The Business Case for Structural Health Monitoring for Floating Wind

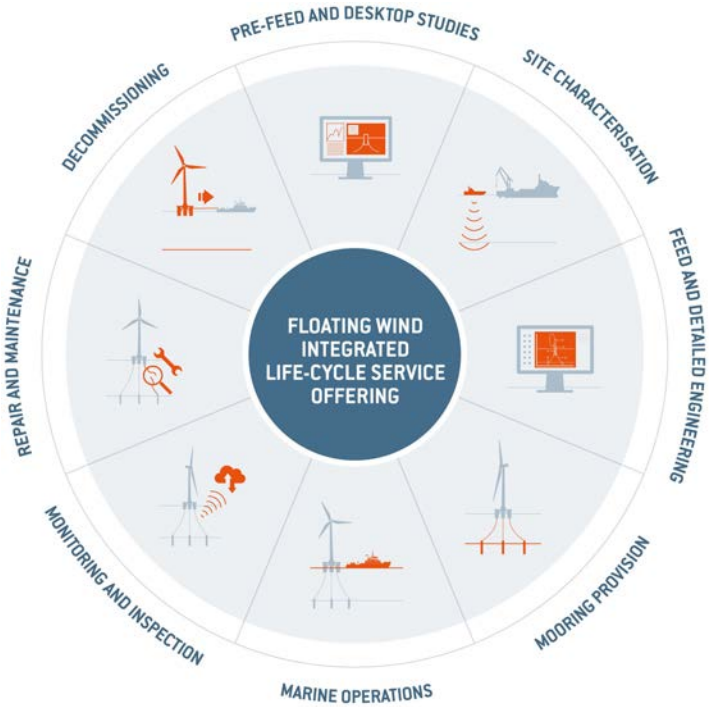
Wolfgang Ruf – Vice President

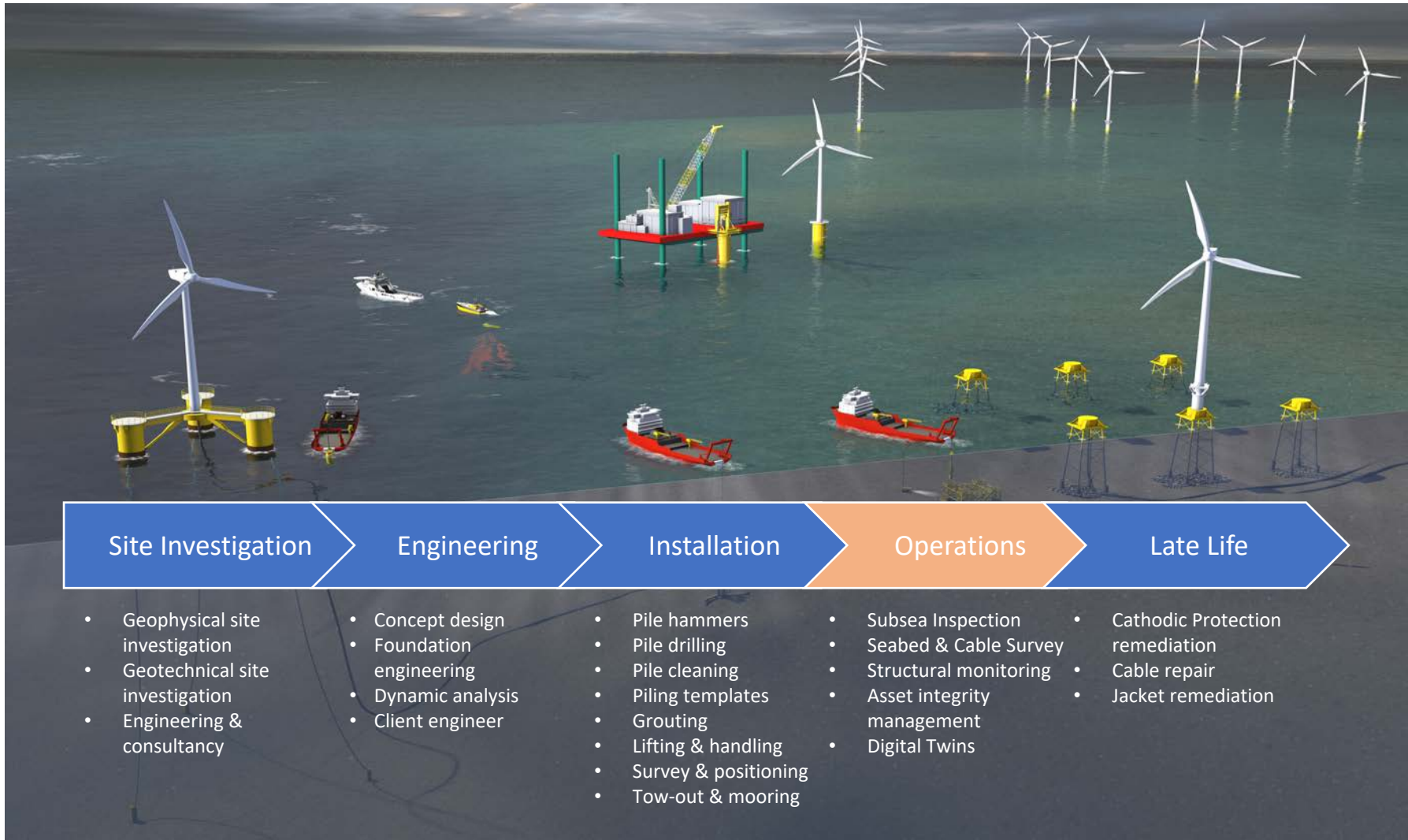
Pulse Structural Monitoring

Wolfgang Ruf
Mobile: +1 281-777-3100

OFFSHORE FLOATING RENEWABLE SERVICES

ACTEON





Site Investigation	Engineering	Installation	Operations	Late Life
• Geophysical site investigation • Geotechnical site investigation • Engineering & consultancy	• Concept design • Foundation engineering • Dynamic analysis • Client