Fabrication and installation constraints for floating wind and implications on current infrastructure and design

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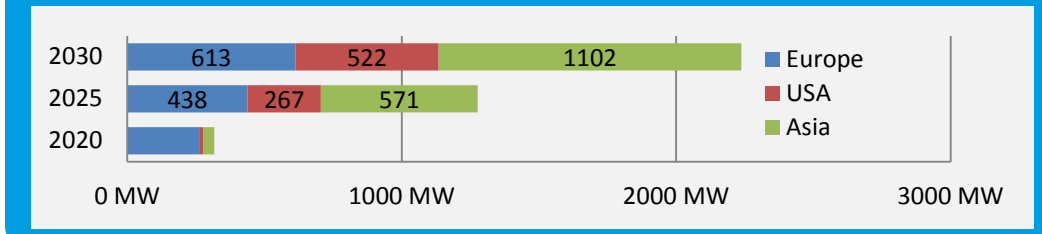
Qualification of innovative floating substructures for 10MW wind turbines and water depths greater than 50m

The research leading to these results has received funding from the European Union Horizon2020 programme under the agreement H2020-LCE-2014-1-640741.

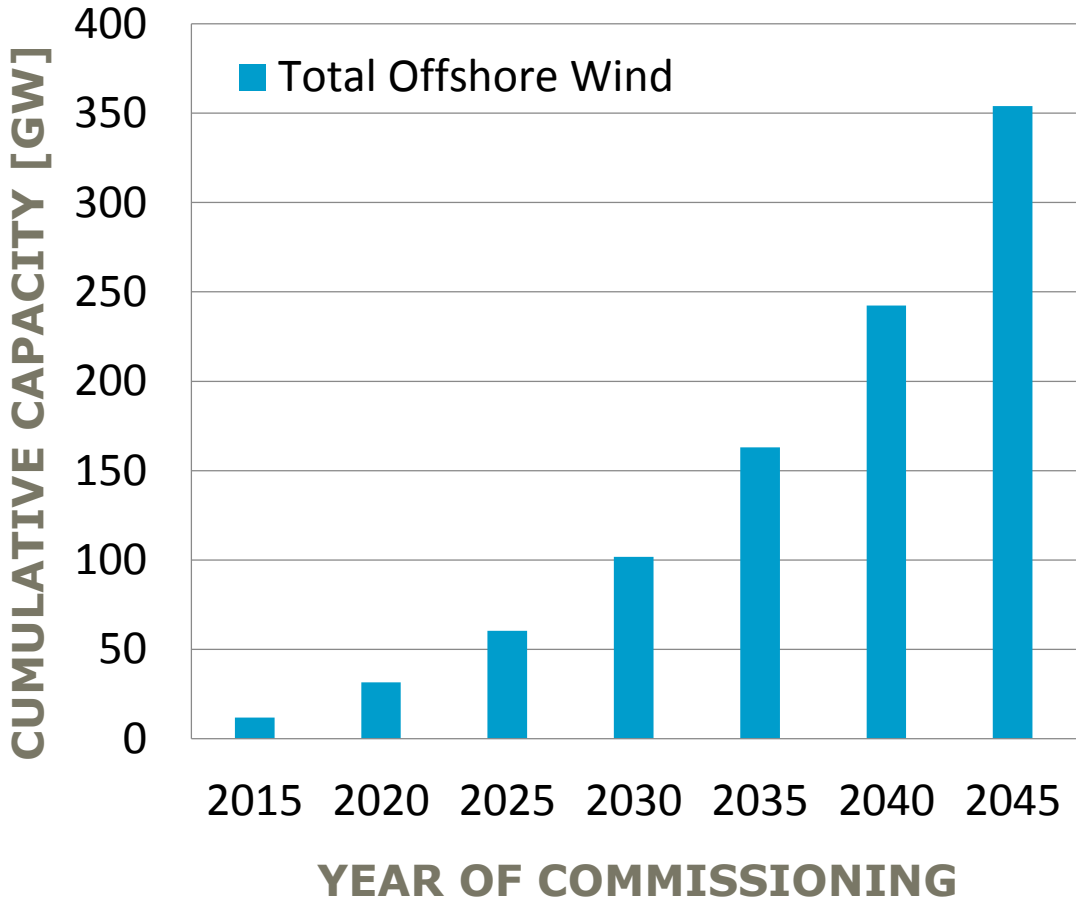
LIFES50+

INTRODUCTION

Floating Wind Projects
Already in planning phase [INNOSEA]:



- Large offshore floating wind farm projects expected by 2025
- EU H2020 LIFES50+ scenario:
  - 10 MW Wind Turbine
  - 500 MW wind farms at 3 sites
- Fabrication and Installation Constraints need to be identified and addressed before large scale deployment



Forecast based on IRENA 2016, "INNOVATION OUTLOOK **OFFSHORE WIND"**

NOTE: All data/results present herein are generic/hypothetical and not related to LIFES50+ concepts from Olav Olsen, Iberdrola, Nautilus and Ideol

FABRICATION
STEEL

- Pre-fabrication
  - Typically in shipyards
  - Many ports do not provide capability
- Transport (if not in shipyard)
  - Accessibility to Cargo vessels, Rail, Road
  - Size restrictions
- Storage for mass production
  - Space required for pre-fabricated parts
  - Bearing capacity & weather restrictions
- Assembly
  - Dry dock or Quayside (water depth)
  - Bearing capacity & crane restrictions
  - Weather restrictions for welding

