Masterclass – OPEX modelling of offshore energy

06th October 2021 - online

Interreg
EUROPEAN UNION
North-West Europe
OPIN
European Regional Development Fund

Welcome

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- Attendees’ microphones will be muted during the event.
- After each presentation there will be time for a short Q&A. After the session there will be an additional Q&A.
- Questions can be formulated in the chat at any time, and they will be addressed during the Q&A session.
- The event will be recorded, and the slides will be shared on the OPIN website.

Speakers

Anna Garcia Teruel
University of Edinburgh

Anthony Gray
Offshore Renewable Energy Catapult

Nis Ebsen
Floating Power Plant A/S

Annicka Wann
Exceedence Ltd.

Agenda

11:00 – 11:10 **OPIN Introduction** *Simon Stark – Dutch Marine Energy Centre*

11:10 – 11:35 **Benefits of detailed O&M models to quantify investment KPIs** *Anna Garcia-Teruel – The University of Edinburgh*

11:35 – 12:00 **A developers perspective on O&M models for devices and projects** *Nis Ebsen – Floating Power Plant*

12:00 – 12:25 **A combined floating wind and wave energy O&M model** *Anthony Gray – Offshore Renewable Energy Catapult*

12:25 – 12:45 **Relevance of OPEX estimates in project modelling and uncertainty analysis** *Annicka Wann – Exceedence Ltd.*

12:45 – 13:00 **Final Q&A**

What is OPIN ?

Interreg North-West Europe OPIN
European Regional Development Fund
EUROPEAN UNION

Ocean Power Innovation Network (OPIN) is a **European collaborative network**

OPIN Aim:

- Develop both cross-regional and cross-sectoral **collaboration**

OPIN Targets:

- Support over 100 companies
- Develop a self-sustaining network (>200 members)

4 years from 2019 to 2022

2.6M€ total project budget

1.5M€ in financial support from Interreg North West Europe

Join the network (free)

Who are OPIN ?

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North-West Europe
OPIN
European Regional Development Fund
EUROPEAN UNION

7 partners from Ireland, UK, Belgium, France, the Netherlands and Germany

Project Partners	Countries/Regions
Sustainable Energy Authority of Ireland (SEAI)	Ireland
Scottish Enterprise (SE)	Scotland
Offshore Renewable Energy Catapult (OREC)	United Kingdom
Sirris, het collectief centrum van de technologische industrie (SIRRIS)	Belgium
West Atlantic Marine Energy Community, École Centrale de Nantes (WEAMEC)	France Pays de la Loire
Dutch Marine Energy Centre (DMEC)	Netherlands
Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V. (Fraunhofer IEE)	Germany

What can OPIN do for you?

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Receive **travel support**

- ✓ Enabling Irish and Scottish Enterprise SMEs to travel abroad for OPIN events

Access **expert advice** on your technology (TAPs)

- ✓ Independent expert opinion – e.g. on the route to market, on reducing development risks and costs, etc.
- ✓ Advice on next steps, funding and collaboration opportunities

Support **collaborative projects** (CIGs)

- ✓ Preparatory step to National and EU research calls
- ✓ Find ways to solve technical or financial problems you are facing
- ✓ Expand your network nationally and internationally
- ✓ Benefit from the experience of those in other industries

OPIN Resources

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OPIN Members list

OPIN Library:

- Workshops/masterclasses presentations
- Value chain study - summary report
- Ocean energy challenges and recommendations: Desktop analysis of studies and reports

OPIN Twitter and Linkedin groups. Join us for the latest updates!

Email us at: OPIN@seai.ie

Innovative, low cost, low weight and safe floating wind technology optimized for deep water wind sites

Benefits of detailed O&M models to quantify investment KPIs

Anna Garcia-Teruel, PhD
The University of Edinburgh
Email: a.garcia-teruel@ed.ac.uk

OPIN Masterclass– October 06th 2021

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 815289

The Policy and Innovation Group

Services:

- Techno-economic and socio-economic assessment
- Life Cycle Evaluation
- Array Optimization Analysis
- Strategy Planning and roadmapping
- Consultancy

"The group analyses the dynamics of innovation in energy systems, especially the relationships between policy, investment and innovation."

Team Leader:
Henry.Jeffrey@ed.ac.uk

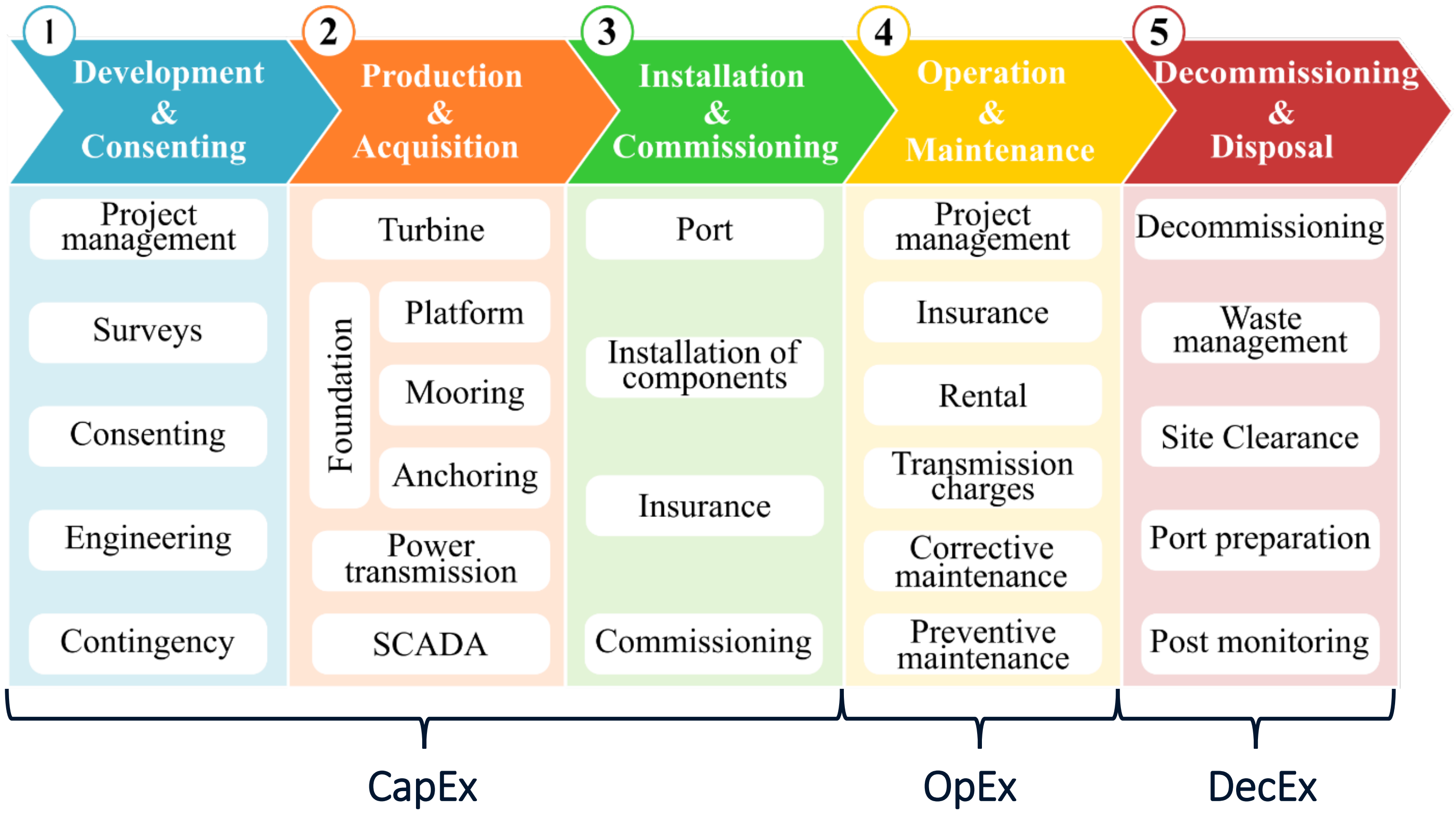
Main partners:

www.policyandinnovationedinburgh.org

Outline

- Introduction
- Motivation
- Approach: integrating O&M model in techno-economic assessment
- Results:
  - How do the results compare to using simple assumptions?
  - Are there any added benefits?
- Conclusions

Introduction – Life Cycle Cost Analysis



Source: [2] A. Garcia-Teruel and H. Jeffrey, "The economics of floating offshore wind – A comparison of different methods." figshare, 2020.

Introduction – What are common cost indicators?

- Investments cost or Capital Expenditures (CapEx)
- Levelised Cost of Energy (LCoE)

$$LCoE = \frac{PV(CapEx + OpEx + DecEx)}{PV(AEP)} \qquad PV(x) = \sum_{t=0}^{n} \frac{x_t}{(1+r)^t}$$

r : Discount rate
n : Lifetime
t : Year

- Net Present Value (NPV)

$$NPV(x) = \sum_{t=0}^{n} \frac{Cashflows_t}{(1+r)^t}$$

- Pay-Back-Period (PBP) or Discounted Pay-Back-Period (DPBP)

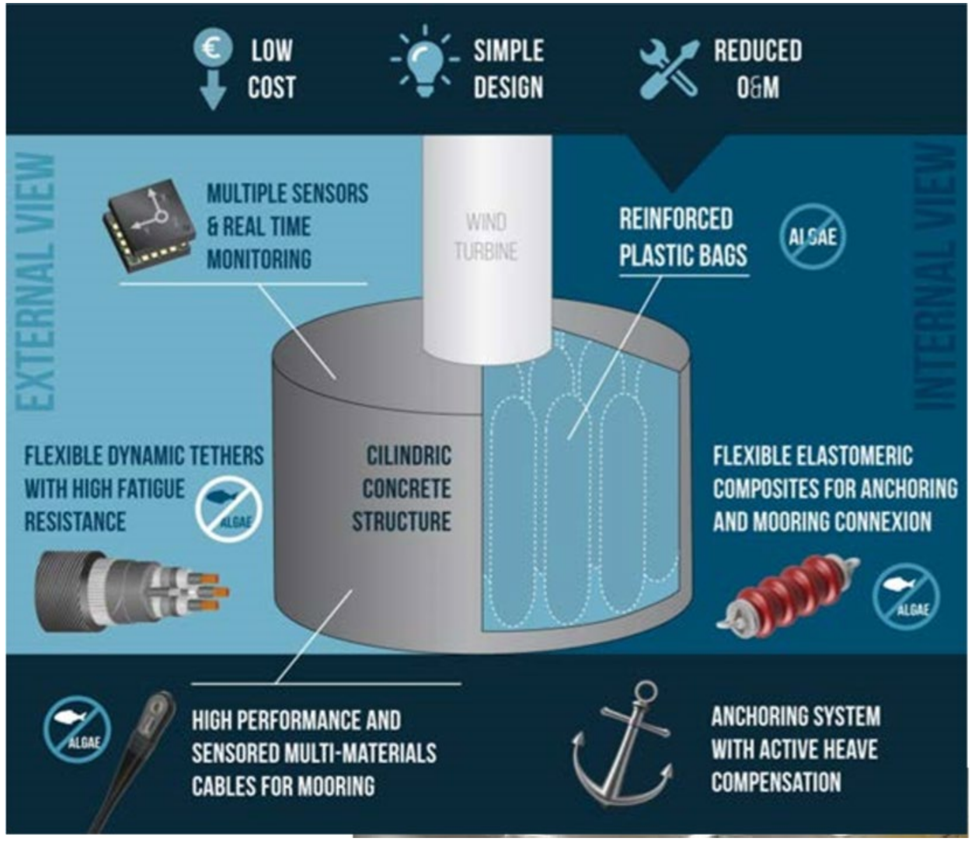
  Time required to recover the original investment

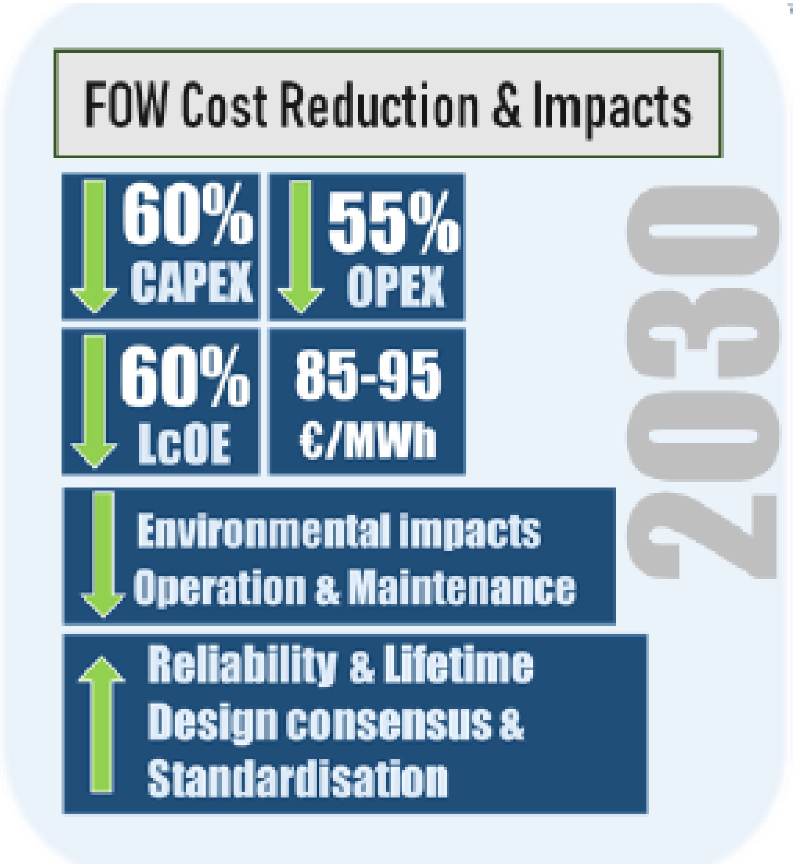
- Internal Rate of Return (IRR)

  Indicator for the profitability of a project

Introduction – The FLOTANT project

Innovative, low cost, low weight and safe floating wind technology optimized for deep water wind sites





Introduction – The FLOTANT project collaboration results

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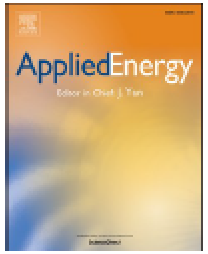
journal homepage: www.elsevier.com/locate/apenergy



Incorporating stochastic operation and maintenance models into the techno-economic analysis of floating offshore wind farms

Giovanni Rinaldi [a,*], Anna Garcia-Teruel [b,*], Henry Jeffrey [b], Philipp R. Thies [a], Lars Johanning [a,c]

[a] *Renewable Energy Group at the University of Exeter, Penryn Campus, Treliever Road, TR109FE Penryn, Cornwall, UK*
[b] *School of Engineering, Institute for Energy Systems, The University of Edinburgh, Edinburgh EH9 3JG, UK*
[c] *Harbin Engineering University, Yiman St, Nangang, Harbin, Heilongjiang, China*

https://doi.org/10.1016/j.apenergy.2021.117420

Source: [1]

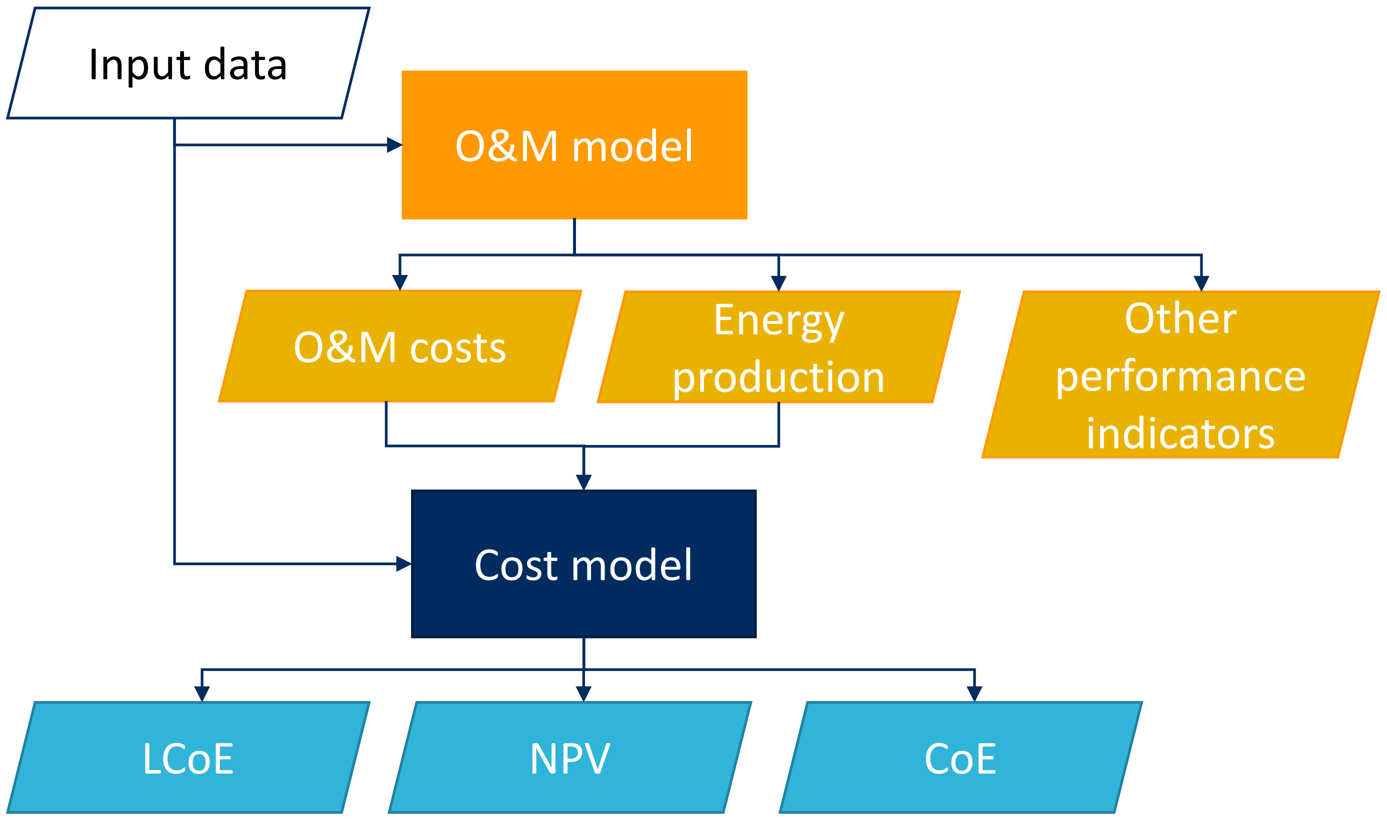
Motivation

More specific KPIs that break down the different considerations and assumptions used within the calculation of the LCoE can **support technology comparison**

Especially relevant in logistics and assets management, where very little experience exists & oversimplified approximations are used in techno-economic assessment models.

