Provides support for the design and positioning of wind turbine generators.
- It is important to comprehend for engineering issues concerning large structures due to their interaction with atmospheric turbulence (such as wind turbines) and the generation of wind speed energy.



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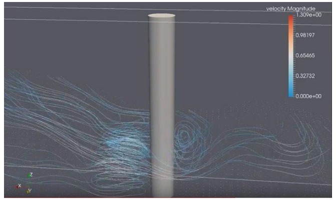
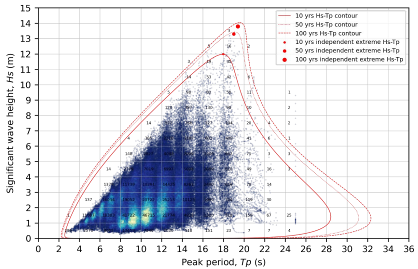




International Cooperation and Standardization

1

Collaboration

A unified effort across borders amplifies progress and innovation within the offshore wind sector, bolstering efficiency and safety.

2

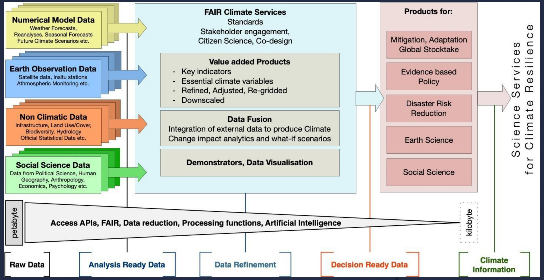
Best Practices

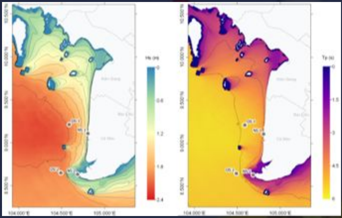
Sharing of knowledge and standardizing operations ensures operational excellence and consistency in renewable energy deployment.

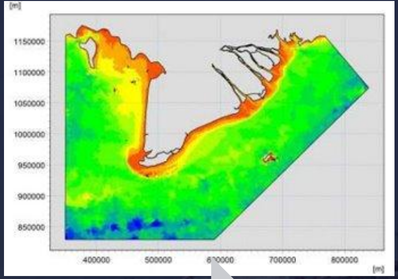
3

Global Standards

Setting global standards is essential in meeting the diverse regulatory and operational requirements of various regions.







DNV·GL

SERVICE SPECIFICATION

DNVGL-SE-0073 Edition January 2018

Project certification of wind farms according to IEC 61400-22

3.3 Project certificate wind turbines

3.3.1 General

This subsection provides the details of DNV GL's verification activities for each of the phases of the DNV GL project certification scheme according to IEC 61400-22 for the asset that consists of the wind turbines and their support structures.

Once the verification of design basis, design, manufacturing, transport, installation, commissioning for the asset wind turbines and their support structures has been successfully completed and the final evaluation has been performed, DNV GL shall issue a project certificate wind turbines.

3.3.2 Phase I: Design basis

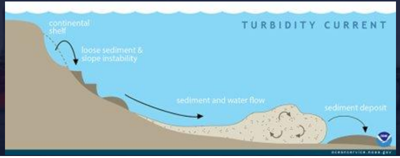
The purpose of the verification of the design basis is to evaluate if the site conditions and the basis for design are properly established and documented. This includes general specifications, criteria, parameters, design approach, manufacturing, quality requirements, suppliers' qualification and other assumptions relevant for design. The design basis shall document a safe design and adequate implementation of the turbines and their support structures in the specific project.

The standards, codes and additional requirements shall be agreed within the design basis (see [1.6.4]).

A design basis shall be provided to DNV GL. This design basis shall include documentation of the following:

a) site conditions
b) standards, codes and additional requirements
c) design criteria
d) manufacturing, transport, installation and commissioning requirements
e) operation and maintenance requirements
f) wind turbine type(s).

The design basis identifies the basic assumptions, specification, methods and requirements for the project design. In case of the project being implemented as a multi-contract project, the design of assets, such as the wind turbines and the support structures, may be carried out by different parties. In such cases the design basis forms an essential tool with a view to ensure, document and verify the safety of the total system and consistency between the different project parts. It is strongly recommended that the design basis is developed as an integrated document to be applied for all parts. If the development of the design basis is divided between suppliers of parts of the project, the design basis for each part shall contain all information of relevance for the design of that part.