Photo – Principle Power, WindFloat 1

Photo – Navantia, Hywind Scotland

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FABRICATION
CONCRETE

- *Precast*
  - *Concrete factory*
  - *No weather dependence*
  - *Transport to assembly port*
- In-situ
  - Local concrete plant or mobile batching plant
  - Weather restrictions apply (drying)
  - Longer production periods
  - Cast in one part
- Bearing capacity of construction site (for assembly crane and/or structure)

Photo by IDEOL
IDEOL Floatgen

Photo by MT Højgaard
Cranefree® Gravity foundation

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FABRICATION
SUMMARY

Steel

Advantages	Challenges

• **Established** in the offshore wind industry:
  ○ Know-how existing
  ○ Proven solutions and standards exist to avoid issues related to corrosion due to saltwater and salty air, wind turbine load, etc.
• **Assembly** can be executed **relatively fast** if components are pre-fabricated (consists of welding operations and positioning of the parts only)
• **Lighter substructures** are possible (compared with concrete)
	• Expensive material, **price fluctuating**, planning difficult
	• **Specialized equipment** (e.g. large scale welding machines and cranes with sufficient lift capacity) required, shipyard preferable
	• Large dimension **components/parts**:
	  ○ Need to be built at shipyards/factories, typically not at construction site, which is a challenge for mass production
	  ○ Heavy/large parts need to be transported to construction site, suitable access (road, railways, waterways) required
	  ○ Suitable storage area at port required

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FABRICATION
SUMMARY

Concrete

Advantages	Challenges

• **Concrete local supply** adaptable to local conditions and project requirements:
  ○ Ready-mix concrete
  ○ Mobile batching plant
  ○ Installation of a stationary batching plant at the construction site
• **No specialized equipment**, like large scale welding machines, required (construction at lower costs)
• **Low costs of concrete** as a raw material
• Ready-mix concrete only: **less storage area required** (no raw material has to be stored for batching at port)
	• **Limited use in offshore wind** industry
	• **(Often) larger dimensions of concrete floaters** require large construction area for mass production
	• **High weight of concrete floaters** (restrictions to the bearing capacity and space)
	• Concrete cannot bear **tension loads**, therefore additional procedures (e.g. pre-tensioning, avoiding of upending actions) necessary
	• Wide range of **weather restrictions** for construction/drying process (e.g.no construction during frost or heavy rain)
	• Mixing process at the construction site possibly more inaccurate (additional quality assurance necessary)

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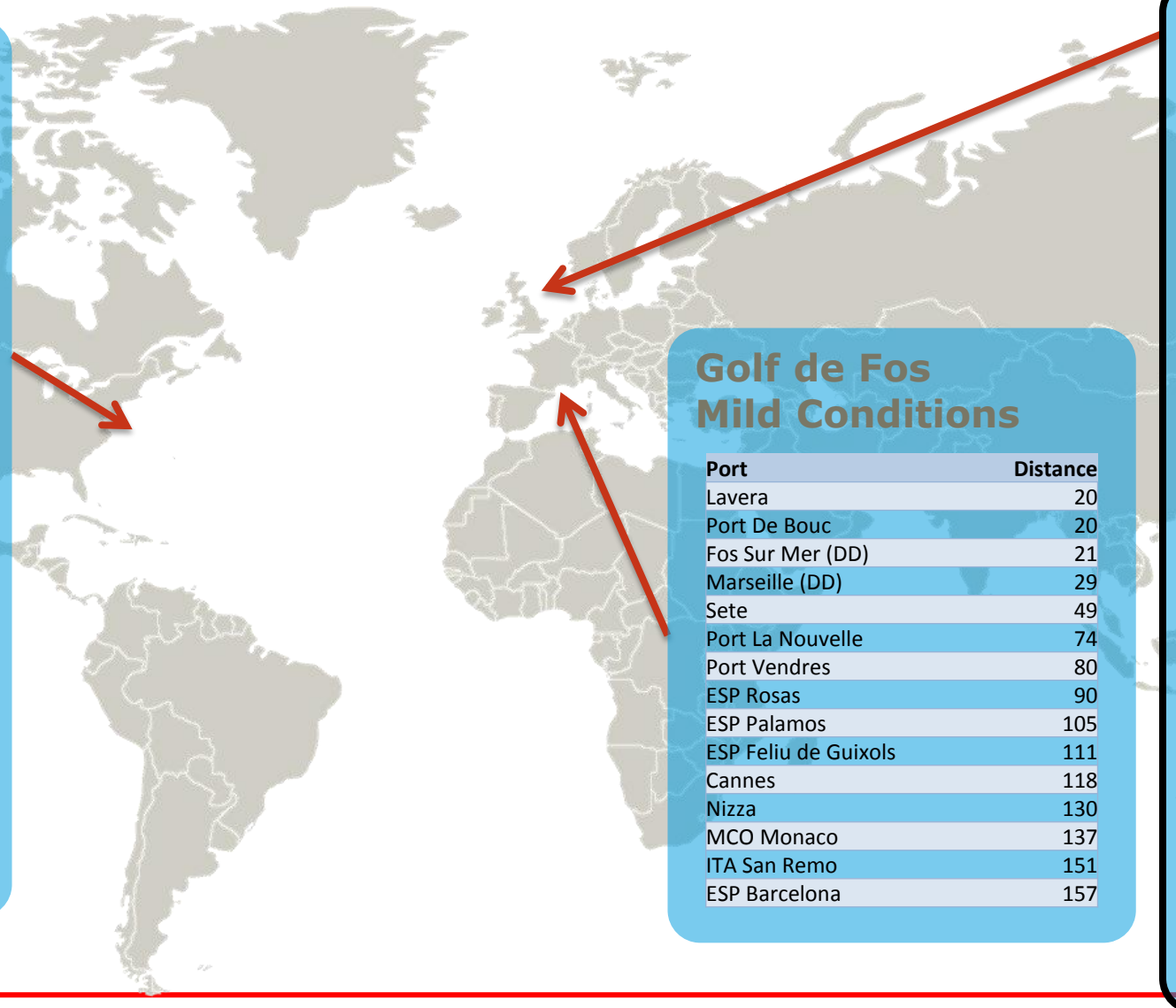
LIFES50+ SITES
RELEVANT PORTS