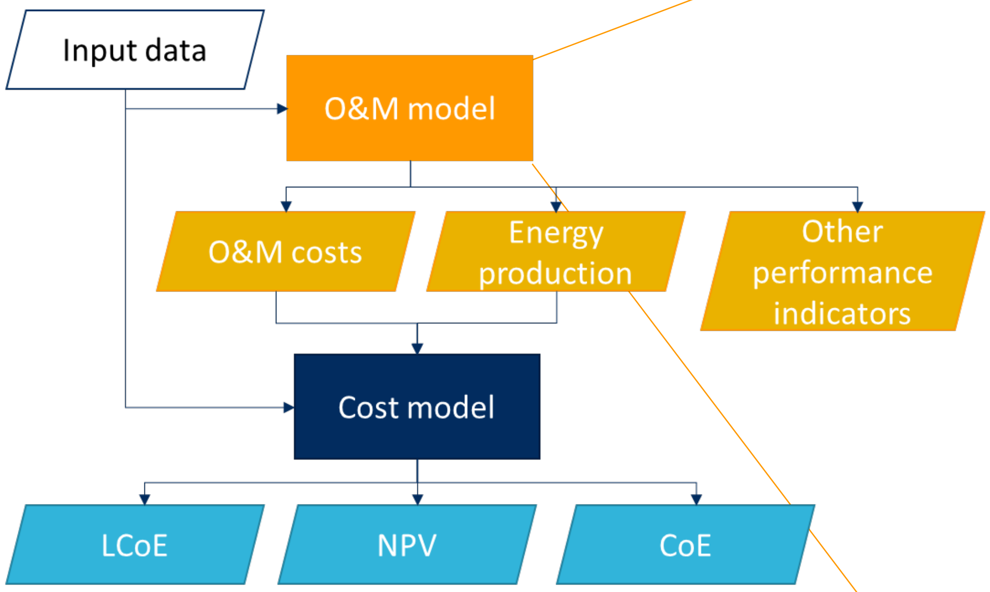
Reduce the uncertainties in the estimation of the technical and economical parameters of the project & support in the decision-making process.

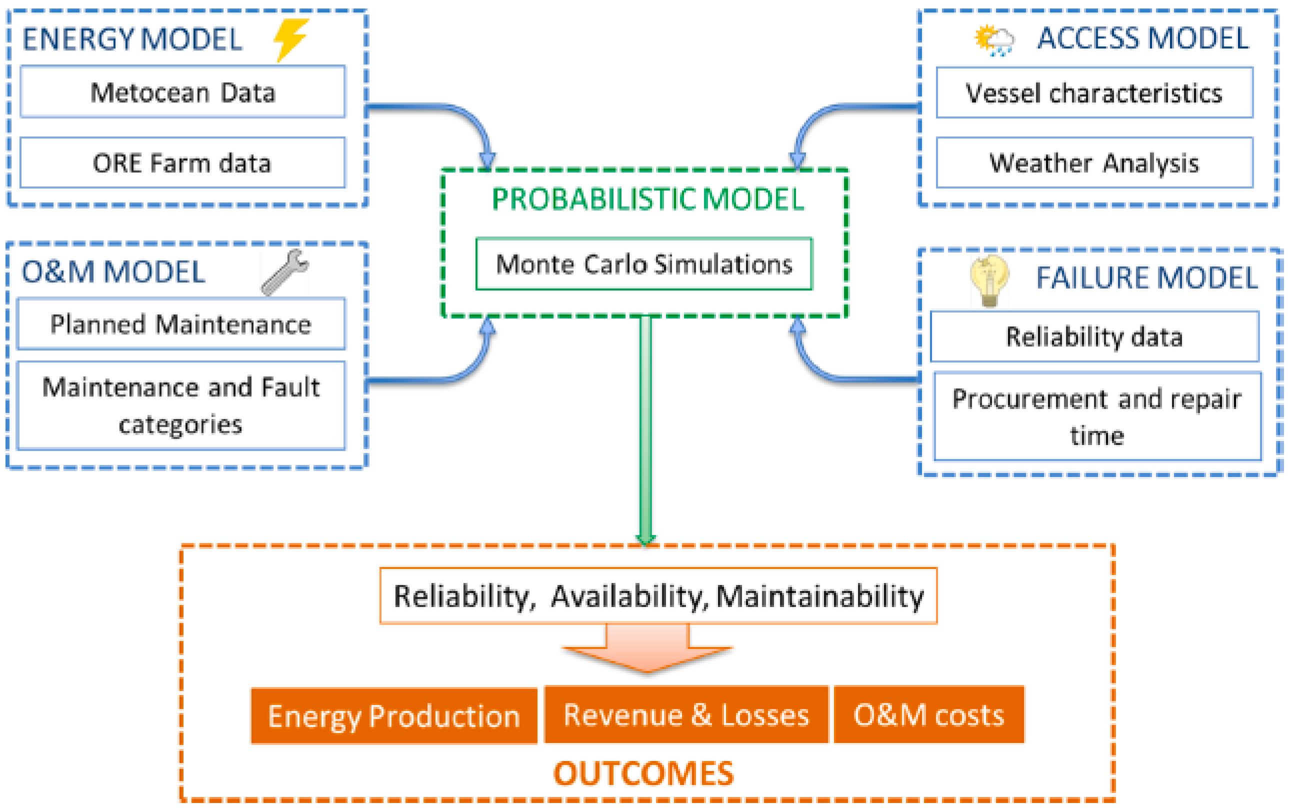
Approach – Integrating O&M model into cost model



Source: Adapted from [1]

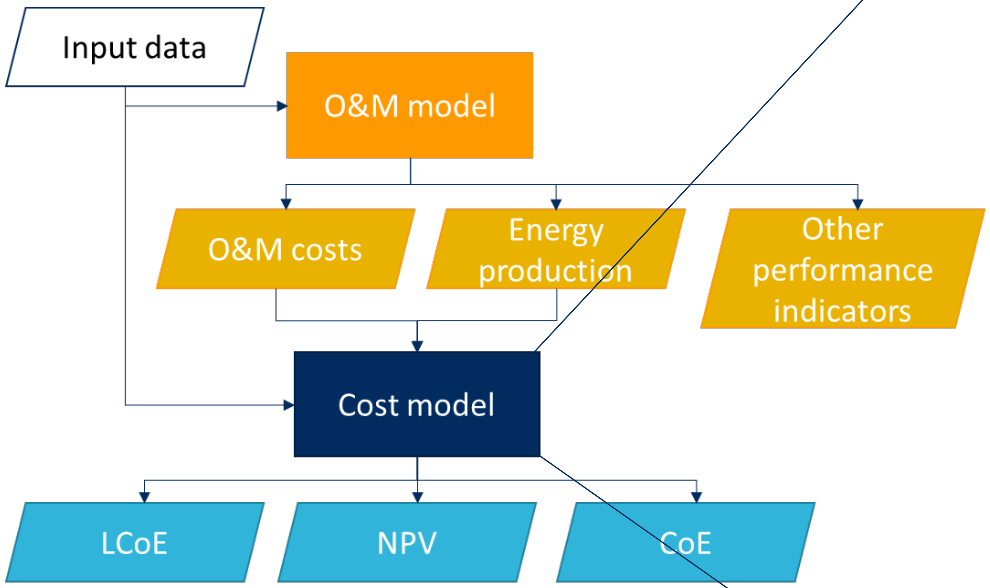
Approach – Stochastic O&M model





Source: Adapted from [1]

Approach – Cost model



- $$LCoE = \frac{PV(CapEx + OpEx + DecEx)}{PV(AEP)}$$

  $$PV(x) = \sum_{t=0}^{n} \frac{x_t}{(1+r)^t}$$

- $$NPV(x) = \sum_{t=0}^{n} \frac{Cashflows_t}{(1+r)^t}$$

- $$CoE = \frac{CapEx + OpEx + DecEx}{AEP}$$

Approach – Case studies inspired by pilot parks

Source: [1]

Characteristic	Case study 1	Case study 2
Inspired by	Hywind	Kincardine
Turbine model	SWT-6.6-120	V164 – 9.5
Turbine rating [MW]	6	9.5
Number of turbines	5	5
Substructure	Spar	Semi-submersible
Water depth [m]	95-129	60-80
Distance to shore [km]	25	15

Results – Overview of obtained KPIs

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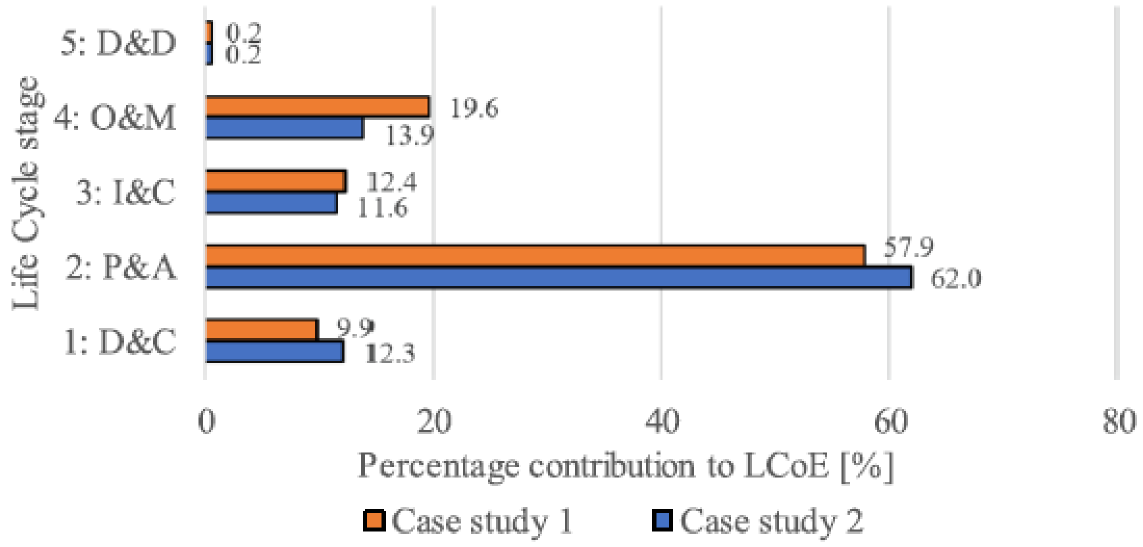
	Quantity / Parameter	Case Study 1	Case Study 2
O&M model	Average AEP [GWh]	131.9	168.7
	Average annual energy lost [GWh]	8.5	13.1
	Energy-based availability [%]	93.9	92.8
	Net capacity factor [%]	50.2	40.5
	Equivalent hours	4396	3551
	O&M costs undiscounted [m£$_{2019}$]	111.1	101.1
	Normalised O&M cost per energy produced [£$_{2019}$/MWh]	33.7	24.0
Cost model	CoE [£$_{2019}$/MWh]	79.3	72.4
	LCoE [£$_{2019}$/MWh]	171.8	172.5
	NPV [m£$_{2019}$]	-93.6	-120.1

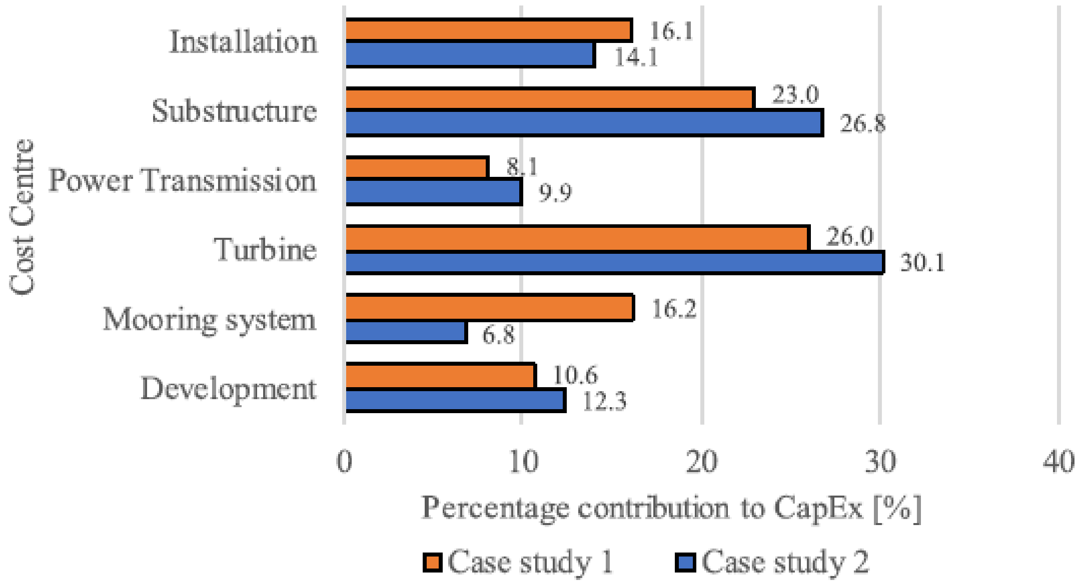
FLOTANT

Results – Common cost indicators

Levelised Cost of Energy



Capital Expenditures



Source: [1]

Results – Comparison to simple O&M representations #1

	Case Study 1		Case Study 2	
	O&M model (77.1% CapEx)	Approximation (25% CapEx)	O&M model (51.3% CapEx)	Approximation (25% CapEx)
OpEx [m£$_{2019}$]	111.1	36.0	101.1	49.3
Normalised O&M cost per energy produced [£$_{2019}$/MWh]	33.7	11.1	24.0	11.9
CoE [£$_{2019}$/MWh]	79.3	56.6	72.4	60.1
LCoE [£$_{2019}$/MWh]	171.8	149.1	172.5	160.2
NPV [m£$_{2019}$/MW]	-93.6	-74.9	-120.1	-107.3

Source: Values from literature from [4]

- LCoE is the cost indicator the varies the least
- LCOE underestimated by 7.4-14.2%

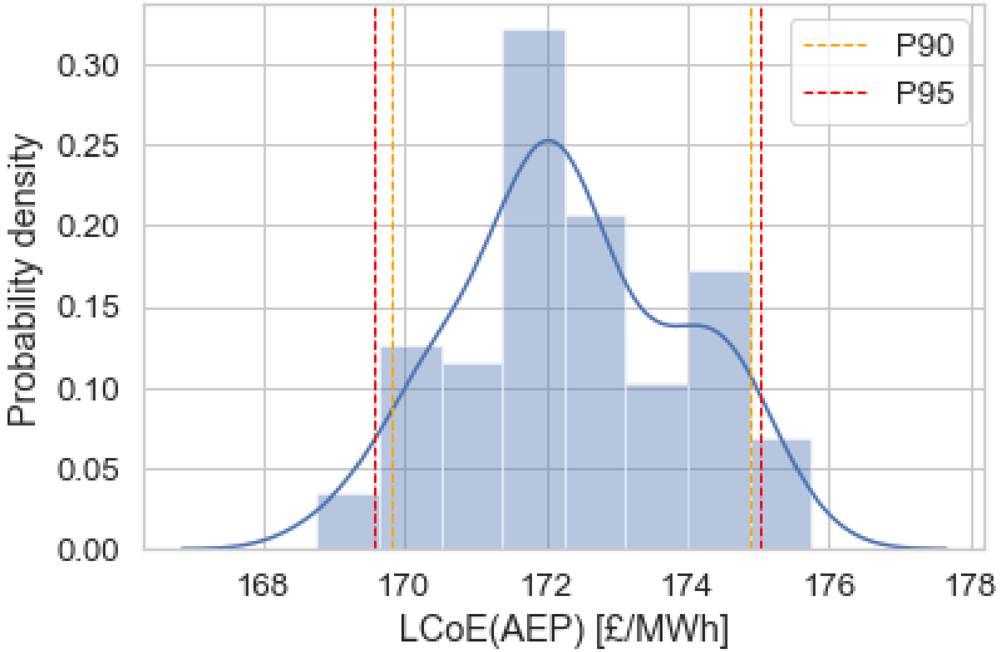
Results – Comparison to simple O&M representations #2

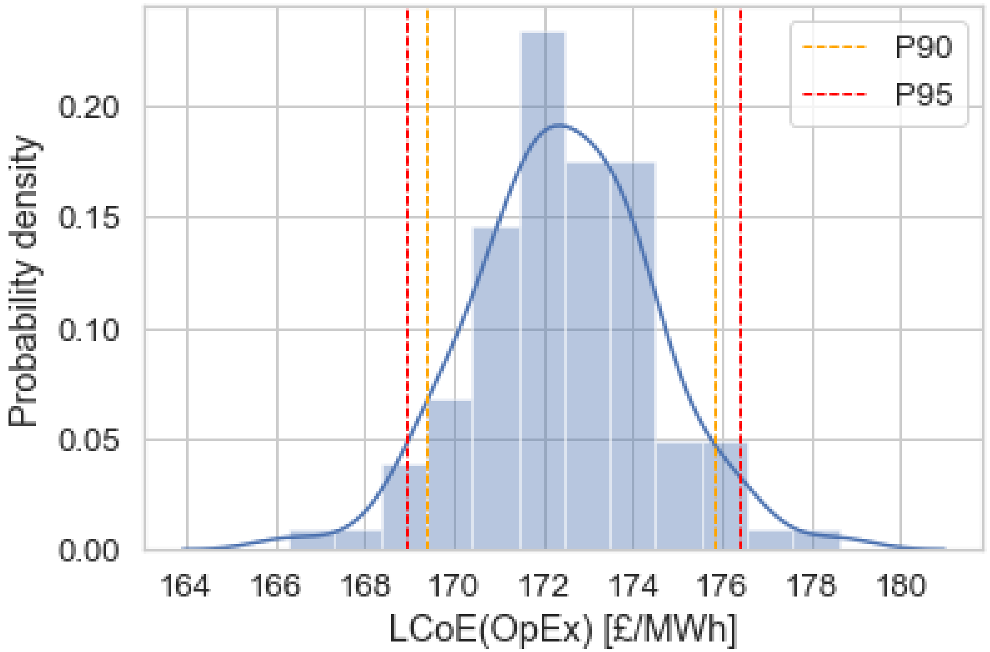
	Case study 1			Case study 2		
Normalised O&M cost per energy produced [£$_{2019}$/MWh]	O&M model (33.7)	9.2	28.5	O&M model (24.0)	9.2	28.5
OpEx [m£$_{2019}$]	111.1	30.0	92.9	101.1	38.3	118.7
CoE [£$_{2019}$/MWh]	79.3	54.7	73.8	72.4	57.5	76.6
LCoE [£$_{2019}$/MWh]	171.8	147.2	166.3	172.5	157.6	176.6
NPV [m£$_{2019}$/MW]	-93.6	-73.5	-89.1	-120.1	-104.6	-124.5