engineer	• Pile hammers • Pile drilling • Pile cleaning • Piling templates • Grouting • Lifting & handling • Survey & positioning • Tow-out & mooring	• Subsea Inspection • Seabed & Cable Survey • Structural monitoring • Asset integrity management • Digital Twins	• Cathodic Protection remediation • Cable repair • Jacket remediation

Agenda

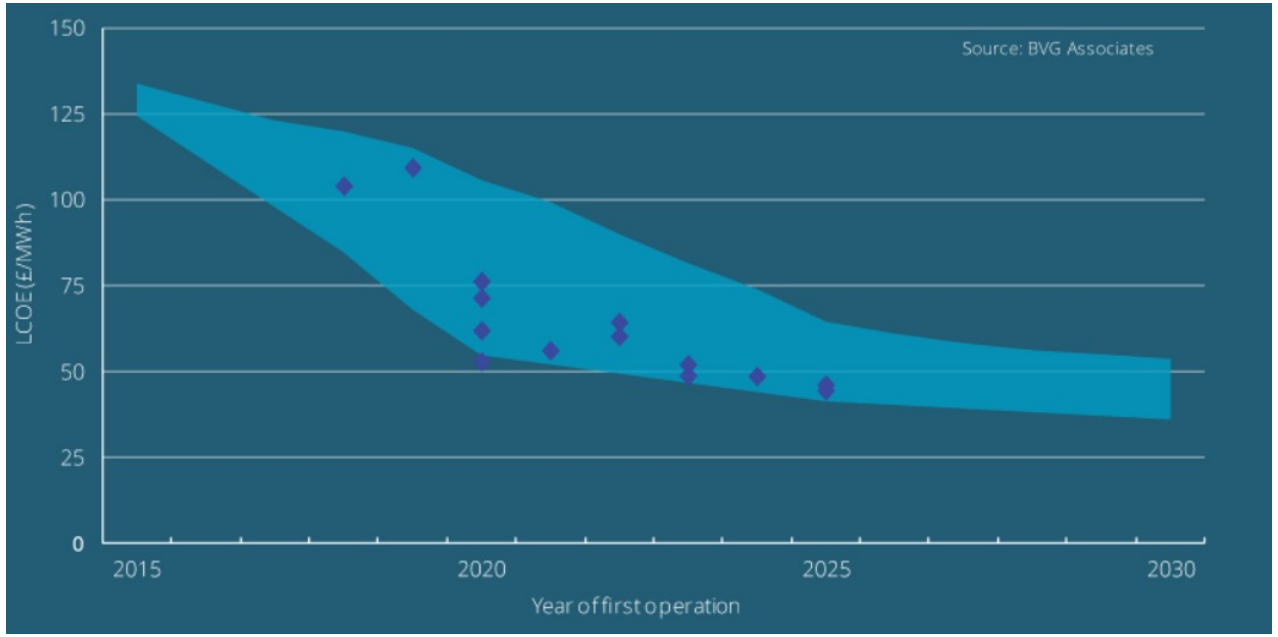
- FOW Challenges / Drivers of LCOE
- What is Monitoring
- How to Monitor
- Data Management and Insight
- OPEX Optimization
- Summary and Take Away