Gulf of Maine Medium Conditions

Port	Distance
Port Clyde	23
Bath	28
Yarmouth	33
Portland	35
Rockland	42
Belfast	58
Bucksport	71
Bar Harbor	79
Gloucester	82
Bangor	85
Salem	90
Boston (DD)	102
Provincetown	104
Plymouth	110
Sandwich	118
Eastport	139
Hyannis Harbor	140
Nantucket Harbor	140
CAN Yarmouth	143
CAN Port Maitland	145
CAN Meteghan	147
CAN Beaver Harbor	150
Oak Bluff	151
CAN Bayside	154
CAN Weymouth	159



Golf de Fos Mild Conditions

Port	Distance
Lavera	20
Port De Bouc	20
Fos Sur Mer (DD)	21
Marseille (DD)	29
Sete	49
Port La Nouvelle	74
Port Vendres	80
ESP Rosas	90
ESP Palamos	105
ESP Feliu de Guixols	111
Cannes	118
Nizza	130
MCO Monaco	137
ITA San Remo	151
ESP Barcelona	157

West of Barra Severe Conditions

Port	Distance
Castlebay	18
Lochboisdale	35
Lochmaddy	62
Mallaig	69
Lochaline	75
Glensanda	87
Kyle of Lochalsh	87
Kishorn	88
Crinan Canal	94
Port Askaig	94
Coleraine	100
Loch Gairloch	100
Arnish	105
Stornoway	106
Corpach	107
IRL Rathmullen	110
IRL Moville	112
Port Ellen	114
IRL Burtonport	117
Londonderry	121
Ullapool	121
Campbeltown	130
Carnlough	132
Larne	141
Cairnryan	152
Girvan	152
IRL Killybegs	152
Kilroot	154
Stranraer	156
Belfast (DD)	159

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STORAGE SPACE AND SIMULTANEOUS INSTALLATION
INVESTIGATED PORTS

Well-suited, high potential manufacturing ports with short distance to LIFES50+ Site C:

Arnish (Distance: 105 NM)

Kishorn (Distance: 88 NM)

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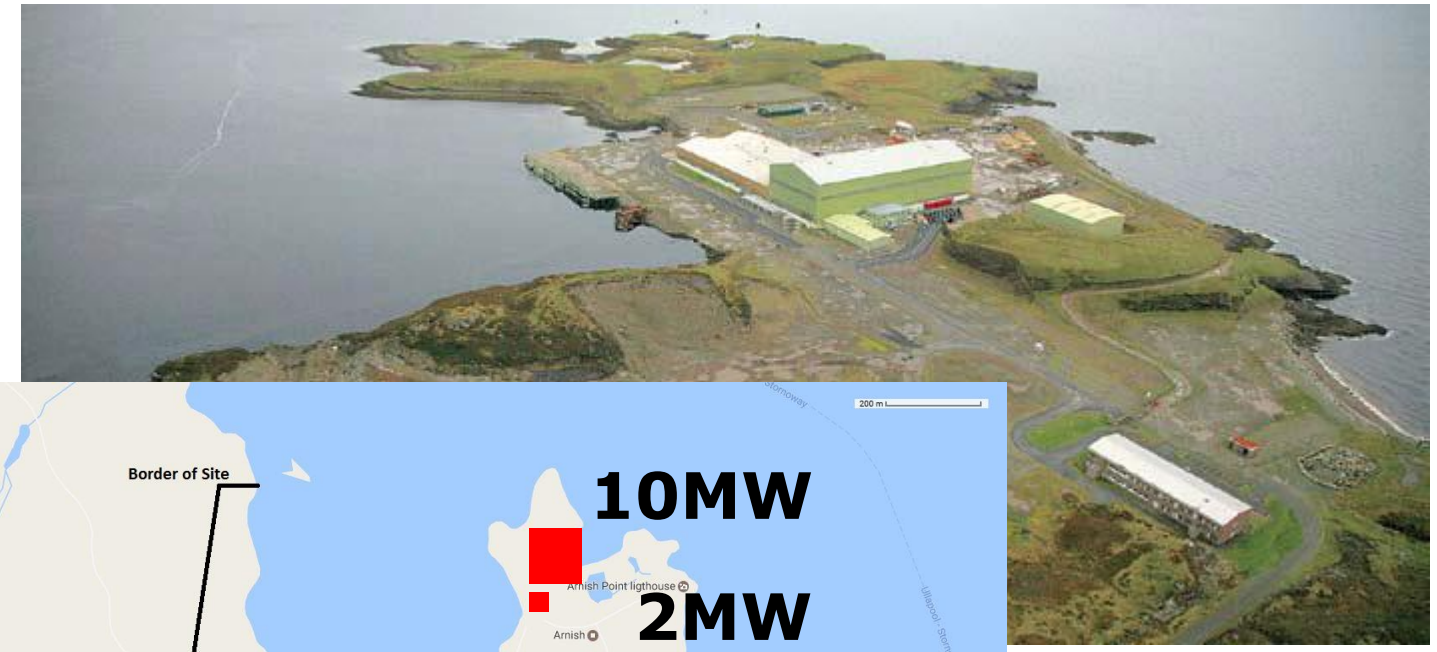
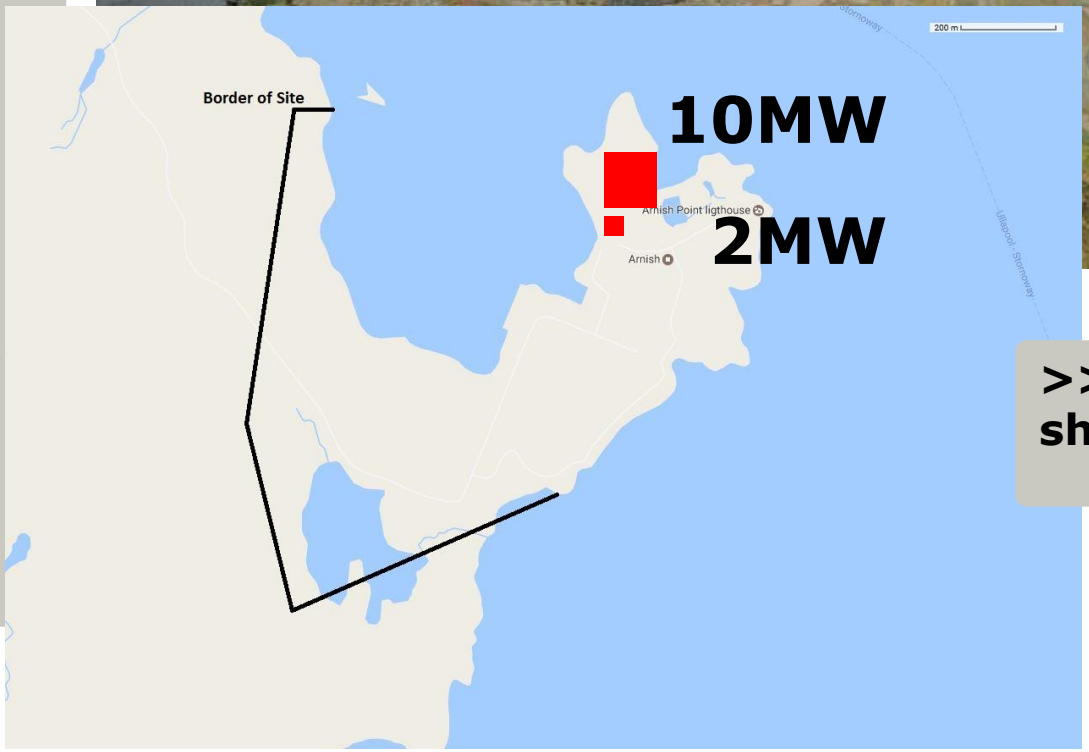
STORAGE SPACE AND SIMULTANEOUS INSTALLATION CHALLENGES