LCOE difference of 3.2 – 15.4%

LCOE difference of -2 – 9%

Results – Further insights provided by O&M model

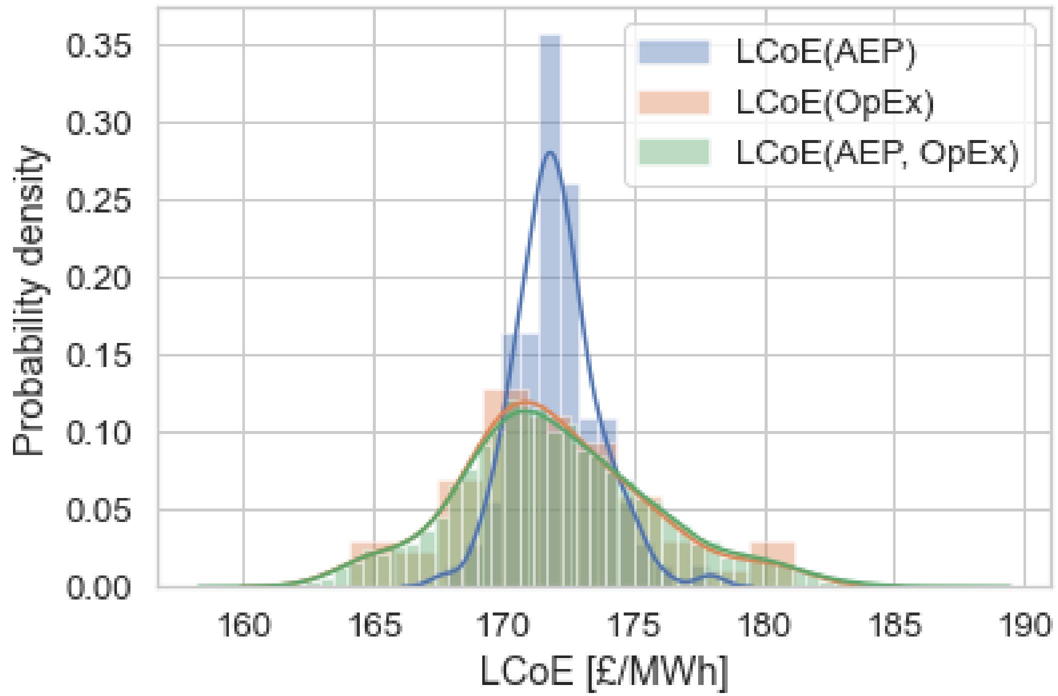




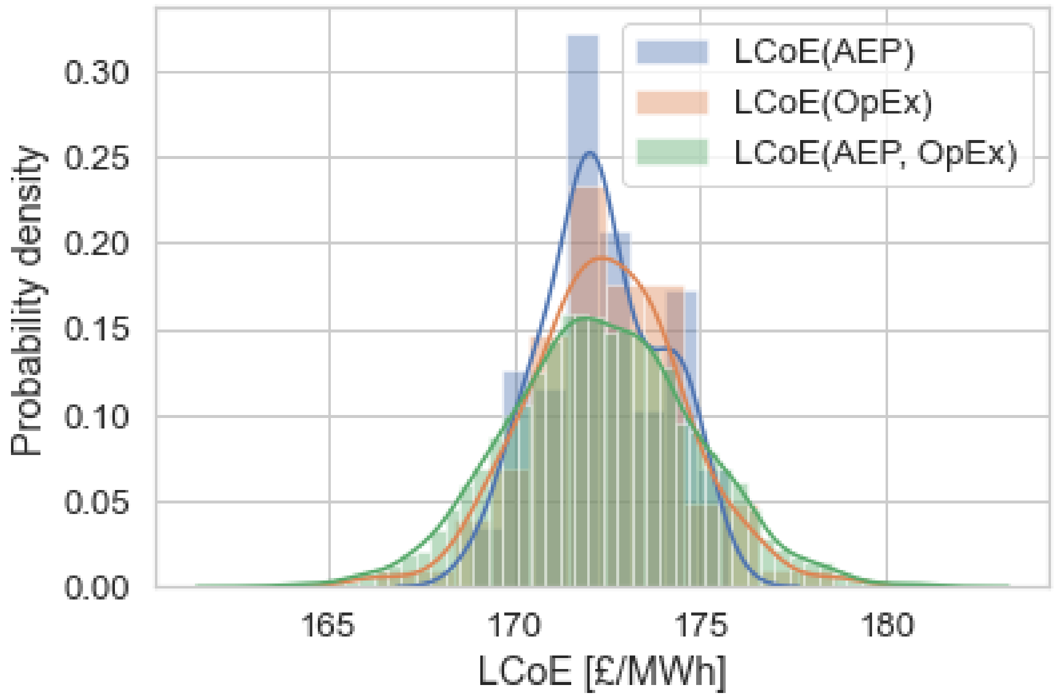
Source: [1]

Results – Further insights provided by O&M model

Case study 1

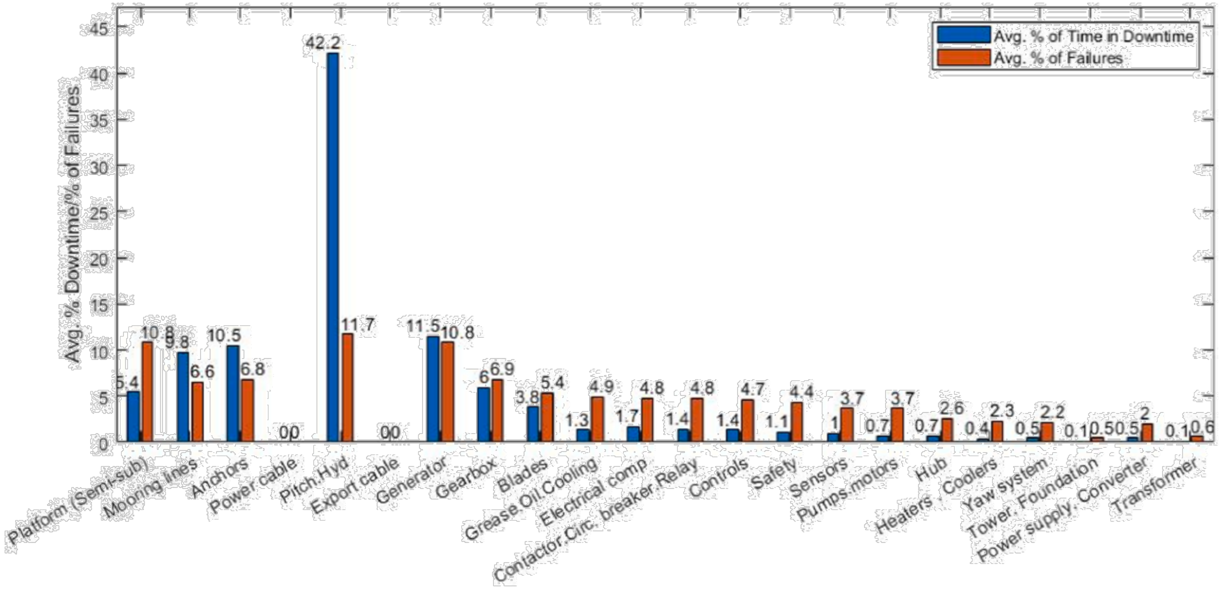


Case study 2



Source: [1]

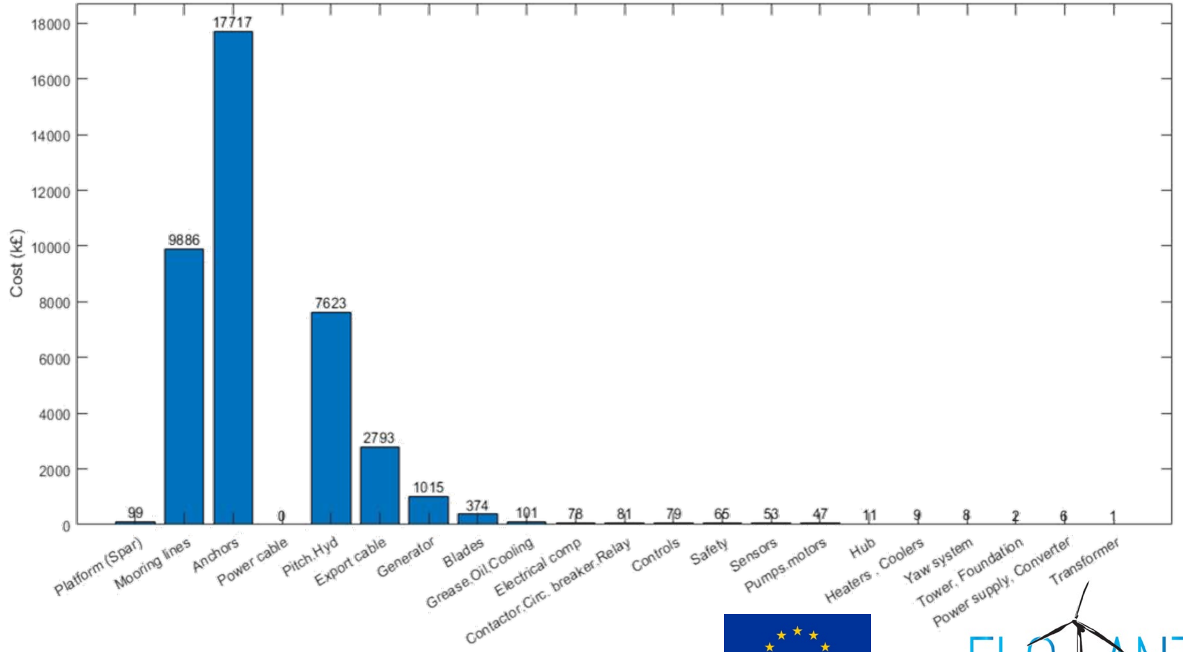
Results – Further insights provided by O&M model



% Downtime associated to a component

% Failures associated to a component

Cost contribution of each component to OPEX



Source: [1]

Conclusions

- Using more detailed O&M models allows us to:
  - Assess the variation in costs due to differences in resource, weather conditions, distance to shore, or vessel availability.
  - Assess the impact of applying different O&M strategies on the overall costs
  - Better understand the uncertainty around cost estimates
  - Better understand the sources of different costs and to identify key cost drivers such as critical operation and maintenance procedures and components whose reliability characteristics should be improved within the context of minimising the overall system costs.
- Using simplified representations of OpEx may lead to underestimation of the total costs with variations in LCoE estimates of up to 15% (for the studied cases).

References

[1] G. Rinaldi, A. Garcia-Teruel, H. Jeffrey, P. R. Thies, and L. Johanning, “Incorporating stochastic O&M models into the techno-economic analysis of floating offshore wind farms,” *Appl. Energy*, 2021. doi: 10.1016/j.apenergy.2021.117420

[2] A. Garcia-Teruel and H. Jeffrey, “The economics of floating offshore wind – A comparison of different methods.” figshare, 2020. doi: 10.6084/m9.figshare.12656300

[3] A. Garcia-Teruel and H. Jeffrey, “The economics of floating offshore wind – A comparison of different methods”, *In Proc. of RENEW conference*, 2020.

[4] Eik A. Statoil’s contribution to the North East future economy. Aberdeen: 2017.

[5] Gonzalez-Rodriguez AG. Review of offshore wind farm cost components. *Energy Sustain Dev* 2017;37:10–9. https://doi.org/10.1016/j.esd.2016.12.001.

Questions & getting in touch

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 815289

FLOATING POWER PLANT

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A developer's perspective on O&M modelling

October 2021

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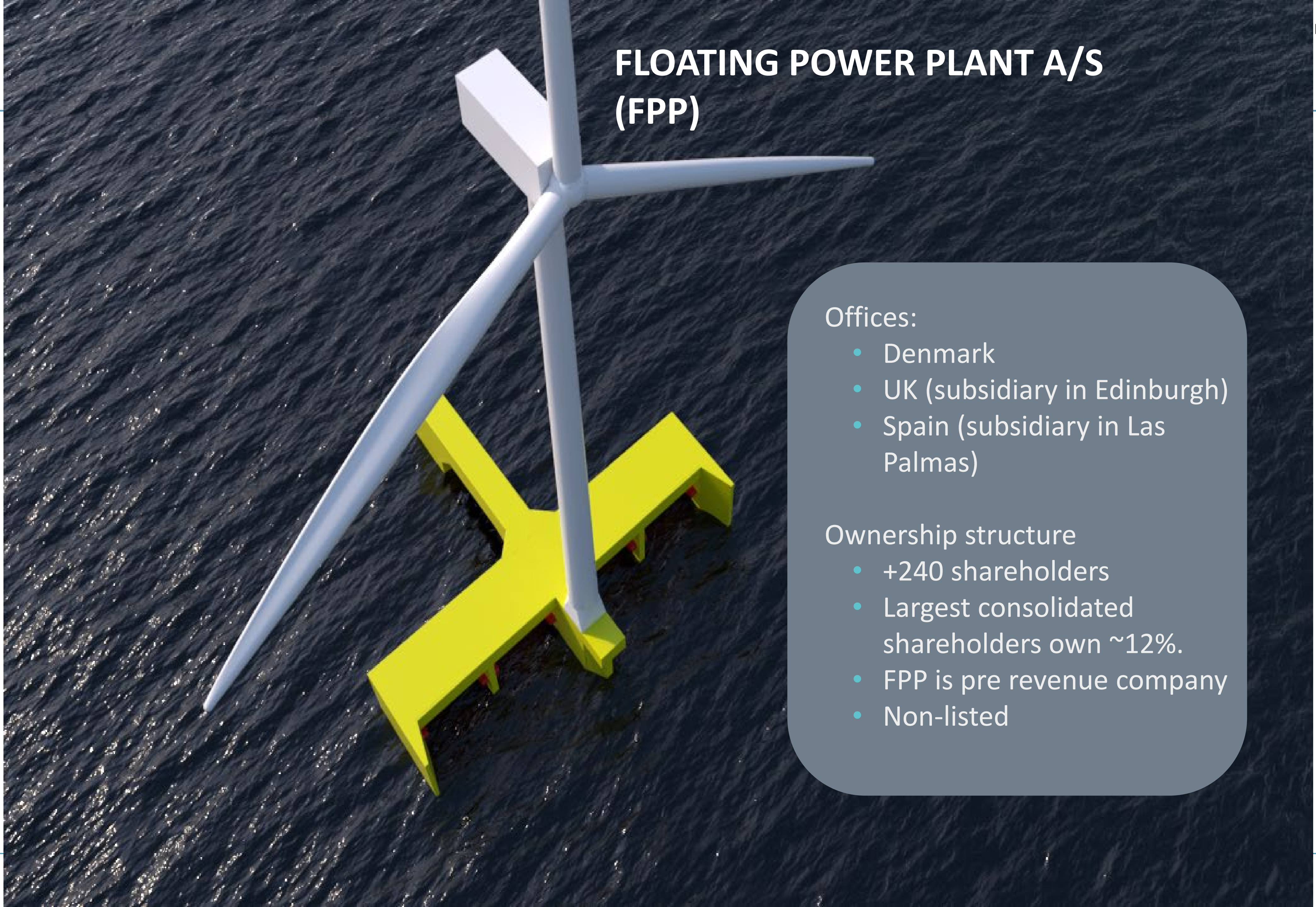
FLOATING POWER PLANT A/S (FPP)



Offices:
- Denmark
- UK (subsidiary in Edinburgh)
- Spain (subsidiary in Las Palmas)

Ownership structure
- +240 shareholders
- Largest consolidated shareholders own ~12%.
- FPP is pre revenue company
- Non-listed

WE DEVELOP IN PARTNERSHIPS (IN THE PUBLIC DOMAIN)

SIEMENS

Global leader in power generation

DEME

Global leader in offshore service (70 projects in 50 countries)

efront TECHNOLOGY Marine Technology Development

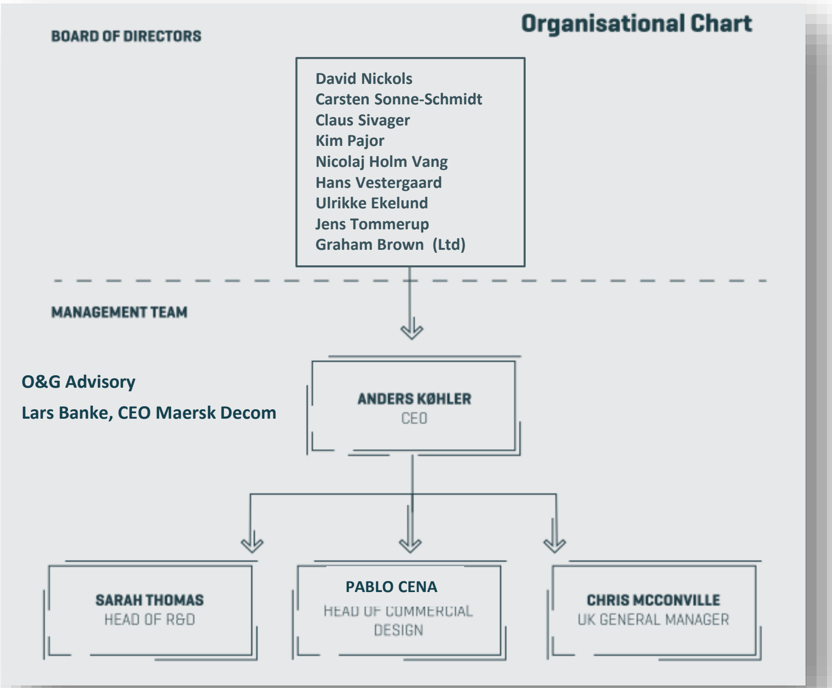
Technology VC developer for the oil and gas market

