Floating Wind *Solutions*

# Translating Oil & Gas Cost Reduction Experience into Floating Offshore Wind


Alan Whooley

Company wood.



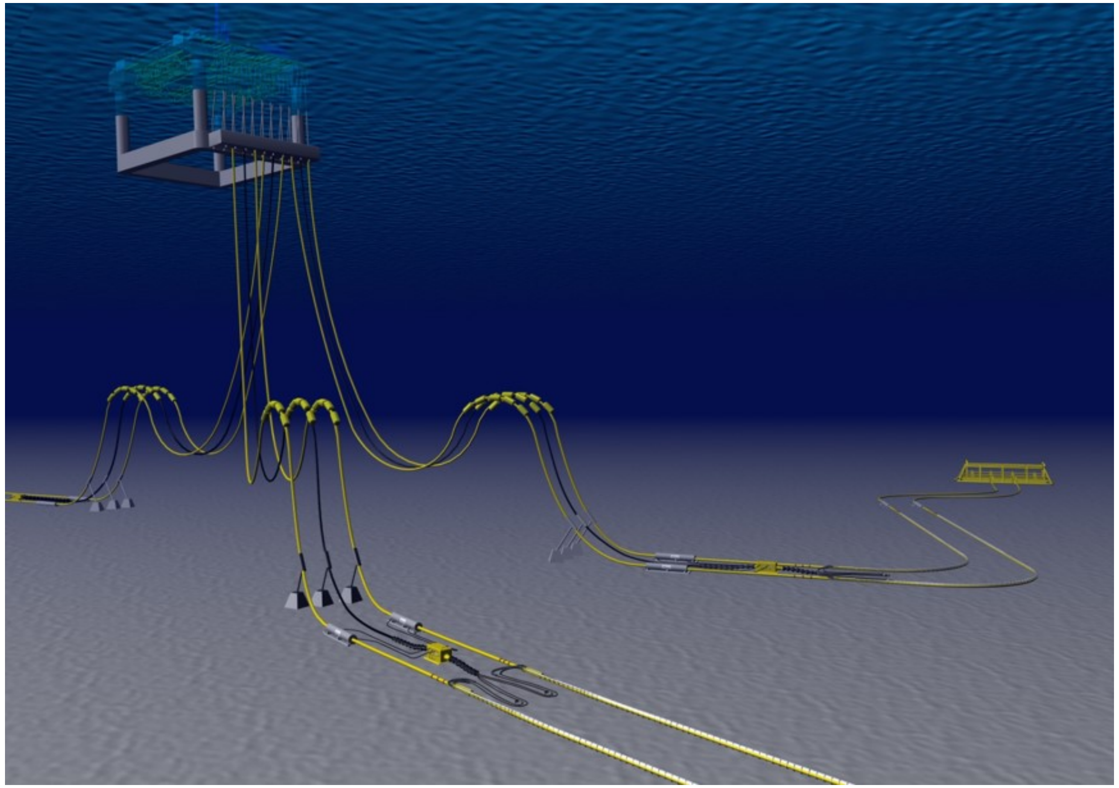
Organized by QFWE Quest Offshore

FWS

The Westin Houston, Memorial City 28-29 June 2021

# 40 years of Oil & Gas

- Hostile & deep waters
- Supply chain – boom and bust
- Innovation – JIP's, DNV-RP-A203
- Reliability – API 17N
- Specialist vessels – lay rate increase
- Standardization – JIP33
- Collaboration – JIP's, cross industry bodies
- Automation – Autonomous underwater vehicles
- Digitalization – Subsea valve monitoring