Arnish (Distance: 105 NM)
- Former oil and gas fabrication
- 80t/m² heavy lift
- In redevelopment for fabrication of jacket subcomponents

Challenges for 10MW Floating + Simultaneous Installation
- Quay length 100m (+200m)
- Space 48ha (10ha developed)
- Water depth 6.5m (intended to 8,5-9m depth)
- No large cranes

>> Significant investments in infrastructure is likely required





>> Belfast with shipyard (156nm)

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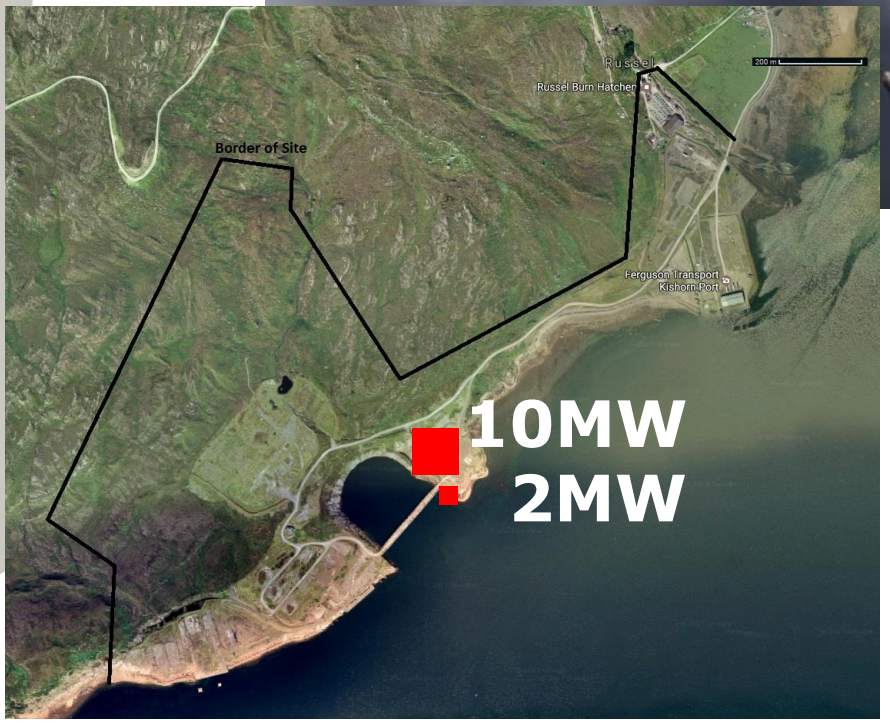
STORAGE SPACE AND SIMULTANEOUS INSTALLATION CHALLENGES

