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Review on floating offshore wind farm design: identification of the interactions between subsystems

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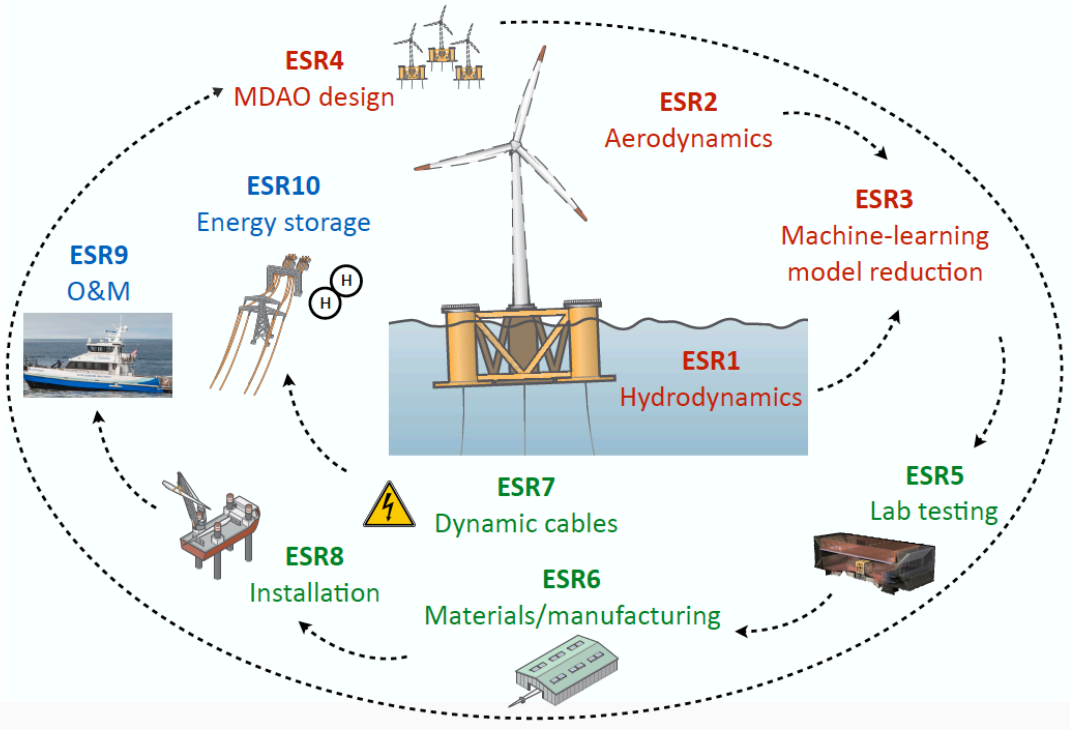
STEP WIND

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 860737.

STEP4WIND

- H2020 Marie-Curie Innovative Training Network
- Industrial Doctorate programme

Modified from https://euraxess.ec.europa.eu/worldwide/australia-nz/results-msca-itn-call-2020-published



From STEP4WIND: Bridging the gap between academic research and industrial development of floating offshore wind farms Viré, FOWT 2020, Marseille

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Multidisciplinary design analysis and optimisation for floating wind farms