Ensure data accuracy and reliability through calibration and maintenance of equipment.

Consider historical data and trends to anticipate future conditions

Utilize statistical and mathematical tools to analyze metocean data, such as time series analysis, extreme value analysis, probabilistic methods

Establish safety protocols and procedures specific to metocean conditions

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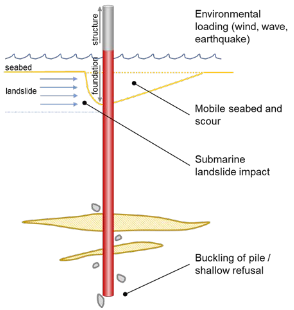
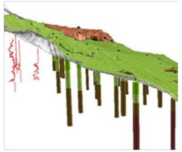
Site Considerations & Risk Management



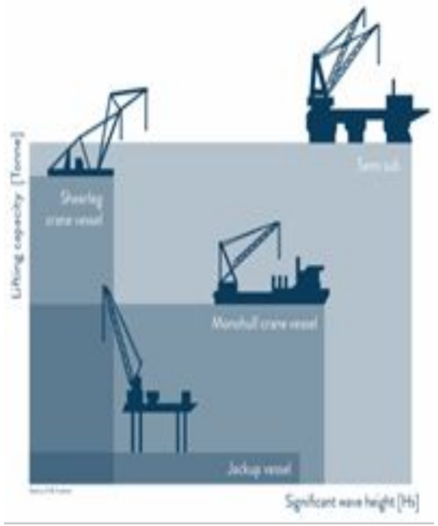


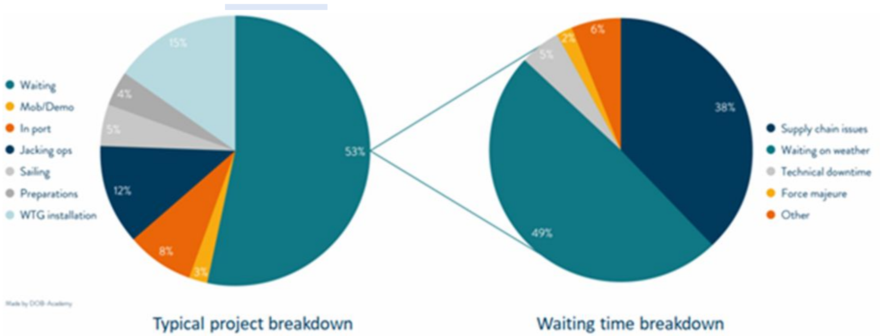
Robust Site Considerations

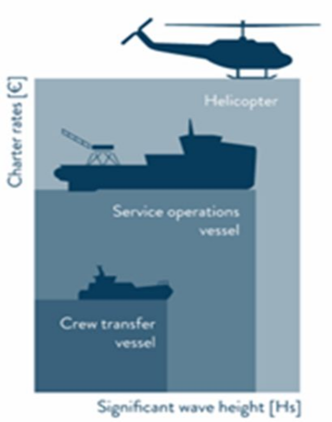
The system incorporates robust site considerations to mitigate potential risks and challenges in offshore wind farm operations.

Risk Assessment Focus

There is a focused approach to risk assessment, emphasizing the importance of a proactive strategy to manage uncertainties.







Source GL Garrad Hassan, 2013 "A Guide to UK Offshore wind operations and Maintenance",Scottish Enterprise and The Crown Estate

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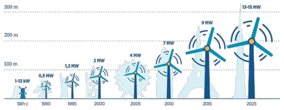
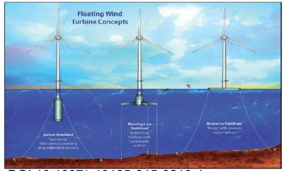
Technical Support for Wind Turbine Generator Design

Optimized Design	Technological Advancements
The integrated system offers comprehensive support for optimizing wind turbine generator design.	It leverages technological advancements to enhance the efficiency and reliability of wind turbine generators.