Kishorn
- Former fabrication of O&G platforms
- Heavy lift capacities
- Quays: 3.5m - 10m depth
  80m & 120m length
- Dry-dock: 8m (LAT), 12m (HAT)
  150m gate
- Concrete casting facility on site

Challenges for 10MW Floating + Simultaneous Installation
- Significant space limitations
- No cranes

>> Significant investments in infrastructure is likely required



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INSTALLATION SUMMARY

Start
Substructure and wind turbine at construction/launch site

Dep. on distance

8h – 55h

Float Out (Tide)
Hook up of harbor tug boats;
Float out from construction/launching site;
Ballasting of substructure (and removing of temporary buoyancy modules, if used);
Dis- and reconnecting of towing lines to sea-going tugs; Towing of the floater towards open sea

11h

Transit (Hs 2.5m)
Transit to wind farm;
Positioning of floater at exact position (dynamic positioning); Deployment of teams onto floater

Installation (Hs 1.5m)
Work preparation for installation (including power supply);
Anchor Supply Vessel takes over messenger line;
Messenger and mooring line pulled in;
Mooring handed over to floater;
Pre-tensioning of mooring, locked by chain stoppers;
Ballasting

11h

22h

Dynamic Cable Installation (1.5m)
Positioning of Cable Lay Vessel/or other suitable vessel;
Crew transfer and work preparation;
Cable inspection and pick up of messenger line;
Pull in of cable;
Installation of temporary security modules (e.g. hang off clamp) for connection;
Tests to confirm the functionality

Termination (1.5m)
Crew transfer and work preparation;
Removing armoring, preparation of conductors;
Cable connection, test preparation and conduct;
Permanent hang off;
Clean up and disembarking

Dep. on distance

Return
Transit back to coast and port; Unload of equipment

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INSTALLATION
ANALYSIS METHOD

SETUP

SITE Setup
- Site Selection
- Port Selection
- Minimum Weather Window

PROJECT Setup
- Vessel Types
- Vessel Numbers
- Vessel Properties
- Project Data
  - Starting Dates
  - Dimensions

CALCULATION

DATABASES
- Vessel Properties
- Weather Data
- Port Properties
- Work Break-Down

CALCULATION
- Required Time
  - Weather Window
  - Installation Time
- Estimated Costs
  - Use of Vessels

RESULTS

REQUIRED TIME
- Site/Port-specific
- One FOWT and whole Farm
- Operational Time and Stand-by Time

ESTIMATED COSTS
- Indicative Results
- Fixed Costs and Variable Costs

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INSTALLATION
LIMITATIONS OF ANALYSIS METHOD

- Limitations
  - Generic installation non-optimized procedure assumed
    >> with real substructures differences are expected
  - Weather persistence data was estimated and no accurate persistence data available for all 3 sites
  - Vessel cost fluctuation is high
    >> influences the conclusions on key aspects
  - No consideration of availability of vessels
    >> only possible in commercial setting with specific timelines
  - Calculation is static and not suited for short term planning
    >> here time-domain Installation/O&M planning tools are required

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INSTALLATION ASSUMPTIONS

Vessel		Bollard Pull	Fix Costs	Variable Costs
[Abbreviation]	[Name]	[Figs. By DAMEN]	[average €/d]	[average €/d]
HT	Harbor Tug	BP: 40 t	7000	1000
AHTS-280BP	Anchor Handling Tug Supply Vessel (A-Type)	BP: 280 t	130000	20000
AHTS-180BP	Anchor Handling Tug Supply Vessel (C-Type)	BP: 180 t	64000	6000
AHTS-85BP	Anchor Handling Tug/ Offshore Supply Vessel	BP: 85 t	36000	4000
OT-80BP	Offshore Tug	BP: 80 t	17000	3000
OT-50BP	Offshore Tug	BP: 50 t	8500	1500
CTV	Crew Transfer Vessel		3000	500
(CLV)	Cable Lay Vessel		55000	5000