FRITZ SCHUR ENERGY

Global leader in hydraulic pitch control systems (e.g. Siemens Wind)

TechnipFMC

Global leader in Offshore hydrogen and O&G EPC



- Integrate knowledge and experiences
- Prepare value chain for ramp up
- Reduce capital expenditure

DTU Danmarks Tekniske Universitet

World-leading university within wind

UPPSALA UNIVERSITET

Uppsala University

AALBORG UNIVERSITET

Lloyd's Register

DNV

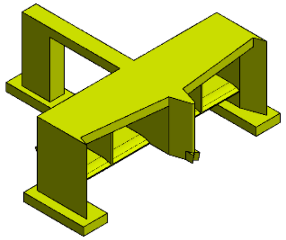
Global Leading third party certification

APL NOV

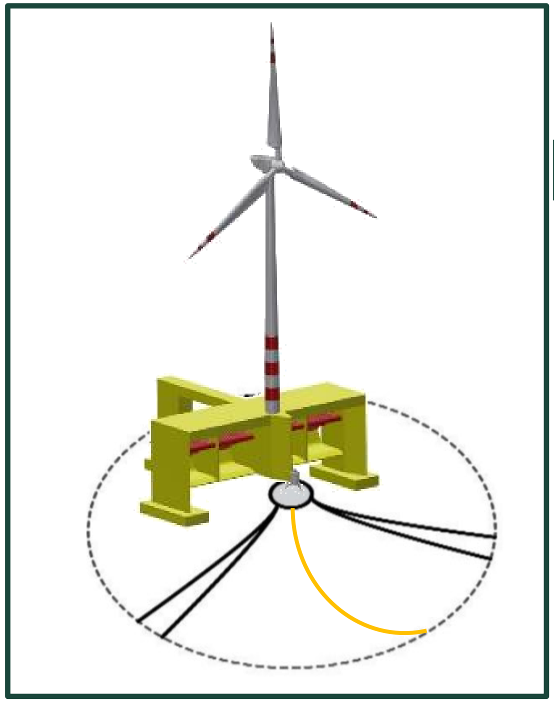
Seasystems A part of Scana

Global Leaders in turrets

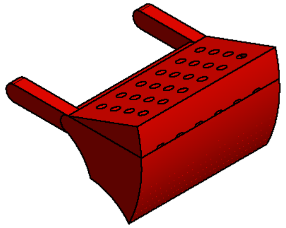
WHAT TECHNOLOGY ARE WE DEVELOPING



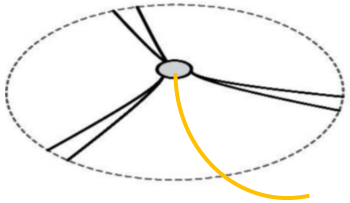
Semi-submersible platform



4-15 MW wind turbine

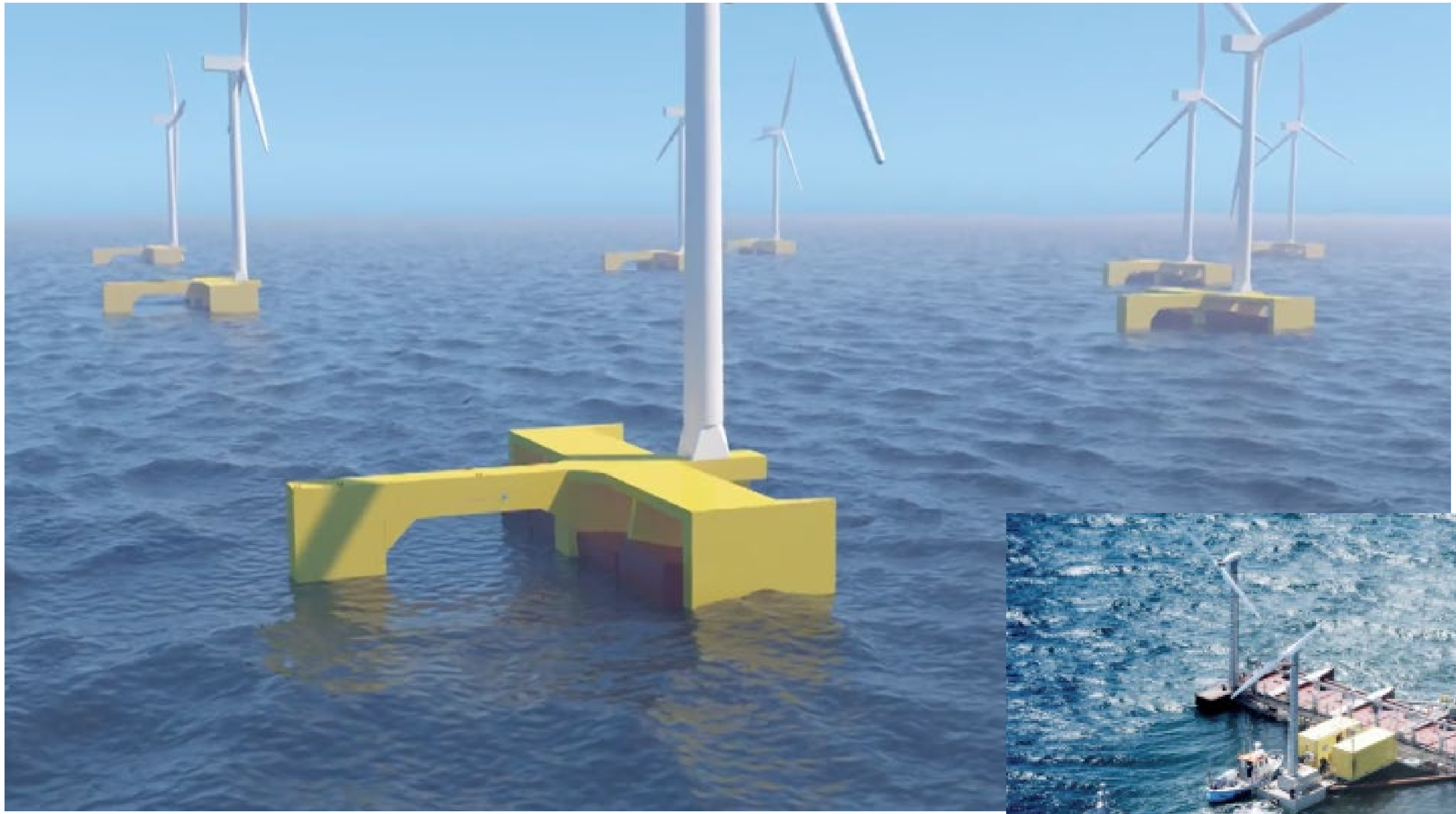


Unique, patented WEC and PTOs
1- 4 MW



Disconnectable turret mooring
With export cable

THE FPP PLATFORM



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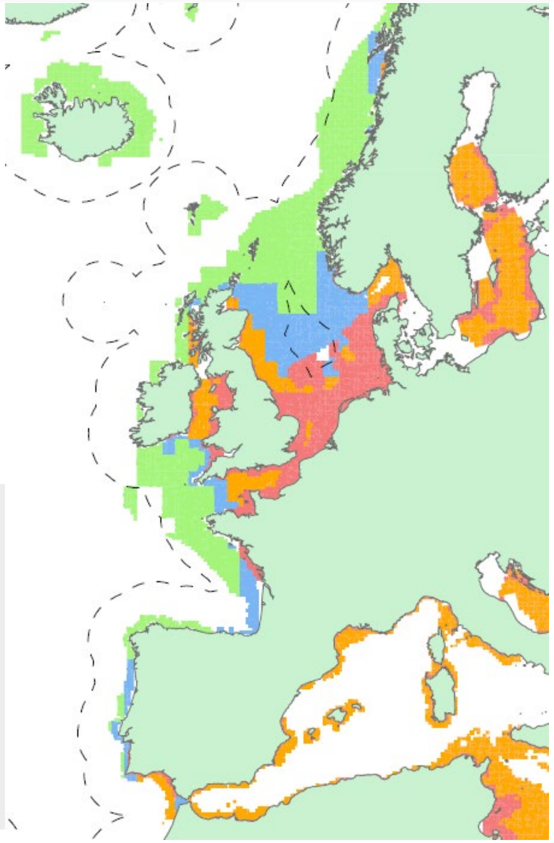
FPP positioned as a leader in deep water and high wind areas

The technology has unique and proven attributes in deep water segments, the next frontier of offshore wind

Market segments by distance from shore and wind speeds

Segments	Wind speeds at 100m height
Fixed foundation market - Depth < 45m - Mean wind > 7m/s - Wave power < 20 kW/m	All dist. = 9.2 <30 km = 9.0 30-60 km = 9.4
Floating wind only - Depth < 45m < 500m - Mean wind > 7m/s - Wave power < 10 kW/m	All dist. = 8.7 <30 km = 8.6 30-60km = 8.9
FPP and Floating wind - Depth < 45m < 500m - Mean wind > 7m/s - Wave power < 10 - 25 kW/m	All dist. = 10.3 <30 km = 10.0 30-60 km = 10.1
FPP - Market Leader - Depth < 45m < 500m - Mean wind > 7m/s - Wave power < 20 kW/m< 50 kW/m	All dist. = 11.0 <30 km = 11.0 30-60 km = 11.0



Competitive in standard areas and the market leader in deeper waters

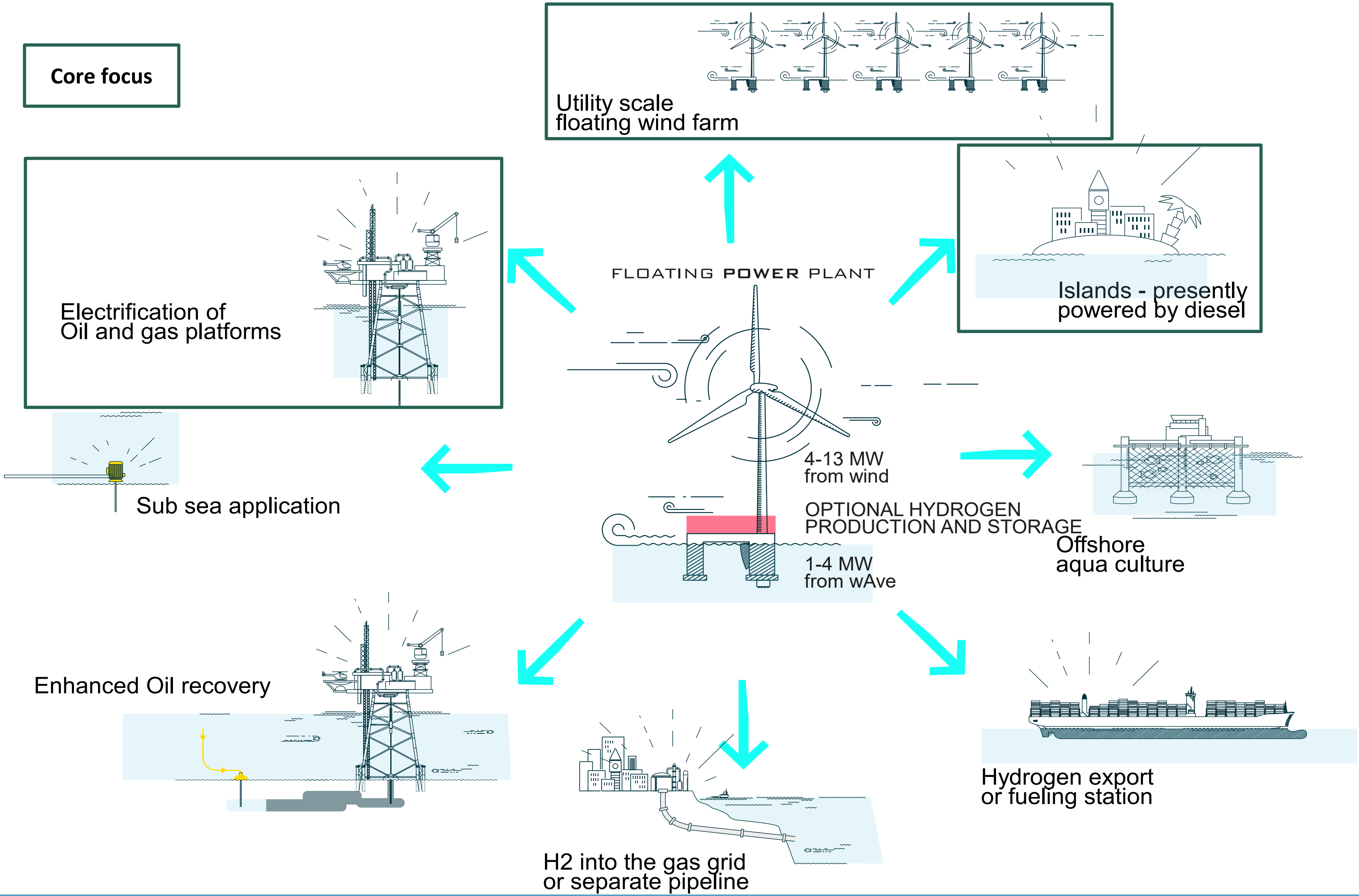
Criteria and ranges

Water depth (in m)	**45-500m** Minimum draft is also wave dependent. Deeper than 500m is possible
Wind (mean m/s)	Business cases start from 7 m/s, but most sites where FPP is **market leader (green area)** are **over 10 m/s**
Wave resource (mean KW/m)	Business cases start from 15 KW/m, but most sites where FPP is **market leader (green area)** are **over 25 KW/m**
Wave 100 year (peak Hs m)	Platform is currently designed for Hs **15 m**, but can be adapted to **higher waves**
Current (m/s)	Peak surface speed should be **under 1.2 m/s**

Source: Management information; (1) depending on wave resources at site location

One technology – a multitude of green applications

Floating Power Plant enables the energy transition through a multiple market approach



Source: The company

PIPELINE GROWING FAST

Floating wind market

- **Plocan commercial demonstration**
- **3 SPVs with an Irish Client (50% ownership)**
  - England, Scotland and Ireland
- **100 MW small Array in Wales**
  - UK client (competitive bid)
- **Demonstration project application in Japan**
  - Tier 1 partners
- **Multiple client engagement in Scotwind leasing round**
- **Etc.**

Power-2-x (Island and electrification)

- **150 – 300 MW array in Canaries**
- **6 operators in UK for Electrification**
  - Concept select for first field
- **3 Operators in Brazil**
- **Norway**
  - One bids with FPP technology + Hydrogen for a charter agreement setup
  - One longer term client
- **More coming and fast**

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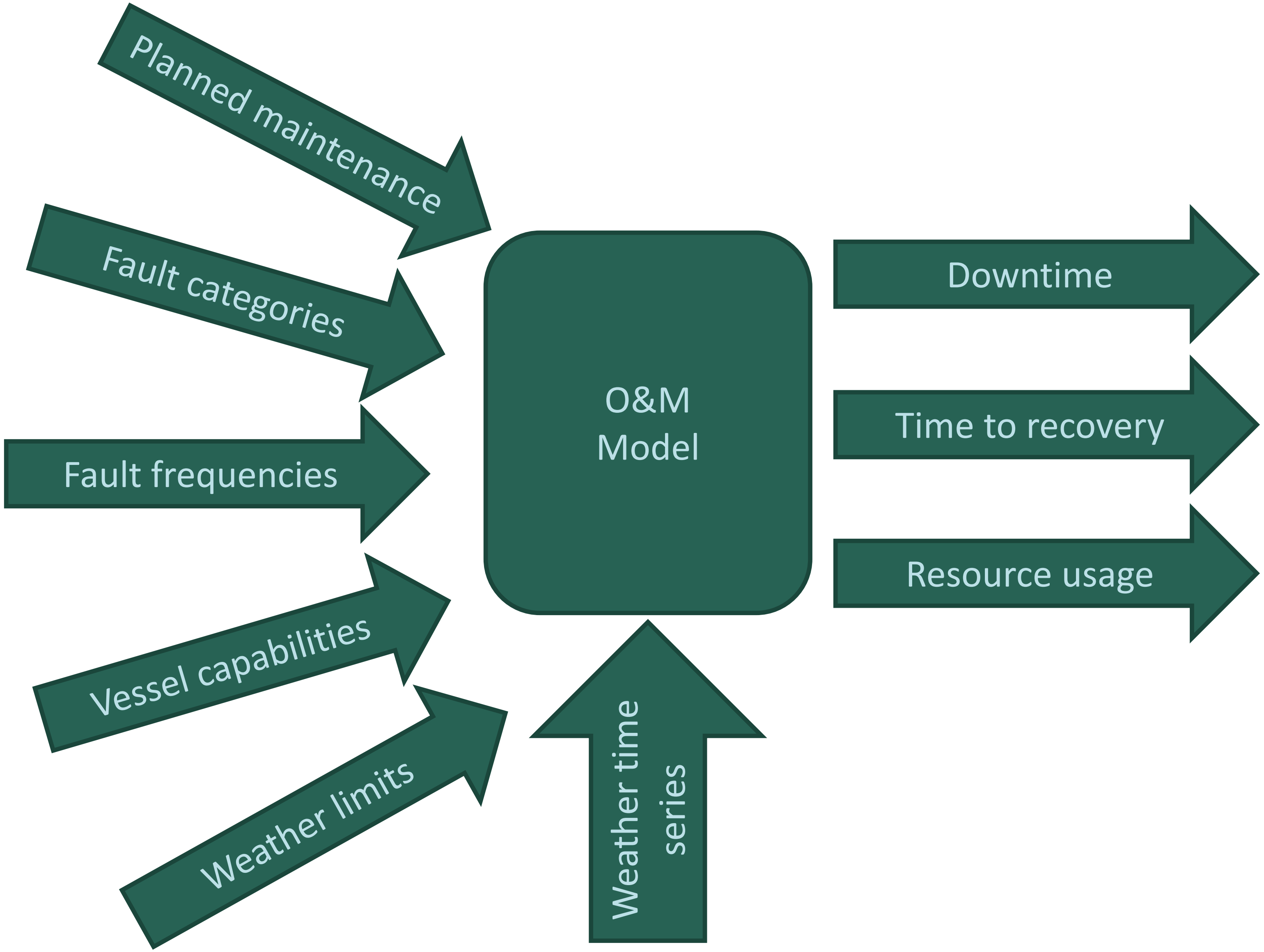
FOCUS OF THIS O&M MODELLING TALK IS THE FLOATING WIND MARKET