**"TOTEX lessons from oil price fluctuations for $10 to $140/bbl"**

# Wood floating wind priorities

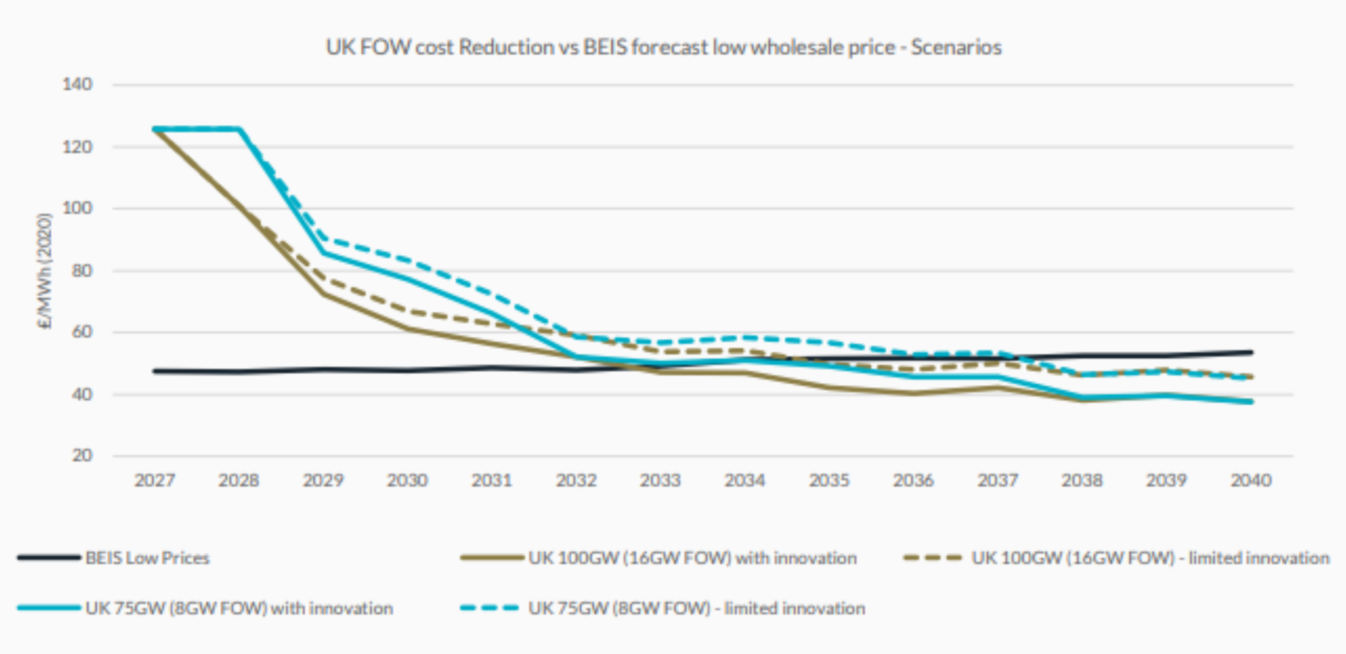
- An industry partner, committed to driving total project costs down
- Technology and solutions enabler / agnostic
- Holistic, TOTEX approach.  From blue-to-blue.
- Data driven and digitally enabled
- System integrator and supply chain 'glue’
- Bringing access to specialist partners
- Delivery partner -  through life

**“Striving for cost parity with fixed wind”**

Link to Wood Sustainability Goals
https://www.woodplc.com/company/sustainability

# The cost reduction goal

- CAPEX reduced by 65% by 2040
- OPEX reduced by 36% by 2040




Ref: OREC - Floating Offshore Wind: Cost Reduction Pathways To Subsidy Free

**Table ES2. Summary of the Fixed-Bottom Reference Project using 6.1-MW Wind Turbines**

| | 6.1-MW Offshore Wind Turbine ($/kW) | 6.1-MW Offshore Wind Turbine ($/MWh) |
|---|---|---|
| Turbine capital cost | 1,301 | 17.7 |
| Balance of system | 2,131 | 29.0 |
| Financial costs | 645 | 8.8 |
| CapEx | **4,077** | **55.6** |
| | | |
| OpEx ($/kW/yr) | **124** | **29.0** |
| FCR (real) [%] | 5.8% | |
| Net annual energy production (MWh/MW/yr) | 4,270 | |
| Net capacity factor (%) | 48.7% | |
| **Total LCOE ($/MWh)** | **85** | |