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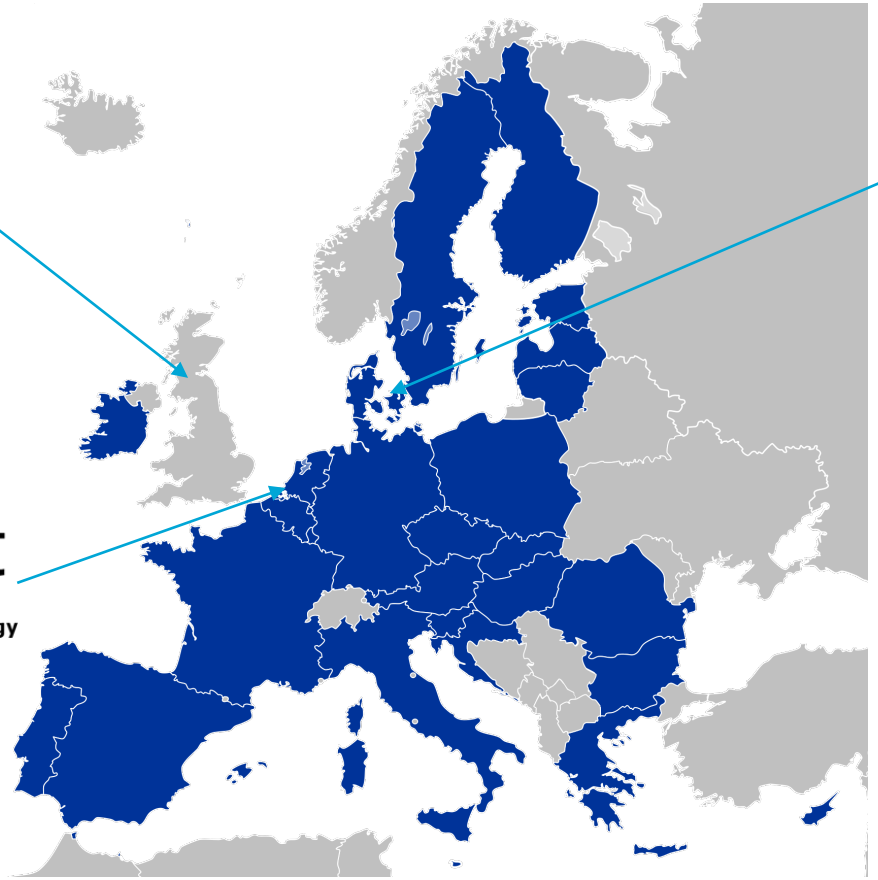

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STEP4WIND

Review on floating offshore wind farm design:
identification of the interactions between subsystems

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Review on floating offshore wind farm design: identification of the interactions between subsystems

- Motivation for this research
- Methodology
- Interactions

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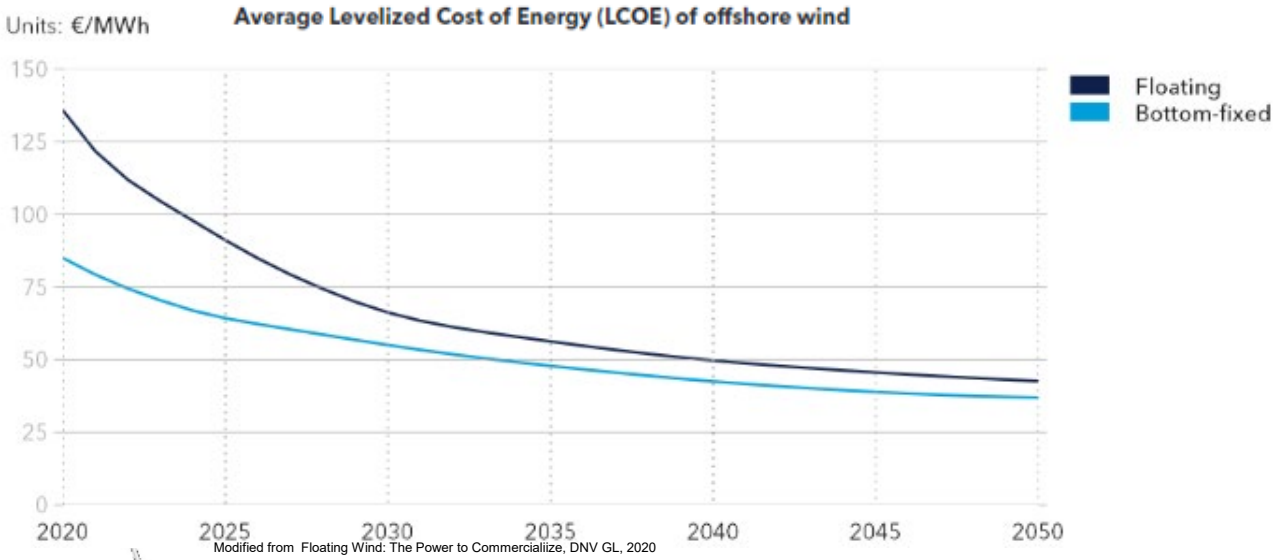
Drivers for floating wind

