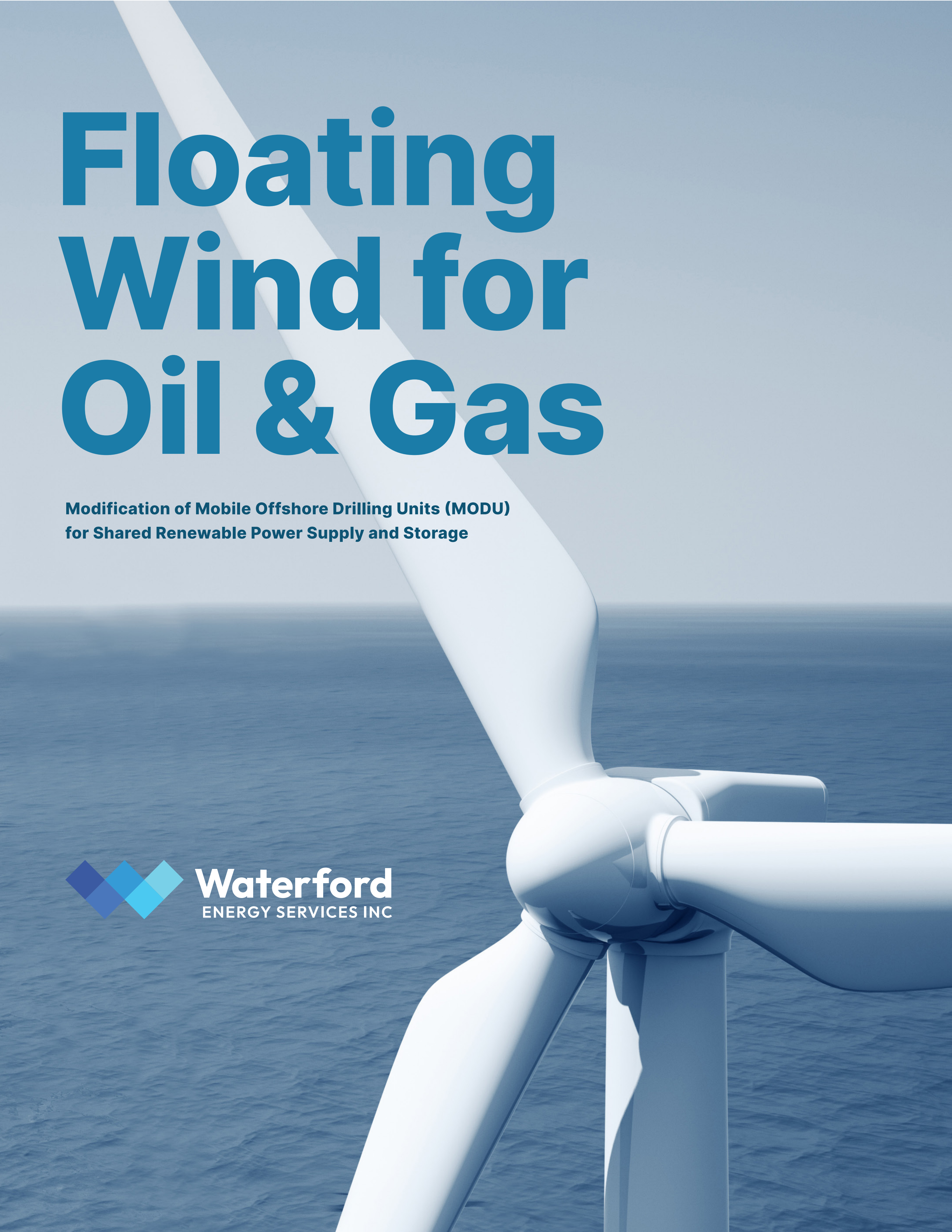
Floating Wind for Oil & Gas

Modification of Mobile Offshore Drilling Units (MODU) for Shared Renewable Power Supply and Storage



Waterford
ENERGY SERVICES INC

ACKNOWLEDGMENTS

Waterford Energy Services Incorporated secured $1.653 million CAD in funding from Natural Resources Canada's Emissions Reduction Fund, Offshore Research, Development and Demonstration program. This fund is managed by Energy Research & Innovation Newfoundland & Labrador and was designed to support projects that advance solutions to reduce emissions in Newfoundland and Labrador's offshore industry.

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EXECUTIVE SUMMARY

There is increasing pressure on the oil and gas industry to explore and produce hydrocarbons responsibly, cost effectively, and with the lowest emissions.

By employing renewable energy, Waterford Energy Services Inc. (WESI) outlines a solution using Floating Offshore Wind Turbines (FOWT) to power offshore installations. It is anticipated that Greenhouse Gas (GHG) emissions can be reduced 83% by combining wind power and battery energy storage.

This paper describes a conceptual design of a 'Plug and Play' hybrid power solution in the Canadian offshore oil and gas industry, designed with Newfoundland and Labrador's offshore environment in mind. FOWTs are electrically connected to offshore installations such as Mobile Offshore Drilling Units (MODU) in a harsh environment to replace large portions of the onboard power generation. This concept is also scalable to larger electrical consumers such as Floating Production Storage and Offloading (FPSO) and fixed production platforms. Battery Energy Storage Systems (BESS) are incorporated to transition from wind power, increase efficiency, provide safety backup, power FOWT utilities, and enhance emissions reduction.

Newfoundland and Labrador's offshore environment is extremely harsh but also contains a world-class wind resource. WESI proves the excellence of the available resource and the resilience of the entire system in this challenging environment.

The conceptual design considers the wind turbine power output and examines the components required to deliver the power to the installation's electrical system (e.g., transformers, batteries, switchgear, static and dynamic cables, disconnects, communications/monitoring, and required safety systems). This design was developed via extensive engineering by WESI and input from third-party experts.

The outcomes of this study estimate that, with the addition of hybrid wind power, 33,000 tonnes of CO_2 could be avoided annually. By 2030, yearly savings are expected to be $16.5 million CAD in fuel cost (based on $1,200/m^3) and $2.8 million CAD for carbon tax, plus an additional $3.8 million CAD in tradable credits.

The MODU's onboard electrical power generation is directly proportional to the emissions from burning fuel. The emissions savings calculations for this report are directly tied to the offsetting of power generation. In other words, the percentage of power generation offset by renewable power will result in the same percentage of emissions reduced.

WESI's study concluded that floating wind power is clearly a viable option because:

- The floating wind turbine platform "floater" technology exists and is at TRL 8 on other projects globally.
- Existing "world class" wind resources, adjacent to oil and gas facilities, can be harnessed to significantly reduce emissions.
- Turbine capacity has increased to a point where industrial quantities of wind power can be produced in remote areas.
- Significant carbon tax savings can be realized.
- Wind energy can eliminate the majority of emissions, resulting in tradable carbon credits.
- Significant fuel cost savings can exist depending on the fuel source being replaced.

Oil and gas operations are ideal applications of this decarbonization approach, presenting an opportunity to mature FOWT technology, which can readily adapt to other grid-isolated applications such as remote communities, aquaculture, and near-shore Industries.

introduction

The offshore oil and gas industry continues to explore and develop oil and gas fields using installations powered by generators burning either natural gas or Marine Gas Oil (MGO), a product that is much like diesel. Given the current focus on environmental protection and emissions reduction, there is increasing pressure on the oil and gas industry to explore and produce hydrocarbons responsibly, cost-effectively, and with the lowest emission rates.

One method of reducing emissions is to connect the offshore oil and gas installation to a land-based electric grid. This method is currently in use in several areas around the world. The process involves laying a long-distance cable from a shore-based connection to the installation.

Another method of reducing emissions, and the method chosen by WESI, involves the use of local renewable power sources, specifically wind. In the WESI model, Floating Offshore Wind Turbines (FOWT) are used to power offshore oil and gas installations off the coast of Newfoundland and Labrador (NL). The initial focus of WESI was to develop a renewable power system for powering a Mobile Offshore Drilling Unit (MODU). MODUs include semi-submersible, drillship or jack-up designs. This report will demonstrate that WESI's chosen technology has the potential to, not only substantially reduce Greenhouse Gas (GHG) emissions, but to prove very cost-effective over time due to significant fuel and carbon tax savings.

This concept is also scalable to larger electrical consumers such as Floating Production Storage and Offloading (FPSO) and fixed production platforms.

KEY QUESTIONS

To prove the feasibility of wind power in the offshore oil and gas industry, WESI set out to create a beneficial and applicable solution off the coast of Newfoundland and Labrador.

Some of the key questions WESI wanted to answer included:

- Will there be sufficient wind resources?
- Will the turbine's floating structure be suitable in an ice-prone environment?
- Will the structure withstand the harsh metocean (wind, wave, current and ice) conditions?
- Can intermittent power be integrated into a highly variable micro-grid such as a MODU?
- How should Battery Energy Storage Systems (BESS) be integrated with renewable power solutions?
- How many turbines and what sizes would be required to meet the demand of a MODU?
- What quantity of GHG emissions can be displaced by floating offshore wind turbines?
- What fuel savings can be achieved?

There is increasing pressure on the oil and gas industry to explore and produce hydrocarbons responsibly, cost effectively, and with the lowest emissions.

CREDIT: PRINCIPLE POWER

COMPANY BACKGROUND

WESI, based in St. John's NL and Halifax NS, was formed in 2003. Since inception, WESI has provided engineering consulting and field personnel to assist in planning and execution of offshore oil and gas projects throughout various regions of the world. In recent years, WESI has been providing similar services in the offshore renewables sector.

Saitec Offshore Technologies, based out of Bilbao, Spain, is a spin-off company of Saitec Engineering which is heavily involved in many civil and industrial engineering specialties including roads, railways, water, industry, and energy. Saitec Offshore Technologies was formed to produce a cost-effective solution to aid the floating offshore wind industry. They developed the design and managed the construction of a floating unit for offshore wind production known as the Swing Around Twin Hull (SATH) as illustrated in **Figure 1**.

For the purposes of this project, WESI and Saitec Offshore formed a non-exclusive partnership in 2019 to pursue the potential of using floating wind power for offshore oil and gas installations. WESI and Saitec have leveraged their individual expertise to combine offshore oil and gas with floating wind to produce a detailed assessment of the proposed concept for powering MODUs with renewable (floating wind) power.

An offshore MODU generates electricity by burning fossil fuels to run generating units. Electrification via the renewable energy produced by floating wind turbines eliminates or reduces the requirement for local power generation, decreasing operational expenditures and emissions. The results of this study, "**Modification of Mobile Offshore Drilling Units (MODU) for Shared Renewable Power Supply and Storage**", are presented in this report.

FIGURE 1: Saitec Offshore Technologies' SATH "Floater" Wind Turbine Platform[1]

project objectives

The objectives of this study were to:

- Elevate the Technological Readiness Level (TRL) of a FOWT power system in the North Atlantic for the purpose of utilizing an alternative, renewable power source. The scope aimed to move the TRL from TRL 2 to TRL 3 such that upon completion the findings may be applied to a prototype construction and test project.
  NOTE: there are several FOWT projects globally at TRL 8.
- Demonstrate that the proposed system is adequate for operation in a harsh metocean and ice prone environment.
- Fill the existing knowledge gap associated with renewable power conversion for MODUs that currently inhibits vessel owners, operators, and other participants from planning and budgeting towards power sharing in their operations.
- Contribute to the eventual application of shared wind power in the operation of MODUs in Newfoundland and Labrador for significant reduction in emissions.
- Develop local knowledge and expertise of shared power conversion scopes to provide future opportunities for Newfoundland and Labrador businesses, operators, and vessel owners.

PROJECT SCOPE

Phase I of the project began with an evaluation of all the major aspects needed to connect the floating turbine with the MODU. This included performing a wind resource assessment to defining technical requirements. From there, WESI set out to design a renewable power system that would reduce GHG emissions in the Canadian offshore oil and gas industry. WESI's solution will be accomplished via a 'Plug and Play' system using FOWTs connected to a highly variable micro-grid, specifically a MODU. An example of this scalable system is illustrated in **Figure 2**. The percentage of renewable energy supplied is a function of the turbine size, wind resource, electrical losses, BESS capacity, and the rig electrical load dynamics.

Review work performed by the team in the project's initial stages mainly revolved around fixed-bottom turbines that deliver power to large grids as these were predominant. In this layout, a substation is required either offshore or nearshore. It was clear from WESI's research that it would be economically beneficial to have a solution that did not need a substation, as this required the building, staffing, and maintenance of an additional floating asset. Efforts, therefore, were made early in the design process to look for alternate solutions.

A survey of one or more MODUs in Newfoundland and Labrador was planned to assist with the equipment layout and modifications required to accept a renewable power source onboard the unit. Due to COVID-19 and ongoing health restrictions plus the changing availability of local MODUs, it was not possible to perform this work.

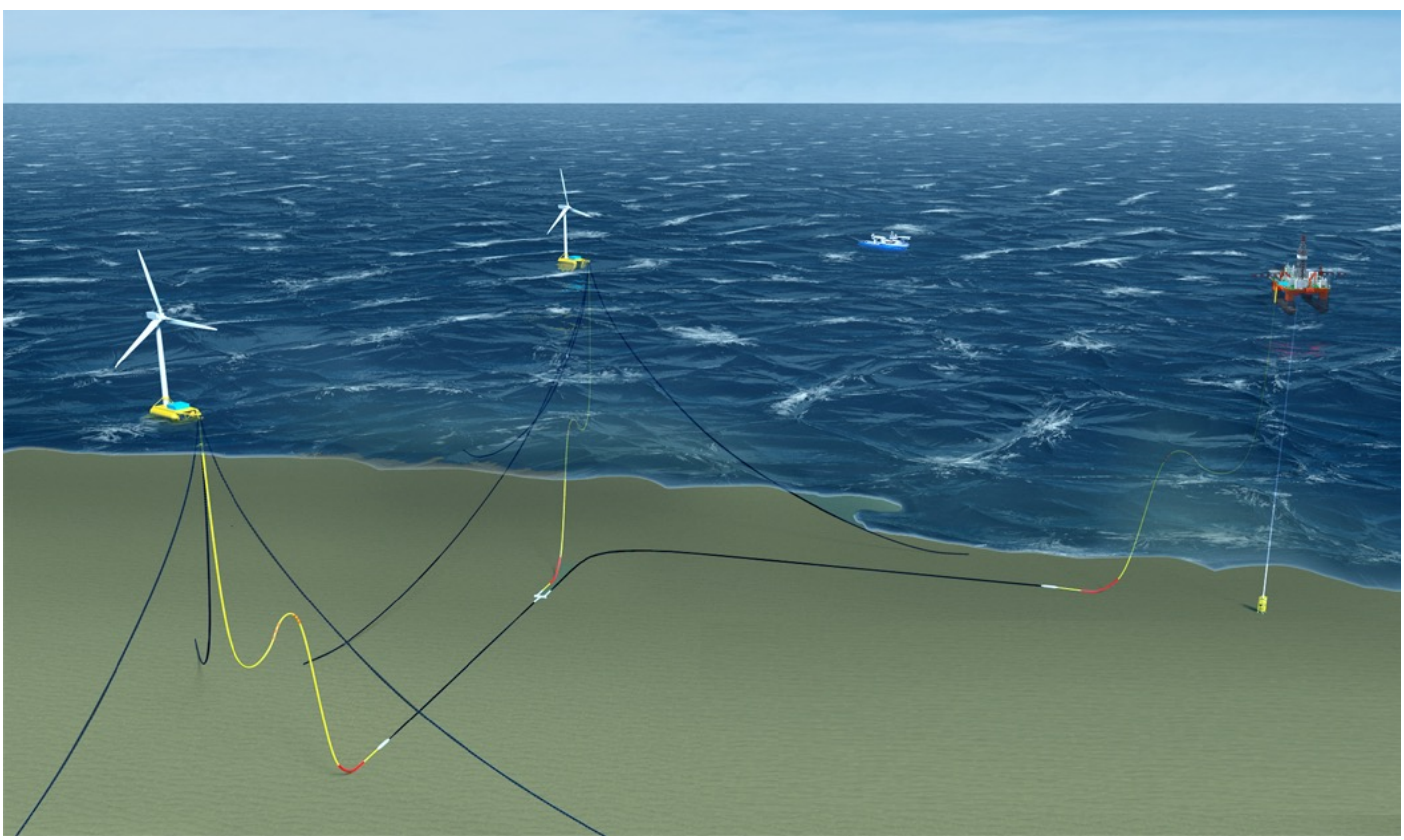
The group adapted by:

- Making use of technical leaders from MODU owners, and
- Consulting specialized vendors who had intimate knowledge of several MODUs including the general arrangements and electrical system layouts and functions.

By using this approach, WESI was able to collaborate with some of the worlds leading OEMs and specialists, enabling mutual technology transfer.

Phase 2 will involve progressing this technology and advancing the floating wind industry in Canada. **Phase 2** also proposes a further refinement of the initial concept, leading to the demonstration of a wind turbine connected MODU, production installation, or local micro-grid.