**Table ES3. Summary of the Floating Offshore Reference Project using 6.1-MW Turbines**

| | 6.1-MW Floating Offshore Wind Turbine ($/kW) | 6.1-MW Floating Offshore Wind Turbine ($/MWh) |
|---|---|---|
| Turbine capital cost | 1,301 | 22.7 |
| Balance of system | 3,237 | 56.6 |
| Financial costs | 790 | 13.8 |
| CapEx | **5,328** | **93.1** |
| | | |
| OpEx ($/kW/yr) | **130** | **39.2** |
| FCR (real) [%] | 5.8% | |
| Net annual energy production (MWh/MW/yr) | 3,328 | |
| Net capacity factor (%) | 38.0% | |
| **Total LCOE ($/MWh)** | **132** | |

Ref: NREL- 2019 Cost of Wind Energy Review

# Cost Model – What are the drivers?

- A series of cross discipline CoLabs to develop a TOTEX cost model *(CAPEX+OPEX+DECOMEX)*
- UK base case, bench marked against OREC model
- Sensitivities
  - Design life
  - Turbine size
  - Material costs
  - Labor costs
  - Component reliability
  - Industrialization
  - Fabrication hook up innovation
  - Mooring innovation
  - Individually and combinations

**"Identification of key cost drivers on LCoE"**

**"Level of change needed to match fixed wind"**

# Cost Modeling Results

- 2025 case: 15MW, 33Turbines, 495MW, Steel, Europe, 50% capacity, 6% discount, 3% inflation, 25-year design life, 100m water depth, 100km from shore - **$184/MWh**
- 2040 case: As above, 20MW, 25 turbines, Far East fab, 50% less failures, 50% less vessel rates, 50% less fab cost 50% less installation cost - **$101/MWh**
- 2040 case: As above, 30yr Design Life **$96/MWh**
- 2040 case: As above, 60% capacity factor **$80/MWh**
- 2040 case: As above, 60% less fab costs **$59/MWh**
- 2040 case: As above, 1 GW farm **$51/MWh**

| Base Case | 2025 Case |
|---|---|
| Turbine Size (MW): | 15 |
| Turbine No.: | 33 |
| Wind Farm Size (MW): | 495 |
| Distance (km): | 100 |
| Water Depth (m): | 100 |
| Design Life (yrs): | 25 |
| Fabrication | Europe |
| Capacity Factor | 50% |
| Discount | 6% |
| Inflation | 3% |

Ref: Wood, Reducing the TOTEX of floating offshore wind developments, March 2021

# System Design – Design Life

- O&G looking at 60years plus
  - Demand for system fatigue life and life extension
  - Deferred decommissioning
- Can FOW do 50 years?
  - FID based on 25years electricity price
- Longer design life enhances future value
- Longer pay back
- Higher initial cost
- Tighter specifications

**"Make design life as long as possible"**

**"Build with enablers to allow for longer life"**

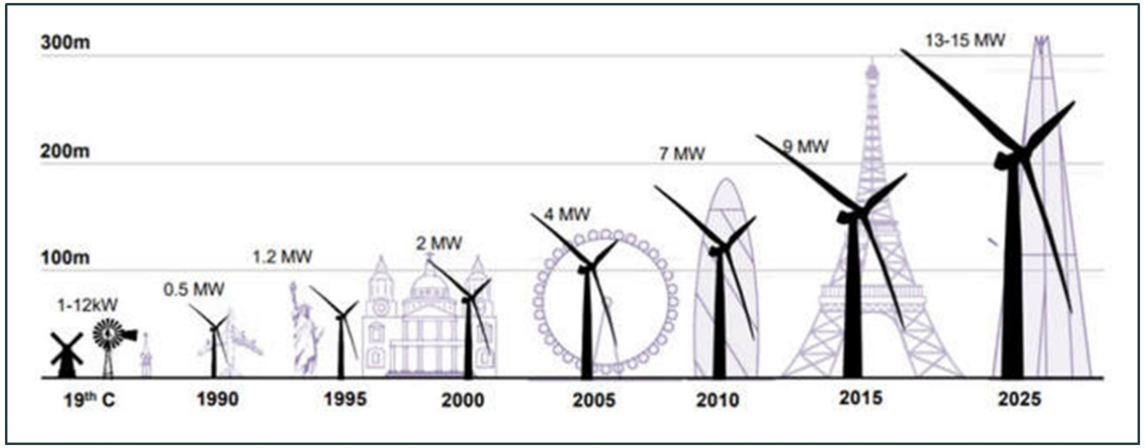
| 2025 Base Case: 15MW, 33Turbines, 495MW, Steel, Europe, 6% discount, 3% inflation, 25-year design life, 100m water depth, 100km from shore | LCOE $184/MWh |
|---|---|
| 30 years | $178/MWh |