- +100 MW projects
- 25 years operational lifetime
- Deep, energetic sites (green and blue areas)
- Projects competing on LCoE
- Under warranty (Repairs and power curve / production warranty)

TARGETS AND O&M IMPACT

- High uptime
- Low maintenance requirement (one scheduled visit pr year)
- Safety during offshore operations
- Low cost – O&M cost have a significant impact on LCoE

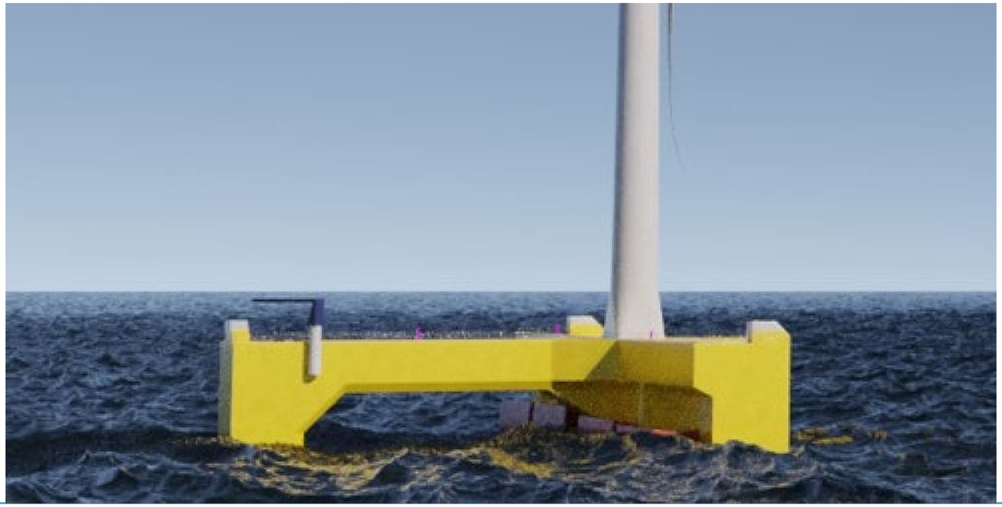
O&M SIMULATION TOOL CONCEPT



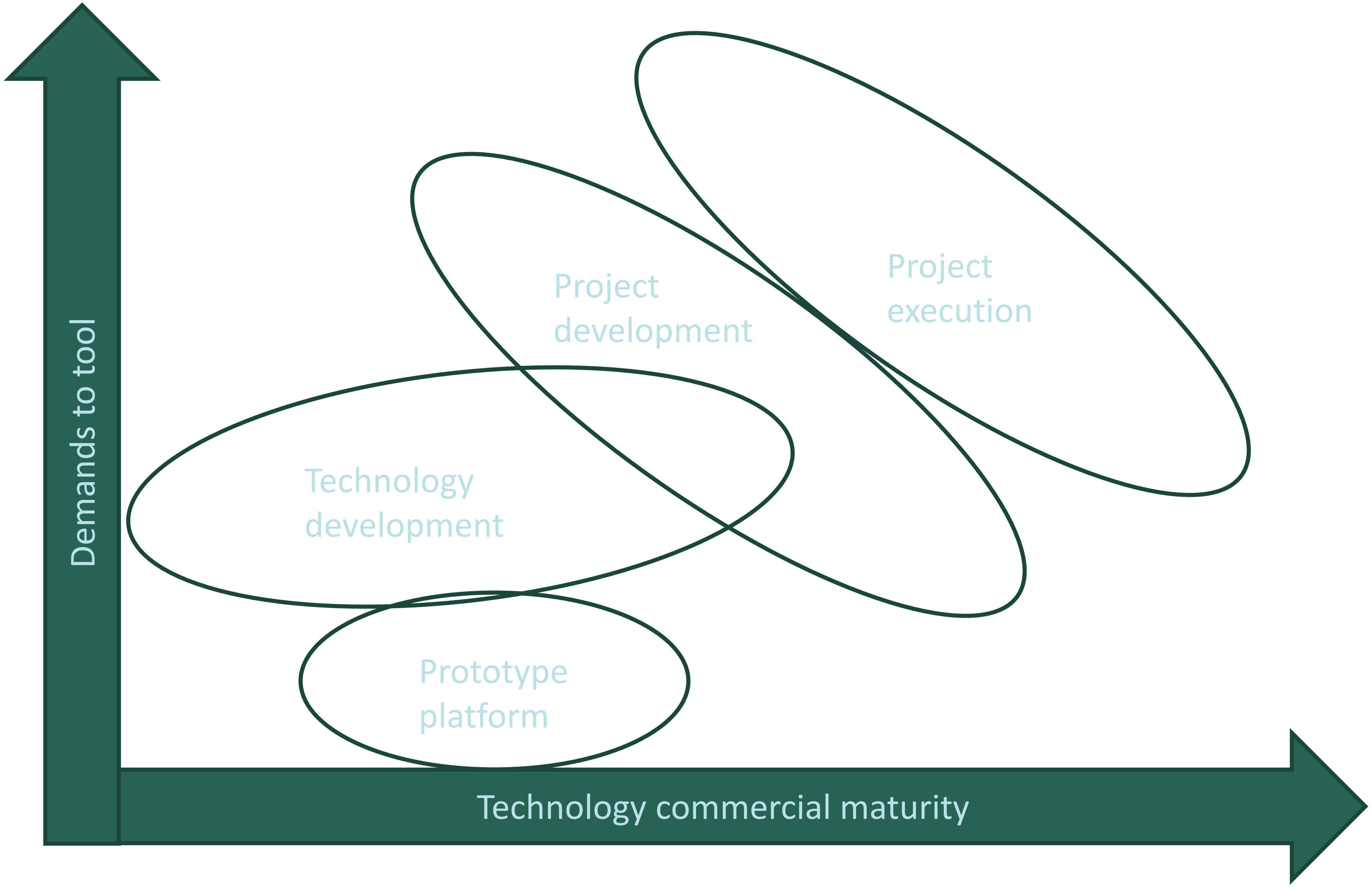
FPP O&M TRAITS

- The “harbour” effect of the FPP platform gives significantly more “access hours” due to wave height reduction
- Boat landing behind platform for safe access
- All systems indoor, comfortable and safe working conditions
- Space for handling and storing spares / possibility for emergency shelter
- FPP have used different modelling approaches to quantify these benefits

- No existing tools available that captured all of these traits out of the box, when we started

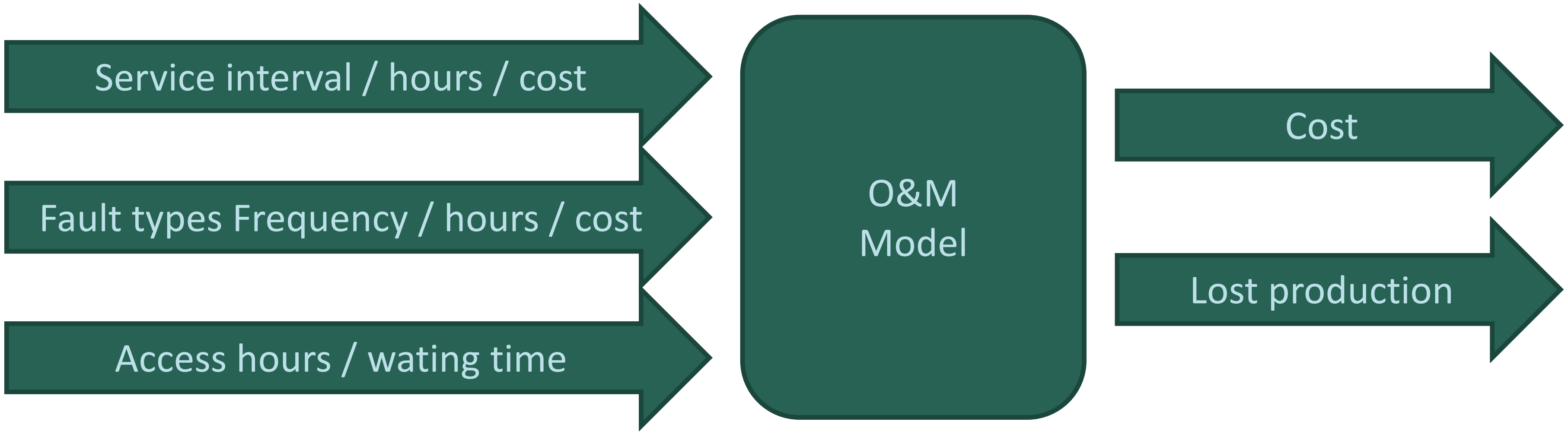


USE OF O&M MODELLING IN ALL STAGES OF DEVELOPMENT



TECHNOLOGY DEVELOPMENT

- **Basic need to estimate O&M conditions and costs:**
  - Guide development by identifying and quantifying O&M cost drivers
  - Generic assumptions for site conditions
  - Educated guesses on O&M consequences of design choices
  - Simplified model can be used



PROJECT DEVELOPMENT

- **Basic need to assess specific projects / sites to determine**
  - Feasibility
  - Downtime
  - Vessel and crew sizes
  - Installation / tow time and weather windows
  - Cost of energy

- **Different levels of detail at different stages of project development**
  - Site screenings – generic assumptions, simple model
  - Paid site study or FEED – site relevant data and assumptions, full analysis
  - Commercial project – detailed site-specific data and cost drivers, full analysis

PROJECT EXECUTION

- **Basic need to anticipate and plan operations and tasks**
  - Vessel and crew sizes
  - Installation / tow time and weather windows

- **Different levels of detail at different maturity stages**
  - Prototype project (P37 platform) - simple planning of activities, low experience
  - Demonstration project – better model, better data and assumptions, ad hoc setup
  - Commercial project – detailed season and day to day planning, full O&M organization

WHAT IS EASIER AND WHAT IS STILL HARD COMPARED TO WHEN WE STARTED

Easier

- Access to excellent tools. Commercial and free.
  i.e. OREC O&M tool
- Access to detailed weather data and time series. Commercial and free.
  i.e. DHI metocean data portal and Copernicus ERA5

Still hard

- Hard to estimate fault frequency and repair time
- Hard to get access to experience data from wind industry


FLOATING POWER PLANT
END

Overview of ORE Catapult's Publicly Available O&M Simulation Tool

OPIN Masterclass: OPEX Modelling For Marine Renewable Energy Technologies And Projects

Interreg
EUROPEAN UNION
North-West Europe
OPIN
European Regional Development Fund

06/10/2021 | Dr Anthony Gray

CATAPULT
Offshore Renewable Energy

Agenda

- ORE Catapult
- Model Background
- Access and References
- High-level model overview
- The interface
- How to add a fault category?
- How to add a scheduled maintenance category?
- How to access the source code?
- How to model a floating wind farm?
- Limitations
- Contact details

The Offshore Renewable Energy Catapult

The UK's leading technology innovation and research centre for offshore renewable energy

Mission: to accelerate the creation & growth of UK companies in the offshore renewable energy sector.

- Unique facilities, research & engineering capabilities
- Bringing together innovators, industry and academia
- Accelerating creation and growth of UK companies
- Reducing cost and risk in renewable technologies
- Growing UK economic value
- Enabling the transition to a low carbon economy

Model Background

- ORE Catapult has developed a unique Operations & Maintenance (O&M) simulation tool for calculating the operational feasibility and profitability of hybrid floating wind-wave sites, boosting the potential investability of these projects.
- The simulation tool was developed by ORE Catapult using open-source code from Wave Energy Scotland (WES) under a pilot project for the Ocean Energy Scale-Up Alliance (OESA). The first simulation has been for a hybrid floating wind-wave platform being developed by Floating Power Plant (FPP). The Katanes site, located off the north coast of Scotland, has a potential capacity of 300MW.
- **There's no reason someone can't adapt the O&M tool for their own uses – e.g. a floating wind farm**

wave energy SCOTLAND

Original model available from

Interreg North Sea Region OESA

European Regional Development Fund

EUROPEAN UNION

Modified model funded by

Access and References

- A case study report focussing on the FPP Katanes site, which was published in conjunction with the WindEurope Offshore 2019 conference, can be accessed with the following link. This gives the reader some idea of how the O&M simulation tool can be used.

https://ore.catapult.org.uk/?orecatapultreports=operations-and-maintenance-modelling-of-floating-hybrid-systems.

- The user guide can be accessed from the ORE Catapult website with the following link. This page also contains a request form for the model itself.

https://ore.catapult.org.uk/stories/hybrid-floating-om-simulation-tool/.

- Access to the model can also be achieved by emailing magnus.willett@ore.catapult.org.uk.

- The original wave energy focussed O&M tool can be accessed from the Wave Energy Scotland website (free registration required) with the following link.

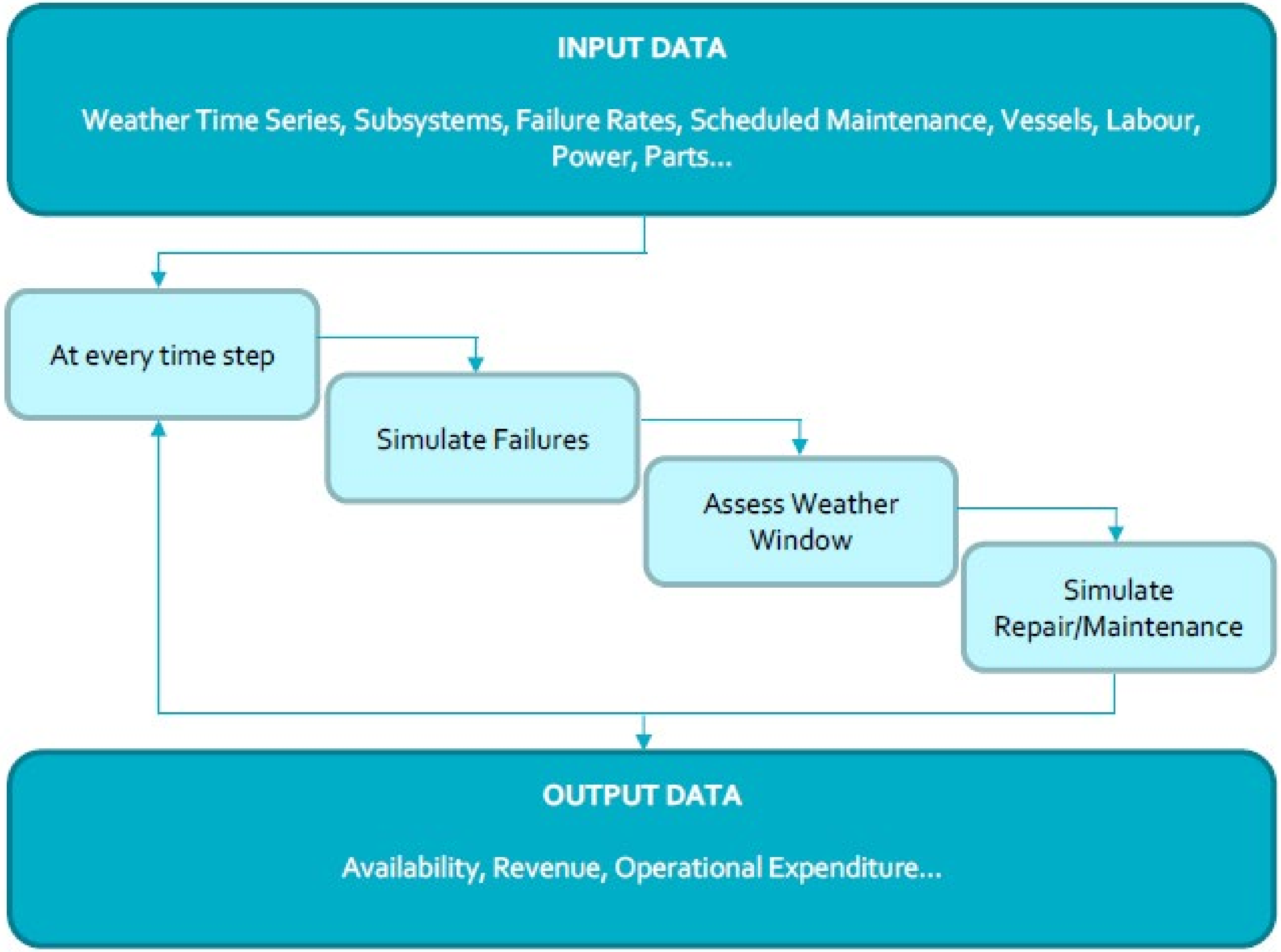
https://library.waveenergyscotland.co.uk/other-activities/design-tools-and-information/tools/om-simulation-tool/

- Useful reference for a high-level overview of O&M simulation models:

https://ore.catapult.org.uk/analysisinsight/what-are-operations-and-maintenance-simulation-tools/.

High-level model overview

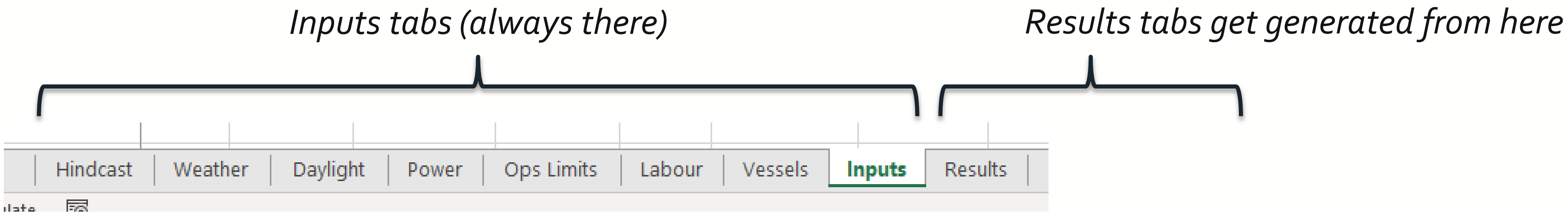
- A time-domain model based in an Excel workbook – the programming is VBA*
- 'Steps' through hourly hindcast weather data
- Simulates the occurrence of faults that need to be repaired (corrective maintenance) – Monte Carlo analysis
- Devices can be due for scheduled maintenance
- Takes the 'state' of the device at any one time to assess marine logistics
    - Is the vessel available?
    - Are the people available?
    - Is the weather suitable?