Challenges of FOW

- Novel
- Increasing Turbine Capacities
- Ever Increasing Structures (Taller)
- Complex Dynamic Response
- Harsh Marine Environment
- Service life >25 years

Drivers of LOCE (Levelized Cost of Energy)

- CAPEX
- Financing
- Energy Production
- Operations



Source: Catapult

Average LCOE for European Projects – Decreasing Trend

High Level Economics of Fixed Offshore Wind

Fixed Offshore Windfarm Key Parameter	
Parameter	**Value**
Wind farm rating (MW)	1000
Wind turbine rating (MW)	10
Water depth at site (m)	30
Annual mean wind speed at 100m height (m/s)	10
Distance to shore, grid, port (km)	60
Efficiency Factor Average	37%
Efficiency Factor MAX	51%
Efficiency Factor MIN	29%
Offtake price MWh US-$	100

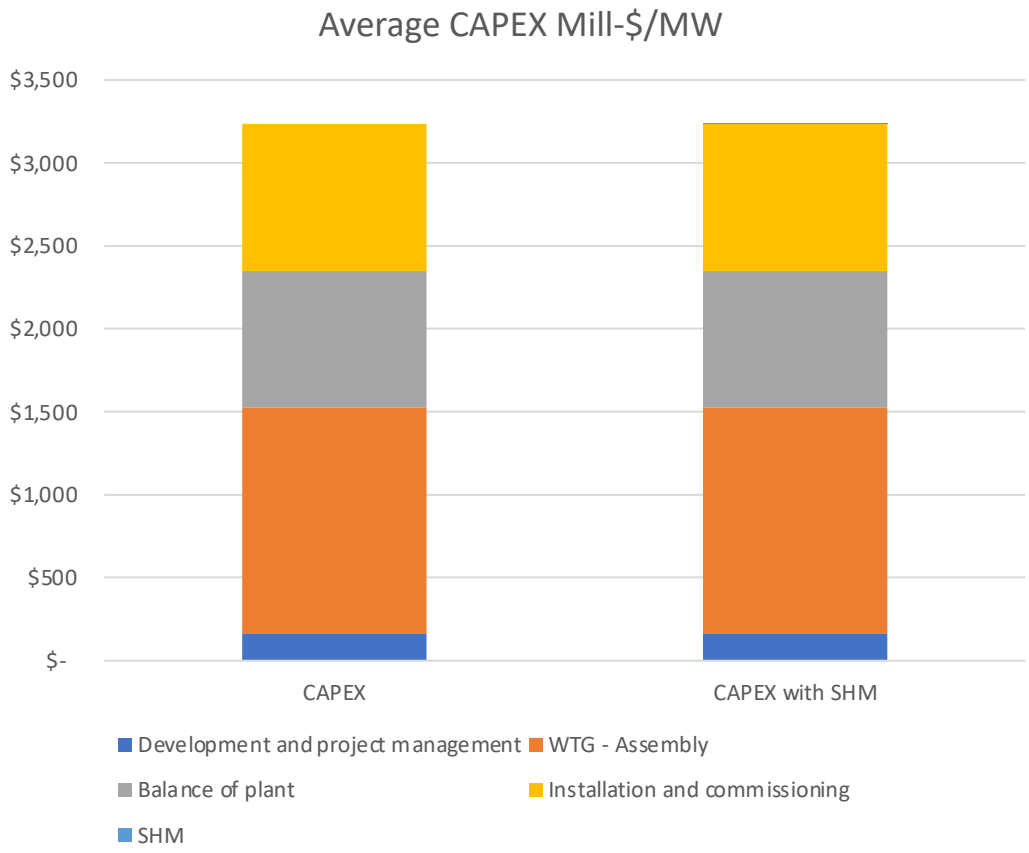
Source: Catapult

Fixed Offshore Windfarm Cost@20 Years Service		
Category	Cost Estimate Mill-US$/MW	
Development and project management	$	163
WTG - Assembly	$	1,364
Balance of plant	$	820
Installation and commissioning	$	888
SHM	$	3
Decom	$	442
OPEX	$	2,067
Sub Total	**$**	**5,748**

Source: Catapult

Average Fixed Offshore Wind Development and Operating Cost – INDICATIVE ONLY

CAPEX and Leverage Opportunities



Source: Catapult

Leverage

- Technology Maturity
- Standardization
- Production to Scale
- Optimize Supply Chain
- Reduce Project Risk