# System Design – Turbine & Wind Farm Size

- Less units & narrow gap to fixed wind
- New technology risk
- Larger hulls
- Bigger fabrication facilities
- More difficult to integrate

**"Bigger turbines will bring new risks and design challenges"**

**"Possible constraints on local content related to deeper draft"**



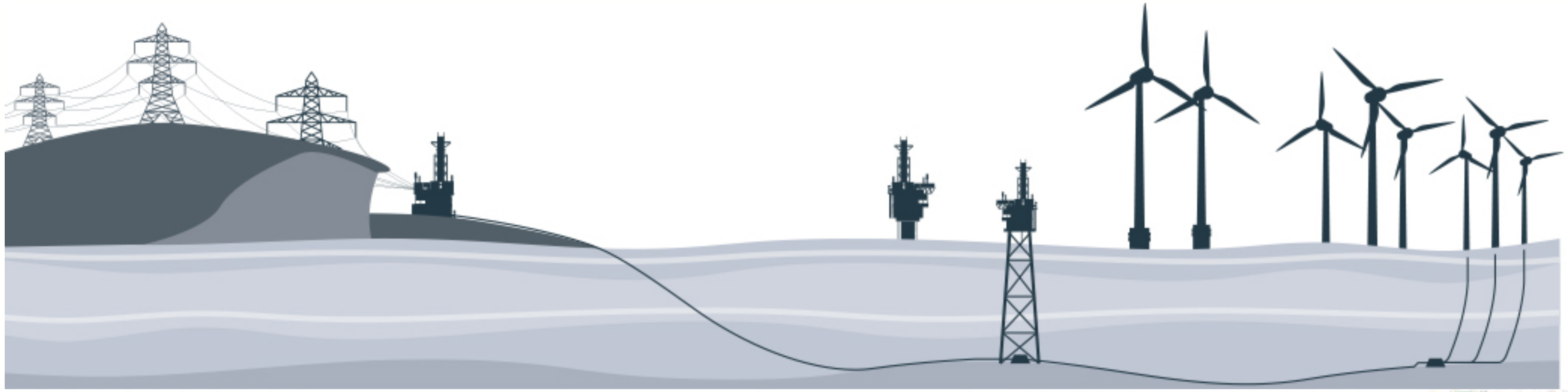

| 2025 Base Case: 15MW, 33Turbines, 495MW, Steel, Europe, 6% discount, 3% inflation, 25-year design life, 100m water depth, 100km from shore | LCOE $184/MWh |
|---|---|
| 20MW 33 Turbines 660 MW | $161/MWh |
| 20MW 25 Turbines 500 MW | $172/MWh |

# System Design – System Integration

- System engineering can be complex
- Complex component integration
  - Turbine and hull
  - Hull and mooring
  - Hull to cable
- Create a no silo mentality and organization
- Start early to protect supplier IP but allow system integration

**"Create a clear system owner"**

**"There is value in combined turbine and hull technology evaluation"**



# System Design – Design Standards

- Mature technical standards
  - Guidelines/Standards (DNV, ABS) being adopted by designers to make their floating designs more efficient
  - This will also drive cost down
- Need for clarity on technical requirements driven by reliability
- No gold plating
- JIP33 – standardization