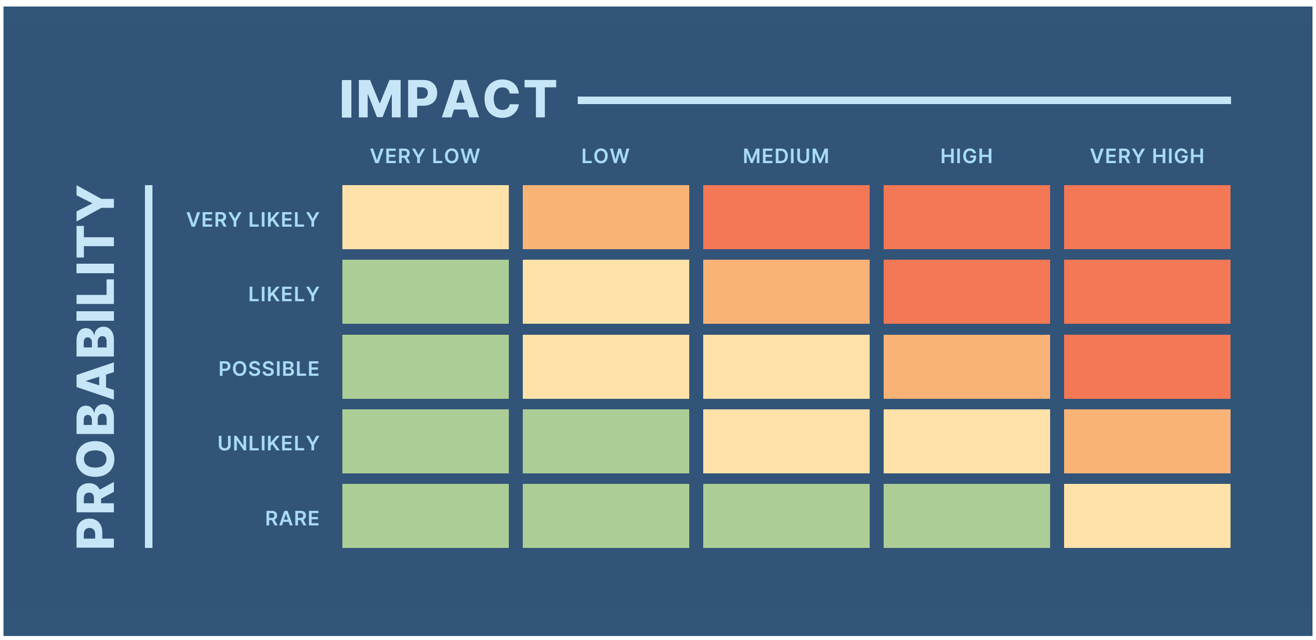
FIGURE 2: FOWT System Providing Renewable Power to a MODU (Scalable n+1 Turbines)



RISK ASSESSMENT APPROACH / METHODOLOGY

To determine whether the proposed solution was viable, WESI carried out risk assessments to evaluate the technology and electrical design for the integration of the renewable electrical power onto the MODU. The risk assessment approach was useful for identifying gaps in existing state of the art as well as areas of limited understanding or concern for successful implementation. The risk assessment matrix in **Figure 3** shows the resulting risk profile of the combination of impact and probability of an event occurring. This facilitates prioritization and focus areas. These concerns were mitigated through in-house engineering and collaboration with third party researchers and technology partners to resolve areas of technical risk.

FIGURE 3: Risk Assessment Matrix Used to Assess Technology[2]



OUT OF SCOPE

The concept proposal focused on the technical requirements, readiness, and integration needed to bring the MODU wind energy concept together. This meant that some aspects of floating offshore wind, although recognized for their importance, were not assessed. During the investigation of the concept, however, several of these topics were monitored for their potential state of readiness and industry advancement.

Topics such as manufacturing, logistics, maintenance, port requirements, and regulatory readiness are not discussed, however; WESI is monitoring the rapid advances in the offshore wind Industry's regulations, technology, capacity and infrastructure to support either a demonstration or full scale wind farm development.

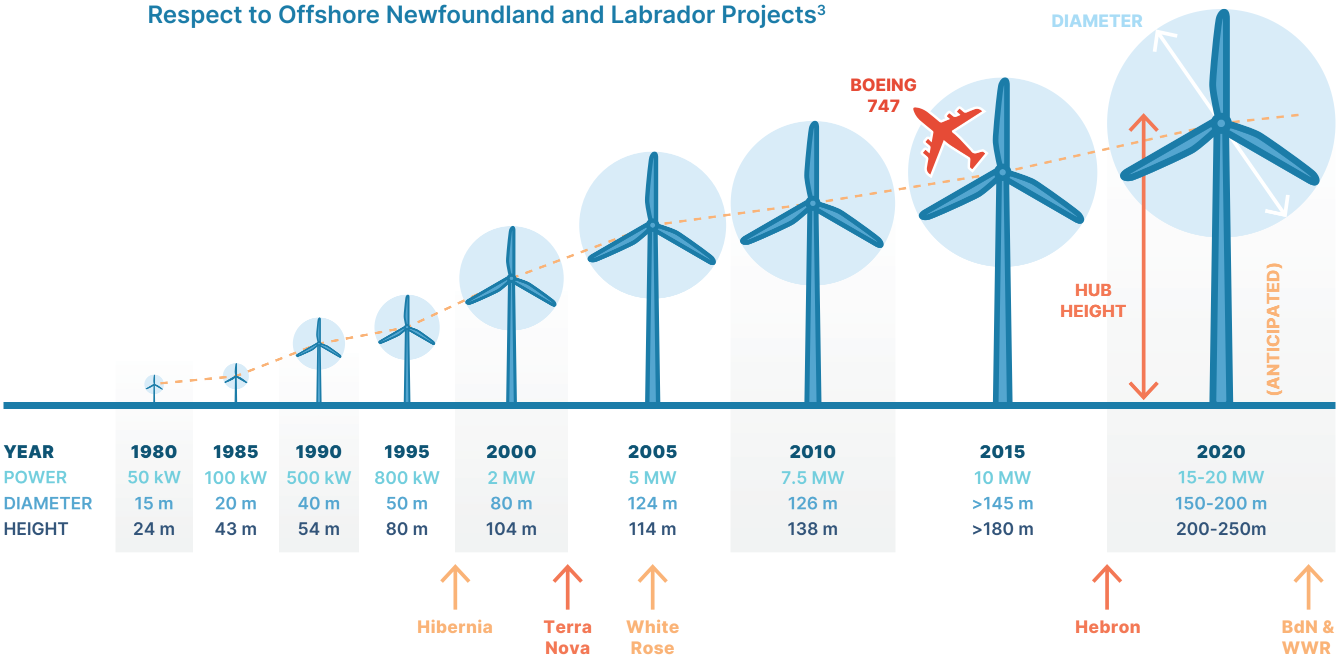
offshore wind why (not) now?

Floating offshore wind evolved from both onshore and offshore fixed-bottom wind turbines. While a relatively new concept in Canada, fixed-bottom wind solutions have been installed for more than twenty years in European waters.

As the amount of shallow seabed available for fixed-bottom wind farms is becoming more limited, the industry is looking to further offshore locations in deeper water. For the industry to expand, floating solutions will be required. An added benefit of these deep-water locations is that they hold a tremendous wind resource as the winds are typically stronger, more consistent and do not interact with land features.

To use the power of wind in an oil and gas application, large capacity turbines are required. **Figure 4** demonstrates how turbine technology has advanced and how it is now at a point where it can generate large amounts of power per unit. When most Newfoundland and Labrador oil development projects were brought online in 1997, the available turbine technology was generally smaller and land-based with limited capacity to produce power. With the evolution shown in **Figure 4**, it is now reasonable to consider these large turbines as a viable means to supply power to offshore installations.

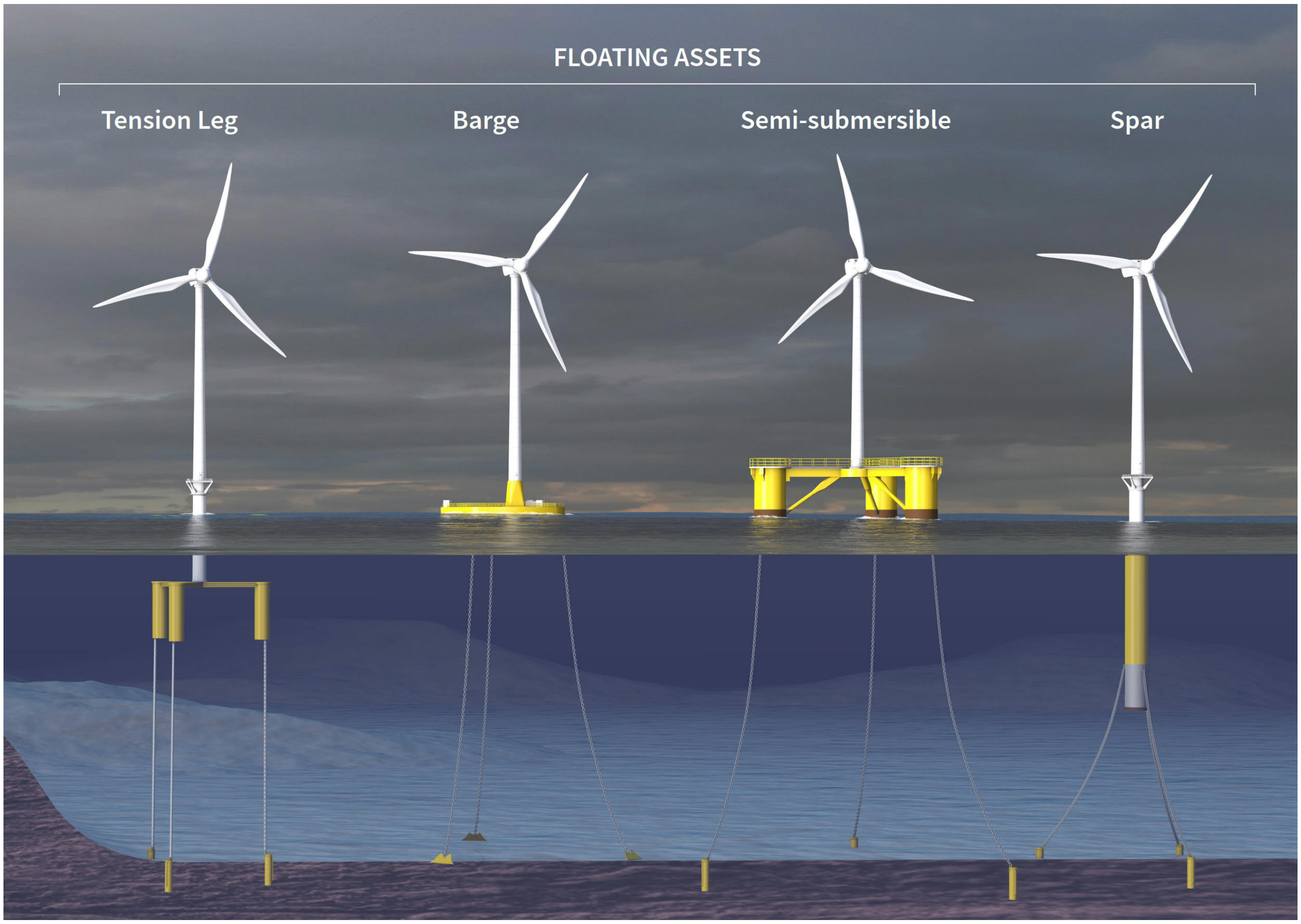
FIGURE 4: Evolution of Wind Turbine Technology with Respect to Offshore Newfoundland and Labrador Projects[3]



As the competitiveness of floating wind development continues to evolve, research and development into various floating wind platform designs has also increased. **Figure 5** shows some common designs that are in use or moving through technical assessments and scale testing in the open ocean.

There are several examples of floater types - semi-submersible, barge, spar, tension leg platform (TLP), each looking to provide an economic solution to installing turbines in deeper water. Floater designers have been addressing the suitability of turbines in various sea conditions to achieve optimal designs and industrialization benefits.

FIGURE 5: Floating Wind Turbine Platform Technology[4]



Floater designs must also assess the manufacturing and construction efficiency through several key features:

- Steel versus concrete building material
- Onshore versus in-the-water construction
- Reduced draft to allow construction in a wider range of ports, and
- Modular components that lend to serialized fabrication and production.

Given the need for new cleaner offshore technologies and the increased focus on progressing this technology, now is the time to fully examine the capabilities of wind power and what it has to offer. As technology and cost conditions improve, greater focus has been placed on the enormous potential of offshore floating wind. Almost 80% of the offshore wind resources worldwide that could be developed are at greater than 60 m water depth; therefore, fixed turbines will not be feasible[5]. This means there are tremendous opportunities to pursue floating wind projects in most major energy markets.

CURRENT FLOATING WIND PROJECTS

There are several examples of floating offshore wind projects shown in Figure 6 which are currently operating in European waters and are at TRL 8.

They provide supporting evidence for FOWTs in offshore ocean environments and include:

- **Hywind Scotland**, based on a deep spar steel hull design. This is a tall, slender tower which requires a deep-water port for construction. In 2017, five turbines totaling 30 MW were installed off the coast of Scotland and are consistently the best performing offshore wind turbines in the North Sea[6].

- **Windfloat Atlantic**, installed offshore Portugal in mid-2020, consists of three turbines for a total of 25 MW. This low draft floater is a steel semi-submersible style common to oil and gas installations.

- **Kincardine in Scotland** was fully commissioned in late 2021. It consists of six semi-submersible turbines totaling 50 MW.

- **Hywind Tampen**, developed by Equinor, uses a concrete deep spar concept with eleven 8 MW turbines. A first for the wind and oil and gas industries, this project will connect power to offshore oil and gas platforms in the Norwegian North Sea in 2022.

- **Saitec's DemoSATH**, set to launch in the summer of 2022, will be the first floating wind turbine connected to Spain's grid. The SATH is based on a single point mooring arrangement and is primarily concrete, making it suitable for construction in many parts of the world.

FIGURE 6: Floating Offshore Wind Projects Underway [1, 7, 8, 9]


EQUINOR HYWIND - SCOTLAND (2017)
TAMPEN - NORWAY (2022)


WINDFLOAT ATLANTIC -
PORTUGAL (2020)


KINCARDINE - SCOTLAND (2021)


DemoSATH - SPAIN (2022)

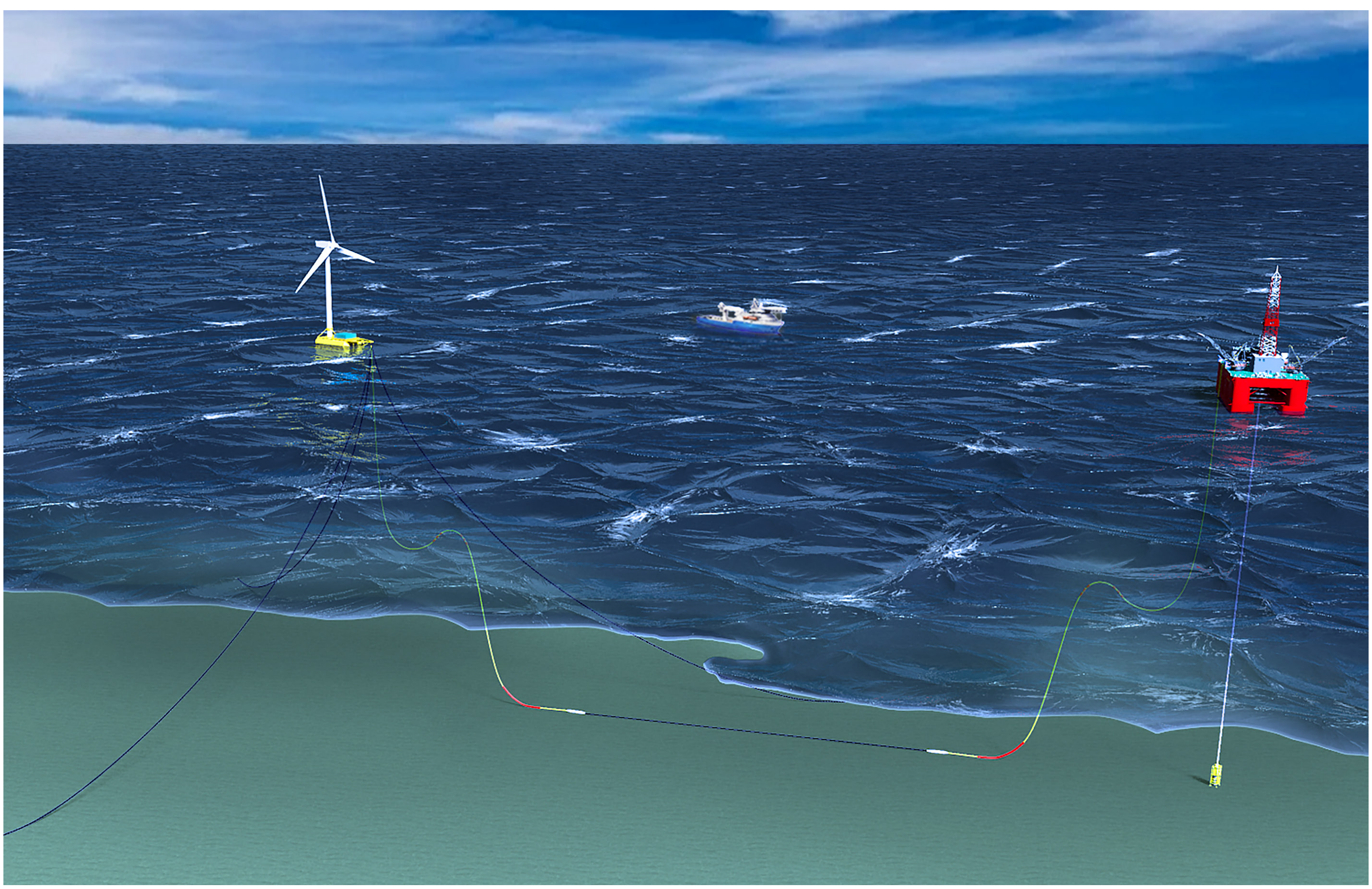
Given the need for new cleaner offshore technologies and the increased focus on progressing wind power, now is the time to fully examine the capabilities and what wind has to offer.

project description

SYSTEM OVERVIEW

Figure 7 provides a visual representation of the proposed WESI solution. It involves connecting a floating turbine to a floating drilling unit – a MODU - via an electrical AC cable system, placed on the seabed, which supplements the onboard power generation. The SATH floater supports a BESS and maintains position with a series of mooring chains and anchors. There is also a BESS component on the MODU to transition to onboard generators in the event of abrupt loss of power.