Strong variation in fixed costs

RAMBOLL

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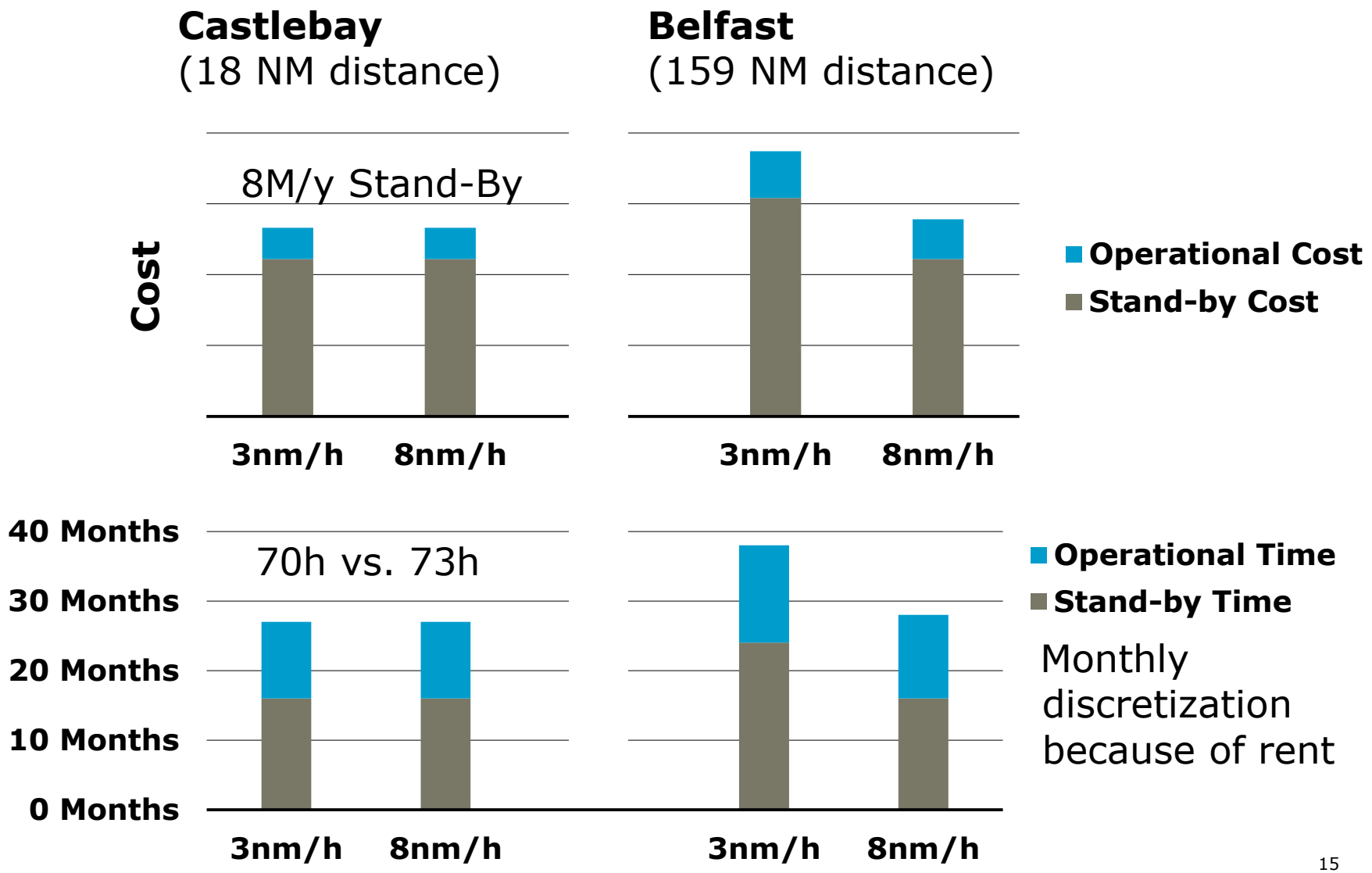
INSTALLATION
PORT LOCATION

Port Distance & Towing speed

Scenario
Site C (West of Barra)

- Option 1:
  Max. Towing Speed = 3 NM/h
- Option 2:
  Max. Towing Speed = 8 NM/h
- ***1 FOWT installed simultaneously***

- **Towing speed important for small fleets and large distance**
- **Considerable influence of dist., but more weather dominated**



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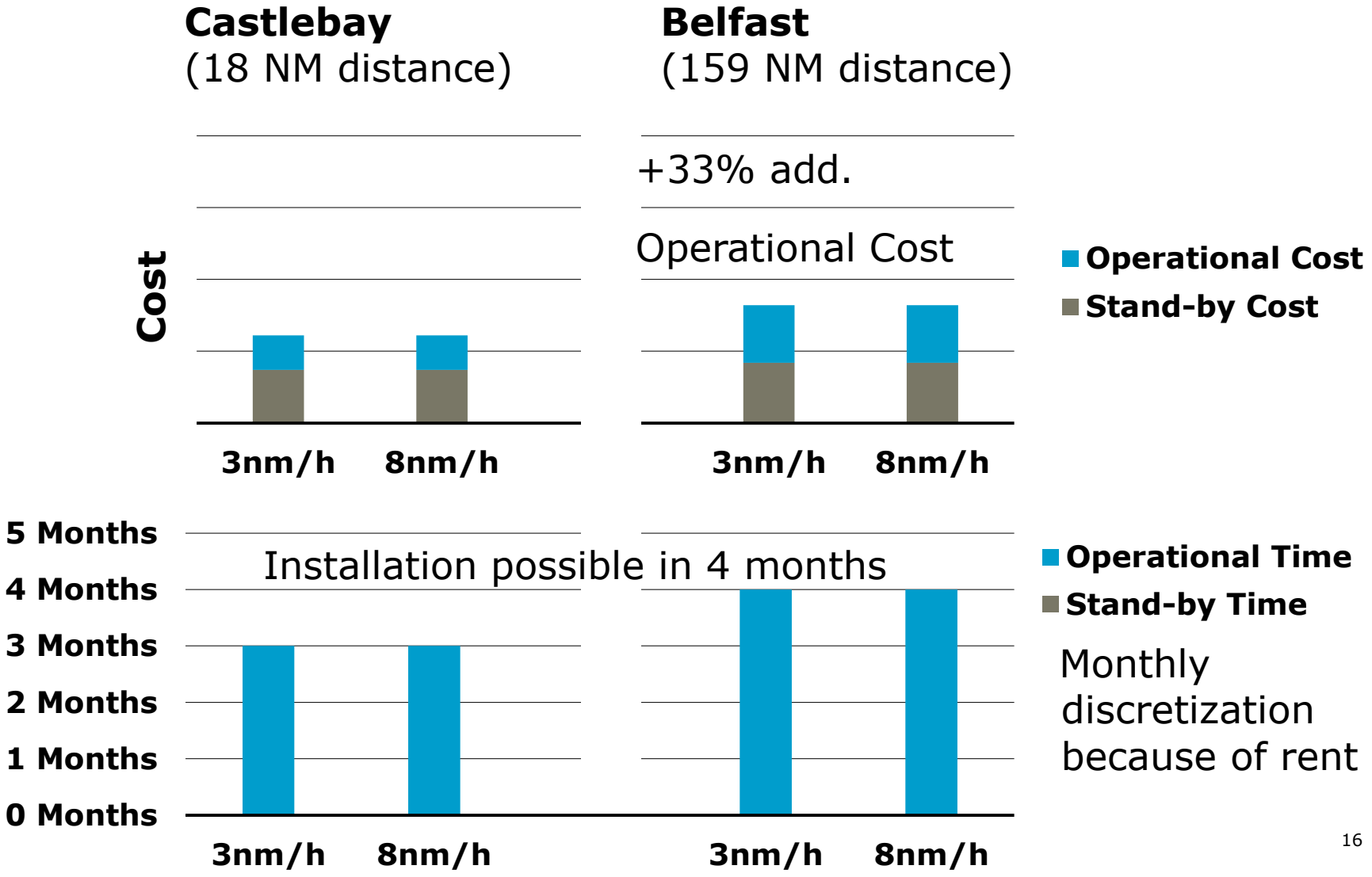
INSTALLATION
PORT LOCATION