Floating wind allows the exploitation of deep waters

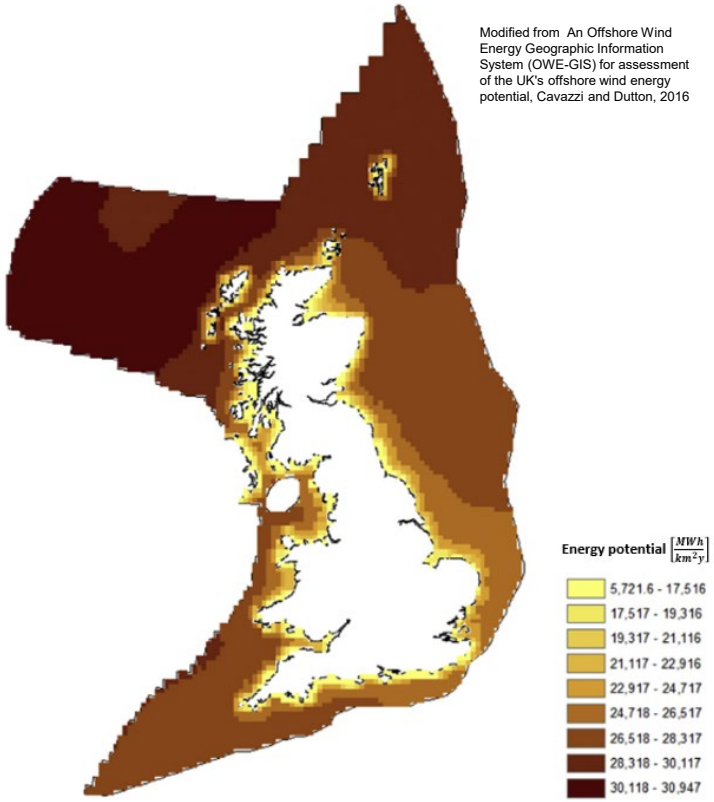
- New markets
- More abundant resource
- Lower environmental and visual impact

Forecasts foresee a significant increase of the installed capacity, fostered by a considerable reduction of LCOE

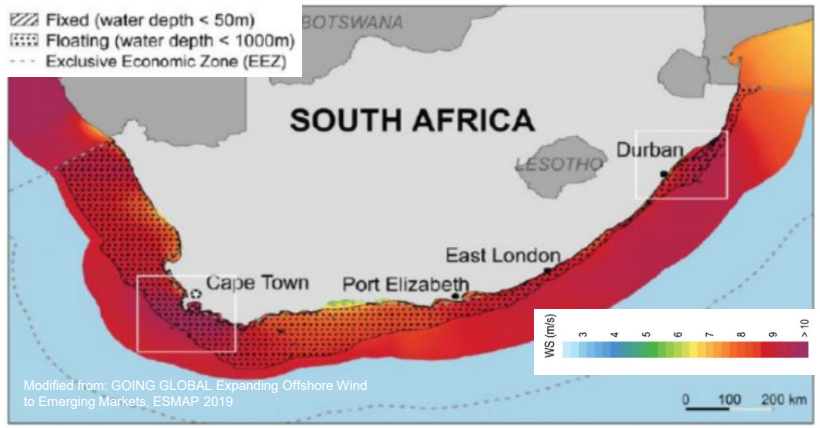
From pilot scale wind farms to larger, commercial-scale plants



Modified from Floating Wind: The Power to Commercialiize, DNV GL, 2020



Modified from An Offshore Wind Energy Geographic Information System (OWE-GIS) for assessment of the UK's offshore wind energy potential, Cavazzi and Dutton, 2016