FIGURE 7: WESI's Concept for Powering MODUs with Floating Wind Turbines



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PROJECT DESCRIPTION

PROJECT LOCATION

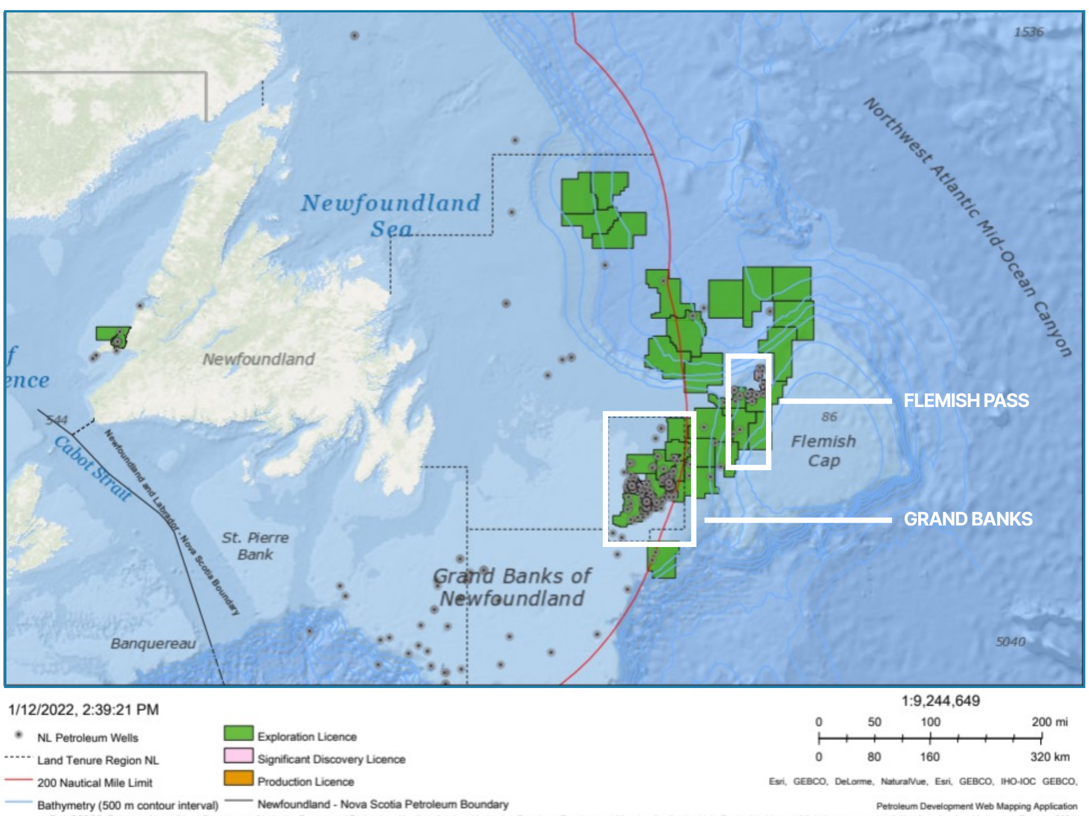
For the purposes of this study, two specific locations were selected as being representative of both present and future oil and gas activities in offshore Newfoundland and Labrador - the Grand Banks in approximately 100 m of water and the Flemish Pass in 1200 m of water (**Figure 8**). These two locations have similar meteorological, oceanographic (otherwise known as metocean), and sea ice exposure conditions, with the Flemish Pass being more severe than the Grand Banks.

Understanding the physical environment of both locations is vital for characterizing the design loads required to accurately model the forces applied by the marine environment.

PHYSICAL ENVIRONMENT

The Grand Banks and Flemish Pass data sets were obtained from the Meteorological Service of Canada 50 (MSC 50 – 1954 to 2018) and the North Atlantic wave hindcast. This hindcast consists of the application of numerical wind and wave models together with historical meteorological data to simulate the evolution of surface winds and ocean wave responses in the region of interest[11].

FIGURE 8: Study Areas Offshore Newfoundland and Labrador (Grand Banks – 100m of water & Flemish Pass – 1200m of water)[10]



The principal design bases in terms of metocean design conditions for a FOWT were extracted by Saitec and used during the execution of the floater analysis. This analysis adheres to the International Electrotechnical Commission (IEC) 61400 Series Standards[12]. Further details on the analysis of the metocean data can be found in **Appendix A**.

Other sources of environmental data were collected from various Environmental Impact Assessment (EIA) reports submitted for oil and gas projects in Atlantic Canada, the Nalcor Exploration Strategy System (NESS), and Environment Canada historical ice charts.

ICE ASSESSMENT

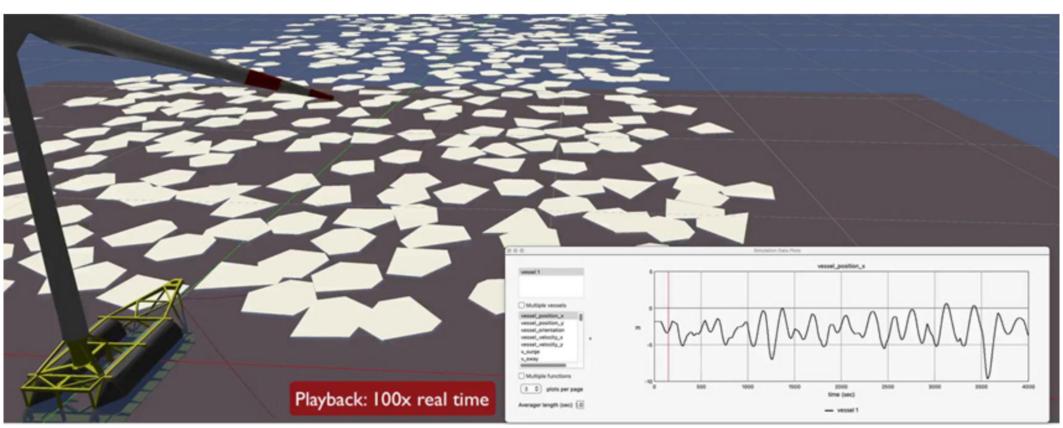
When operating facilities in a harsh ice prone environment like offshore Newfoundland and Labrador, it is important to assess the environmental risks to the facility. Where large icebergs pose a significant threat to offshore facilities, an ice management strategy will need to be adopted.

WESI engaged researchers to conduct an initial assessment of the SATH in pack ice that has historically been encountered on the Grand Banks and Flemish Pass. Characterization of the pack ice was based on Environment Canada's historical ice charts and photos of the ice that was encountered by vessels on the Grand Banks.

The analysis was conducted using computer modelling to simulate pack ice interactions and subsequent dragging forces (**Figure 9**).

The results of the analysis indicated that there is limited risk to a floating wind turbine in an area such as the Grand Banks; however, hull material selection, mooring connections, electrical cable routing, and exposed structural members require further assessment for impact resistance and/or shielding from the impacts of ice.

FIGURE 9: Pack Ice Simulation of the Saitec SATH Credit: Claude Daley



ICE MANAGEMENT

Floating offshore wind turbines adjacent to oil and gas facilities will fall under well-established ice management plans and practices used in offshore Newfoundland and Labrador for over twenty-five years. It is expected that these strategies will be effective at protecting floating wind turbines located in proximity to oil and gas assets.

Ice management strategy elements include:

- **Surveillance** – forecasting, patrolling, and tracking of icebergs and pack ice
- **Avoidance** – movement of the facilities away from ice where possible
- **Intervention** – movement or deflection of an iceberg's course or the breaking up of pack ice that may impact the facility

Inherent in the system design is the ability to de-energize the system and disconnect the MODU from the incoming power cable in the event of an emergency or planned MODU move.

SEA STATE / OCEANOGRAPHY

The Grand Banks and Flemish Pass are well known for large waves. The 50-year return period extreme significant wave height (Hs) was calculated to be 15.2 m based on analysis of the historical MSC50 database. The floater analysis established that the design was resilient in all modeled cases. The currents at the project locations are not considered to be difficult to manage with maximum speeds in the range of 1.2 m/s. Further details of wind and wave analysis are included in **Appendix A**.

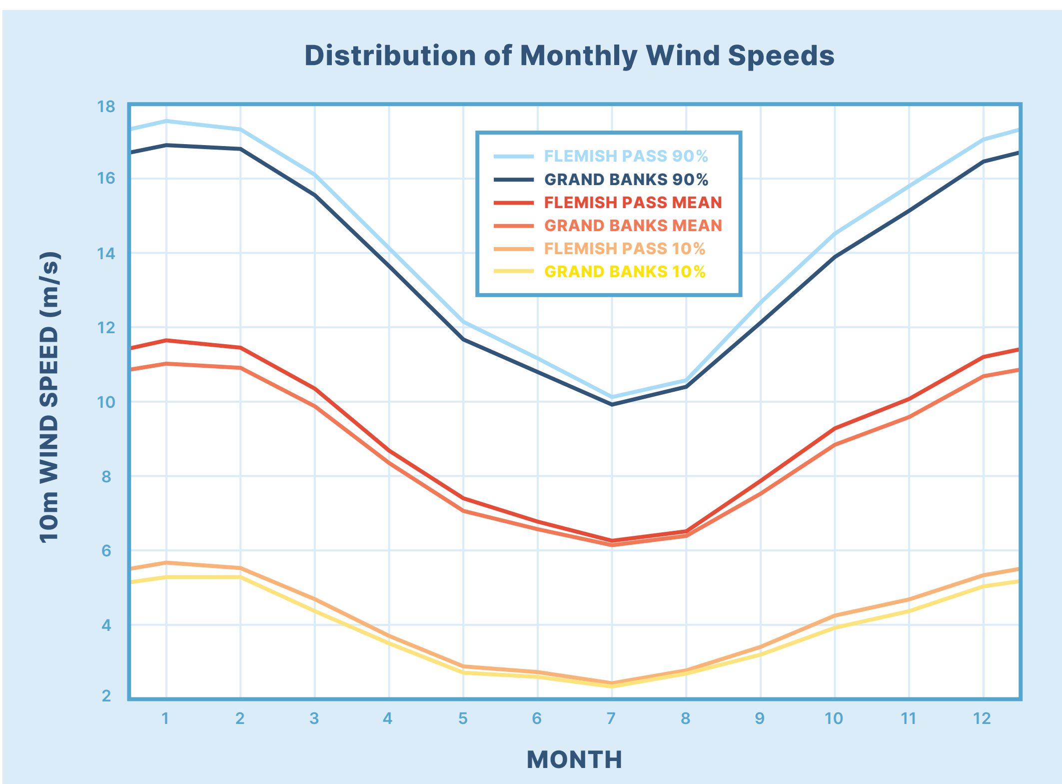
WIND SPEED – WIND RESOURCING

Wind speeds were analyzed for the quantification of wind power production potential in both project locations. The wind speed, extracted from the MSC50 data set for the project locations, has a strong seasonal trend with summer average speeds less than 7 m/s and winter speeds greater than 10 m/s at the 10 m meteorological observation level as seen in **Figure 10**.

It was expected that there would be limited wind resources in the summer, but this assumption was inaccurate. Weather observation data from oil and gas platforms operating on the Grand Banks has demonstrated a seasonal vertical wind shear response (the factor by which wind speed increases with height) with scaling in the summer of approximately 180% and in the winter of approximately 140% of the reported MSC50 data set.

Once the wind speeds were scaled up to the wind turbine hub height (~150 m) and the wind resource potential accurately assessed, analysis demonstrates that the turbine has the potential to generate power more than 90% of the time.

FIGURE 10: Wind Speed Distribution in Project Area Offshore Newfoundland and Labrador



FLOATER TECHNOLOGY

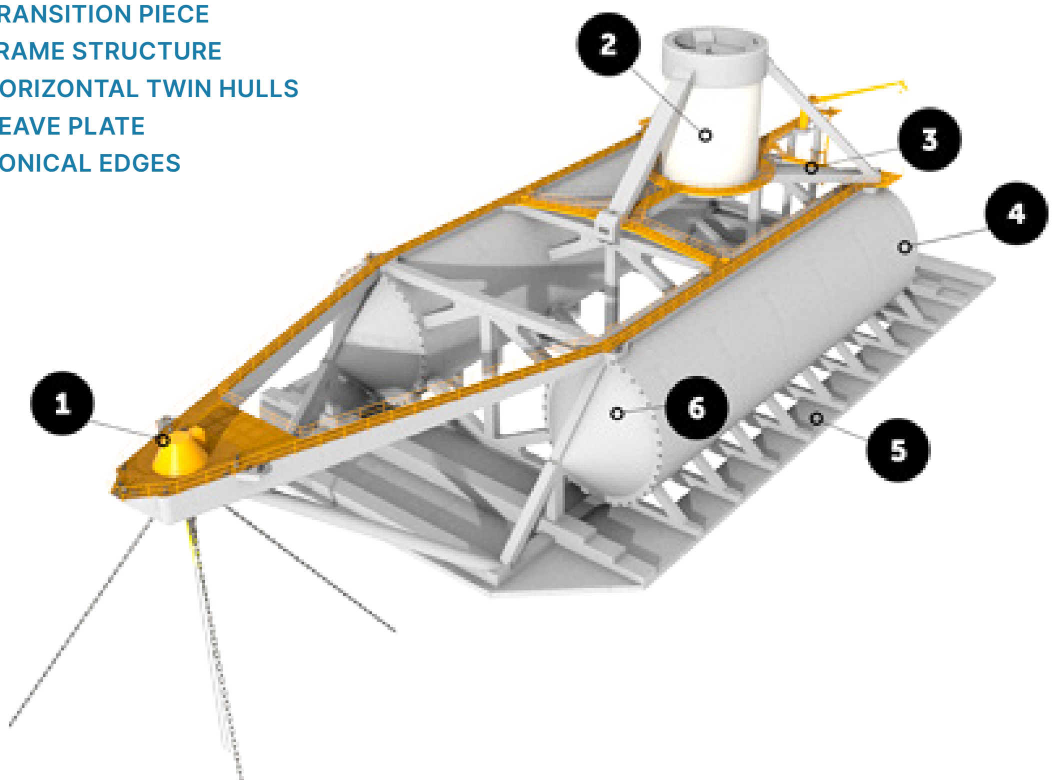
The wind turbine generators are supported on floating platforms known as "floaters" that are designed to withstand the metocean conditions of an open-ocean environment and provide the stability necessary to generate electricity. The complete system of "floater," turbine, tower, and blades are referred to as a FOWT. The "floaters" are evaluated on a site-specific basis for design suitability to ensure they can withstand the environmental conditions for up to 25 years. The key environmental conditions to be considered are waves, winds, currents, temperatures, and sea-ice.

The floater designed by Saitec is almost completely concrete, allowing manufacturing in almost every region of the world. The floater holds position via a single point mooring (Item 1 in **Figure 11**) that allows the unit to swivel and face into the waves. The main body is made up of two elongated pontoons and a heave plate underneath the structure. The main deck area is suited for additional equipment by adding bracing and supports.

Note: the Figure below is a generic design and not speciailzed for application in the North Atlantic.

FIGURE 11: Saitec Offshore Technologies' floating wind turbine platform (SATH)[13]

1. SINGLE POINT MOORING
2. TRANSITION PIECE
3. FRAME STRUCTURE
4. HORIZONTAL TWIN HULLS
5. HEAVE PLATE
6. CONICAL EDGES



MOORING AND ANCHORING

Seabed, metocean, and pack ice information are needed to assess the mooring and anchor arrangements. As well, challenging local seabed conditions, subsea infrastructure, lease boundaries, water depth, and current, will result in the anchor and mooring designs increasing in complexity and cost. For FOWTs, a key difference versus oil and gas applications is the unmanned nature of the FOWT. This generally means the consequences of mooring failures are less severe. Although still highly undesirable and costly, FOWT mooring failures would normally not threaten human life nor risk hydrocarbon release to the environment. When FOWTs are positioned near oil and gas installations, additional factors must be considered. Although the consequences for the FOWT itself are not as severe, if it were to drift towards a manned installation, the potential risk profile would change.

The SATH floater is held in place by a system of wire and chains (known as mooring lines) and seabed anchors. Based on analysis of the floating platform and the local conditions, there will likely be between three and six mooring lines connecting the floating unit to the anchors. Shallow water depths require larger and heavier chains as there is less slack in the system so the chains and anchors must resist higher forces. As the water depth increases, the chains (or substitute), have more of a spring-like tendency and soften the motion of the floater. This allows smaller and possibly fewer lines to be used for support.

Three mooring lines are possible for semi-submersible and tension leg style FOWT concepts; however, this quantity could potentially double depending on environmental loads. By comparison, moored oil, and gas semi-submersibles or FPSOs may have eight to twelve mooring lines when operating in the North Atlantic.

ELECTRICAL TRANSMISSION CABLE SYSTEM

A typical subsea electrical cable is shown in **Figure 12**.