Select Leverage, Impact and Sensitivity

Efficiency Factor

OPEX-Cost

Lifecycle Savings

Scenario Efficeny Factor - US-$/MW

	Average EF	MAX EF	MIN EF
Capex	$ (3,235,440)	$ (3,235,440)	$ (3,235,440)
Opex	$ (2,06		(2,067,200)
Decom	$ (44		(442,000)
Revenue	$ 6,48		5,080,800
Sub-Total	**$ 737,760**	**$ 3,190,560**	**$ (663,840)**

Potential Revenue Range Mill US-$4,000

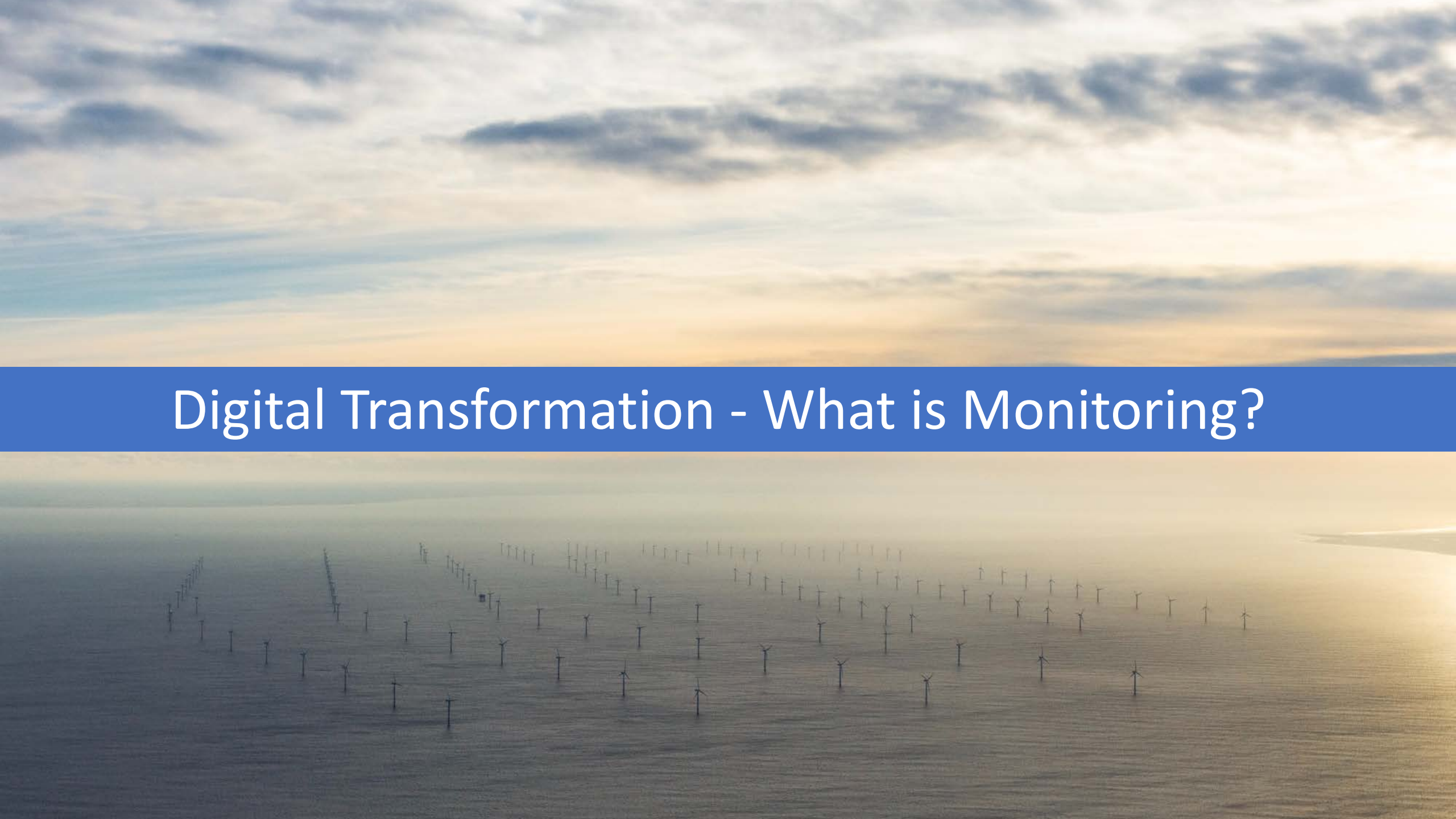
Average-37% Min-29% Max-51%

Scenario OPEX Variation- US-$/MW

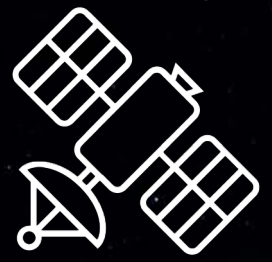
Item	Average OPEX	OPEX Increase (2%/year)	OPEX Reduction (2%/year)
Capex	$ (3,235,440)	$ (3,235,440)	$ (3,235,440)
Opex	$ (2,06		,717,802)
Decom	$ (44		(442,000)
Revenue	$ 6,48		,482,400