- Understand wind turbine characteristics for wind farm conceptualization, dimensions, masses, power, and thrust curves.
- Evaluate wind turbine performance to facilitate project transactions with wind and metocean dataset.
- Interface with wind turbine suppliers regarding geospatial and metocean data and understand the T&I, O&M capabilities.



Evolution of Wind Turbine Power and Rotor Diameters over Time.
Source: IRENA



DOI:10.1007/s40435-015-0210-1

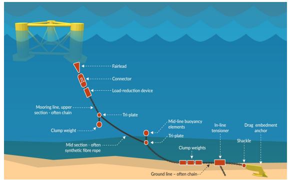
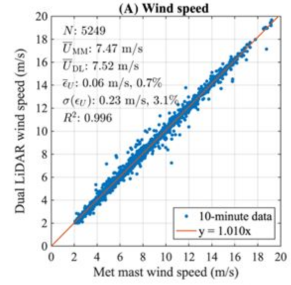
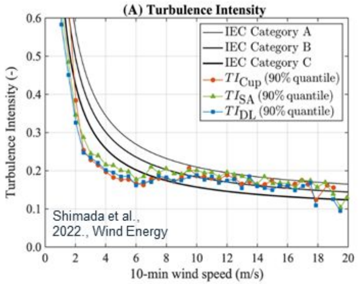
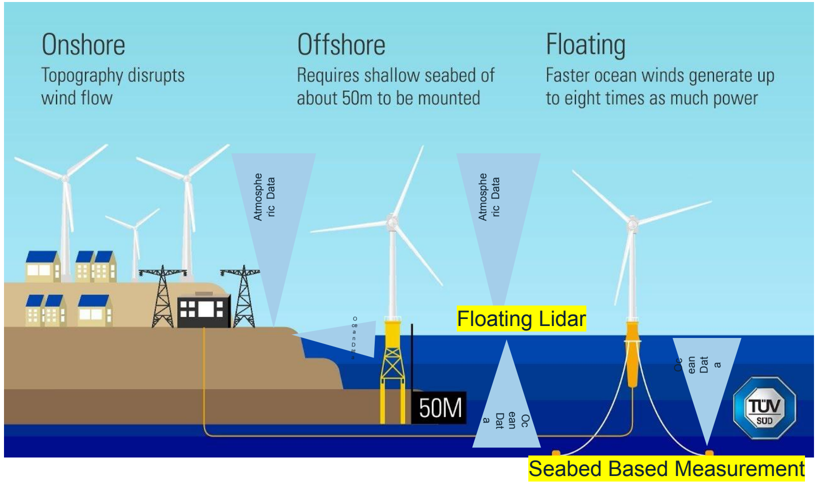


Image Source: BVG Associate

Wind Class/Turbulence	Annual average wind speed at hub-height	Extreme 50-year gust
Ia High wind - Higher Turbulence 18%	10 metres per second (36 km/h; 22 mph)	70 metres per second (250 km/h; 160 mph)
Ib High wind - Lower Turbulence 16%	10 metres per second (36 km/h; 22 mph)	70 metres per second (250 km/h; 160 mph)
IIa Medium wind - Higher Turbulence 18%	8.5 metres per second (31 km/h; 19 mph)	59.5 metres per second (214 km/h; 133 mph)
IIb Medium wind - Lower Turbulence 16%	8.5 metres per second (31 km/h; 19 mph)	59.5 metres per second (214 km/h; 133 mph)
IIIa Low wind - Higher Turbulence 18%	7.5 metres per second (27 km/h; 17 mph)	52.5 metres per second (189 km/h; 117 mph)
IIIb Low wind - Lower Turbulence 16%	7.5 metres per second (27 km/h; 17 mph)	52.5 metres per second (189 km/h; 117 mph)
IV	6.0 metres per second (22 km/h; 13 mph)	42 metres per second (150 km/h; 94 mph)







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Metocean Data Integration for Asset Maintenance