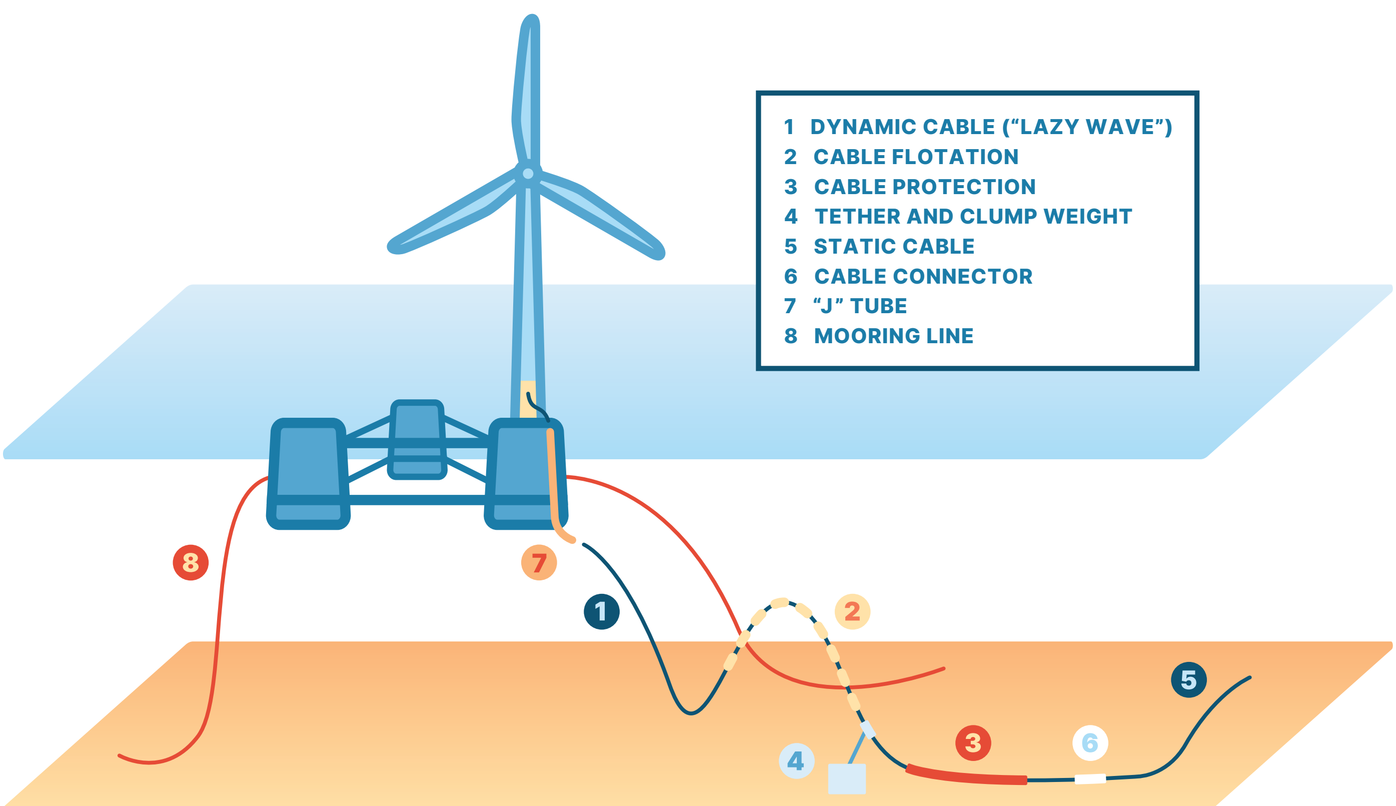
The cable which leaves the floating unit is called a dynamic cable because it is free to move in the water column and experiences many of the same forces as the mooring lines. It is a highly specialized cable design that is meant to last the life of the wind turbine, which could be in the range of 25 to 35 years.

As the cable reaches the seafloor, there is a transition component, and the cable is considered static. This static cable is expected to remain immobile on the seafloor until the entire system has passed its useful life and is removed. Static cables are buried or protected by other means from dropped objects or other users of the sea.

When a cable reaches the MODU, it rises through the water column and is brought onboard to connect to the power system. Similar analysis is performed on this section of the cable to ensure dynamic responses can handle any forces imposed by the movement of the MODU.

When the cable is brought onboard the MODU, it is held by a component that supports the cable weight and can cut the cable if required. MODUs by nature move from location to location to drill or service wells. They may also be required to move off a location temporarily due to a planned or unplanned event. In a planned event, there is time to disconnect the electrical connection of the cable and install a protective shield to prevent water from causing issues with the cable when it is dropped overboard. In an unplanned event, however, there may not be sufficient time for an orderly disconnection and preservation of the cable. These events are very rare and only due to emergency situations. Should they occur, it is expected that some damage to the dynamic cable is an acceptable choice to expedite the MODU's ability to move off location. Reconnection of the cable would only be possible after inspection and possible repair or replacement.

FIGURE 12: Dynamic Cable and Seabed Layout



HOST PLATFORM MODIFICATIONS

Modifications to the installation are driven by the electrical topology and equipment selected for the concept. Equipment is determined by the amount of demand, existing power generation, electrical bus configuration, energy storage scheme, and the available area for new equipment. Additionally, electrical isolation requirements must be considered.

The WESI system is designed to be 'Plug and Play', and to limit intrusion onboard the MODU. The equipment has been optimized to minimize footprint thus no major structural modifications are anticipated.

CONSUMER LOADS

Load characterization of the electrical consumers that the floating wind solution could be connected to was completed by WESI. This includes assessing the nature and size of the load, as well as the electrical configuration of the consumer. The results define the sizing of the FOWT solution, the equipment that must be installed on the power consumer, the power management and control systems, and the wind turbine controls. Sample consumers are outlined in **Table 1** below, with a focus on offshore oil and gas consumers, as well as a land-based grid for comparison.

TABLE 1: Oil and Gas Micro-Grid Consumers [16, 19]

Target Consumer	Installation Description	Description of Load	Bus Configuration	Primary Power/ Fuel Source
MODU	Semi-submersible, drillship or jack-up	Low loads however highly variable due to Dynamic Positioning and Well Construction Operations. (Rapid changes in load observed; especially during storm conditions.)	Island: Split bus configuration. Bus configuration can be operated both open and closed. During drilling operations, bus is typically "open" and is "closed" during transit.	MGO
FPSO	Typically ship shape	Significantly higher load and less variability than MODU. (Steady production with variable station keeping loads.)	Island: Split bus configuration; normally operated closed bus-ties	Natural Gas
FIXED PLATFORM	Bottom founded structure	Large loads and much less variability due to the lack of station keeping requirements. (Steady production loads.)	Island: Split bus configuration; normally operated with closed bus-ties	Natural Gas
LAND CONNECTED GRID	(Included for reference)	Standard grid cycling (very low variability), infinite demand.	Extensive land grid; complex structures and ties	Grid Dependent (coal, oil, natural gas, nuclear, hydro, wind, solar, etc.)

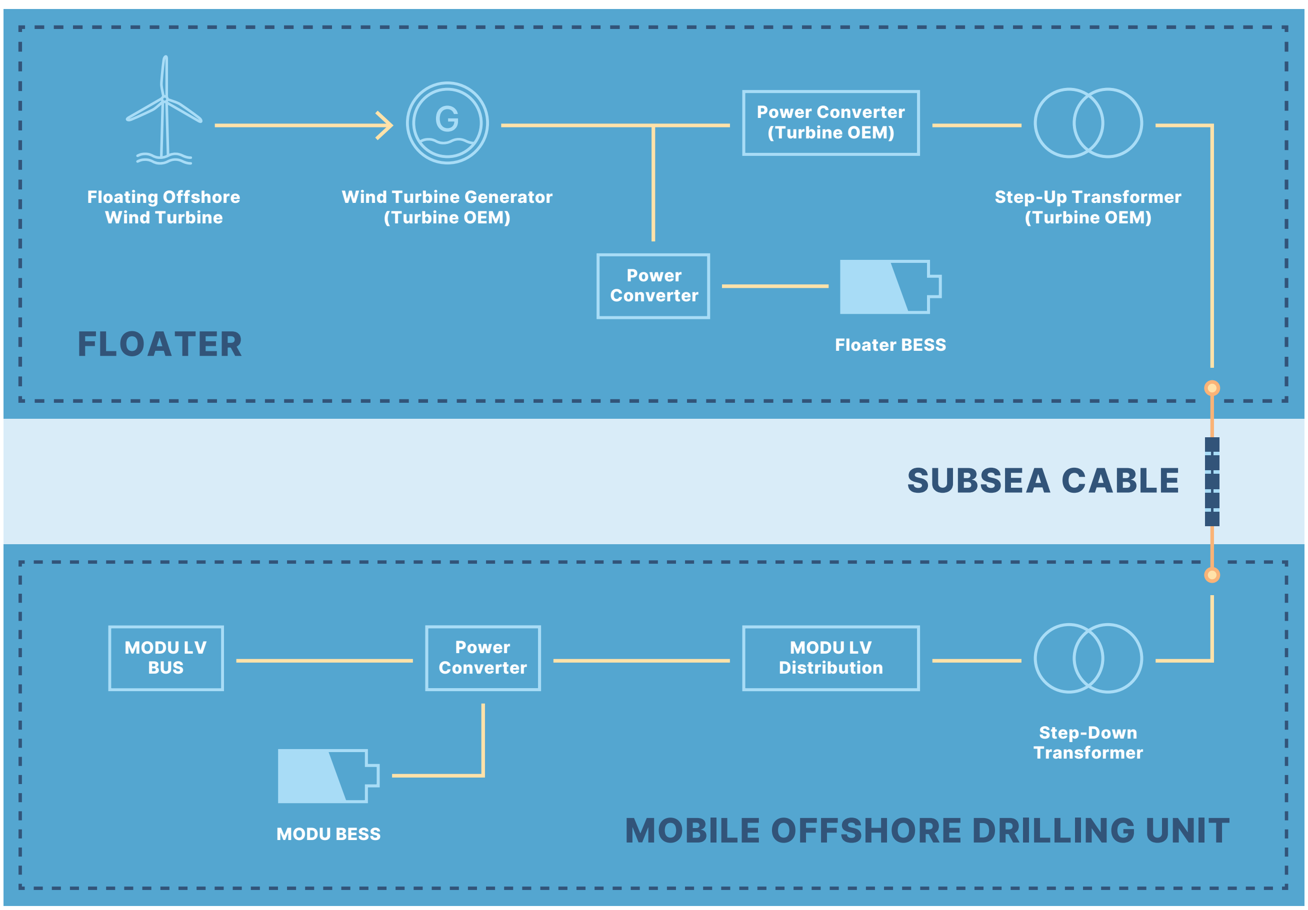
ELECTRICAL SYSTEM DESIGN

The basic topology of WESI's proposed system is one or more floating platforms, with each containing a turbine with a generator, a power converter, a step-up transformer, high-voltage switchgear, cable terminations, and a BESS as illustrated in **Figure 13**. There are also auxiliaries in place to support all the listed equipment. A combination of subsea dynamic and static cables supplies power to the installation.

Onboard the installation, a means of electrical and physical connection/disconnection is required. WESI's system includes the addition of a step-down transformer on the MODU to reduce transmission voltage to the installation's operating voltage. Additional WESI kit includes low-voltage switchgear to distribute power to the main buses through power converters which incorporate modular distributed BESS systems and maintain the installation's required bus isolation and class compliance. WESI's solution is designed to be 'Plug and Play' and is easily adaptable to the requirements of a wide variety of offshore installations including FPSOs, MODUs, and fixed platforms.

The choice of transmission voltage is determined by considering the standard Original Equipment Manufacturer (OEM) voltage from the wind turbines, subsea cable limitations, and the available footprint on the MODU. While the OEM output voltage of turbines is

FIGURE 13: Hybrid Wind Power Electrical Topology



climbing as submersible cable technology advances, standard offshore turbines normally deliver 33 or 66 kV. Typically, standard MODU bus voltages vary between 11 and 15 kV. As such, the standard wind turbine transmission voltage must be stepped down.

Offshore installations can operate using several electrical configurations. Typically, they have a multi-Low-Voltage (LV) bus set up, with each bus having its own generators and with bus-ties to the other power buses. These bus-ties can be kept open or closed. On a MODU, they are typically open for fault isolation during drilling operations and closed during transit and while at port. It is critical to maintain the isolation established by the existing configuration. Systems are designed to allow for complete isolation between buses (using the open bus configuration) to reduce the propagation of faults through the onboard electrical system. Because wind turbine power is supplied via a single feed versus generators on each bus, additional isolation is required to maintain system fault security. This is achieved via back-to-back power converters and Direct Current (DC) buses. It is dependent on operating mode and class restrictions which are also critical for the implementation of additional battery storage on the installation.

Detailed equipment design will vary based on target installation and required functionality. It should be chosen to reduce footprints wherever possible on the installation and on the wind turbine floater. Equipment must be rated for use offshore and be able to withstand metocean conditions, as well as rated for fire and explosion designated locations as required. The International Association of Classification Societies (IACS) classification is required for final design and implementation. Power modeling, Computer-Aided Design (CAD), and 3D modeling will help identify an optimal system.

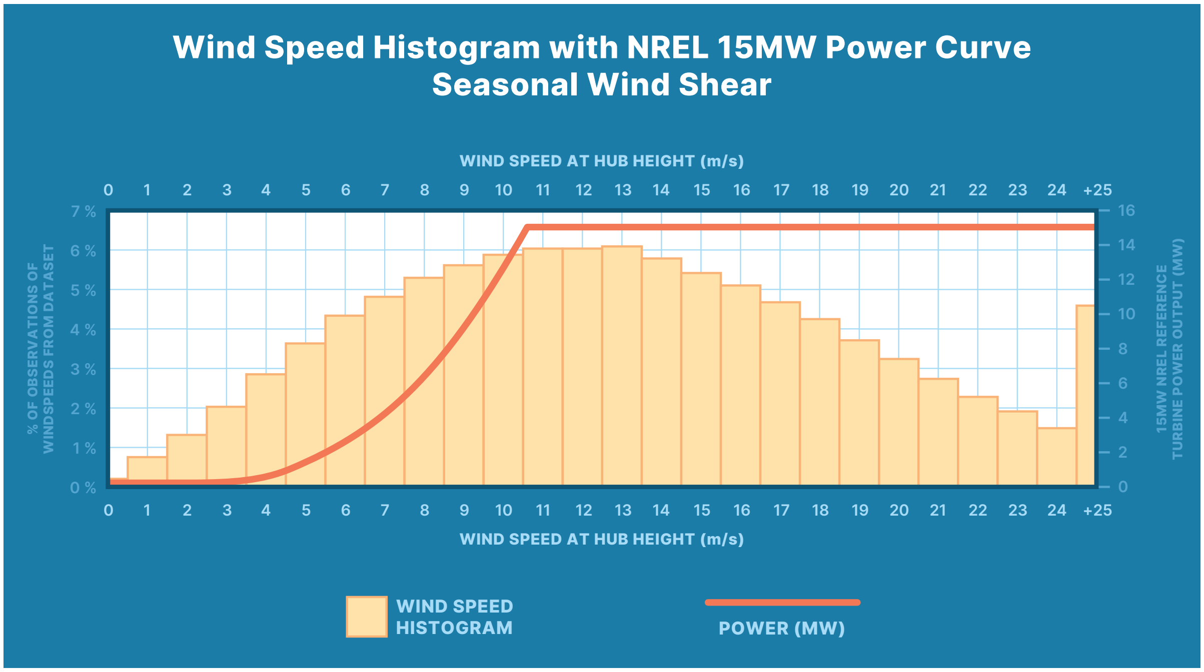
WIND POWER DISTRIBUTION MODEL

Experts were consulted to develop a model to simulate hybrid wind, battery, and onboard power generation to explore performance in terms of energy production, cost, carbon emissions, and fuel consumption.

A 10-year wind history for the location on the Grand Banks was constructed for the project. The wind history was scaled to hub height using seasonal scaling factors as observed on the Hibernia Platform anemometer (139m above sea-level). The power production was based on the power curve in **Figure 14**.

Once the wind speed dataset was scaled with the addition of high-resolution variability, speeds were converted to wind turbine power output based on the power curve from the National Renewable Energy Laboratory (NREL) 15 MW reference turbine[14].

FIGURE 14: Grand Banks, NL Wind Speed Distribution at Hub Height for the 15MW NREL Reference Turbine



Applying the Grand Banks wind resource to the NREL Reference Turbine Power Curve resulted in a 77% Gross Capacity Factor (i.e. average annual power output at this location is 77% of the turbines rated capacity). This is considered to be a “world-class” wind resource.

BATTERY MODEL

To supplement the sometimes-intermittent nature of wind power, the SATHs are also used to house batteries.

The BESS is charged when there is wind available and performs three key functions:

- Supplies utility power to run the components on the floater
- Discharges power to the MODU to supply additional power to cover ‘peak load’ scenarios, and
- Provides power to the MODU in cases where the wind is dropping and the MODU needs time to start the onboard generators and avoid situations of insufficient power.

There is also a BESS component on the MODU. These batteries perform two key functions:

- Allow an orderly transition to onboard generation in the event of abrupt loss of power from the wind turbines; and
- Link the onboard systems so that power generators can be run more efficiently, saving fuel and GHG emissions while producing only the required power.

A battery model was constructed to characterize charging/discharging along with a control algorithm (**Figure 15**). The objective of the control algorithm was to minimize onboard MODU generation, resulting in significantly reduced GHG emissions.