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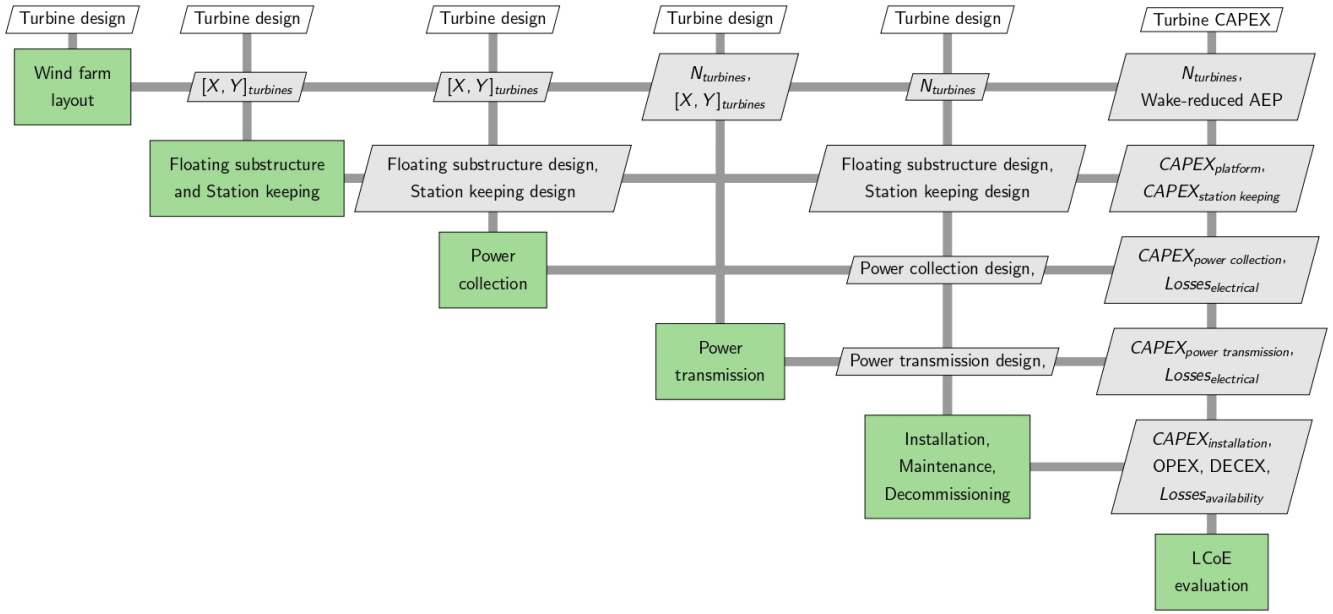
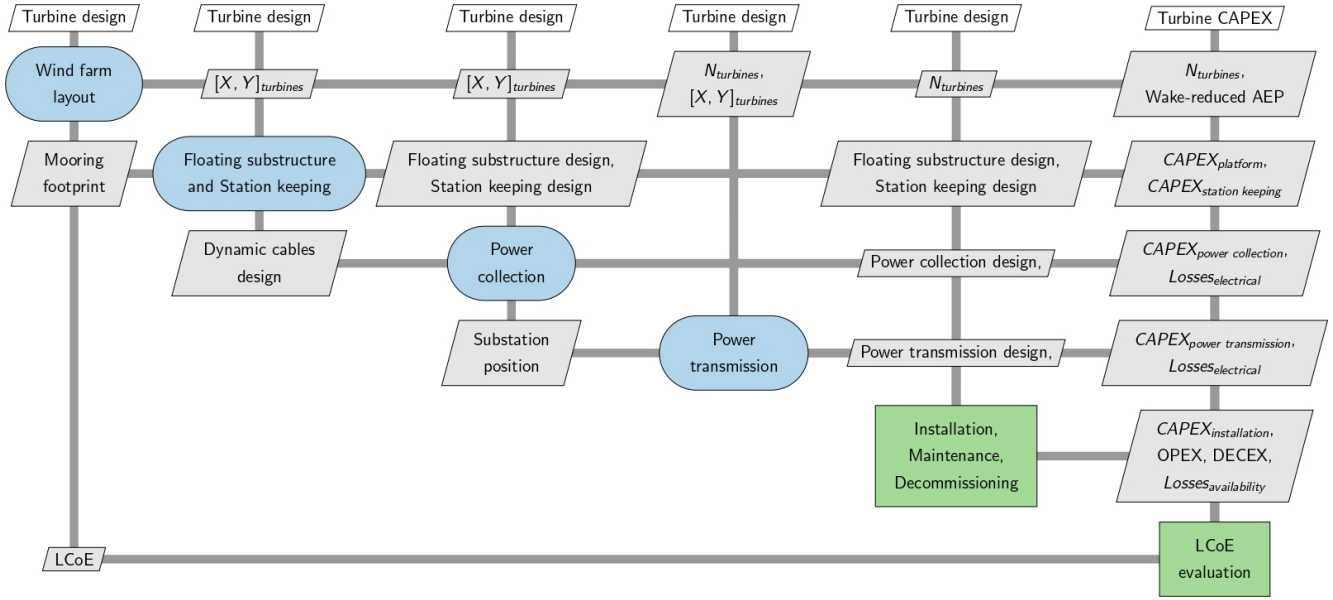
Systems engineering approach