Source: Model user guide

**VBA = Visual Basic for Applications*

The interface



Universal Inputs	
Number of platforms	30
Number of fault categories	13
Number of scheduled maintenance tasks	3
Array lifetime	25
Install ops limits type	2
Installation vessel	AHTS with Tug
Install time (hours)	3
Connect/disconnect technicians required	5
No. platforms allowed at base	30
No. platforms allowed at base for maintenance	30
Night operations?	Yes
Array location	North Scotland
Use current weather? (KAT-025-001)	Yes
Choose specific dataset?	No
Currency	€
Output format	m

Fast Run

Full Run

Stat Run

- 'Universal inputs' – essentially where you define your farm (yellow means user inputs needed)
  - Number of platforms (or devices)
  - Array lifetime (in years)
  - Installation details (operational weather limits are defined by the user in the 'Ops Limits' tab
  - O&M base restrictions (i.e. number of portside berths)
  - Weather dataset to use
  - Currency and outputs units for monetary values
- The other input tabs are explained in detail in the documentation

How to add a fault category?

ID	Fault category	Example	Consequences	Knock on effect	Effect on power capture	Power loss	Remote Indication	External visual indication	Relevance	Basis of probability	Prob of fail (/year)	Prob not fail (/year)	Action required	Vessel required	Time required offshore (hours)	Ops limits type	Time required onshore (days)	Parts cost	Other costs	Technicians required
1	Major fault - Platform	TBC	Harbour repair	TBC	Full shutdown	0.0333	TBC	TBC	Platform	0.050	0.0488	0.9512	Retrieve platform	AHTS with Tug	3	1	5	250000	0	5
2	Large fault - Platform	TBC	Offshore repair	TBC	Full shutdown	0.0333	TBC	TBC	Platform	0.150	0.1393	0.8607	Onsite repair	CTV	20	3	0	30000	0	2
3	Large fault - WTG	TBC	Offshore repair	TBC	Full WTG shutdown	0.0333	TBC	TBC	WTG	0.350	0.2953	0.7047	Onsite repair	CTV	20	3	0	30000	0	2
4	Large fault - WEC	TBC	Offshore repair	TBC	Full WEC shutdown	0.0333	TBC	TBC	WEC	0.700	0.5034	0.4966	Onsite repair	CTV	20	3	0	30000	0	2
5	Medium fault - Platform	TBC	Replace module	TBC	Full shutdown	0.0333	TBC	TBC	Platform	0.500	0.3935	0.6065	Onsite repair	CTV	5	3	0	12500	0	2
6	Medium fault - WTG	TBC	Replace module	TBC	Full WTG shutdown	0.0333	TBC	TBC	WTG	1.000	0.6321	0.3679	Onsite repair	CTV	5	3	0	12500	0	2
7	Medium fault - WEC	TBC	Replace module	TBC	Full WEC shutdown	0.0333	TBC	TBC	WEC	2.000	0.8647	0.1353	Onsite repair	CTV	5	3	0	12500	0	2
8	Minor fault - Platform	TBC	Minor repair	TBC	Full shutdown	0.0333	TBC	TBC	Platform	0.550	0.4231	0.5769	Onsite repair	CTV	1	3	0	2000	0	2
9	Minor fault - WTG	TBC	Minor repair	TBC	Full WTG shutdown	0.0333	TBC	TBC	WTG	1.100	0.6671	0.3329	Onsite repair	CTV	1	3	0	2000	0	2
#	Minor fault - WEC	TBC	Minor repair	TBC	Full WEC shutdown	0.0333	TBC	TBC	WEC	2.250	0.8946	0.1054	Onsite repair	CTV	1	3	0	2000	0	2
#	Remote reset - Platform	TBC	Downtime	TBC	Full shutdown	0.0333	TBC	TBC	Platform	1.500	0.7769	0.2231	Remote reset		1	0	0	0	500	0
#	Remote reset - WTG	TBC	Downtime	TBC	Full WTG shutdown	0.0333	TBC	TBC	WTG	3.000	0.9502	0.0498	Remote reset		1	0	0	0	500	0
#	Remote reset - WEC	TBC	Downtime	TBC	Full WEC shutdown	0.0333	TBC	TBC	WEC	6.000	0.9975	0.0025	Remote reset		1	0	0	0	500	0

- The fault categories table is the main table in the 'Inputs' tab
- Each row represents one fault category, the user needs to specify failure rate and any repair parameters
- To add a fault category, make sure you only move this table down (i.e. select the cells of one row in the table and insert a new row) – DO NOT INSERT AN ENTIRE NEW ROW (this will move the universal inputs table as well as make it unreadable)
    - VBA is very much dependent on cell referencing! So be careful!
- The numbers of the fault categories are their IDs, so make sure they go from 1 to X.
- The ID colours are also important too as they determine priority of repair!
- The repair parameters are 'per instance' - you could use a Failure Modes and Effects Analysis (FMEA) to help you define these fault categories

How to add a scheduled maintenance category?

	Relevance	Tasks	Carry out every... (years)	Staggered?	Time of year	Action required	Vessel required	Time required offshore (hours)	Ops limits type	Time required onshore (days)	Parts cost (€)	Other costs (€)	Inspection costs (€)	Technicians required
1 Routine service	Platform	Inspect all	1	N/A	Summer	Onsite maintenance	CTV	48	3	0	10000	0	0	2
2 Intermediate survey	Platform	Inspect all	4	N/A	Summer	Onsite maintenance	CTV	8	3	0	0	0	30000	2
3 Major components refit	Platform	Major refit	7	No	Winter	Retrieve platform	AHTS with Tug	3	1	30	600000	0	20000	8

- The scheduled maintenance categories are also in the 'Inputs' tab, below the fault categories
- You need to specify the frequency in years
- You can define if you want the maintenance to be staggered between devices. For example, you might have a major maintenance campaign scheduled every five years but you don't want ALL your devices to undergo this in year 5, 10, 15 etc. as this may not be cost-effective. You can stagger the maintenance so some of the devices undergo the work in year 4, 9, 14 etc. for example. The code that controls this process is in the 'array object' in the VBA window (see next slide)
- Maintenance can be specified as onsite (i.e. offshore) or offsite (i.e. at the O&M base) – this is also true for the fault categories
- As with the fault categories, remember to add a row in the table, not an entire new row

How to access the source code?

CATAPULT Offshore Renewable Energy

- Alt + F11 to open the developer window, or add the Developer tab and click Visual Basic
- The code is object-oriented. The WES documentation is extensive and include flow charts of how the modules interact
- Some of the functions were modified for this OESA project so they might not be exactly as stated in the WES documentation – changes are noted in the updated user guide by ORE Catapult
- Remember cell notation in VBA is (row ID, column ID), not (column letter, row ID) like in Excel
    - So cell B5 would be noted as Cells(5, 2) in VBA

A note on the Weather tab:

You need to input these (columns names are important

These are model outputs, so ignore

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Year	Month	Day	Hour	Hs (m)	Tp (s)	u10 (kts)		Average V	WEC energy (	WEC revenue (€m/1hrs)		Average V	WTG ener	WTG revenue (€m/1hrs)	
1	12	1	0	1.25	6	12.5		4815	4815	0.0017334		40556.27	40556.27	0.004867	

How to model a floating wind farm?

CATAPULT Offshore Renewable Energy

- The tool is set up for a floating hybrid wave-wind energy device
- The 'Power' tab needs to contain the power curve for your turbine
  - Cell position is important, so check the code where needed
  - Set all the wave energy power matrix and tariff details (columns A to N) to zero
- Define your fault categories and scheduled maintenance categories in the Inputs tab, with Relevance set to either Platform or WTG
  - Anything but WEC is fine
- This should do the trick! You can tidy the inputs up but you'd need to get familiar with the VBA

R	S	T	U	V	W	X	Y	Z	AA
Assumed WTG tariff =		0.12	€/kWh						
Contract WTG length =		15	years						
WTG tariff after contract =		0.075	€/kWh						
				Wind Turbine Generator					
Rating of WTG =	8	MW		m/s to kts =	1.9438	Capacity factor adjustment =			95.0%
	Vestas								
Wind Speed (m/s)	V164-8MW		**U (kts)**	**U (m/s)**	**x1**	**y1**	**x2**	**y2**	**Power output (kW)**
0	0		2.5	1.29	1	0	2	0	0.00
1	0		7.5	3.86	3	0	4	105	85.63
2	0		12.5	6.43	6	1100	7	1850	1351.88
3	0		17.5	9.00	9	4000	10	5500	3804.25
4	105		22.5	11.58	11	7000	12	7850	7114.53
5	500		27.5	14.15	14	8000	15	8000	7600.00
6	1100		32.5	16.72	16	8000	17	8000	7600.00
7	1850		37.5	19.29	19	8000	20	8000	7600.00
8	2850		42.5	21.86	21	8000	22	8000	7600.00
9	4000		47.5	24.44	24	8000	25	8000	7600.00
10	5500		52.5	27.01	27	8000	28	8000	7600.00
11	7000		57.5	29.58	29	0	30	0	0.00
12	7850								
13	8000								
14	8000								
15	8000								
16	8000								

Limitations

- VBA is very clunky! I now prefer Python and would have made the original WES model in Python if I had known it back then
- Be careful with moving the inputs around, as lots of the code reads from specific cells
- Hourly resolution could be increased, but this adds to run speed
- Run speed is quite slow as it is a time-domain tool
- Can't use Excel when the program is running (very annoying!)

- Remember, the model is publicly available, fully open-source and comes with extensive documentation – so if you want to use the code as a guide for making your own O&M simulation tool in a more familiar programming language, then you are free to do so!
- Any bespoke functionality you want, or any limitations the model has, can be added/solved!
    - You just need someone in your team who knows VBA or can program
    - You could even adapt the tool to model bottom-fixed wind farms if you got familiar enough with the model and read the documentation

Contact details

- OESA O&M model developer at ORE Catapult: anthony.gray@ore.catapult.org.uk.
- OESA O&M model project manager at ORE Catapult: magnus.willett@ore.catapult.org.uk.
- Get in touch to access the model. We hope you find it useful for your analysis!

Contact us

Email us: info@ore.catapult.org.uk

Visit us: ore.catapult.org.uk

Engage with us:

GLASGOW | BLYTH | LEVENMOUTH | GRIMSBY | ABERDEEN | CORNWALL | LOWESTOFT | PEMBROKESHIRE | CHINA

EXCEEDENCE
MAKING RENEWABLES COMMERCIAL

EXCEEDENCE

Relevance of OPEX estimates in project modelling and uncertainty analysis

Annicka WÄNN

Head of Projects

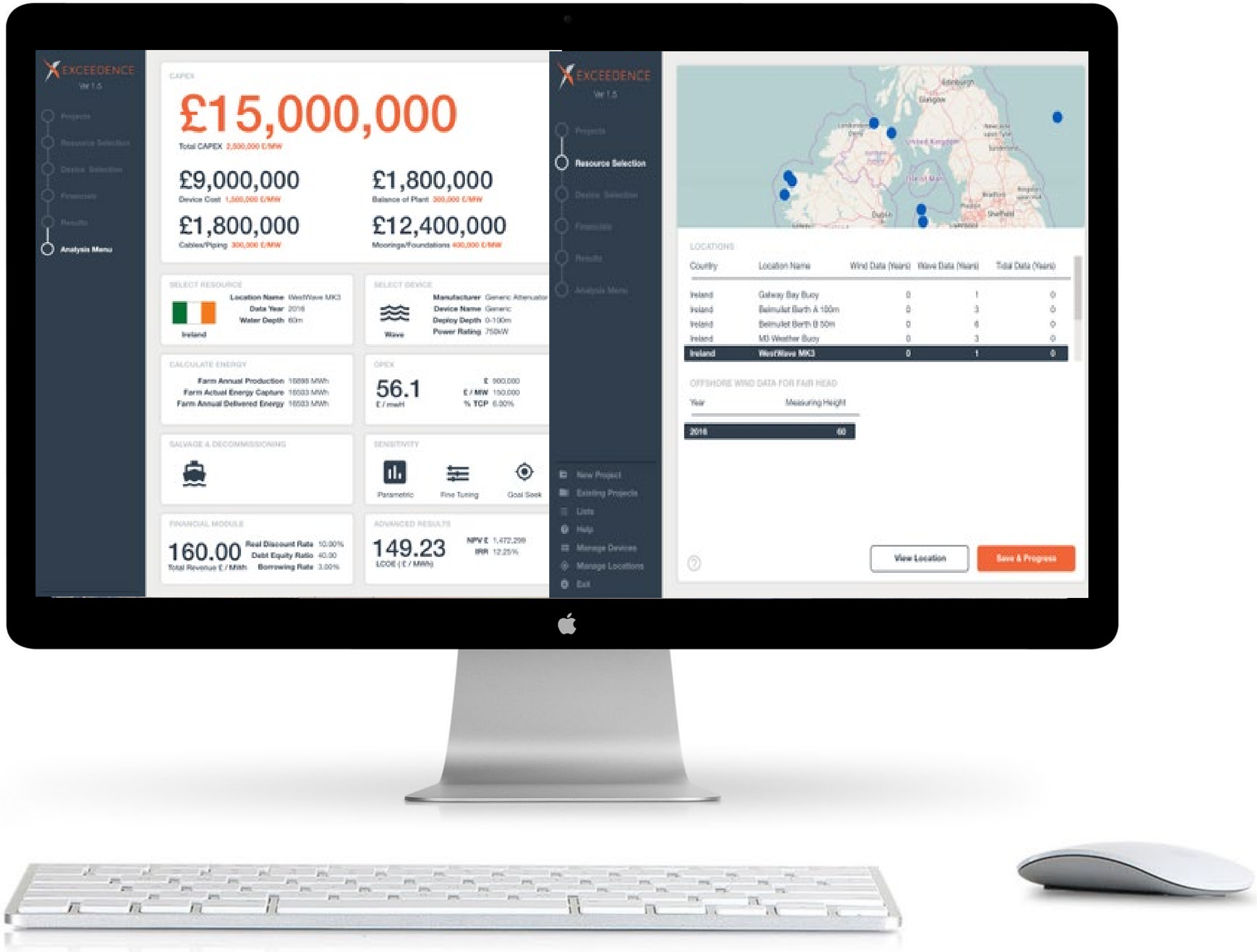
annicka.wann@exceedence.com

Interreg North-West Europe
EUROPEAN UNION
OPIN
European Regional Development Fund

THE Product

ExceedenceFINANCE

A Financial Digital Twin for clean energy : From bidding to building to operating



- A standardised, cloud-based, decision support tool for renewable energy projects.
- Streamlined model build time, allowing users to focus on analytics and adding value.
- Transparent and shareable across teams. Reduced burden for audit and version control.
- Identify and Reduce Risk: Optimise projects against technical and financial KPIs.

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MAKING RENEWABLES COMMERCIAL

HOW WE ADD VALUE

Technology Innovation

Interreg North-West Europe Marine Energy Alliance
EUROPEAN UNION
European Regional Development Fund

- 4 Year Duration €6m Budget
- Software and consultancy to up to 40 SMEs
- Marine and Offshore TRL3-5

PROJECT PARTNERS

THE NETHERLANDS

DMEC Dutch Marine Energy Centre | MARIN | NAVINGO

IRELAND

EXCEEDENCE | MaREI Centre for Marine and Renewable Energy

UNITED KINGDOM

THE UNIVERSITY of EDINBURGH | EMEC THE EUROPEAN MARINE ENERGY CENTRE LTD

FRANCE

CENTRALE NANTES | INNOSEA

BENSON Engineering Swiss Precision in an Irish Setting

mocean energy

Resolute Marine Energy

Pure Marine

TIDAL FLYER LOW FLOW TIDAL ENERGY

Dublin Offshore

centipod Wave Energy

Dolfines

EEL ENERGY

WITT ENERGY

GKINETIC

WAVECO

HelioRec THE FLOATING SOLAR POWER PLANT

WAVERAM OCEAN POWER TECHNOLOGY

EXCEEDENCE

OPIN OPEX MasterClass Results

Analytics

Net Present Value (€)

€2,962,549.37

Capacity Factor

47.54 %

Net Present Value per MW (€)
€74,063.73

Equivalent Annual Charge
€347,979.93

Internal Rate of Return
10.26%

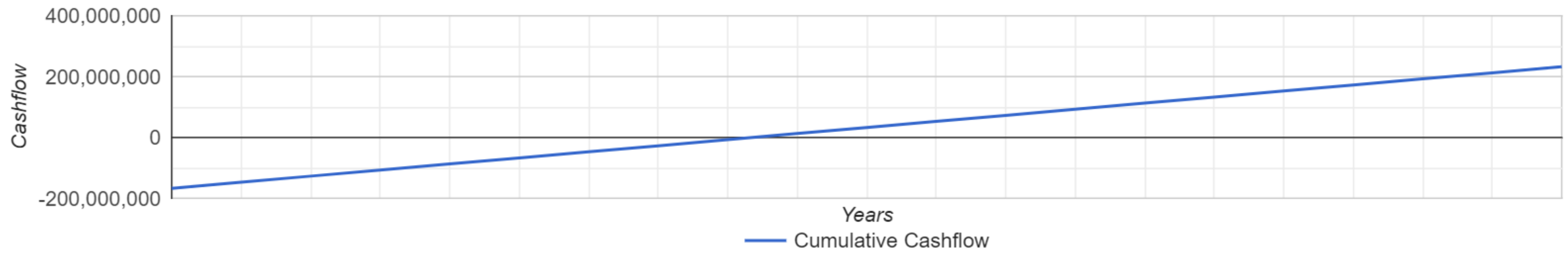
Simple Payback Period (Years)
9.00

Discounted Payback Period (Years)
20.00

Levelised Cost of Electricity (€/MWH)
€147.91

Cash Flow

Cashflow Chart | Cashflow Spreadsheet



LCOE and its influences

LCOE Formula

$$LCOE = \frac{CAPEX + \sum_{t=1}^{n} \frac{OPEX_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{AEP_t}{(1+r)^t}}$$

Where:

$LCOE$ = levelised cost of energy

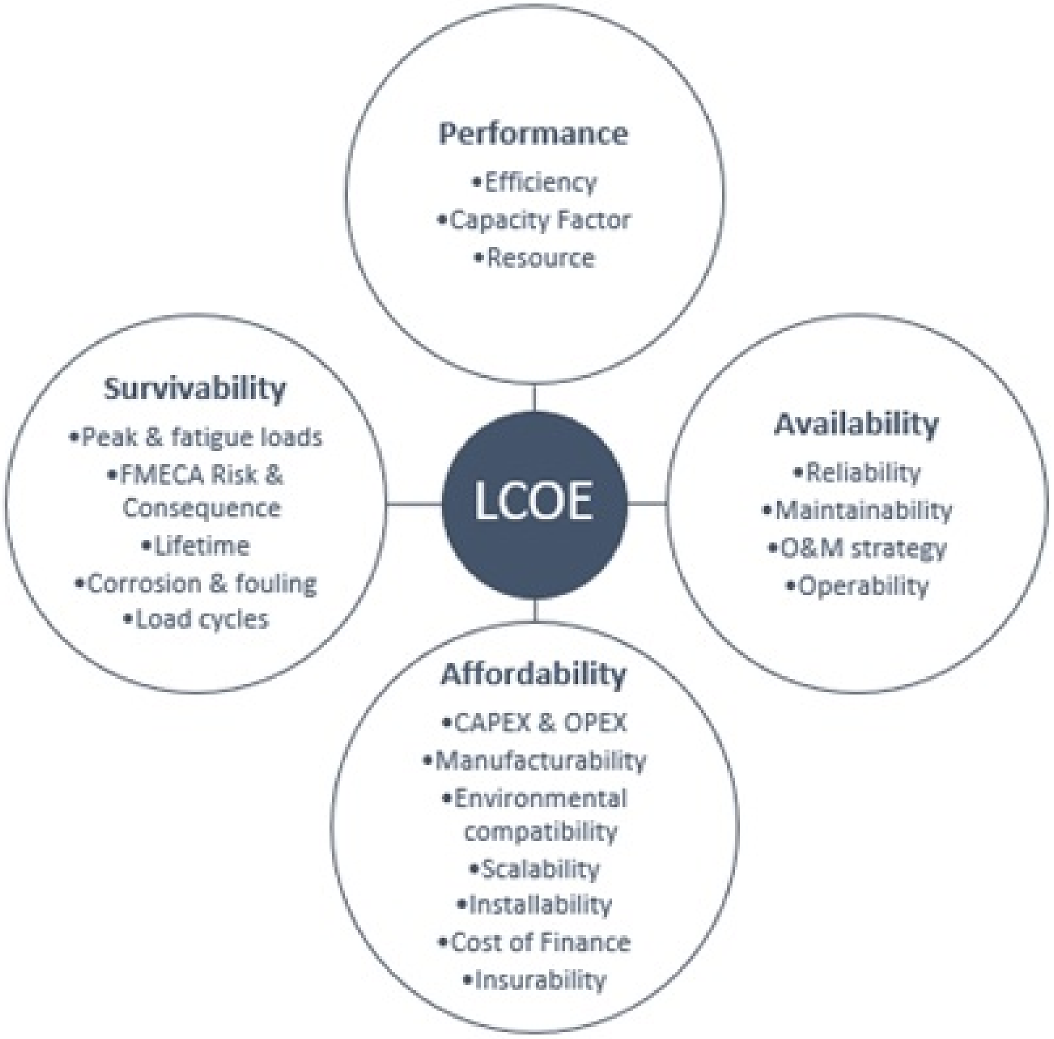
$CAPEX$ = capital expenditures

$OPEX_t$ = operational expenditures

AEP_t = annual electricity production

r = discount rate, and

n = economic life of the system



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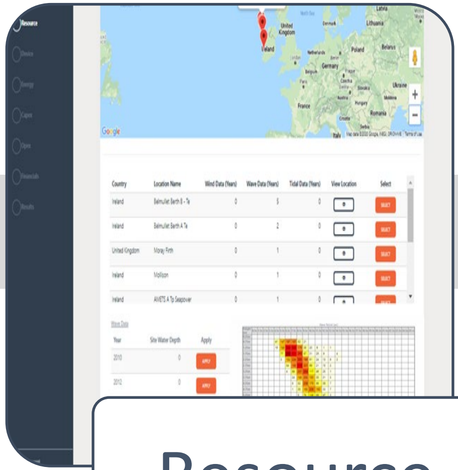
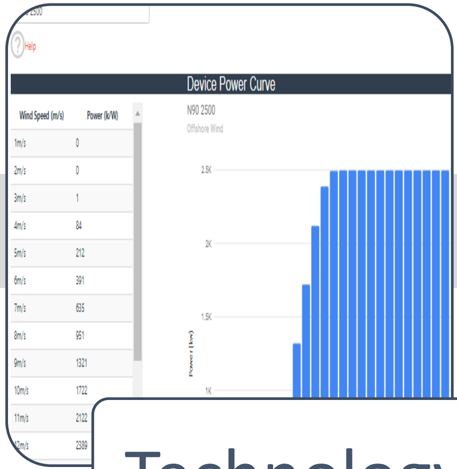
SOLUTION

We have taken a complex techno-financial process & productised it on a Cloud platform

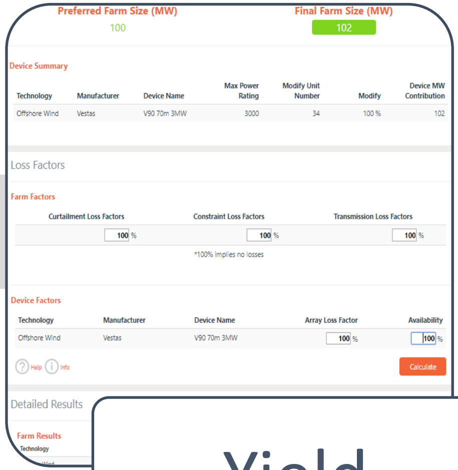
Technical



Resource

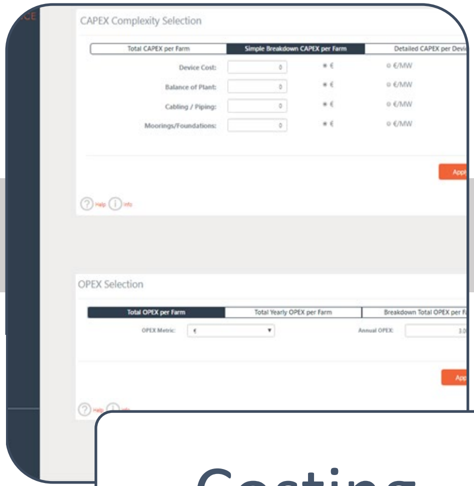


Technology



Yield

Financial



Costing

Revenue & Finance

Results & Analysis

Microsoft Azure

Example Project Data inputs

Lifetime	20 years
Farm size	40MW
Turbine size	5MW
CAPEX	4,180,000 €/MW
OPEX	125,000 €/MW
Discount Rate	10%
Revenue	150 €/MWh

Costings sourced: BVGassociates, 2019. *Ocean Power Innovation Network value chain study: Summary Report*, a report for Scottish Enterprise.

Exceedence Finance

exfinqa.azurewebsites.net/Project/Project?create=1

Apps | Gmail | YouTube | Maps | How to Pass PMP E... | Offshore Gen | Exceedence | Private

EXCEEDENCE

- Project
- Resource
- Device
- Energy
- Capex
- Opex
- Financials
- Results
- Analytics

Create a Project

Project Name	OPIN OPEX MasterClass
Farm Technology	Floating Offshore Wind
Currency	Euro
Preferred Farm Size (MW)	40
Operating Years	20
Development Years	1
Decommissioning Years	0
Comments	Please enter a comment...

Cancel | Continue

Help

My Account
New Project
Existing Projects
Manage Devices
Manage Locations
Sign Out

Exceedence Finance

exfinqa.azurewebsites.net/Project/ResourceModule?selectedId=33&source=SHOW_RESOURCE_DATA&projectid=473

Apps | Gmail | YouTube | Maps | How to Pass PMP E... | Offshore Gen | Exceedence | Private

EXCEEDENCE

- Project
- Resource
- Device
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- Opex
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- Results
- Analytics

Project: OPIN OPEX MasterClass

Choose a column: Location Name | Search...

Location Name	Country	Years of available Wind Data	Years of available Tidal Data	Years of available Wave Data	View Location	Select
WaveHub	United Kingdom	2	1	3		SELECT
Norfolk	United Kingdom	2	0	0		SELECT
Cork	Ireland	1	2	0		SELECT
Holyhead Deep	United Kingdom	11	0	2		SELECT

FloatingOffshoreWind Data

Location Name	Year	Measured Height (m)	Apply
WaveHub	2012	10	Apply
WaveHub	2017	70	Apply

My Account
New Project
Existing Projects
Manage Devices
Manage Locations

https://exfinqa.azurewebsites.net/Project/ResourceModule?selectedId=216&source=SUBMIT_RESOURCE_DATA&projectid=473

Exceedence Finance

exfinqa.azurewebsites.net/Project/DeviceModule?deviceId=0&source=FIRST_CALL&projectId=473

Apps Gmail YouTube Maps How to Pass PMP E... Offshore Gen Exceedence Private

EXCEEDENCE

- Project
- Resource
- Device
- Energy
- Capex
- Opex
- Financials
- Results
- Analytics

Available Devices

Project: OPIN OPEX MasterClass

Choose a column: Device Name

Search...

Device Name	Technology	Classification	Manufacturer	Max Power Rating	Depth/Height	View Device	Select Device
G128 5.0MW.	Fixed Offshore Wind	Horizontal Axis (HAWT)	Gamesa	5000 kW	95m		☑
SWT-2.3-93.	Fixed Offshore Wind	Horizontal Axis (HAWT)	Siemens	2300 kW	10m		☐
XD115.	Fixed Offshore Wind	Horizontal Axis (HAWT)	DARWIND	5000 kW	90m		☐
Test.	Floating Offshore Wind	HAWT	Test	3000 kW	90m		☐

Help Info

Apply

My Account
New Project
Existing Projects
Manage Devices
Manage Locations
Sign Out

Exceedence Finance

exfinqa.azurewebsites.net/Project/EnergyModule?projectid=473

Apps Gmail YouTube Maps How to Pass PMP E... Offshore Gen Exceedence Private

EXCEEDENCE

Project
Resource
Device
Energy
Capex
Opex
Financials
Results
Analytics

Farm Size

Project: OPIN OPEX MasterClass

Preferred Farm Size (MW)

40

Final Farm Size (MW)

0

Device Summary

Technology	Manufacturer	Device Name	Max Power	No. Units	Contribution	Contribution
Fixed Offshore Wind	Gamesa	G128 5.0MW	5000	8	100 %	40 MW

Loss Factors

Device Factors

Technology	Manufacturer	Device Name	Availability	Array Loss	Inter Array Loss
Fixed Offshore Wind	Gamesa	G128 5.0MW	100 %	0 %	0 %

*0% loss implies no losses

Height/Depth Recalculation

Farm Factors

My Account
New Project
Existing Projects
Manage Devices
Manage Locations
Sign Out

Height/Depth Recalculation

Device	Hub Depth/Height	Measured Depth/Height
Gamesa G128 5.0MW	95	70

Please Select One:

No Recalculation	Weibull Distribution	Power Law	Power Law Exponent	Log Law	Surface Roughness Length
○	●	○	0	○	0

Farm Factors

Curtailment Loss Factors	Constraint Loss Factors	Transmission Loss Factors	Grid Connection Limit
0 %	0 %	0 %	40 MW

*0% loss implies no losses

Help Info

Calculate

Detailed Results

Farm Results

Technology	Manufacturer	Device Name	Capacity Factor

Farm Factors

Curtailment Loss Factors	Constraint Loss Factors	Transmission Loss Factors	Grid Connection Limit
0 %	0 %	0 %	40 MW

*0% loss implies no losses

Help Info

Calculate

Detailed Results

Farm Results

Technology	Manufacturer	Device Name	Capacity Factor
Fixed Offshore Wind	Gamesa	G128 5.0MW	47.54 %

Gross Annual Energy Production (MWh)
166,581

Net Annual Energy Capture (MWh)
166,581

Annual Delivered Energy (MWh)
166,581

Continue

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CAPEX Inputs

Project: OPIN OPEX MasterClass

Total CAPEX	Simple Breakdown CAPEX	Detailed CAPEX

Description	Metric	Currency	Cost
Total Capex	Cost per MW	Euro	4180000

Capex Spend Profile

Apply

Help Info **Note:** Only complete one tab

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OPEX Selection

Project: OPIN OPEX MasterClass

Total OPEX per Farm	Total Yearly OPEX per Farm	Breakdown Total OPEX per Farm

OPEX Metric: €/MW

Annual OPEX: 125000

Apply

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Revenue - Basic Inputs

Project: OPIN OPEX MasterClass

Revenue / Feed In Tariff: ◉ **Fixed** ○ **Variable** **€/MWh** 150

Revenue - Extra Inputs

Input Per Annum

Discounting and Inflation Options

Indexation and Escalation Factors

Debt / Equity

Taxation

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Discounting and Inflation Options

- [ ] Do not apply discount or inflation to Cash Flow Sheet
- [ ] Undiscounted Cash Flows with Inflation included
- [x] Cash Flows (no Inflation) to Cash Flow Sheet
- [ ] Cash Flows in Nominal Terms to Cash Flow Sheet

Inflation Rate %:	0
Discount Rate %:	10
Inflation Rate %:	0
Nominal Discount Rate %:	0
Real Discount Rate %:	0

Indexation and Escalation Factors

Debt / Equity

Taxation

Complete

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OPIN OPEX MasterClass Results

Analytics

Net Present Value (€)

€2,962,549.37

Capacity Factor

47.54 %

Net Present Value per MW (€)

€74,063.73

Equivalent Annual Charge

€347,979.93

Internal Rate of Return

10.26%

Simple Payback Period (Years)

9.00

Discounted Payback Period (Years)

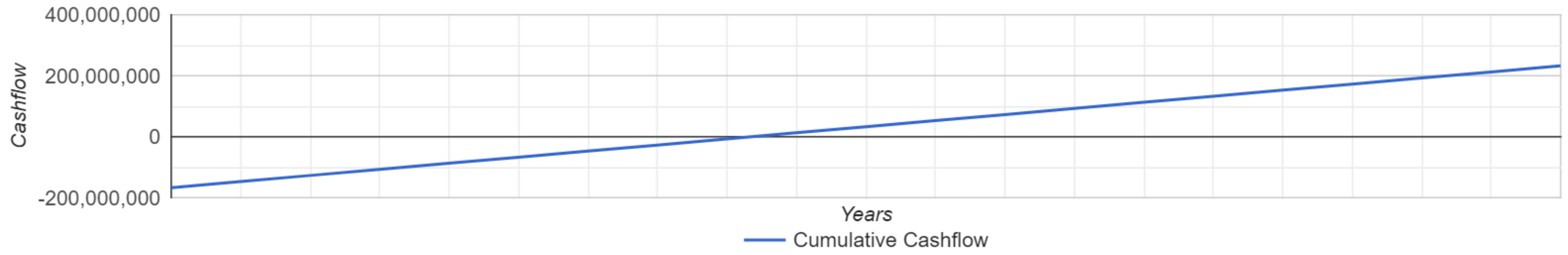
20.00

Levelised Cost of Electricity (€/MWH)

€147.91

Cash Flow

Cashflow Chart | Cashflow Spreadsheet



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OPIN OPEX MasterClass Results

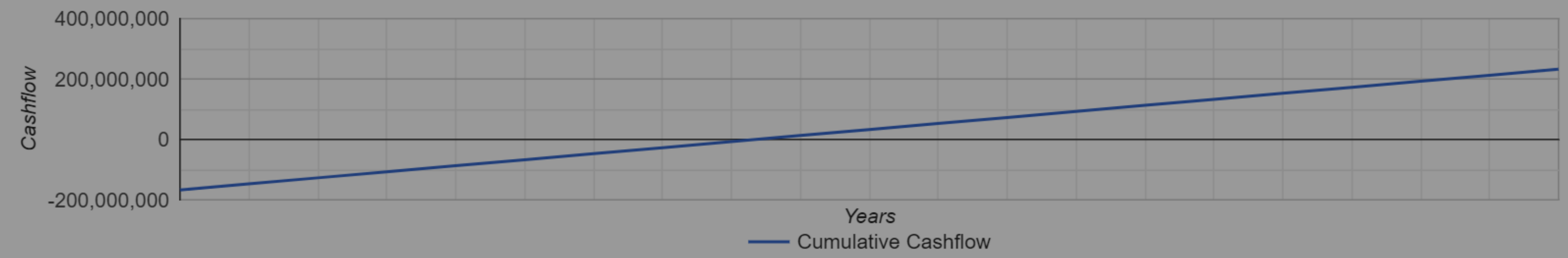
Analytics

Goal Seek | Fine Tuning | Tornado Chart

Simple Payback Period (Years)	Discounted Payback Period (Years)	Levelised Cost of Electricity (€/MWH)
9.00	20.00	€147.91

Cash Flow

Cashflow Chart | Cashflow Spreadsheet



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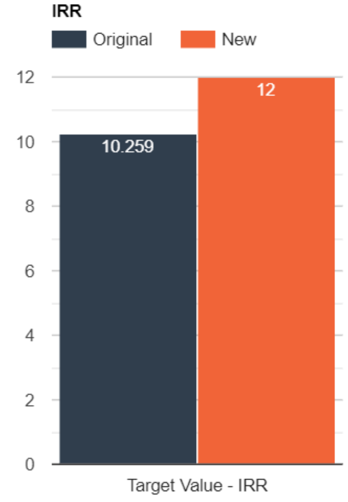
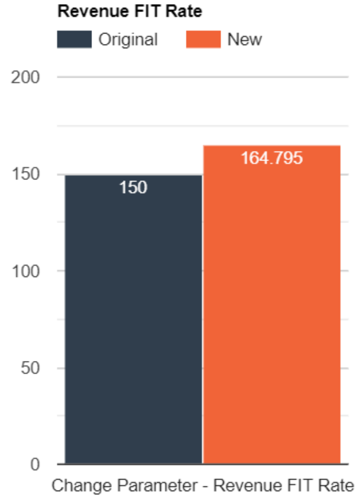
Project: OPIN OPEX MasterClass

Select Target	Target Value	Project Value
IRR	12	10.26%

Select a Change Parameter	Project Value
Energy	
Curtailment Loss Factor	0.00 %
Constraint Loss Factor	0.00 %
Transmission Loss Factor	0.00 %
Annual Delivered Energy	166,581.53 MWh
Device:G128 5.0MW	
No. of Units	8.00
Array Loss Factor	0.00 %
Availability Factor	100.00 %
Capacity Factor	47.54 %
Capex	
Opex	
Finance	
Revenue	
Revenue FIT Rate	150.00 (€)/MWh
Fixed Revenue	150.00 (€)/MWh
Discounting	
Real Discount Rate	10.00 %