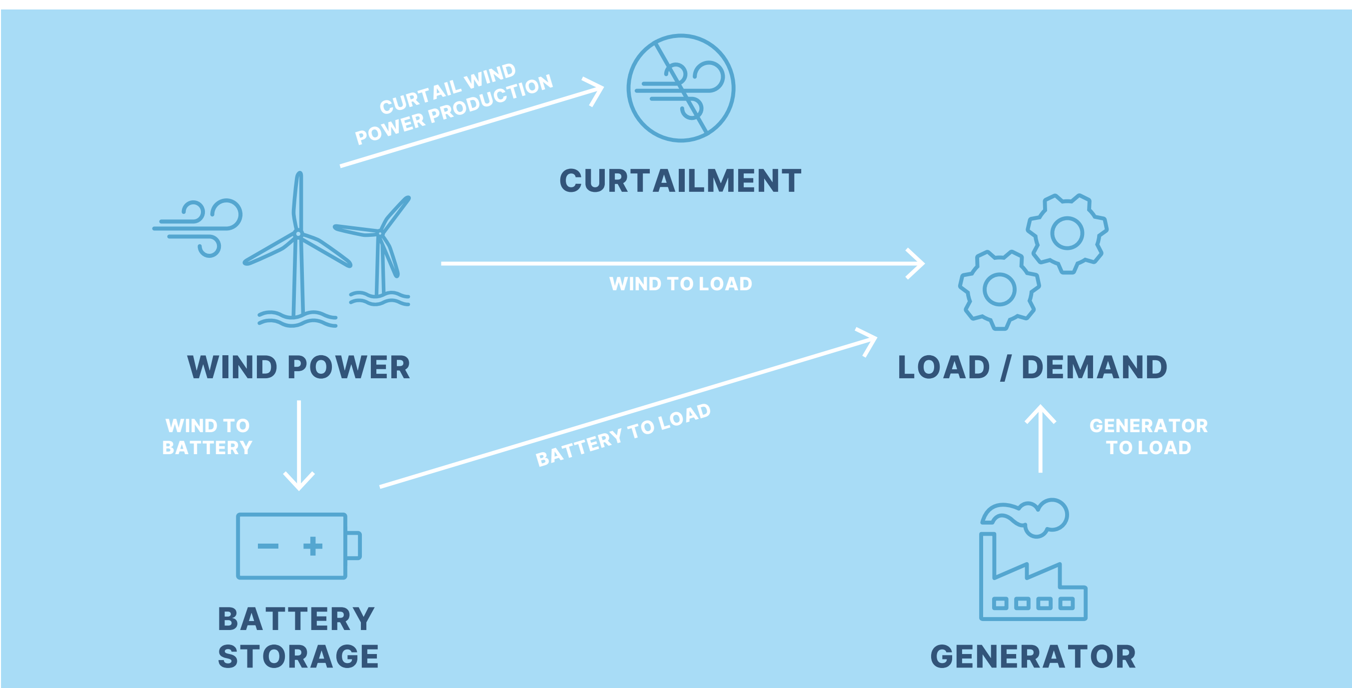
The wind power distribution model resulted in: 80% of the load satisfied directly by the wind turbine, 3% from battery storage, and traditional on-board fuel burning generators providing the remaining power.

Although there is additional wind energy available, it did not align with the MODU Load / Demand and Battery Storage availability, resulting in curtailment of more than 20% of the wind power.

The following occurs in the power model:

- **Wind Power** – electrical power is produced by the turbine according to the power curve. Wind power can be delivered directly to the load/demand or the BESS.
- **Battery Storage** – energy can be stored, then discharged, to meet the demand when winds are low.
- **Curtailment** – occurs when wind power exceeds demand, and battery storage is full. Adjusting the turbine blades to "catch" less wind reduces power appropriately.
- **Generator** – onboard generators will supply power when there is insufficient wind or stored battery energy. For the limited time when generators are operating, GHG emissions will occur at a significantly reduced output.

FIGURE 15: Hybrid Wind Power Distribution Model
(Credit: N. Pearre and L. Swan – Dalhousie University's RESL)



project cost

The CAPEX cost of implementing WESI's proposed system is estimated to be between $4,000 CAD and $6,500 CAD per installed kW[15]. The final costs of this installation are specific to client requirements for battery storage, MODU location, specific target vessel requirements, and supply chain costs at implementation time.

Capital cost of implementing WESI's proposed system is estimated to be between $4,000 and $6,500 CAD per installed kW. A project with minimal battery storage, shallower water depth, and an optimal MODU configuration would be at or below the lower end of this estimate. Increasing battery storage, more complex modifications to the MODU, and a greater water depth result in project costs at the higher end of the scale. Additionally, there is a large variability associated with the supply chain. Prices are predicted to fall in coming years; however, uncertainty in the sourcing of the necessary raw materials for turbine and battery construction indicate that future costs are difficult to predict.

WESI has divided project costs into five main categories, represented in the pie chart in **Figure 16**. These percentages are highly variable based on the economic climate at the time of installation and the final scope of the project. For example, a project with a larger BESS would incur a higher electrical infrastructure cost, without increasing turbine or floater costs.

The following are the main Capex Cost sections:

- **Turbine costs:** turbine, tower, blades, and nacelle, as well as the OEM electrical equipment; generator, power converter and step-up transformer, etc.
- **Floater costs:** floating foundation and mooring costs.
- **Electrical Infrastructure:** all WESI added electrical kit on the floater and on the MODU, and the subsea cable and moorings.
- **Assembly and Installation:** assembly of the floater and turbine, installation in the target location, integration of WESI equipment onto the MODU, and the installation of the subsea cable.
- **Soft Costs:** commissioning and decommissioning, engineering, environmental impact, and lease/licensing as appropriate.

Operating Expenditures (OPEX) are estimated to average 10-20% of total CAPEX costs over the entire life of the project. As the life of the turbine, floater, and electrical equipment is expected to exceed 25 years, OPEX averages well under 1% per year. It is expected that OPEX will be lower in initial years and will rise as more large-scale Operation and Maintenance (O&M) replacements, in addition to standard maintenance and inspections, are required.

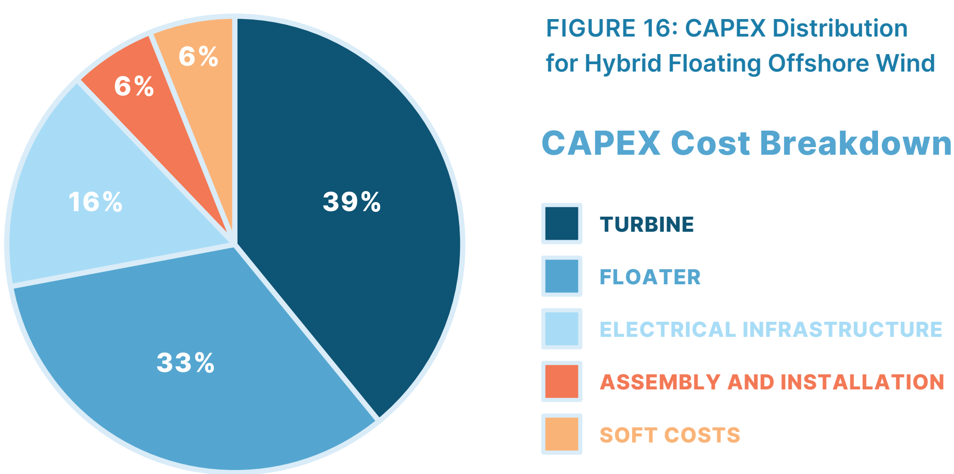


FIGURE 16: CAPEX Distribution for Hybrid Floating Offshore Wind

emissions reduction

GHG ESTIMATES

GHG savings are based on wind energy that can replace traditional fuel used to generate power onboard the offshore facilities. Based on the wind resources analysis, it is expected that wind energy combined with battery storage can replace up to 83% of the fuel traditionally consumed in a year.

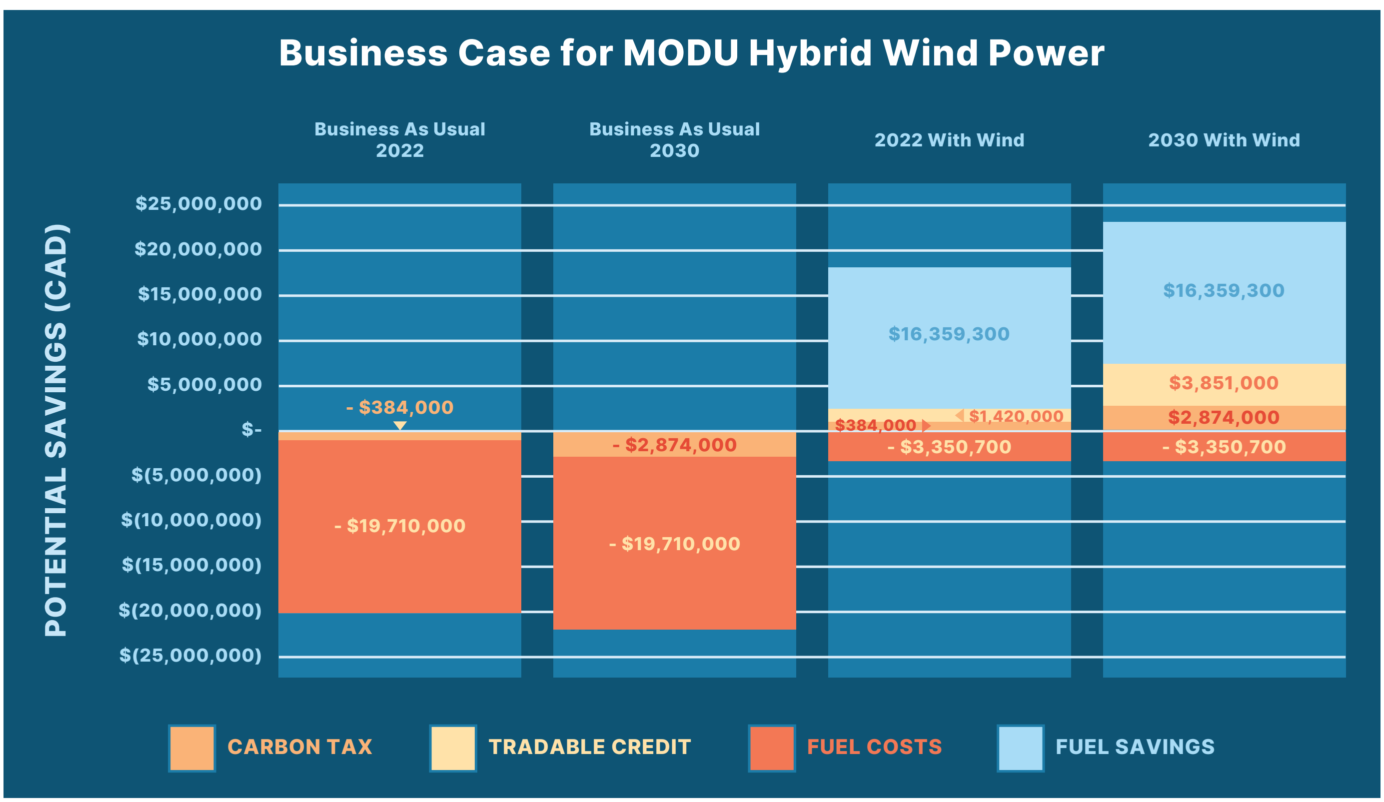
Historically, MODUs (6th Generation) operating in harsh environments have produced 40,000 tonnes of CO_2 per year[16]. With the addition of hybrid wind power, 33,000 tonnes of CO_2 could be avoided yearly.

In addition to environmental impact reductions, there will be significant cost savings associated with reduced fuel usage and lower carbon tax penalties. By 2030, the yearly fuel cost savings are expected to be $16.5 million CAD and $2.9 million CAD for carbon tax plus an additional $3.9 million CAD in tradable credits as shown in **Figure 17**. For comparison, on a typical FPSO or platform, it is quite feasible to replace a natural gas fired turbine generator. In this case, carbon reduction is **140,000 tonnes** per year. Estimated carbon tax savings and tradeable credits is **$25 million per year** while fuel cost savings is negligible.

The MODU's onboard electrical power generation, calculated based on the previously described section Consumer Loads, is directly proportional to the emissions from burning fuel. The emissions savings calculations for this report are directly tied to the offsetting of power generation. In other words, the percentage power generation offset by renewable power will result in the same percentage of emissions reduced (assumes no inflation in fuel costs and excludes 'closed-bus' savings).

Through iterations of the system sizing, the turbine and battery capacities were matched to meet the electrical demand and maximize emissions benefit.

FIGURE 17: Carbon Tax and Fuel Assessment

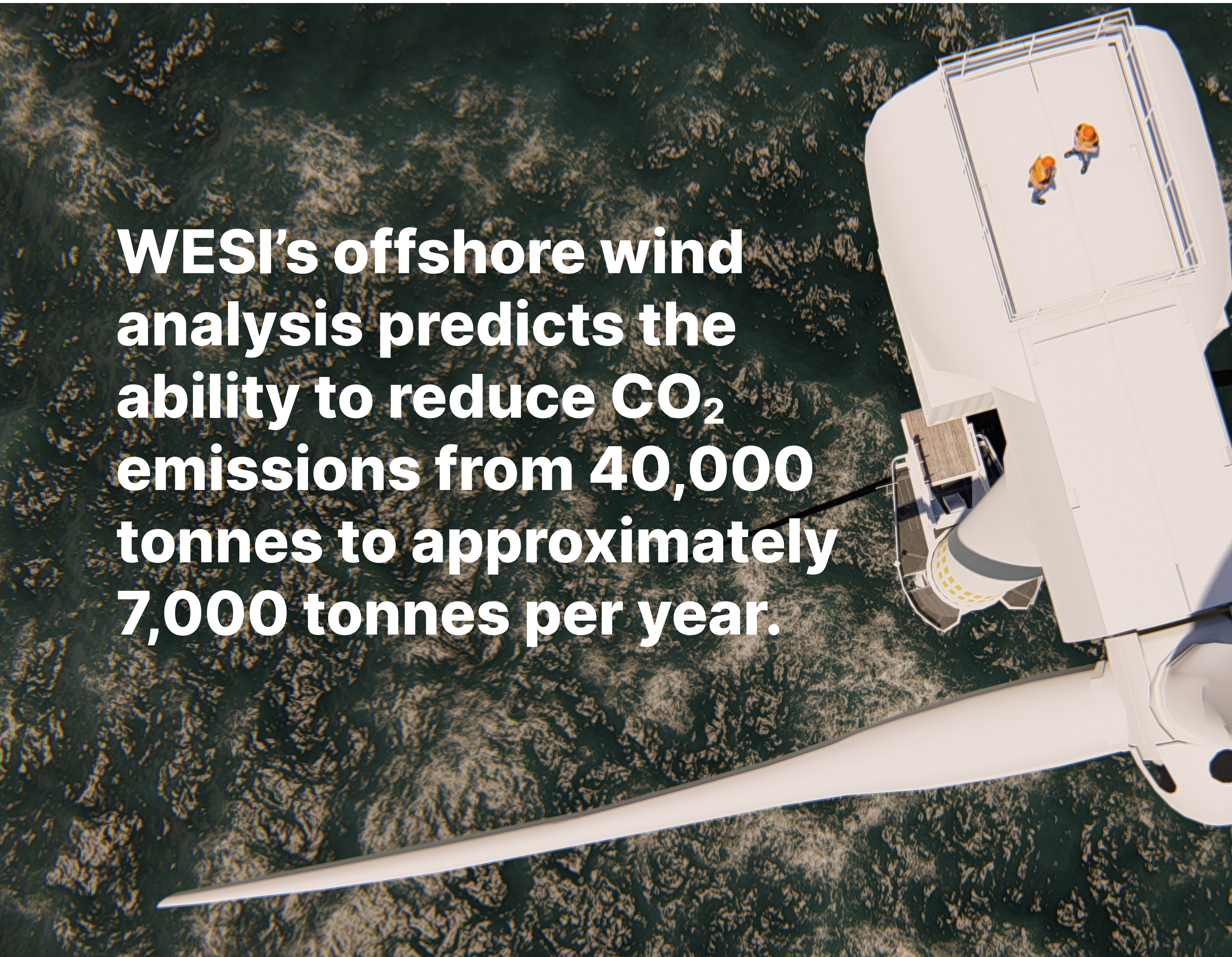


Calculations: MODU Load = 100%

- **8 MW Turbine** - supplying 80% of demand
- **10MWh BESS** - supplying 3% of demand and floater utilities
- **Wind Resource Potential** - capable of 107% of MODU load/demand
- **Wind Curtailment** - 20% production cut calculated based load and supply misalignment
- **MODU Emissions** - 40,000 tonnes CO_2/year[15]
- **Fuel Pricing** - $1200/m3 CAD MGO (February 2022)
- **Gross Capacity Factor*** - 77% (Grand Banks, Newfoundland and Labrador)

Given the significant cost savings available with the implementation of this technology, it is expected that this will be a cost competitive approach for reducing GHG emissions for MODUs operating with long duration work scopes or permanent production facilities / FPSOs.

*Gross Capacity Factor is expected to be reduced approx 5% due to O&M and other factors.



WESI's offshore wind analysis predicts the ability to reduce CO_2 emissions from 40,000 tonnes to approximately 7,000 tonnes per year.

CARBON TAX

In 2019, the government of Canada set a price on carbon pollution across the country that targeted GHG emission reduction of 30% below 2005 levels by 2030[17]. The province of Newfoundland and Labrador followed suit in 2019 with their own climate change action plan[18].

Their plan has two key elements:

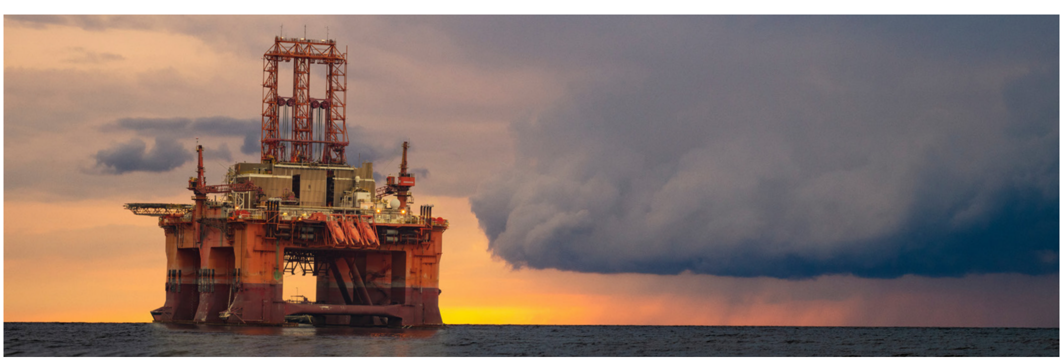
- A carbon tax on all combusted fossil fuels, and
- A 30% reduction of GHG emissions by 2030.