Sub-Total	**$ 737,760**	**$ 293,584**	**$ 1,087,158**

Potential Cost Savings Range Mill US-$800

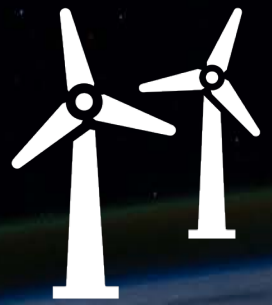
Efficiency Factor is the Ratio of actual electrical energy output over the maximum energy output



Digital Transformation - What is Monitoring?



Creating a Workforce for the Machine Age



Transition to a Sustainable World

Building Trust in the Digital Economy

8.4 Trillion US-$ Select Industry Value

12.7 Trillion US-$ Societal Value

100 Trillion US-$ Combined Estimate for all Industries

Source: World Economic Forum [Digital Transformation]

What Is Monitoring?

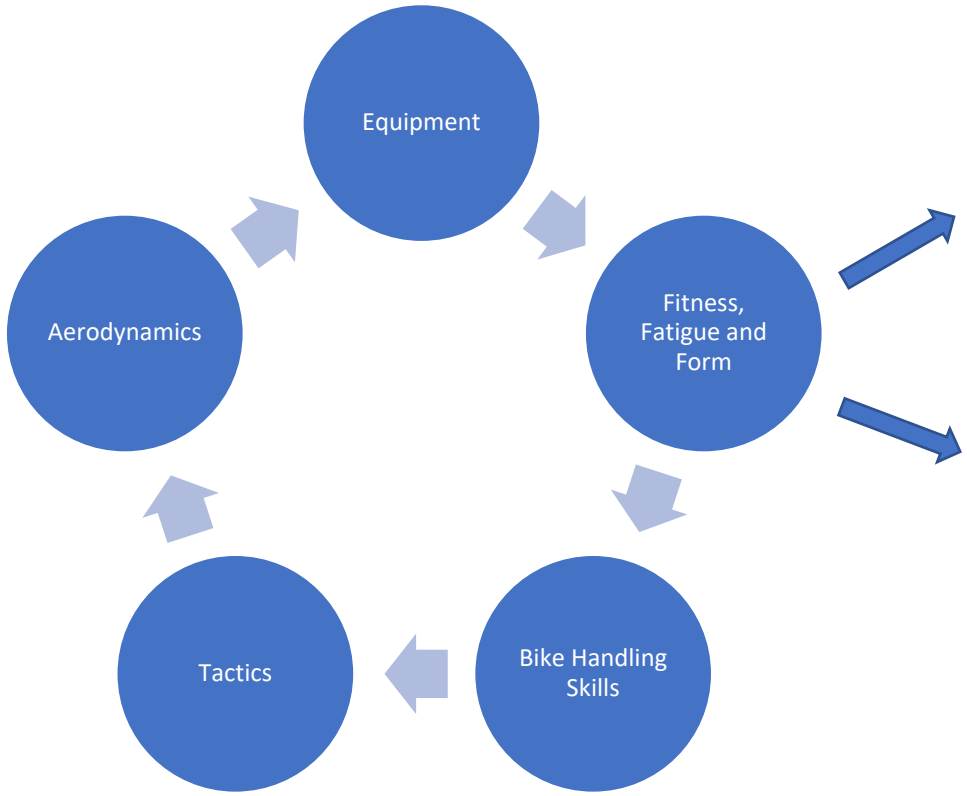
My Personal Digital Transformation Journey