Enhanced Maintenance Strategies

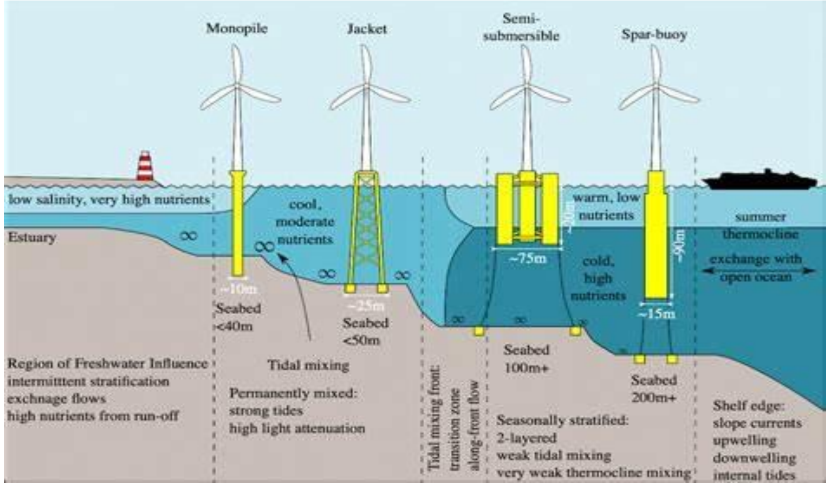
The integration of metocean data significantly enhances asset maintenance strategies, contributing to the sustainability of offshore wind farm operations.

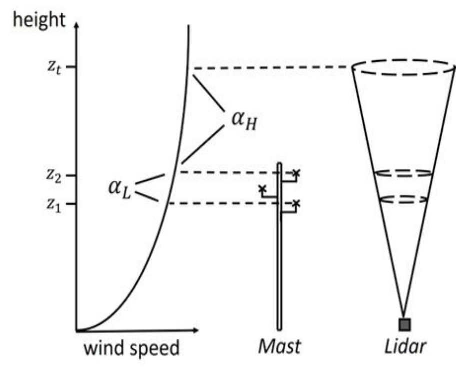
Risk Mitigation

It plays a key role in mitigating risks associated with asset maintenance, ensuring the longevity and reliability of offshore wind farm assets.

Real-Time Insights

The system provides real-time insights essential for prompt and effective decision-making in asset maintenance activities.





For offshore wind measurements, floating lidar systems are the de-facto standard measurement device

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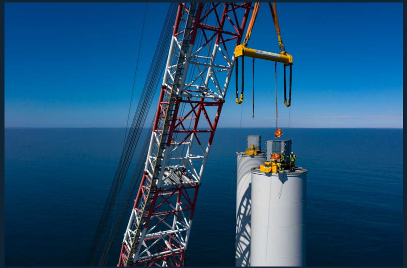
T&I - Project Development & Owner's Engineering

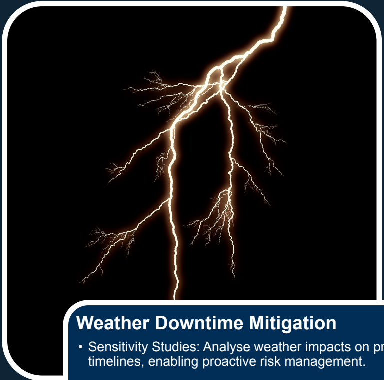
Industry Challenges

- Increasing project scale and WTG & FOU size, heavier components, drive for novel installation concepts (e.g., RNA installation by floating vessel in the Baltic Sea)
- Supply chain and specialist equipment availability (e.g., JUVs, SSCVs, large beam, SS HTVs, shore cranes)
- Innovative/new foundation designs with limited industry track record (e.g., floating, tripod)
- New geographies (Challenging ground conditions, deeper water, further offshore sites, long fetch / challenging metocean conditions e.g., Western US, Australia, NW Scotland)



T&I Concept Development

- Project Requirements Assessment: Meticulously evaluate project needs, geography, and client goals to tailor transportation and installation strategies.
- Sequence Optimization: Utilize expertise to streamline activities, minimizing downtime and ensuring smooth project progression.
- Environmental Impact Analysis: Conduct thorough assessments to develop eco-friendly T&I concepts, ensuring compliance with regulations and preserving natural habitats.



Weather Downtime Mitigation

- Sensitivity Studies: Analyse weather impacts on project timelines, enabling proactive risk management.
- Resilience Enhancement: Provide actionable insights to bolster project resilience, maintaining continuity in adverse weather conditions.
- Operational Efficiency Enhancement: Identify and mitigate weather-related risks to optimize efficiency and resource productivity.