Port Distance & Towing speed

Scenario
Site C (West of Barra)

- Option 1:
  Max. Towing Speed = 3 NM/h
- Option 2:
  Max. Towing Speed = 8 NM/h
- ***4 FOWT installed simultaneously***

- **Minor influence of towing speed**
- **Large influence of distance to port**
- **50 Floaters in 4m required!**



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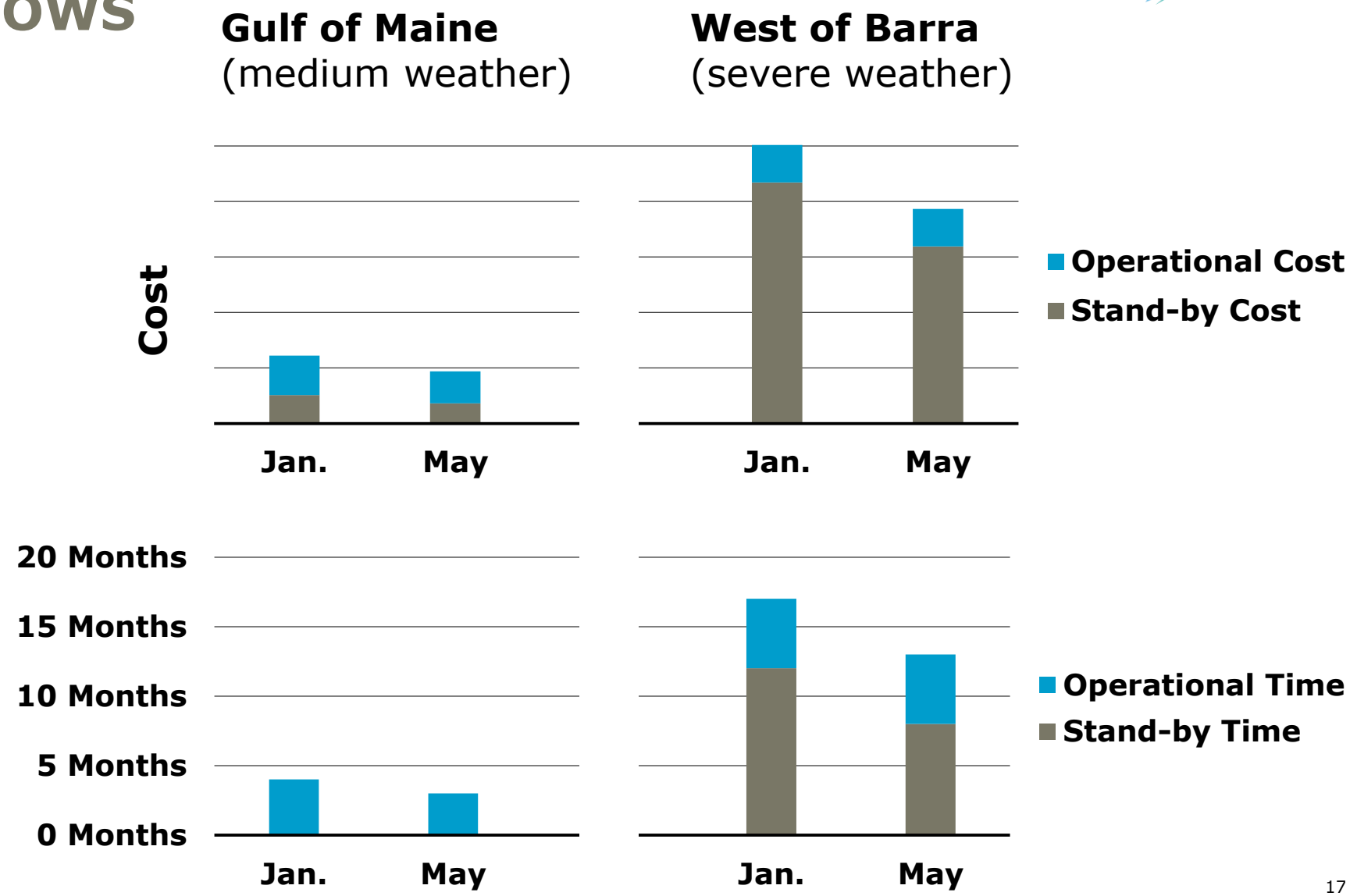
INSTALLATION
WEATHER WINDOWS

Installation Start & Weather at Site

Scenario
Distance Port to Windfarm
approx. 70 NM

- Option 1:
  Operation start in January
- Option 2:
  Operation start in May
- *3 FOWTs installed simultaneously*

- **Start of Operation more important for severe weather sites**
- **Major influence of Site (Weather Windows)**
- **No securing for floaters**