Currently, CO_2 emission costs $50/tonne with prices increasing $15 per year until 2030 when it reaches $170/tonne. For comparison, Norway's carbon tax is $75 moving to $255/tonne in 2022 and 2030 respectively. Performance credits are awarded to those who overachieve their GHG reduction target each year. Credits are tradable across facilities. As the credit price will be determined by the market, it could potentially vary from the federal carbon prices mentioned above.

WESI's offshore wind analysis predicts the ability to reduce CO_2 emissions from 40,000 tonnes to approximately 7,000 tonnes per year. In 2030, these emission reductions will result in yearly carbon tax savings of $2.8 million and an accumulation of $3.8 million in tradable credits. The potential combined value of the benefits from offshore wind from both carbon tax reduction and tradable credits is closer to $6.7 million.

From an economic standpoint, the short-term effects of a pan-Canadian carbon tax at $50 per tonne show that the petroleum and oil and gas extraction industries will face some of the largest production cost increases of close to 25%[19]. Offshore wind resources will aid in the reduction of carbon emissions and mitigate these growing costs.

The fuel savings for MODUs vary based on the BESS capacity. One turbine and batteries can potentially save over $16.3 million in fuel costs per year. One turbine will generate 83% of the power load with the remaining 17% to be placed on the generator. As BESS increases, the generator loads decrease and create additional cost savings on fuel and emissions tax.



key performance indicators

WESI's intent was to prove through rigorous study and analysis that wind power has the potential to be an effective solution to those looking for cleaner alternatives in the oil and gas field. The following points outline the contributions of WESI's study.

1. The report shows how WESI's proposed technology applied in North Atlantic can advance the TRL level from a speculative and unknown technology (Level 2) to one that can be easily applied in a prototype construction and test project (Level 3). Reaching advanced TRL is quite feasible given multiple FOWT projects globally are at Level 8.

2. Saitec proved the SATH floater design is suitable for operations in harsh metocean and ice-prone environments. The chosen location allowed WESI to evaluate how resilient the system can be in challenging oil and gas development areas.

3. WESI showed through their research and quantitative analysis that there are significant environmental and financial benefits from the employment of wind as an energy source.

4. WESI proved the potential of floating wind as a suitable supplemental power source for offshore environments such as Newfoundland and Labrador.

5. WESI provided knowledge to owners, operators, and other decision-making personnel in the oil and gas industry on the use of offshore renewable power hybridization to reduce GHG emissions and increase fuel savings.

6. WESI's concept demonstrated how wind power has many grid-isolated applications such as large oil and gas installations, remote communities, and industrial consumers.

7. By focusing on a specific location, WESI developed their local expertise. Through the study, further applications for the rapidly expanding renewable power industry were identified not only in Newfoundland and Labrador and Canada, but globally as well.

8. Through the course of their study, WESI strengthened local industry connections via presentations at two industry conferences, hosting an industry workshop and publication in a peer reviewed journal. This will be an asset to further the floating wind industry in Atlantic Canada, and Canada in general. It will also assist WESI as they set to undertake **Phase 2** of their project.

knowledge dissemination and capacity building

Over the course of this study, WESI collaborated with several local companies and universities to assist with various aspects of the project.

These resources assisted with ice studies, electrical integration, battery storage and assessment, mooring and anchor arrangements, cable connectors and accessories. Interactions with these groups enhanced WESI's understanding of floating wind capabilities and opportunities which are present in Atlantic Canada and other areas and exposed local companies to opportunities in wind energy production.

WESI leveraged their significant offshore oil and gas experience to develop a practical concept using floating wind to electrify offshore facilities. WESI attended and presented at several oil and gas, as well as renewable energy, workshops, and conferences. WESI was able to introduce a practical application of the technology in Canada's offshore oil and gas industry.

WESI hosted an industry workshop in February 2022, attended by several stakeholders from the Newfoundland and Labrador energy sector.

WESI also published a paper for the Society of Petroleum Engineers (SPE: 208979) on Powering Offshore Installations with Wind Energy.

project benefits

This project has several benefits to those companies who wish to implement wind solutions offshore. There will be significant reductions in GHG emissions by using wind as a power source. This aligns with the goal of the Canadian government to reduce carbon emissions by 2030 using cleaner, green resources.

Given WESI has conducted the necessary analyses to prove that wind is a viable solution in Canada, this should greatly accelerate the adoption of this technology by industry in the local environment.

There will also be significant cost savings via carbon tax credits and fuel savings. These accumulate depending on the amount of wind energy utilization. This will be a major incentive to encourage "decision makers" to transition to cleaner sources of power generation.

Looking to the future, WESI sees several benefits from offshore wind including:

Producing green hydrogen and/or ammonia

Applying this technology successfully to various industries all over the world thereby curtailing fossil fuel usage

Growing local industry capabilities and knowledge to support a broad range of power methods

Supporting local supply chain enhancements

Providing the opportunity for port and related infrastructure improvements

conclusion

KEY QUESTIONS REVISITED

WESI's assessment indicates wind is a viable option for decarbonizing the offshore industry in Newfoundland and Labrador.

This technology:

- **Can withstand the metocean environment**
- **Can operate in areas prone to significant pack ice and extreme weather conditions**
- **Can be a reliable wind resource to power what needs to be powered**
- **Has a clear economic case as provided by the GHG emissions savings and carbon tax credits**
- **Can stimulate job creation and continued use of oil and gas infrastructure.**
- **Has an estimated capital cost of $4,000 to $6,500 per installed kW.**

Most importantly, the technology is ready for implementation now. Powering offshore oil and gas facilities with FOWT will accelerate the development of grid scale commercial offshore wind farms by de-risking the technology.

Floating wind power is clearly a viable option for the following reasons:

- Floater technology already exists in Harsh Environments at TRL 8.
- Existing world class wind resources, adjacent to oil and gas facilities, can be harnessed to significantly reduce emissions.
- Turbine capacity has increased to a point where industrial quantities of power can be produced in remote areas.
- Significant carbon tax savings can be realized.
- Significant fuel cost savings can exist depending on the fuel source being used.
- Offshore installations may be distant from shore, leading to high costs for connecting shore power. Wind can eliminate the need for shore to sea power connections.
- Floating wind is a means to continue utilization of well-developed provincial offshore oil and gas supply chains into 2050 and beyond during construction as well as operations and maintenance.

next steps

Over the next five years, it is anticipated this project will progress to actual demonstrations and implementations of WESI's hybrid power generation solution. WESI plans to develop this concept to a full-scale pilot demonstration of FOWTs for both the oil and gas industry and non-oil and gas grid-connected applications. In parallel, WESI intends to expand their concept to large production platforms, FPSOs, offshore and other grid-isolated consumers as identified in Table 2.

TABLE 2: Grid-Isolated consumers in Canada[16, 19]

Consumer	CDN Sites	Emissions t CO_2/year ea.	Fuel Type	Generating Capacity (MW)	Electrical Generation (MWh/year)
FPSO	2 + 1	450k - 560k	Natural Gas	90 - 135	~700k +
Platform	2 + 1	300k - 450k	Natural Gas	90 - 100	~700k
MODU	2 - 4	40k	MGO	42	50k - 60k
Remote Community (large >10k MWh/y)	~20	42k	Diesel	25.7	59k
Remote Community (small <10k MWh/y)	~115	6.1k	Diesel	3.1	9k
Industrial (Large)	~20	100k	Diesel	25 - 50	180k
Industrial (Small)	~20+	30k	Diesel	5	15k

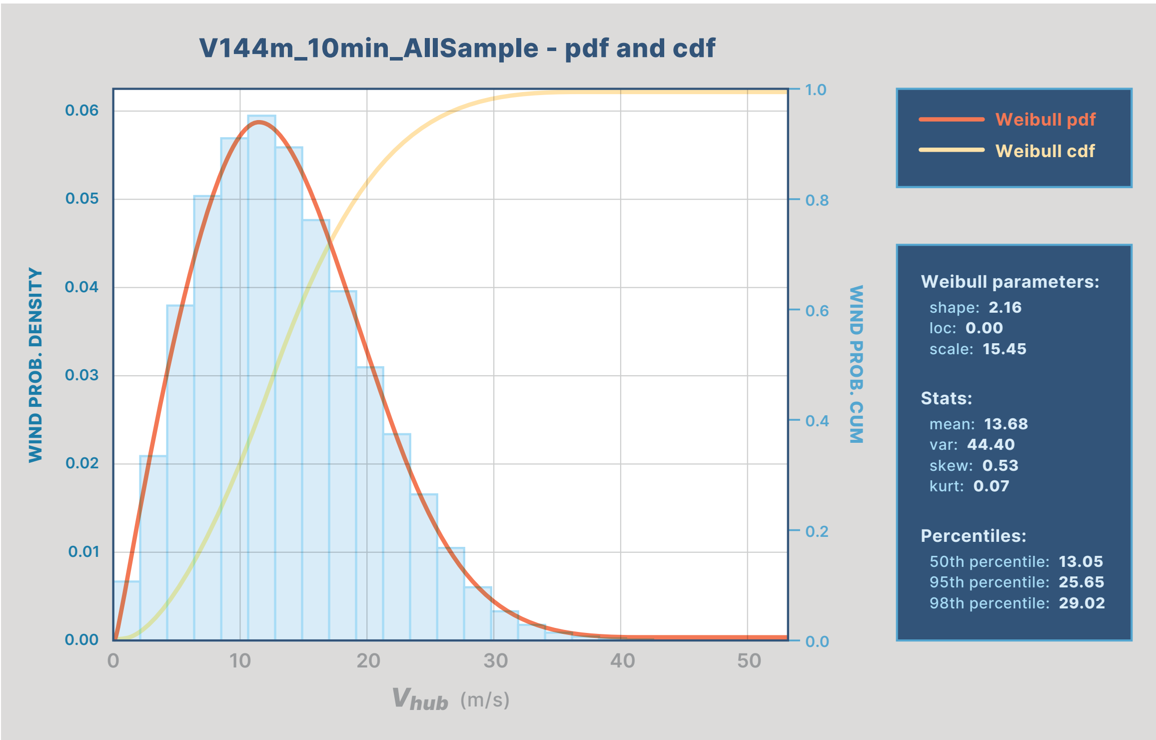
The next steps include:

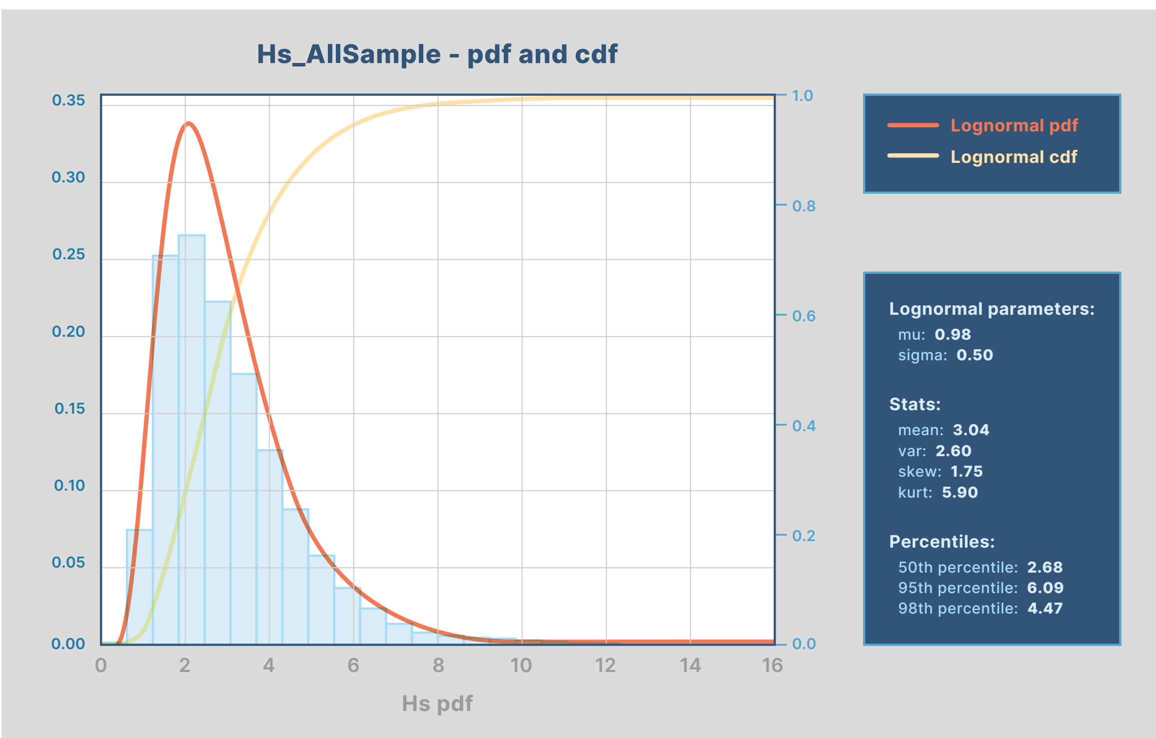
1. Entering Pre-FEED agreements for the electrification of offshore facilities in Newfoundland and Labrador plus other regions of Canada and abroad.
2. Delivering an in-the-water FOWT demonstration project in Canada.
3. Applying micro-grid solutions to alternative industries and communities.
4. Applying floating offshore wind technology to alternative energy storage technologies such as green hydrogen and/or ammonia.
5. Engaging in the regulatory transformation of the offshore wind industry in Canada
6. Aligning with strategic partners to drive projects forward, and
7. Participating in industry groups and seeking out technology transfer opportunities.
8. Increase understanding of local benefits from construction, operations and maintenance of FOWT use.

appendix a

Flemish Pass and Grand Banks - Wind and Significant Wave Heights

FLEMISH PASS METOCEAN DESIGN CRITERIA





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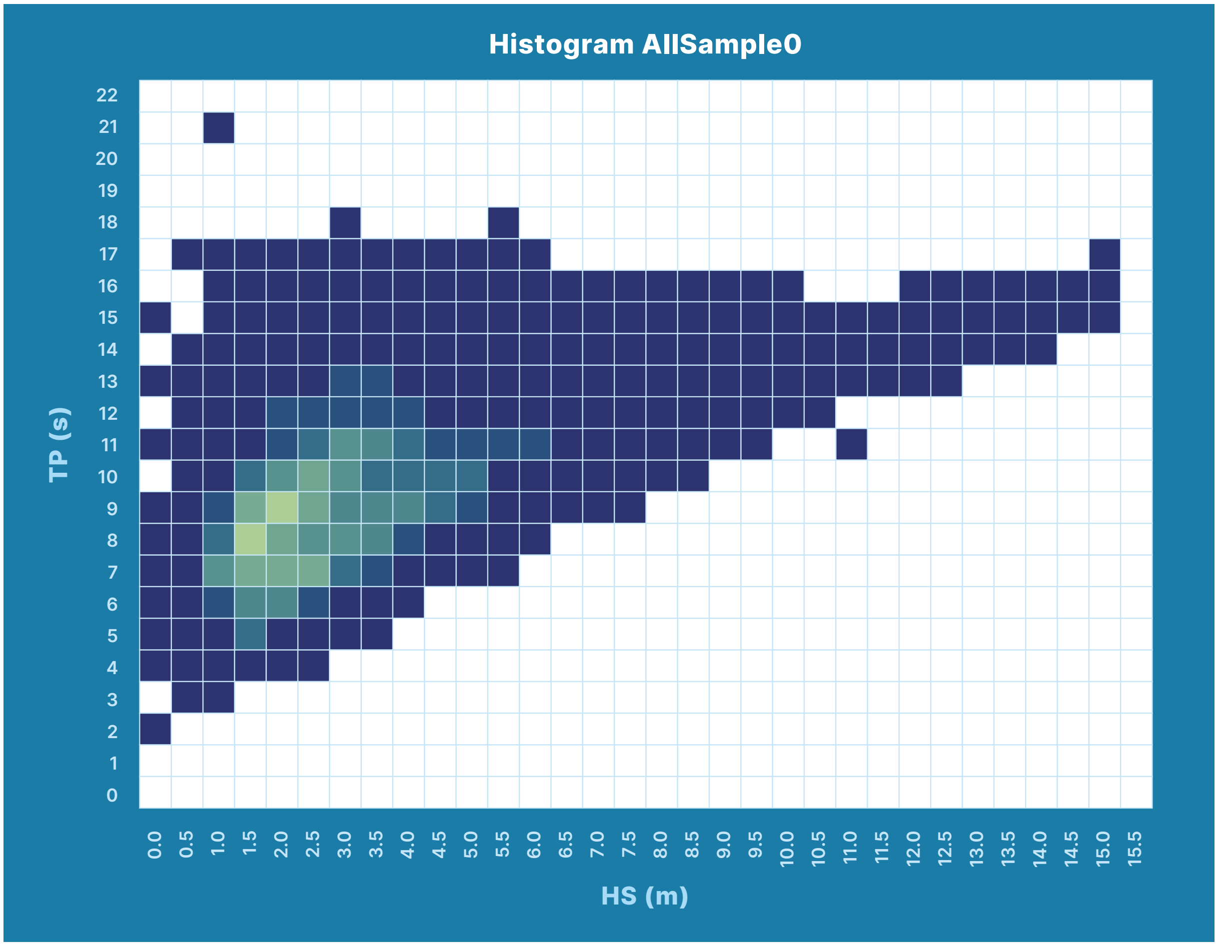