Lifting and Transport Expertise

- Methodology Assessment: Evaluate lifting and transport methods for efficiency and cost-effectiveness.
- Feasibility Analysis: Assess viability of proposed methods, addressing challenges to ensure successful execution.
- Risk Management: Proactively identify and mitigate risks to safeguard personnel, equipment, and project assets.

Impact of Weather Constraints on O&M Operations

1

Downtime Risk

Severe weather conditions pose a risk of operational downtime due to safety concerns and equipment limitations.

2

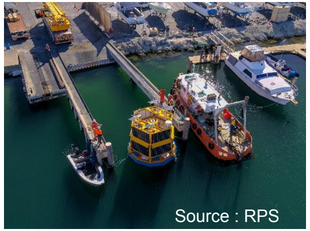
Structural Stress

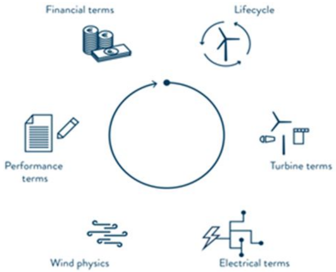
Weather constraints can lead to increased stress on offshore structures and components, impacting their longevity.

3

Safety and Personnel

Ensuring the safety of personnel and assets becomes a critical concern during adverse weather conditions.


Source : RPS



Strategies for Managing Weather Constraints

Early Warning Systems

Implementing advanced weather monitoring systems to provide early warnings for adverse conditions.

Operational Protocols

Developing protocols and procedures to effectively manage operations during challenging weather scenarios.

Fleet and Crew Preparedness

Training and equipping crew members and offshore assets to handle weather-related challenges efficiently.

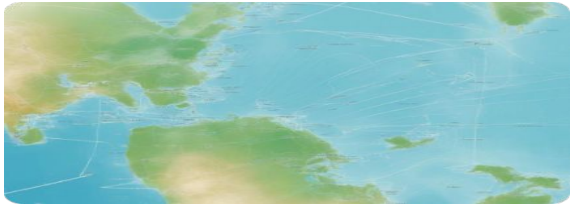
Successful O&M Operations in Challenging Conditions

Advanced Vessel Capabilities

Utilizing modern vessels with specialized features designed to withstand challenging O&M conditions.

Emergency Response Protocols

Successful implementation of emergency response plans to address weather-induced equipment issues promptly and effectively.



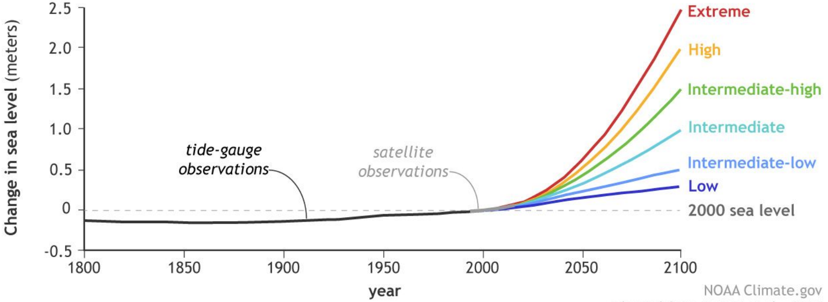
Real-time Monitoring

Utilizing advanced monitoring systems to track and respond to changing meteorological conditions swiftly and carry out continuous data collection.

Data for Socio-economic understanding

The pre-industrial CO2 concentration in the atmosphere was relatively stable at around 280 ppm. However, with the advent of industrialisation and burning fossil fuels, human activities have significantly increased CO2 emissions, leading to a substantial rise in atmospheric CO2 concentrations. The global atmospheric CO2 concentration was approximately 416 ppm.