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INSTALLATION
FLEET SIZE

Fleet Size & Req. Vessels

Scenario
Site B (Gulf of Maine)
70 NM distance

- Option 1:
  Req. number of Vessels x2
- Option 2:
  Regular Number of Vessels
- Operation starts in May

- **Usage of more fleets decreases primarily time**
- **Vessel requirements have large influence on cost >> Optimization potential for floaters**

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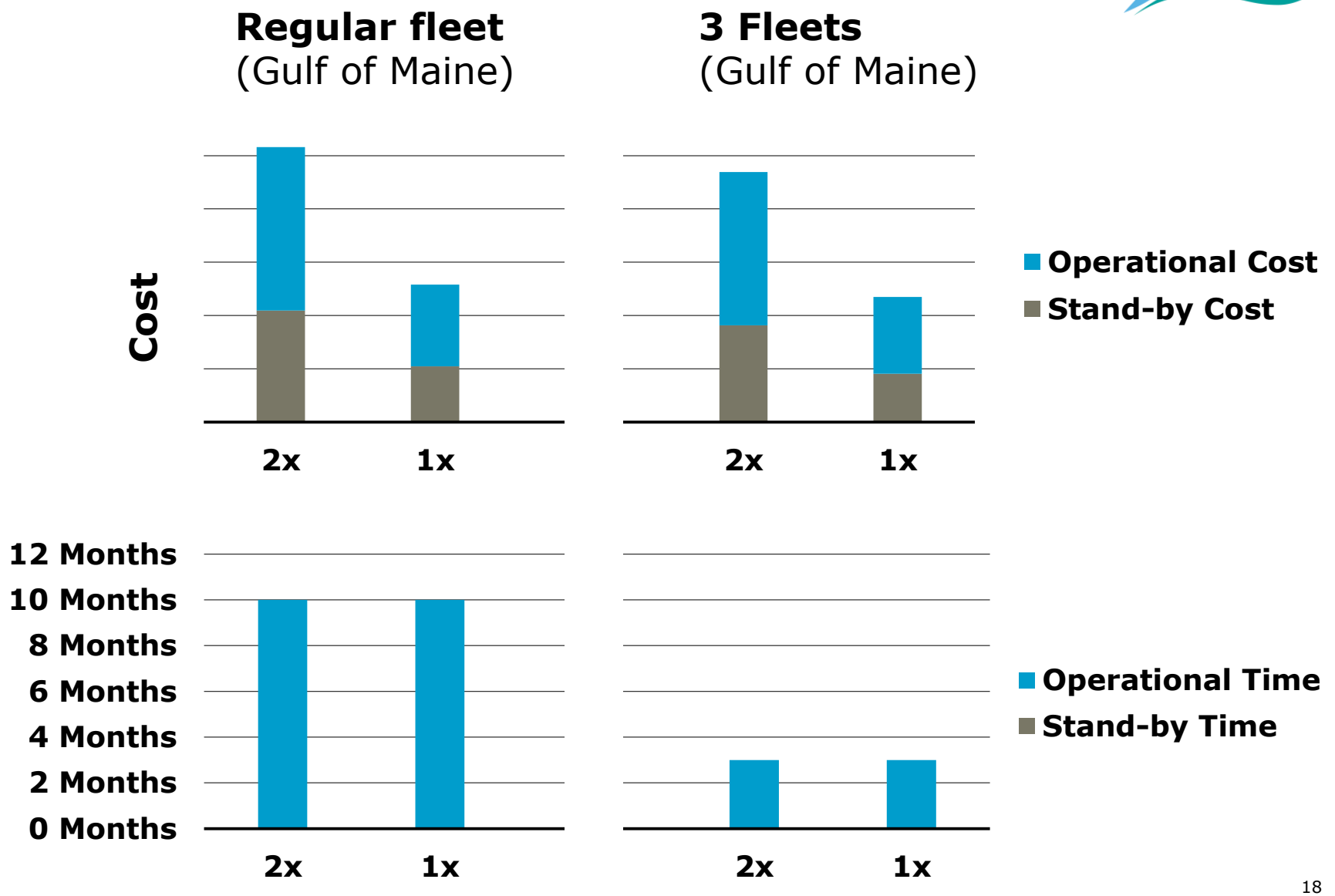

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INSTALLATION
SUMMARY

- Installation Port
  - Major influence of distance -> Transit times & Cost
  - Towing speed important for small fleets and large distance
  - More fleets massively improve cost and time -> Req. fast supply of floaters
  - Min. requirements for selection: Water Depth, Fabrication, Cranes, Space & Bearing Capacities
- Weather Windows
  - Start of Operation more important for severe weather sites
  - Major influence of Weather Windows if distance to port is high
  - Forecasts more important: Challenging to secure structures in case of bad weather (no jack-up)
- Required Vessels and Fleet Size
  - Usage of more fleets decreases primarily time
  - Vessel requirements have large influence on cost -> Optimization potential for floaters

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OUTLOOK
RECOMMENDATIONS & NEXT STEPS IN LIFES50+

Recommendations for large wind farm projects at specific sites:

- Early involvement of manufacturer & early review of installation port restrictions
- Selection of port is of high importance
- Adapt design to capabilities of manufacturer, port and installation procedure

Next steps Phase 2 of LIFES50+:

- Detailed analysis of fabrication and installation procedures of selected designs
- Usage of the tool for installation (&fabrication) strategy optimization (automatic)
- Support to designers in detailing the F&I processes for the LIFES50+ sites and 50 unit wind farms
- Extension of analysis beyond installation to O&M phase

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THANK YOU.

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LIFES50+

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