**“Design standards have a roll to play in driving down TOTEX”**

# System Design – Technology Selection

- Lots of technology to choose from
- 4 or 5 technologies will emerge
- Multi dimensional evaluation criteria needed

Figure 3: Semi-submersible examples: Windfloat (courtesy: Principle Power), Eolink (courtesy: Eolink) & OO Star (courtesy: Dr. techn. Olav Olsen)

**"Wood has done an independent assessment of over 40 promising floating wind concepts"**

Figure 7: Multi-Turbine example: SCD Nezzy2 (courtesy: Aerodyn)

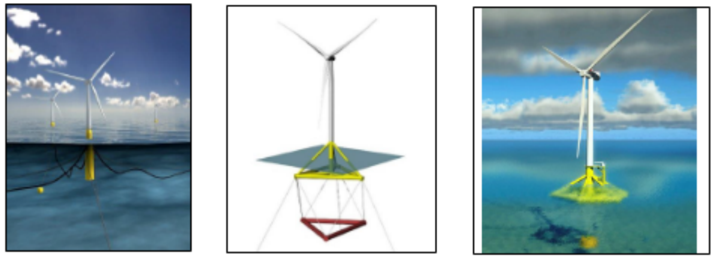


Figure 4: Spar examples: Hywind (courtesy: Equinor), Tetraspar (courtesy: Stiesdal) & Hexafloat (courtesy: Saipem)

| S. No. | Name | Type | Owner | Material | Turbine Axis | TRL |
|---|---|---|---|---|---|---|
| 1 | Windfloat | Semi | Principle Power | Steel | Horizontal | 8 |
| 2 | OO Star | Semi | Olav Olsen | Concrete | Horizontal | 4 |
| 3 | Tetrasub | Semi | Stiesdal | Steel | Horizontal | 4 |
| 4 | Nautilus | Semi | Nautilus | Steel | Horizontal | 4 |
| 5 | EOLINK | Semi | EOLINK | Steel | Horizontal | 3 |
| 6 | Sea Reed | Semi | Naval Energies | Steel / Concrete | Horizontal | 4 |

Figure 6: Barge examples: BlueSATH (courtesy: Saitec) & Ideol Barge (courtesy: Ideol)

Figure 5: TLP examples: SBM TLP (courtesy: SBM) & GICON (courtesy: GICON-SOF)

Ref: Wood, 2020 Qualitative Review of Floating Offshore Wind Concepts April 2021

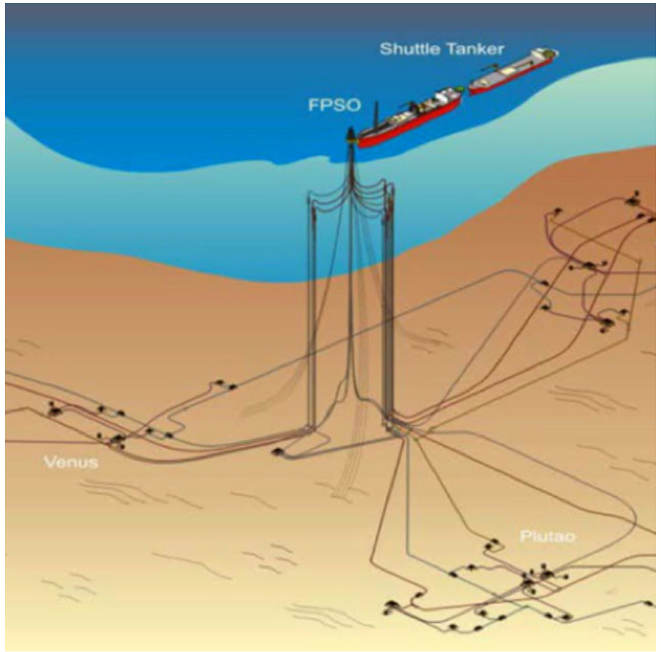
# System Design – Reliability

- Subsea needs reliability to work
- API 17N process developed in response to this
- Sets out a whole of life process for delivering reliability
- Subsea cable reliability a particular concern for offshore wind