Possible future sea levels for different greenhouse gas pathways



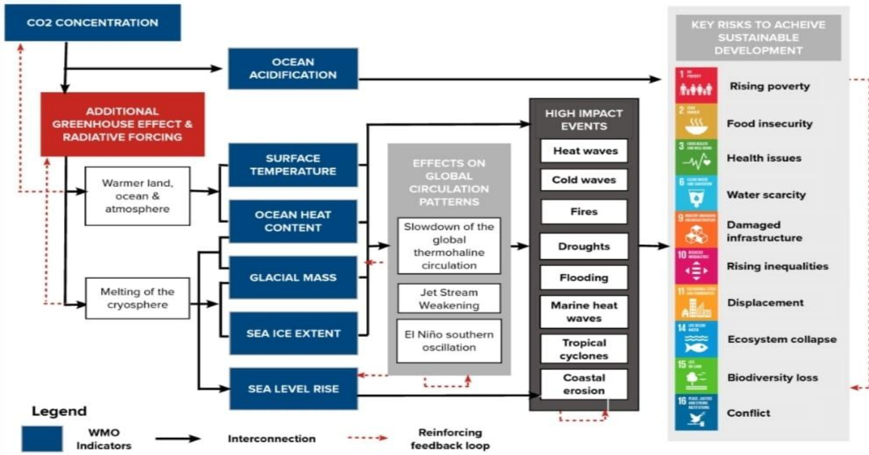
NOAA Climate.gov
Adapted from Sweet et al., 2017

- Clean Energy Generation
- Job Creation and Economic Growth
- Infastructure Development
- Community Engagement and Stakeholder Involvement
- Biodiversity Conservation and Environmental Protection

Wave Energy

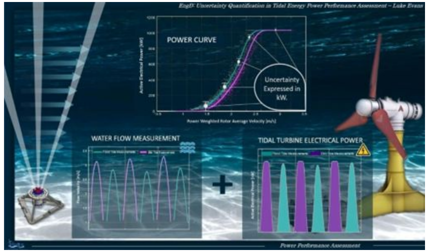
Data

CCS and CCU



Source : IPCC, WMO

Innovation in new technologies for achieving Net Zero / carbon reduction technologies like Tidal power to direct dust/air capture technology



OUTDOOR DUST/AIR CAPTURE

Advanced Dust/Air Capture Technology | Air Cleaning Equipment's | Dust Extractors | Minus DUST

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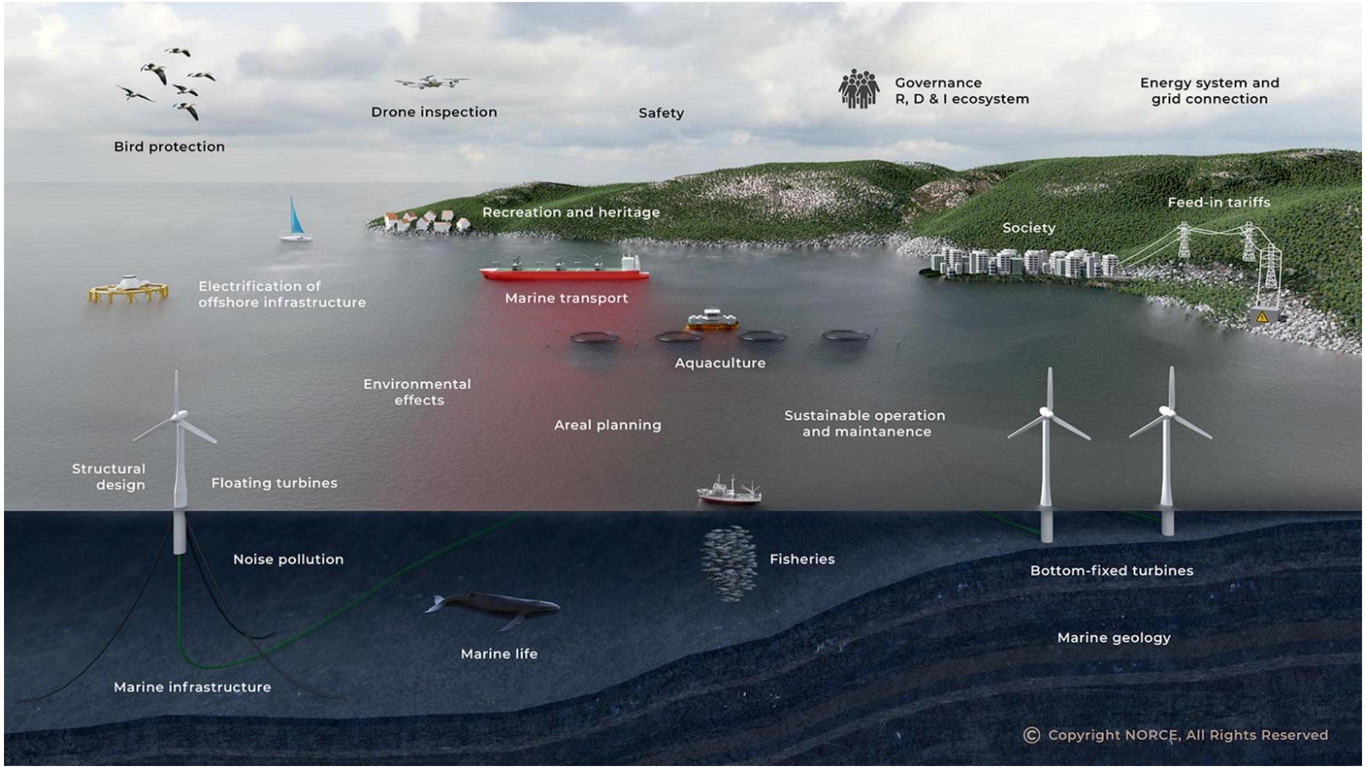
Data and its Importance