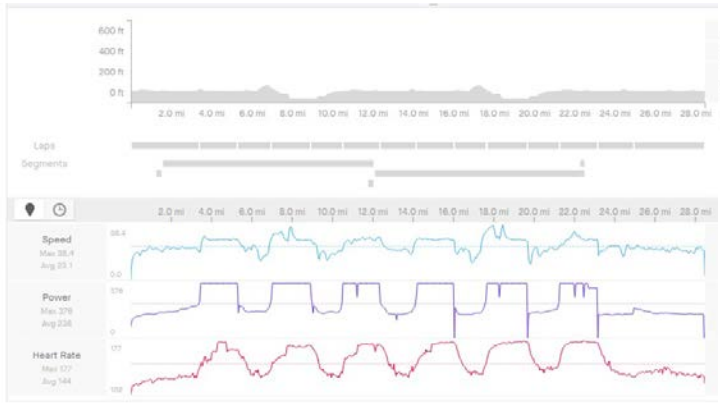
Peak Performance using Structured **Monitored** Training

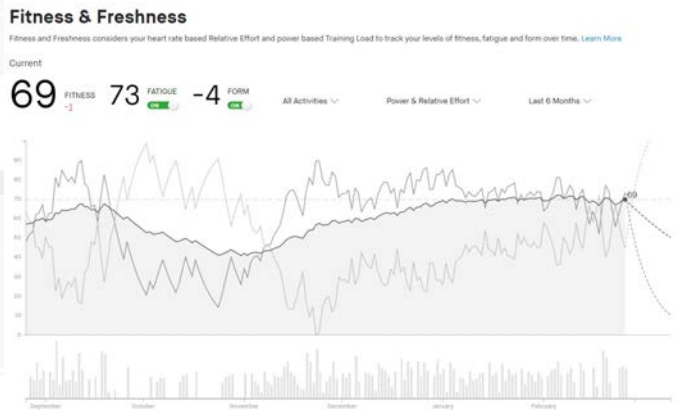
Getting Dropped – A lot!

- Trained
- Bought Expensive Kit
- Surveyed Good Riders

Performance Improvement using Structured Monitored Training







How To Monitor?

Structural Thread to Floating Offshore Wind

Threads

- In service environment and soil strength worse than design
- Vessel motions greater than design predictions
- Dynamic blade thrust loads on tower and platform higher than design
- Excessive corrosion
- Manufacturing defects
- Collision/Impact

Design & Operations Barriers

Degradation Mechanism

- Overstress
- Fracture
- Fatigue
- Corrosion
- Wear
- Loss of Soil Support

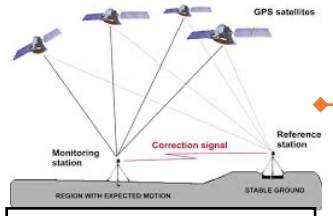
Risk Consequences

- Loss of mooring line
- Power Cable Failure
- Excessive Tilt / heel
- Reduced Operability
- Reduced Power Output
- Damage to Tower
- Loss of Platform Stability and Position

- Low probability but high consequence events
- Probability of risks increase with age

- Need to be managed through inspection and monitoring

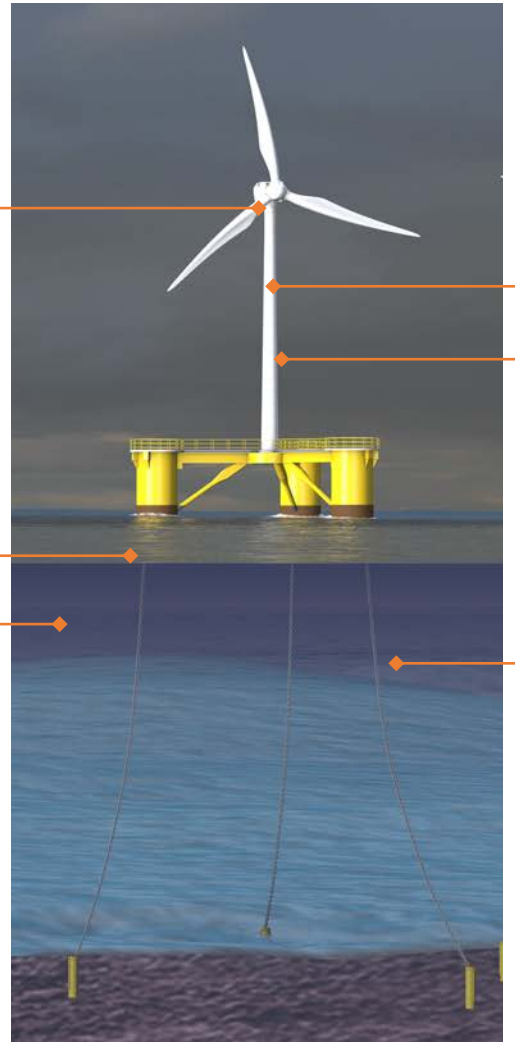
Typical Structural Health Monitoring Systems