**"Reliability is a proven method for reducing OPEX"**

| | TRL | Development Stage Completed | Definition of Development Stage |
|---|---|---|---|
| Concept | 0 | **Unproven Concept** (Basic R&D, paper concept) | Basic scientific/engineering principles observed and reported; paper concept; no analysis or testing completed; no design history |
| Proof of Concept | 1 | **Proven Concept** (Proof of concept as a paper study or R&D experiments) | a) Technology concept and/or application formulated<br>b) Concept and functionality proven by analysis or reference to features common with/ to existing technology<br>No design history; essentially a paper study not involving physical models but may include R&D experimentation |
| | 2 | **Validated Concept** Experimental proof of concept using physical model tests | Concept design or novel features of design is validated by a physical model, a system mock up or dummy and functionally tested in a laboratory environment; no design history; no environmental tests; materials testing and reliability testing is performed on key parts or components in a testing laboratory prior to prototype construction |
| Prototype | 3 | **Prototype Tested** (System function, performance and reliability tested) | a) Item prototype is built and put through (generic) functional and performance tests; reliability tests are performed including; reliability growth tests, accelerated life tests and robust design development test program in relevant laboratory testing environments; tests are carried out without integration into a broader system<br>b) The extent to which application requirements are met are assessed and potential benefits and risks are demonstrated |
| | 4 | **Environment Tested** (Pre-production system environment tested) | Meets all requirements of TRL 3; designed and built as production unit (or full scale prototype) and put through its qualification program in simulated environment (e.g. hyperbaric chamber to simulate pressure) or actual intended environment (e.g. subsea environment) but not installed or operating; reliability testing limited to demonstrating that prototype function and performance criteria can be met in the intended operating condition and external environment |
| | 5 | **System Tested** (Production system interface tested) | Meets all the requirements of TRL 4; designed and built as production unit (or full scale prototype) and integrated into intended operating system with full interface and functional test but outside the intended field environment |
| Field Qualified | 6 | **System Installed** (Production system installed and tested) | Meets all the requirements of TRL 5; production unit (or full scale prototype) built and integrated into the intended operating system; full interface and function test program performed in the intended (or closely simulated) environment and operated for less than 3 years; at TRL 6 new technology equipment might require additional support for the first 12 to 18 months |
| | 7 | **Field Proven** (Production system field proven) | Production unit integrated into intended operating system, installed and operating for more than three years with acceptable reliability, demonstrating low risk of early life failures in the field |

API 17 Technical Readiness Levels



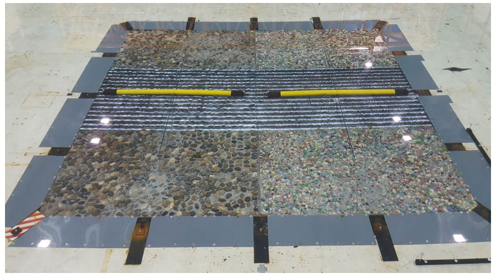

BP Angola – PSVM deepwater subsea project

# Collaboration – How to get it?

- Set up cross industry and through life technical collaboration
- Joint industry technical collaboration
  - DNV pipeline committee
- Joint Industry Projects (JIP)
  - Cability JIP – Cable Stability
  - CALM JIP – Cable Failure RQA
  - SURF-IM JIP – Subsea integrity
  - SUREFLEX JIP – Flexible riser integrity

**"Lots of competition for CfD and leases works against collaboration"**

Levenmouth Wind Turbine Demonstration Project



Cability JIP – Cable Stability

# Innovation – How to get it?

- No one wants to be first
- Much O&G innovation addressed similar challenges
  - Harsh environments & water depth
  - Dynamic risers
  - Mooring systems
- Technology qualification - DNV-RP-A203
- Investment by developers, suppliers, installers and government
- Lots of innovation in floater concepts being demonstrated
- More operations innovation also needed

**"Innovation will help reduce TOTEX by 50% or more"**

**"Cross supply chain innovation often produces best returns"**

Allseas – Pioneer Spirit

# Fabrication Focus Areas

- Supply chain capacity
- Industrialization
- Design one, build many
- Design for fabrication
- Policy direction needed on:
  - Local content
  - Carbon content