Offshore operations

Wind farm development

Marine space utilisation

Blue Economy

Sustainable fishing

Coastal Development & Management

Autonomous and NetZero investment for sustainable shipping

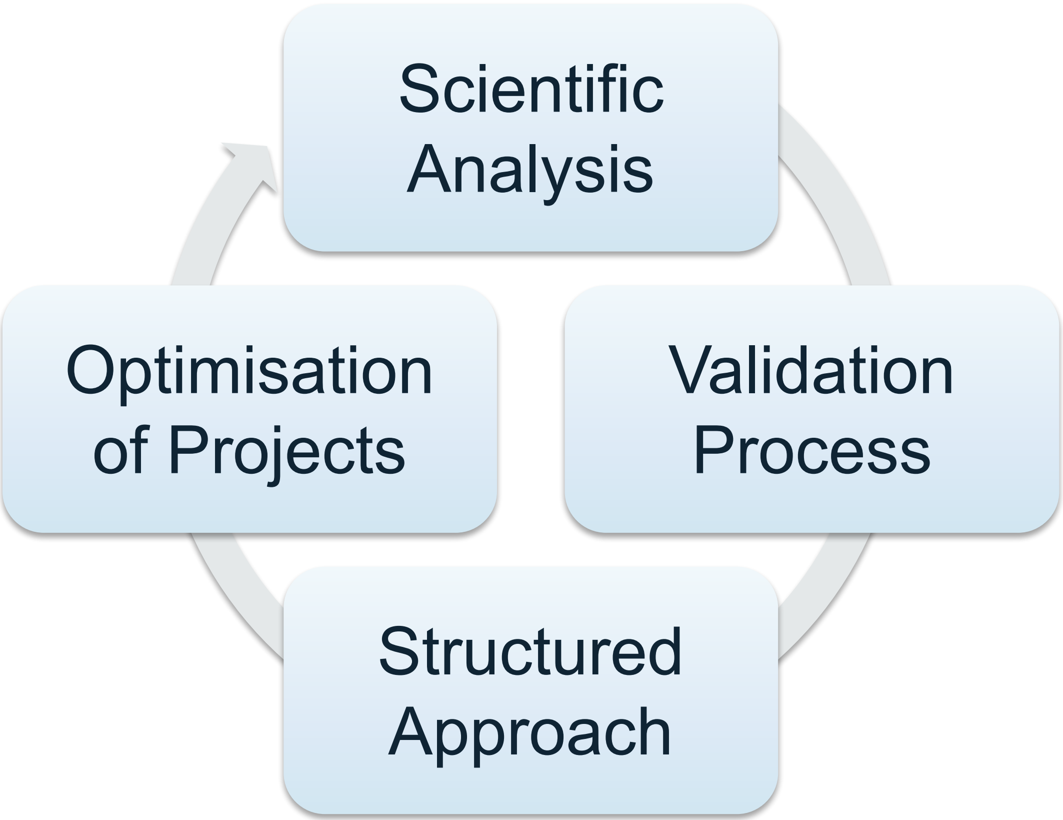
Bird and Marine life protections

Marine Tourism

Offshore Energy

Conclusion

Metocean and **Geospatial Data** for Offshore Renewable Energy **Projects**



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