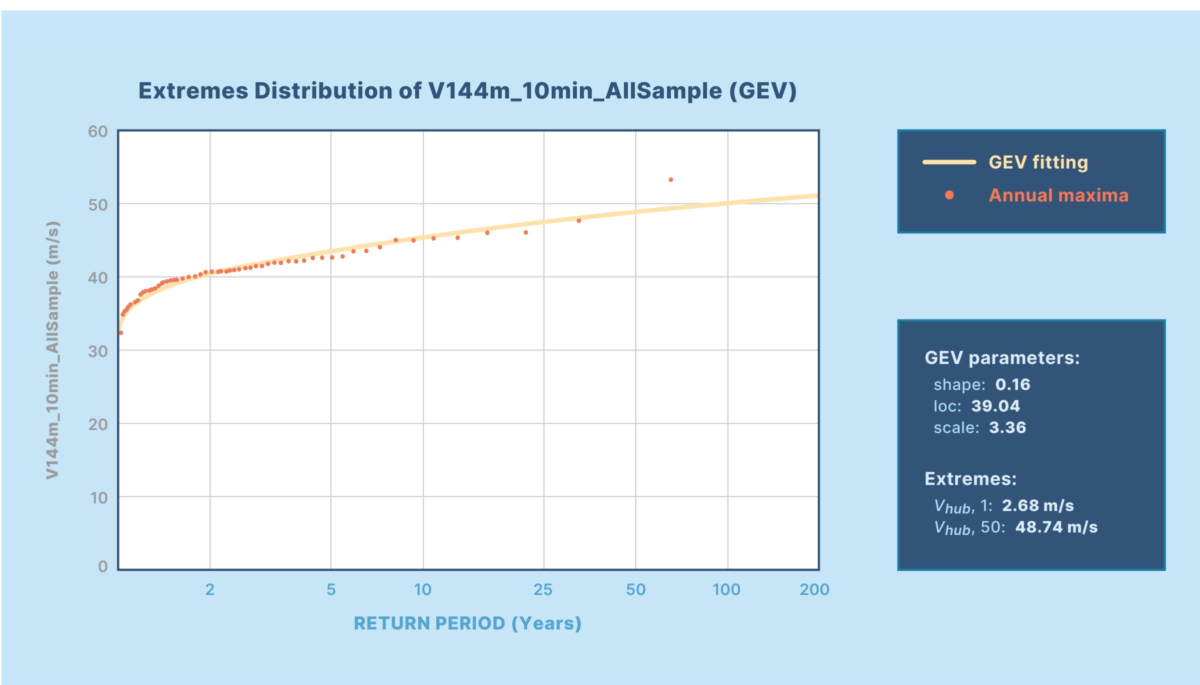

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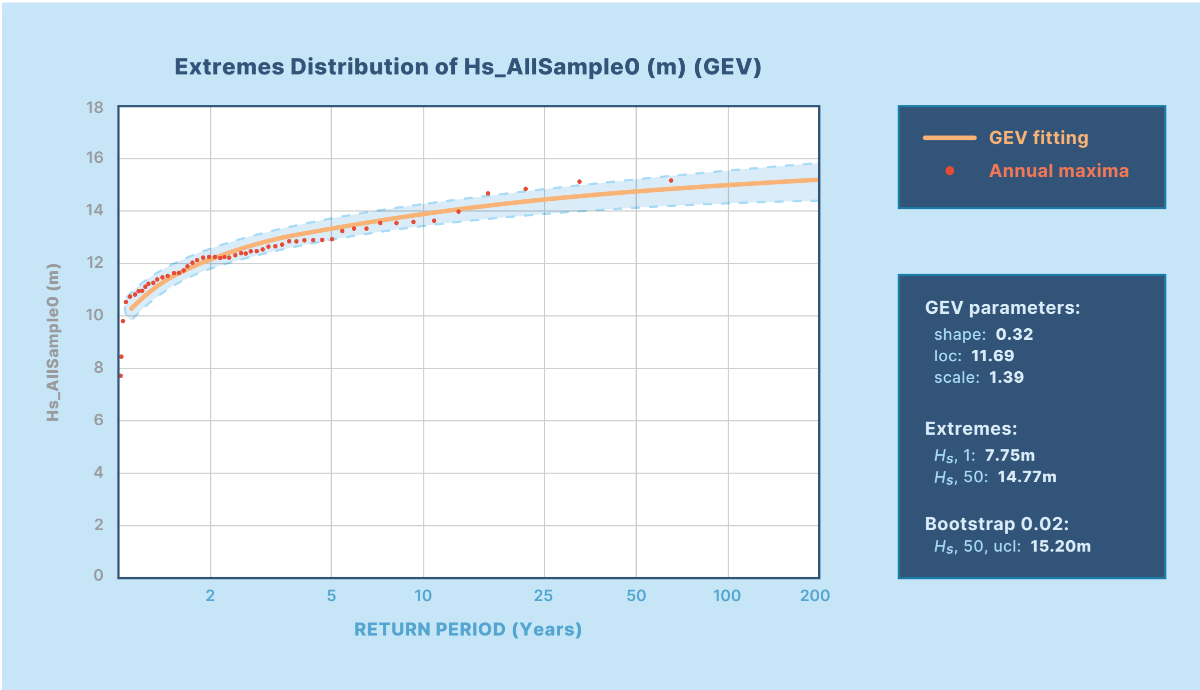

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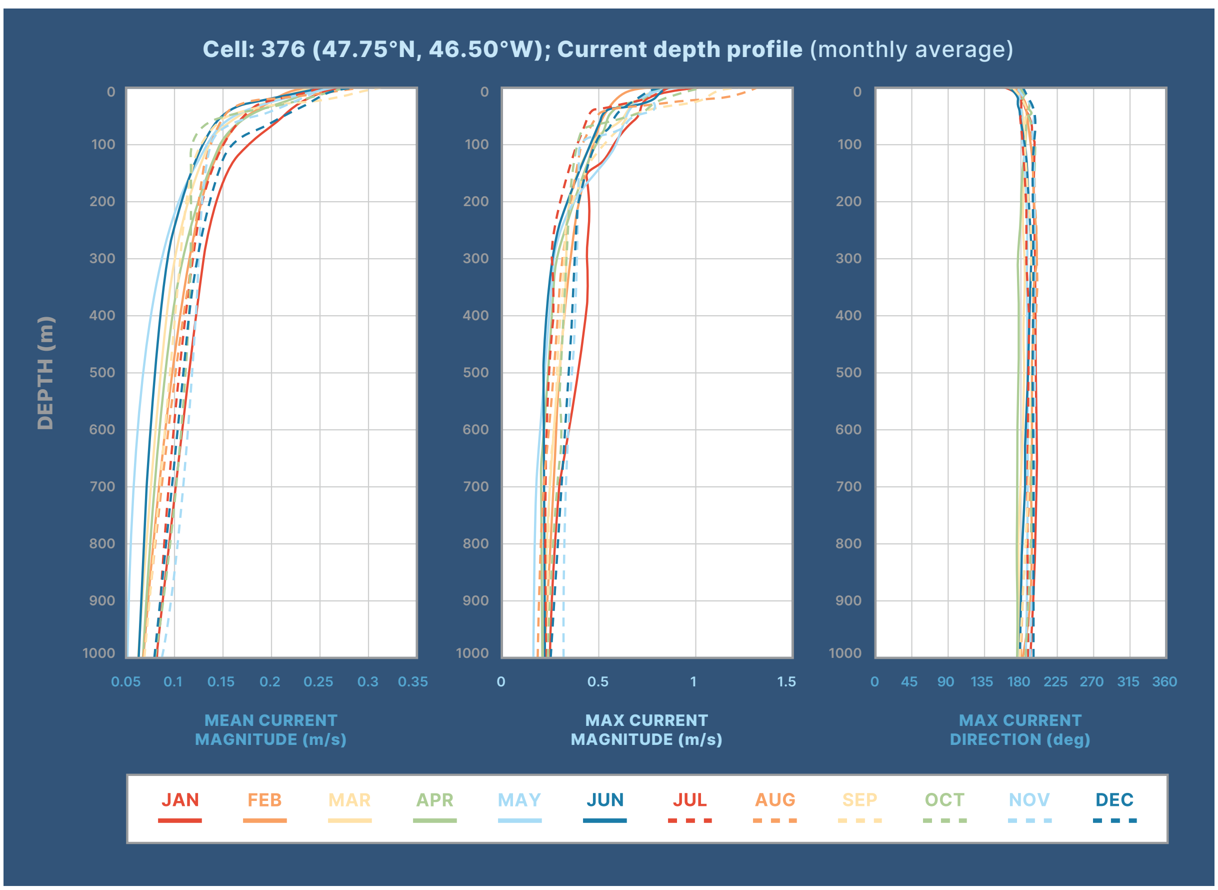

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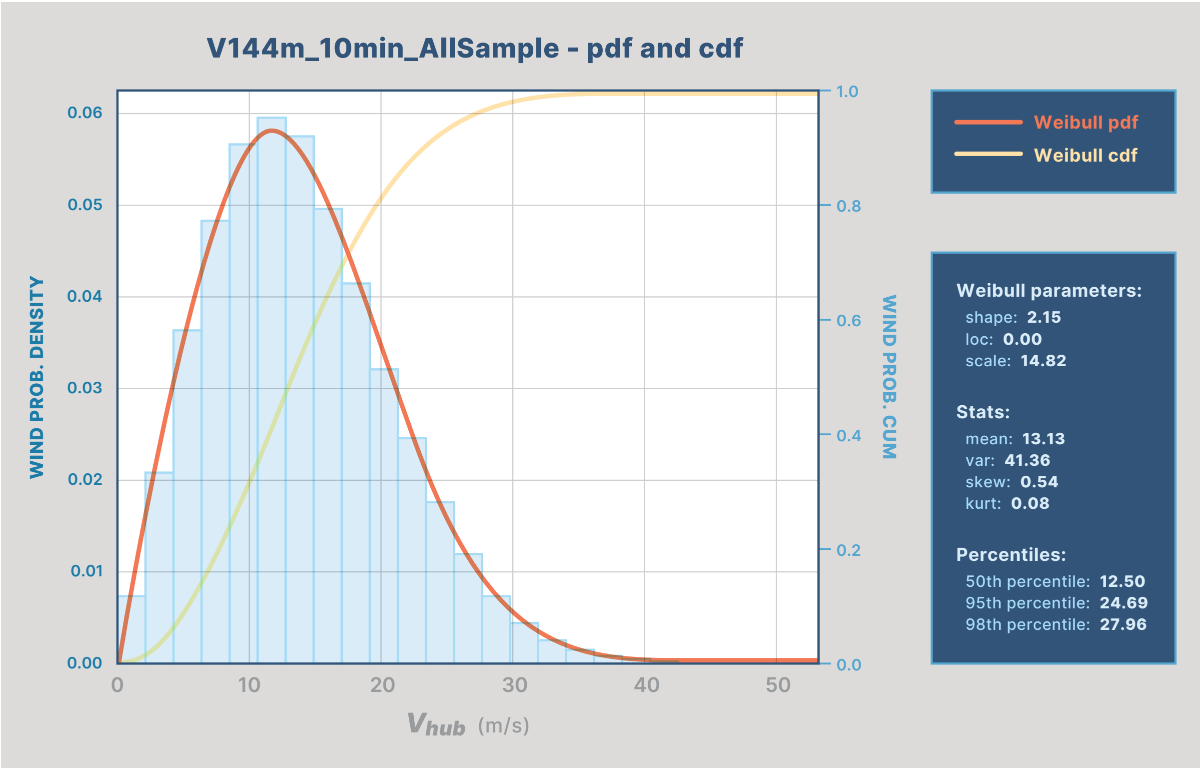

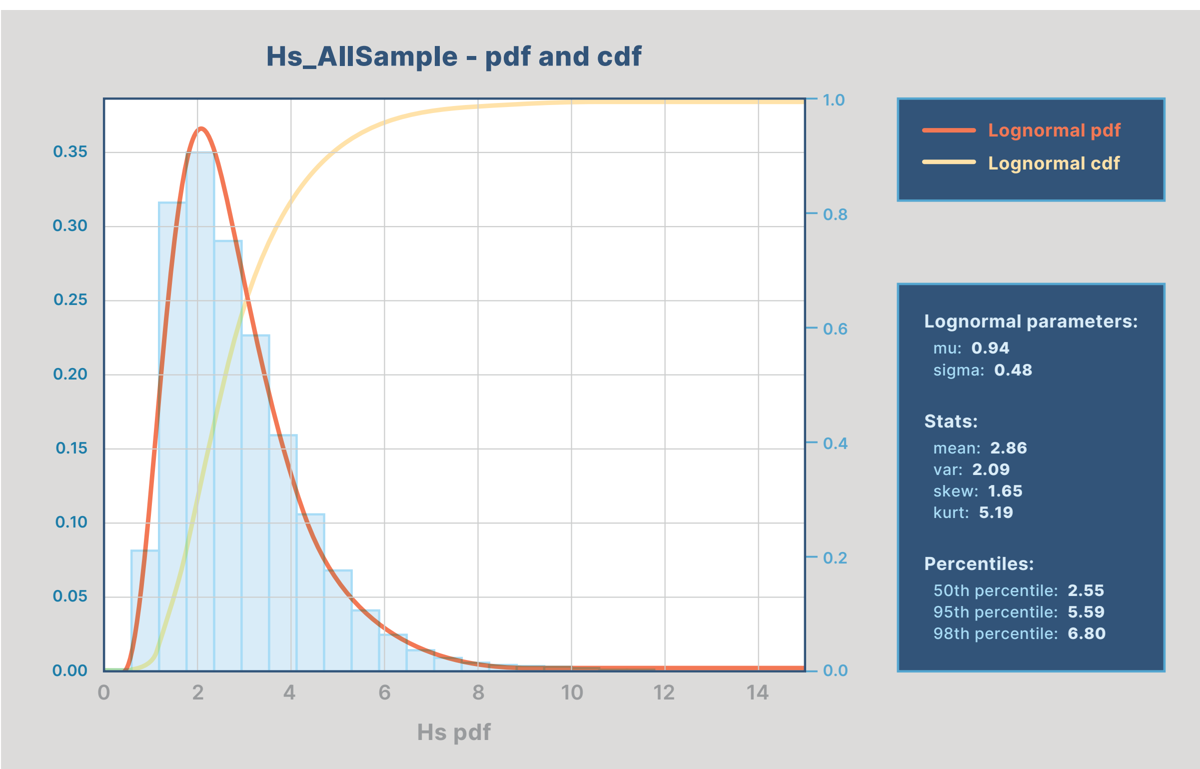

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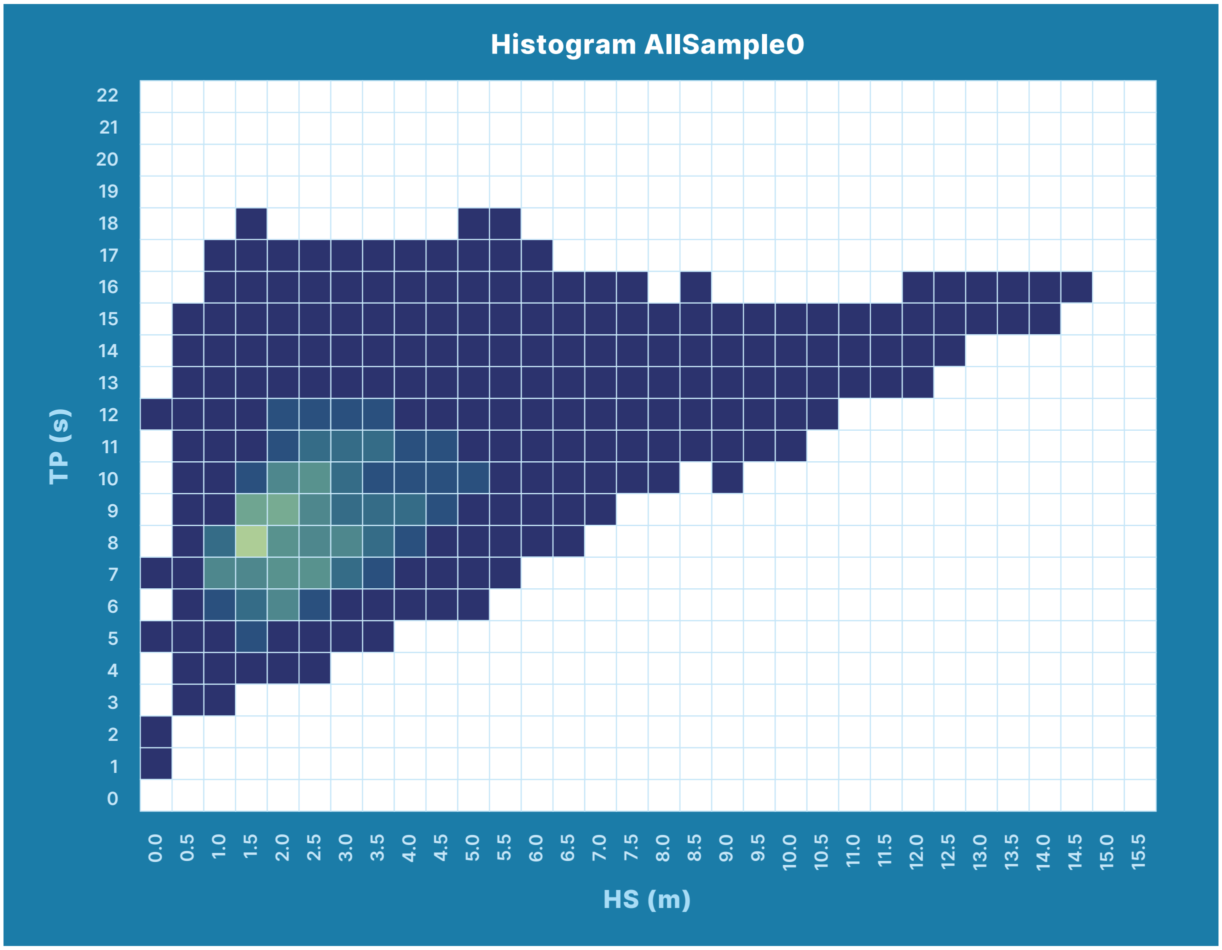