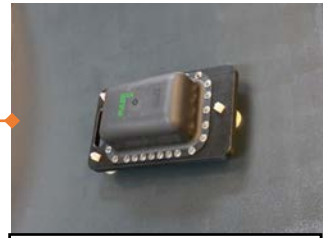


Position& Heading

Mooring and Cable Monitoring

Metocean Wind, Wave



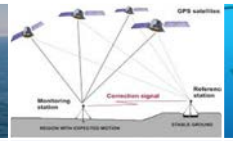


Motion - IMU

Foundation Load Monitoring

Corrosion and CP Potential

Monitoring Systems Distribution Recommendation

Platform	Position and Heading	Mooring and Cable	Corrosion and CP	Metocean	Load Monitoring	Motion	Data Infrastructure and Insight
							
1	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3	Yes	No	No	Yes	Yes	Yes	Yes
4-100	Yes	No	No	No	No	No	Yes

Weighed for Cost and Benefit

Data Infrastructure and Management

Platform - Edge

- Platform Operations SCADA
- Nacelle CMS
- Structural Health Monitoring
- Cable Health Monitoring

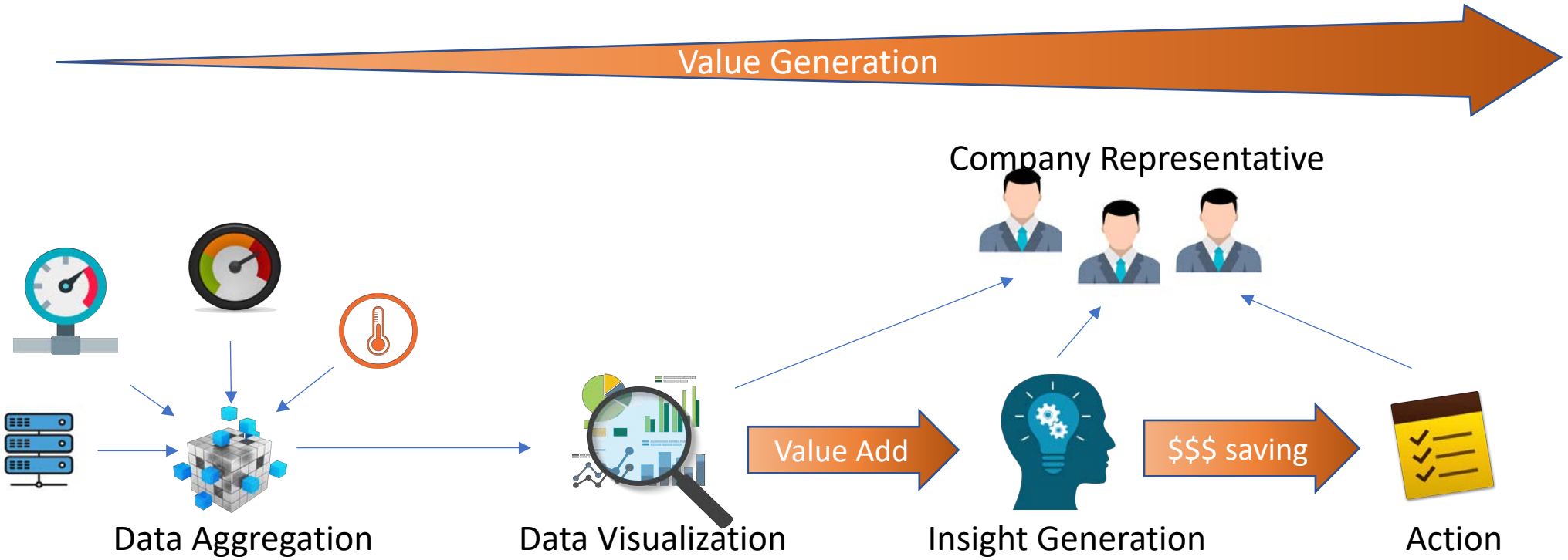
Platform Data Acquisition Server and Visualization

- Data gathering
- QA/QC Algorithm
- Trending
- Data Storage

Beach/ Cloud

- System Health and Status
- Statistics, Trending and KPI
- Service History
- Alarm Generation
- Advanced Analytics (AI and Machine Learning)