**"CAPEX can be boom and bust"**

**"OPEX provides long term jobs"**

| **Scenario** | LCOE ($/MWh) |
|---|---|
| Base Case | $184/MWh |
| Asia Fabrication - Decreased substructure and substation substructure manufacturing costs. Increased substructure transit costs. | $165/MWh |
| Decreased substructure and substation substructure fabrication costs by 25%. | $172/MWh |
| Decreased substructure and substation substructure fabrication costs by 50%. | $161/MWh |
| Decreased turbine cost by 25%. | $173/MWh |
| Decreased turbine costs by 50%. | $162/MWh |

# Installation Focus Areas

- Turbine and hull integration
- Moorings to hull
- Cables to hull
- Specialist vessels

**"Installation provides lots of opportunities for innovation & industrialization"**


Allseas – Lorelay


TechnipFMC - Apache

| Scenario | LCOE ($/MWh) |
|---|---|
| Base Case | $184/MWh |
| Halved all vessel rates in installation phase only. | $177/MWh |
| Doubled all vessel rates in installation phase only. | $199/MWh |
| Reduced cable hook up times by 25% in installation phase only. | $184/MWh |
| Reduced cable hook up times by 50% in installation phase only. | $184/MWh |
| Reduced mooring hook up and lay times by 50% in installation phase only. | $180/MWh |

# Operations Focus Areas

- Sharing of operations assets
- Reduced inspection & repairs
- Control system optimization
- Automation of inspection
- Data Twins and Analytics

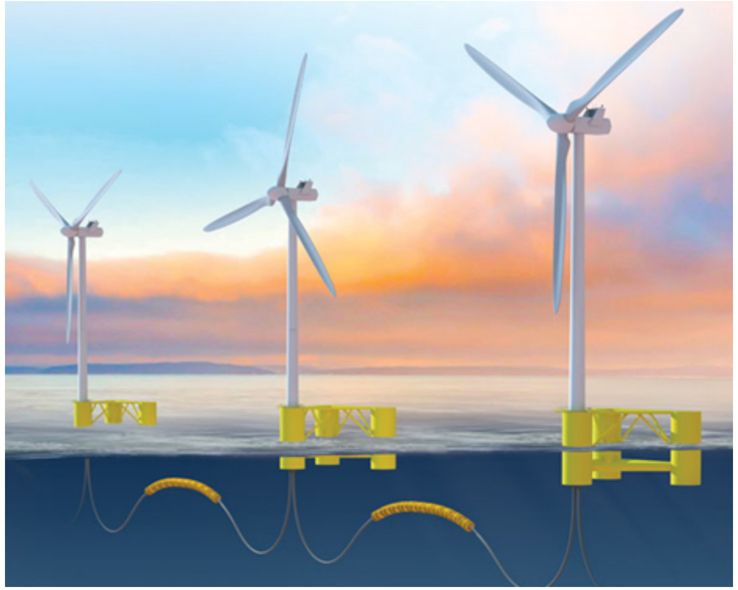
**"Use of API 17N process has reduced failure rates by order of magnitude"**

**"Use of AUV and data analytics has reduced subsea inspection costs by 50%"**

| **Scenario** | LCOE ($/MWh) |
|---|---|
| Base Case | $184/MWh |
| Decreased failure rates by 25% from base case scenario. | $173/MWh |
| Decreased failure rates by 50% from base case scenario. | $162/MWh |
| Decreased failure rates by 100% from base case scenario. | $139/MWh |

# Conclusions

- Cross industry collaboration and innovation needed to deliver best TOTEX reduction
- Proven methods of delivery of technology innovation and reliability exist
- Cost analysis show step changes needed to achieve cost parity
- Wood launching annual floating wind technology review, power cable JIP and concept evaluation tools



**"Driving the cost of floating wind down to the level of fixed wind is doable"**

**"A step change in levels of innovation, collaboration and reliability is needed"**

# Thank You!

Organized by QFWE Quest Offshore