Calculate





16.97% ▲ 9.86% ▲

Parameter	Project Value	New Value	Delta %
IRR	10.26	12	16.97% ▲
Revenue FIT Rate	150.00 (€)/MWh	164.79	9.86% ▲

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Project: OPIN OPEX MasterClass

Select Target	Target Value	Project Value
IRR	12	10.26%

Select a Change Parameter — **Project Value**

Energy

Parameter	Project Value
Curtailment Loss Factor	0.00 %
Constraint Loss Factor	0.00 %
Transmission Loss Factor	0.00 %
Annual Delivered Energy	166,581.53 MWh

Device:G128 5.0MW

Parameter	Project Value
No. of Units	8.00
Array Loss Factor	0.00 %
Availability Factor	100.00 %
Capacity Factor	47.54 %

Capex

Opex

Parameter	Project Value
Opex Yearly Average (selected)	5,000,000.00 (€)

Finance

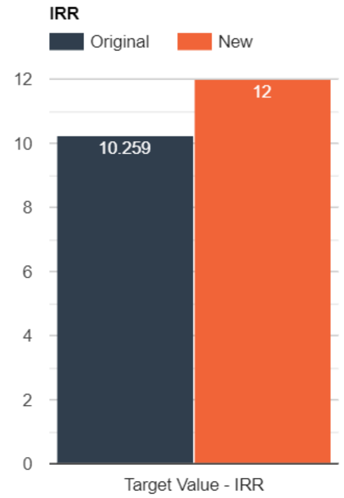
Revenue

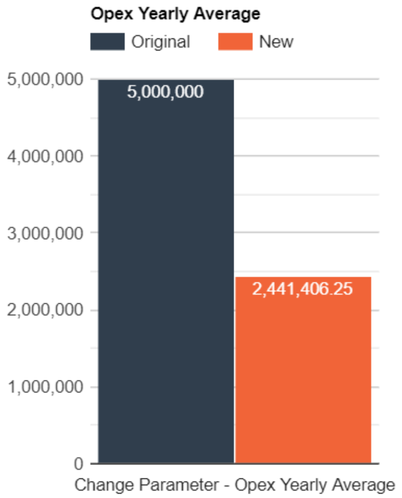
Parameter	Project Value
Revenue FIT Rate	150.00 (€)/MWh
Fixed Revenue	150.00 (€)/MWh

Discounting

Parameter	Project Value
Real Discount Rate	10.00 %

Calculate





16.97% ▲ -51.17% ▼

Parameter	Project Value	New Value	Delta %
IRR	10.26	12	16.97% ▲
Opex Yearly Average	5,000,000.00 (€)	2,441,406.25	-51.17% ▼

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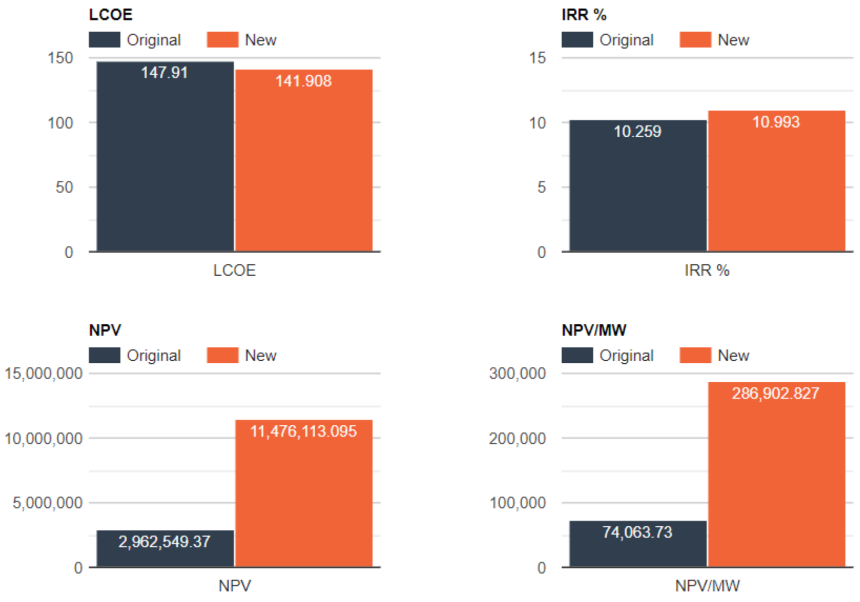
Fine Tuning

Project: OPIN OPEX MasterClass

Parameter	Project Value	New Value	+/- %
Energy			
Curtailment Loss Factor	0.00 %	0.00	
Constraint Loss Factor	0.00 %	0.00	
Transmission Loss Factor	0.00 %	0.00	
Annual Delivered Energy	166,581.53 MWh	166581.53	0.00
Device:G128 5.0MW			
No. of Units	8.00	8.00	0.00
Array Loss Factor	0.00 %	0.00	
Availability Factor	100.00 %	100.00	
Capacity Factor	47.54 %	47.54	
Capex			
Opex			
Opex Yearly Average	5,000,000.00 (€)	4000000.00	-20
Finance			



Parameter	Project Value	New Value	Delta
LCOE €/MWh	147.91	141.91	-4.06 % ▼
IRR %	10.26	10.99	7.16 % ▲
NPV €	2,962,549.37	11,476,113.10	287.37 % ▲
NPV/MW €	74,063.73	286,902.83	287.37 % ▲
LCOEIncTax €	147.91	141.91	-4.06 % ▼

Reset

Calculate

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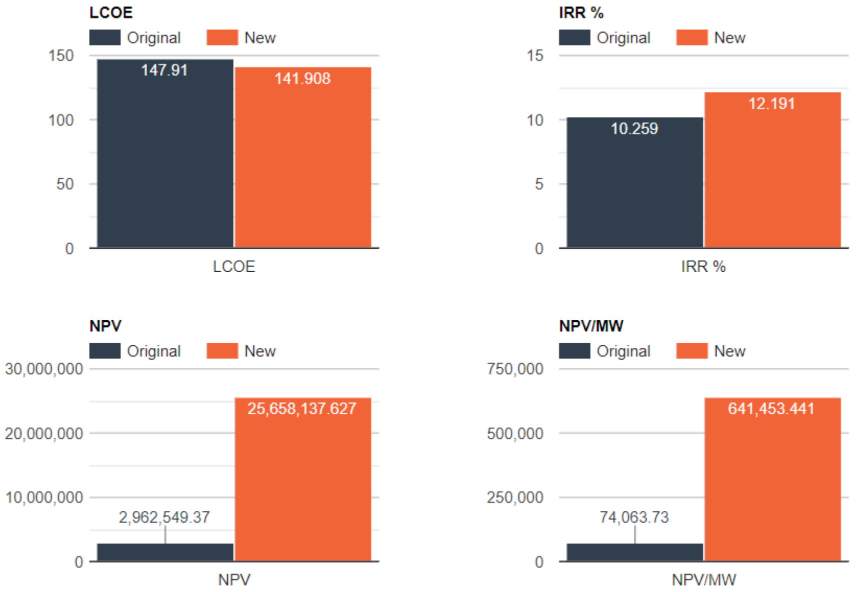
Fine Tuning

Project: OPIN OPEX MasterClass

Parameter	Project Value	New Value	+/- %
Energy			
Curtailment Loss Factor	0.00 %	0.00	
Constraint Loss Factor	0.00 %	0.00	
Transmission Loss Factor	0.00 %	0.00	
Annual Delivered Energy	166,581.53 MWh	166581.53	0.00
Device:G128 5.0MW			
No. of Units	8.00	8.00	0.00
Array Loss Factor	0.00 %	0.00	
Availability Factor	100.00 %	100.00	
Capacity Factor	47.54 %	47.54	
Capex			
Opex			
Opex Yearly Average	5,000,000.00 (€)	4000000.00	-20
Finance			
Revenue			
Revenue FIT Rate	150.00 (€)/MWh	160	6.67
Fixed Revenue	150.00 (€)/MWh	150.00	0.00
Discounting			
Real Discount Rate	10.00 %	10.00	



Parameter	Project Value	New Value	Delta
LCOE €/MWh	147.91	141.91	-4.06 % ▼
IRR %	10.26	12.19	18.84 % ▲
NPV €	2,962,549.37	25,658,137.63	766.08 % ▲
NPV/MW €	74,063.73	641,453.44	766.08 % ▲
LCOEIncTax €	147.91	141.91	-4.06 % ▼

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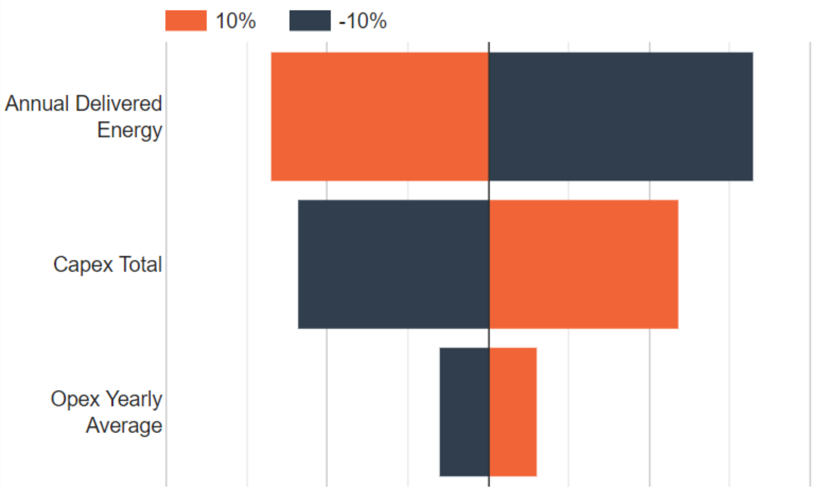
Tornado Chart

Project: OPIN OPEX MasterClass

LCOE	+/- %
147.91	10

Select a Change Parameter	Project Value
Energy	−
☐ Curtailment Loss Factor	0.00 %
☐ Constraint Loss Factor	0.00 %
☐ Transmission Loss Factor	0.00 %
☑ Annual Delivered Energy	166,581.53 MWh
Device:G128 5.0MW	
☐ No. of Units	8.00
☐ Array Loss Factor	0.00 %
☐ Availability Factor	100.00 %
☐ Capacity Factor	47.54 %
Capex	−
☑ Capex Total	167,200,000.00 (€)
Opex	−
☑ Opex Yearly Average	5,000,000.00 (€)
Finance	+

Reset Calculate



LCOE **147.91**

Parameter Change	Output	10%	-10%	Delta
Annual Delivered Energy	LCOE	134.46	164.35	-29.88
Opex Yearly Average	LCOE	150.91	144.91	6.00
Capex Total	LCOE	159.70	136.12	23.58

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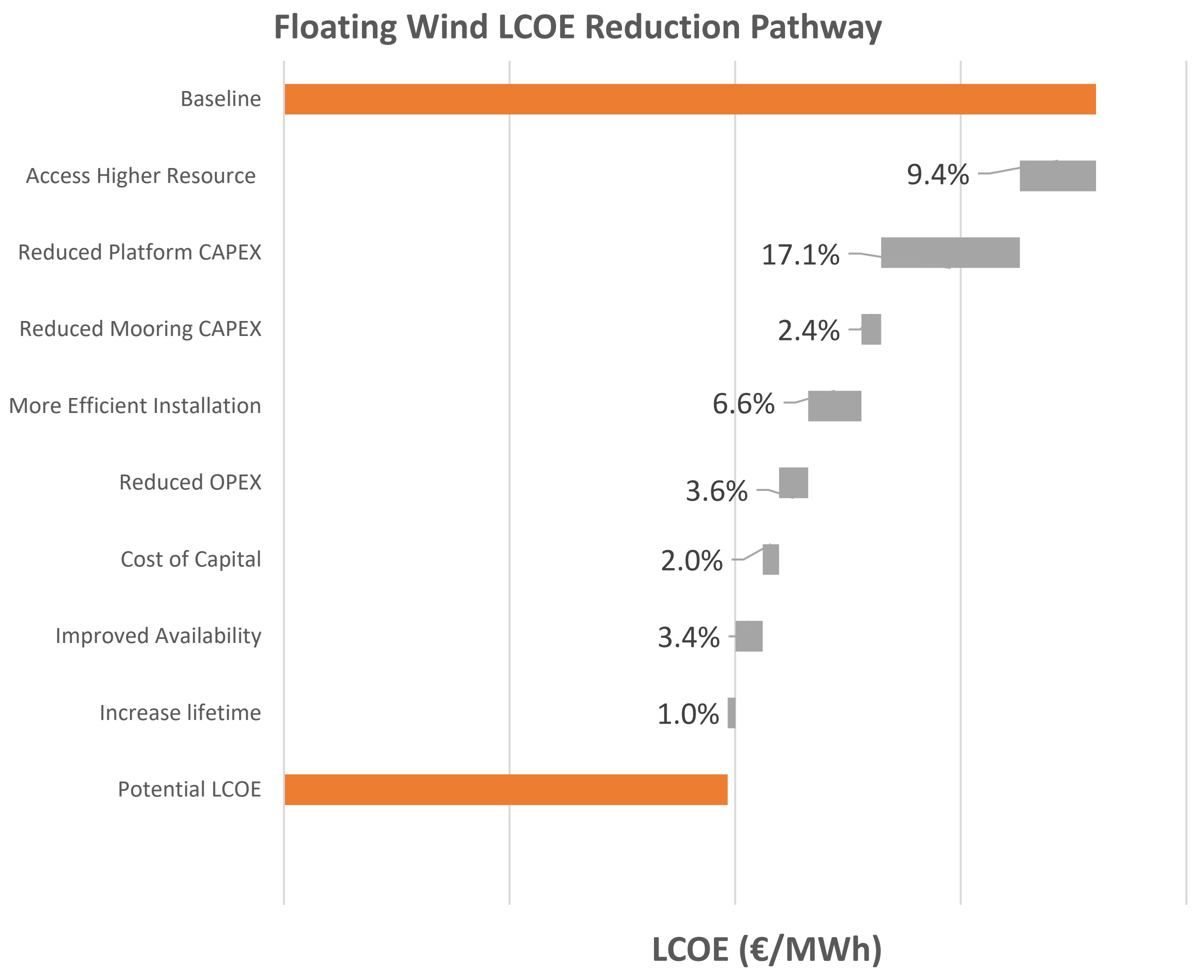
Technology Innovation

Exceedence Finance can

Quantify

Cost Impact

of Technology Innovations



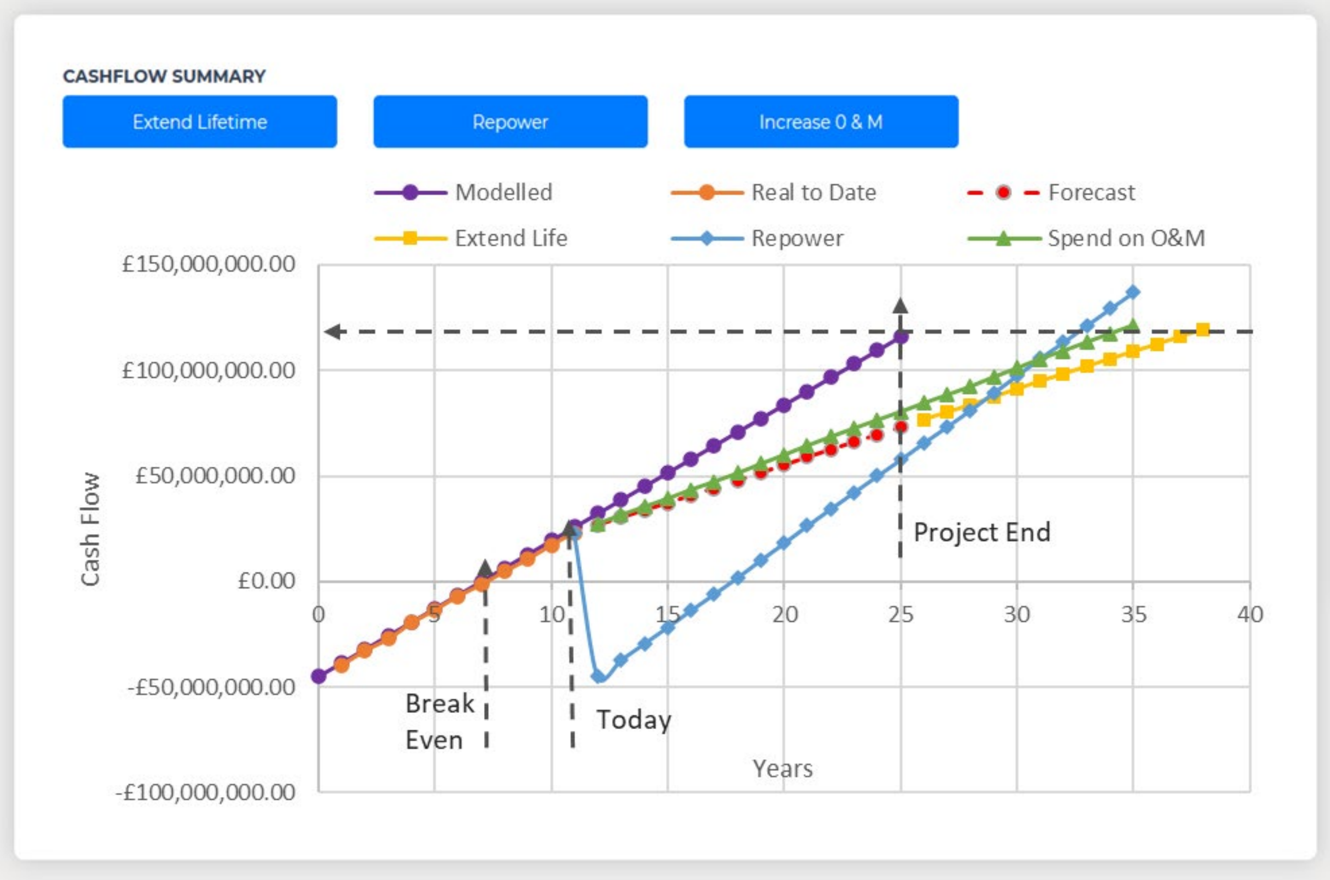
Operational Wind Farms

Comparison Tool can

identify and correct

€30m-€40m

loss in a small project



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E X C E E D E N C E

A Financial Digital Twin for Renewable Energy Projects

Annicka WÄNN
Head of Projects

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Q&A

Please post your questions in the Q&A.