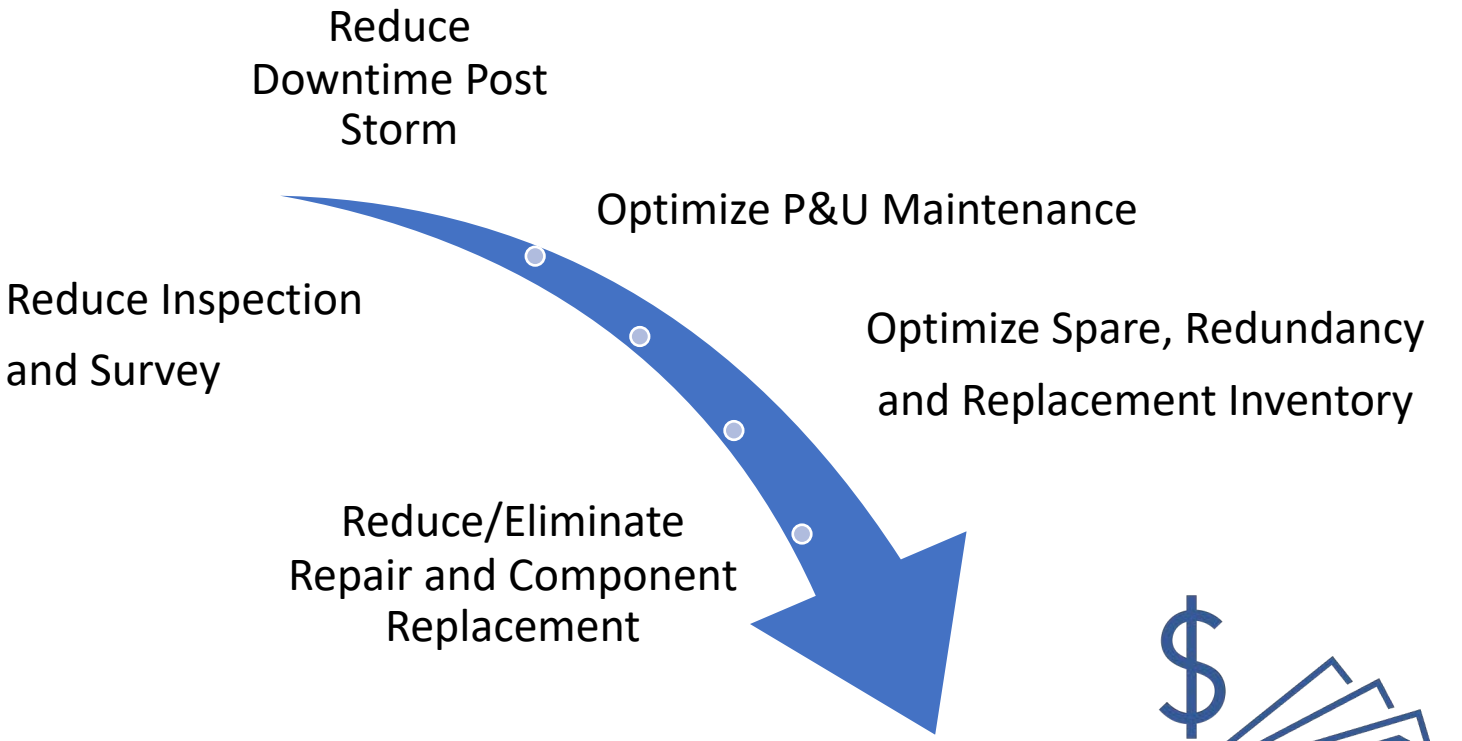
Data Management Insight and Reporting



- Algorithms
- Local Fatigue
- Corrosion Rates
- Digital Twin
- Storm Safe

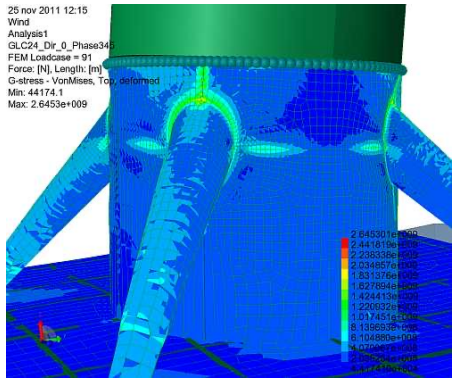
- Optimize Inspection Regime
- Targeted Subsea Survey
- Data Driven IMR

OPEX Optimization through Monitoring



SHM – Value Summary

- Detection of Anomalies
- Optimize Inspection Maintenance and Repair Activity
- Increase Uptime
- Fundamental for Asset Life Extension
- Decrease Carbon Footprint
- Improve Long-Term Bankability



Thank You