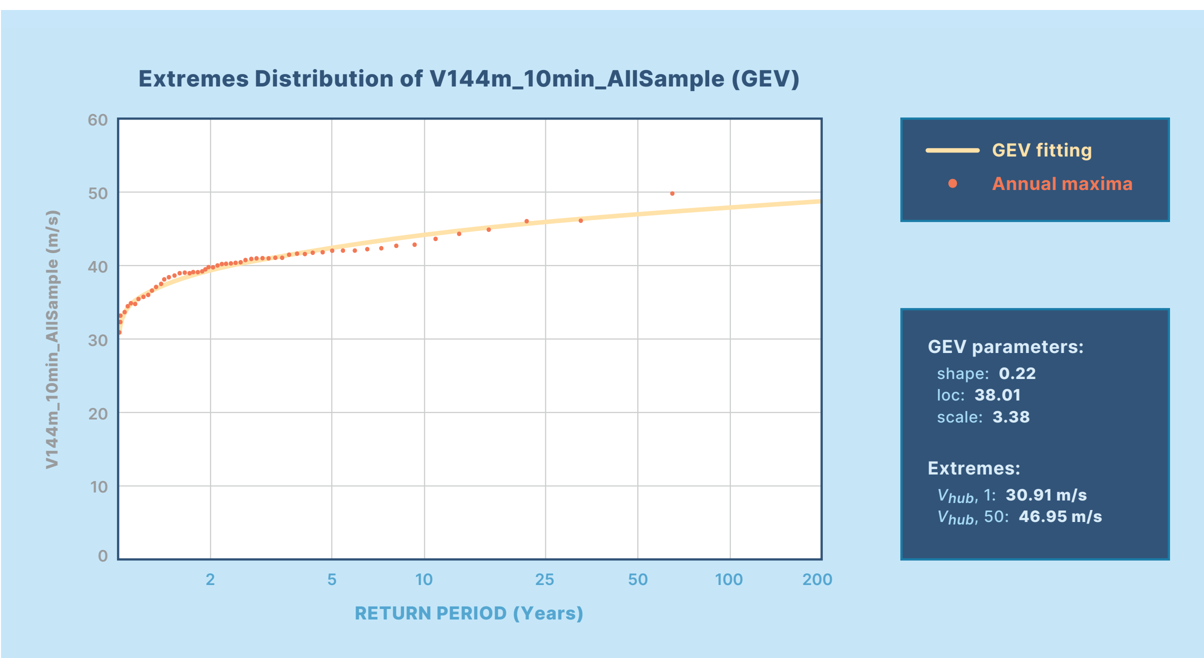

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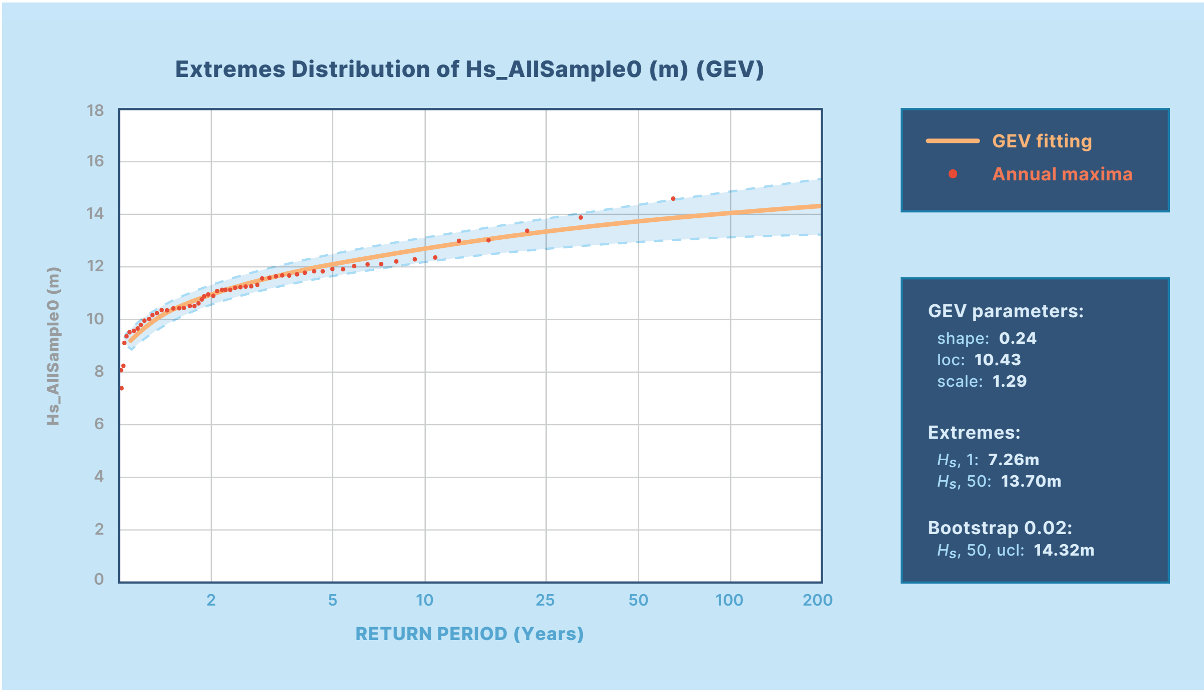

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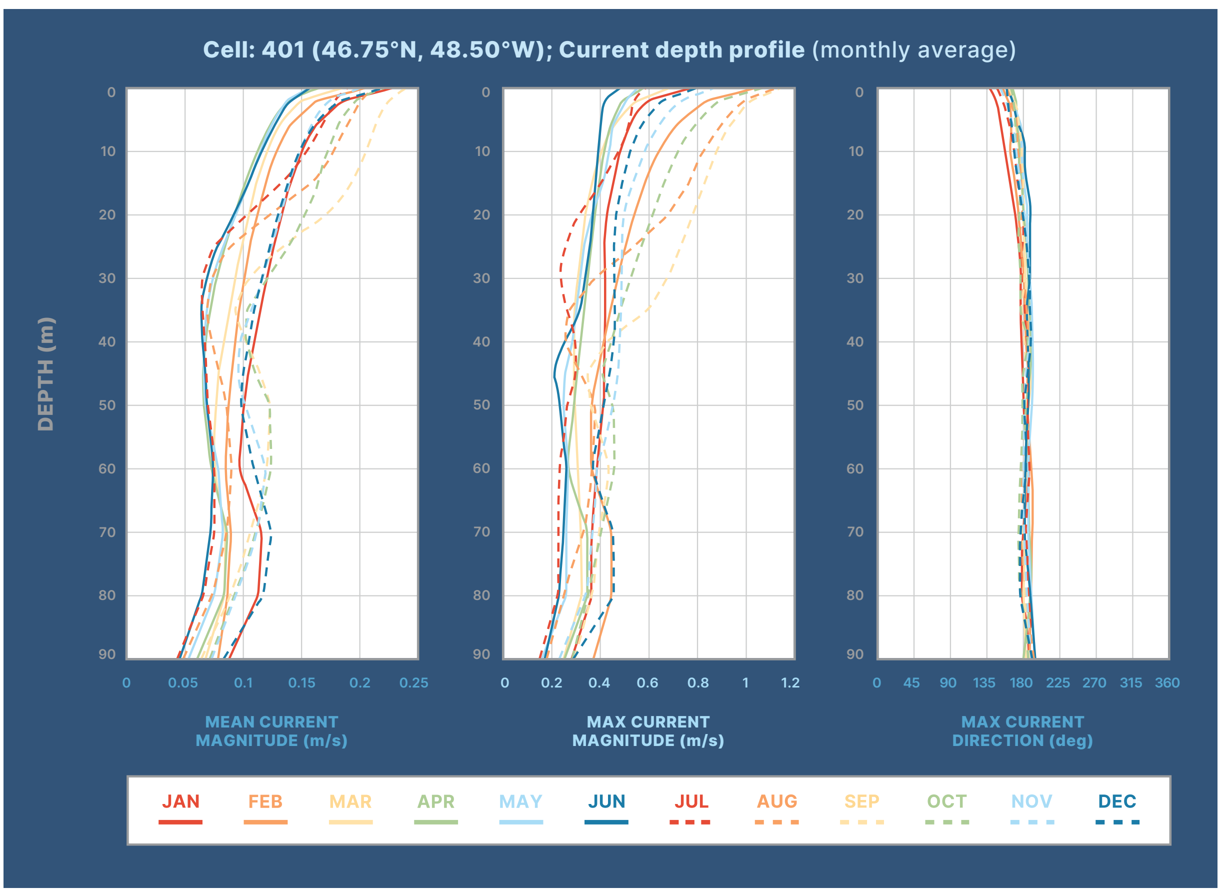

CREDIT: NESS (NALCOR STRATEGY EXPLORATION SYSTEM)

references

[1] *Saitec Offshore Technologies* – Concrete floating foundations. (n.d.). Saitec Offshore Technologies. https://saitec-offshore.com/

[2] *Bizmanualz*. (2015). Bizmanualz. https://www.bizmanualz.com/

[3] Kleiner, G. (n.d.). *VertueLab*. VertueLab. https://vertuelab.org/blog/history-of-wind

[4] *Floating wind: what are the mooring options? - a Q&A with Kent Longridge*. (2020, November 10). Acteon. https://acteon.com/blog/floating-wind-mooring-options/

[5] Aegir Insights. (2022b). *FLOATING OFFSHORE WIND -A GLOBAL OPPORTUNITY*. https://gwec.net/wp-content/uploads/2022/03/GWEC-Report-Floating-Offshore-Wind-A-Global-Opportunity.pdf

[6] *Hywind Scotland remains the UK's best performing offshore wind farm - equinor.com*. (2021, March 23). Www.equinor.com. https://www.equinor.com/en/news/20210323-hywind-scotland-uk-best-performing-offshore-wind-farm.html

[7] World's first floating wind farm has started production - equinor.com (2017, October 17). https://www.equinor.com/news/archive/worlds-first-floating-wind-farm-started-production

[8] Thomas, N. (2021, August 2). UK pushes floating wind farms in drive to meet climate targets. *Financial Times*. https://www.ft.com/content/49085cd7-fe54-4b2d-a24f-29448f0c784f

[9] Linder, C. (2020, January 9). *The World's Largest Floating Wind Farm Is Already Hard at Work*. Popular Mechanics. https://www.popularmechanics.com/science/energy/a30430580/worlds-largest-floating-wind-farm

[10] *Petroleum Development Mapping Application Hub*. (n.d.). Petroleum-Development-Mapping-Application-Hub-Iet-Gis.hub.arcgis.com. https://petroleum-development-mapping-application-hub-iet-gis.hub.arcgis.com/

[11] Swail, V., Cardone, V., & Cox, A. (1998). *A LONG TERM NORTH ATLANTIC WAVE HINDCAST*. https://www.oceanweather.com/about/papers/A%20LONG%20TERM%20NORTH%20ATLANTIC%20WAVE%20HINDCAST.pdf

[12] *Homepage* | IEC. (n.d.). Www.iec.ch. https://www.iec.ch/homepage

[13] *Saitec Offshore Technologies* – Concrete floating foundations. (n.d.). Saitec Offshore Technologies. https://saitec-offshore.com/

[14] Gaertner, E., Rinker, J., Sethuraman, L., Zahle, F., Anderson, B., Barter, G., Abbas, N., Meng, F., Bortolotti, P., Skrzypinski, W., Scott, G., Feil, R., Bredmose, H., Dykes, K., Shields, M., Allen, C., & Viselli, A. (2020). *IEA Wind TCP Task 37 Definition of the IEA Wind 15-Megawatt Offshore Reference Wind Turbine Technical Report*. https://www.nrel.gov/docs/fy20osti/75698.pdf

[15] Historical GHG Emissions Summary Newfoundland and Labrador (1990-2020)

[16] Beiter, P., Musial, W., Duffy, P., Cooperman, A., Shields, M., Heimiller, D., & Optis, M., (2020) The Cost of Floating Offshore Wind Energy in California Between 2019 and 2032. NREL/TP-5000-77384 https://www.nrel.gov/docs/fy21osti/77384.pdf

[17] Canada, E. and C. C. (2021, July 12). *Government of Canada confirms ambitious new greenhouse gas emissions reduction target*. www.canada.ca. https://www.canada.ca/en/environment-climate-change/news/2021/07/government-of-canada-confirms-ambitious-new-greenhouse-gas-emissions-reduction-target.html

[18] *On Climate Change in Newfoundland and Labrador.* (n.d.). https://www.gov.nl.ca/ecc/files/publications-the-way-forward-climate-change.pdf

[19] Government of Canada, Natural Resources Canada, Earth Sciences Sector, Canada Centre for Mapping and Earth Observation. (2018). *Remote Communities Energy Database | Natural Resources Canada*. Atlas.gc.ca https://atlas.gc.ca/rced-bdece/en/index.html

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ACRONYMS AND INDUSTRY TERMS

AC	Alternating Current
BESS	Battery Energy Storage System
BdN	Bay de Nord
CA	Certifying Authority
CAD	Computer-Aided Design
CAPEX	Capital Expenditures
CO_2	Carbon Dioxide
DC	Direct Current
DP	Dynamic Positioning
ERF	Emissions Reduction Fund
ERINL	Energy Research and Innovation Newfoundland and Labrador
ESS	Energy Storage System
FOWT	Floating Offshore Wind Turbine
FPSO	Floating Production Storage and Offloading
GHG	Greenhouse Gas
GW	Gigawatt
HV	High-Voltage
HVAC	High-Voltage Alternating Current
HVDC	High-Voltage Direct Current
HWRT	High Wind Ride Through
IACS	International Association of Classification Societies
I&C	Instrumentation & Control
IT	Information Technology
kV	Kilo volt or 1000 volts
kW	Kilo Watt
LF	Low Frequency
LV	Low-Voltage
m	Meters
MGO	Marine Gas Oil
MODU	Mobile Offshore Drilling Unit (semi-submersible, drillship or jackup)
MV	Medium Voltage
MW	Megawatt
NESS	Nalcor Strategy Exploration System
NL	Newfoundland and Labrador
NRCan	Natural Resources Canada
NREL	National Renewable Energy Laboratory
NOx	Nitrogen Oxides
O & M	Operations and Maintenance
OEM	Original Equipment Manufacturer
OPEX	Operating Expenditures
PCS	Power Converter System
SATH	Swing around Twin Hull (Saitec Floater Technology)
SCADA	Supervisory Control and Data Acquisition
SOx	Sulphur Oxides
TRL	Technology Readiness Level
WESI	Waterford Energy Services Incorporated
WTA	Wind Turbine Array
WTG	Wind Turbine Generator
WWR	West White Rose

Newfoundland and Labrador's offshore environment is extremely harsh and contains a world-class wind resource. WESI proves the excellence of the available resource and the viability of the entire system in this challenging environment.

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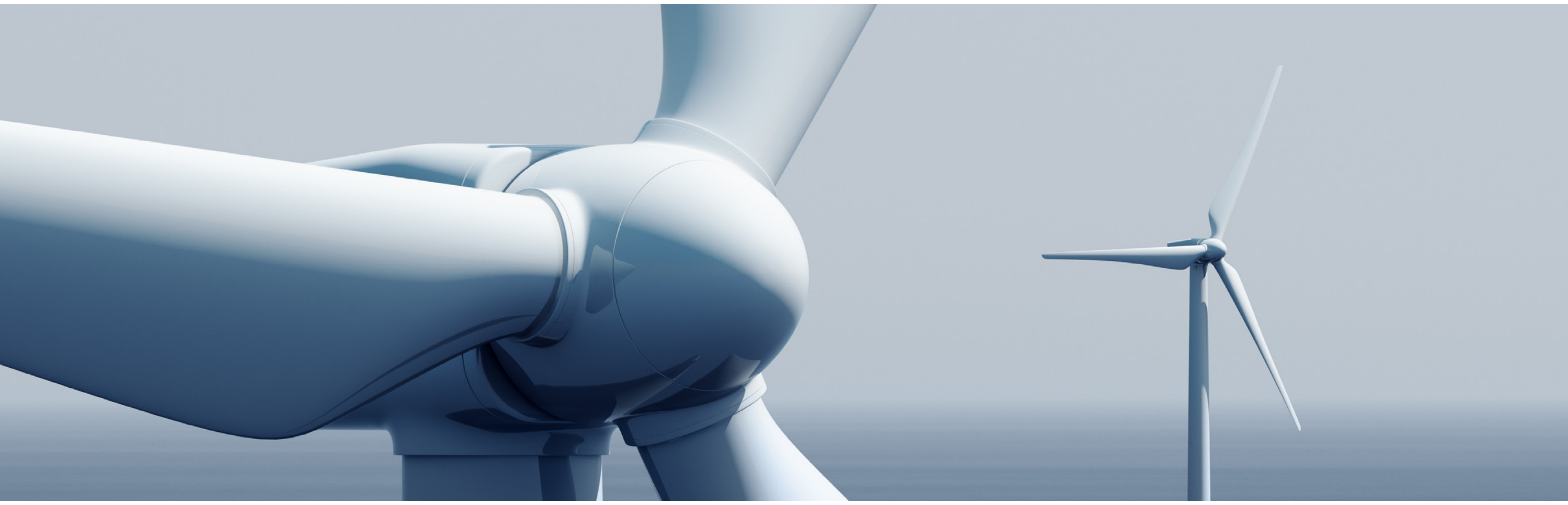

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