- Current design processes of offshore wind farms follow a sequential, partitioned approach
- Different offices or companies take the ownership of a subsection of the design process
- Overlooks the interactions between different subsystems



- There is evidence that a more holistic, systems engineering approach could be beneficial to offshore wind
- This could be even more relevant for floating wind systems



Objective of the review

Where do these interactions occur?

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Agenda

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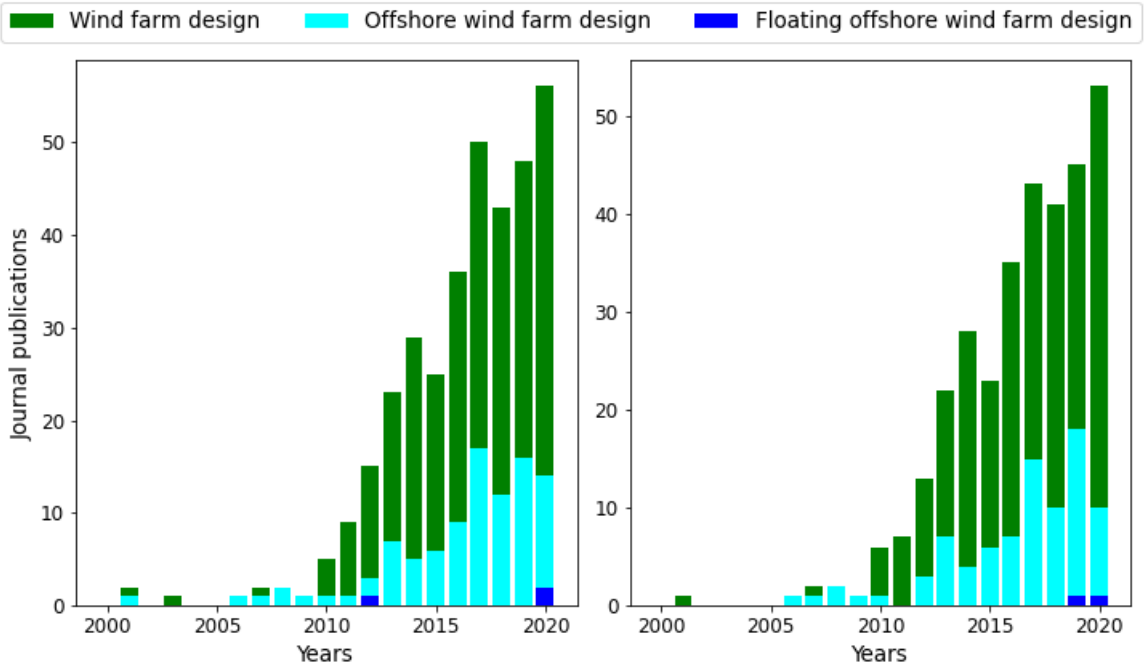
Research trends

- Growing interest in wind farm design
- A few works dealing with the design of floating wind farms
- Focus on specific aspects (e.g. shared moorings and farm control)
- Most of the research on floating wind focuses on single subsystems and procedures
- In line with the sequential, partitioned approach applied to design offshore wind systems.



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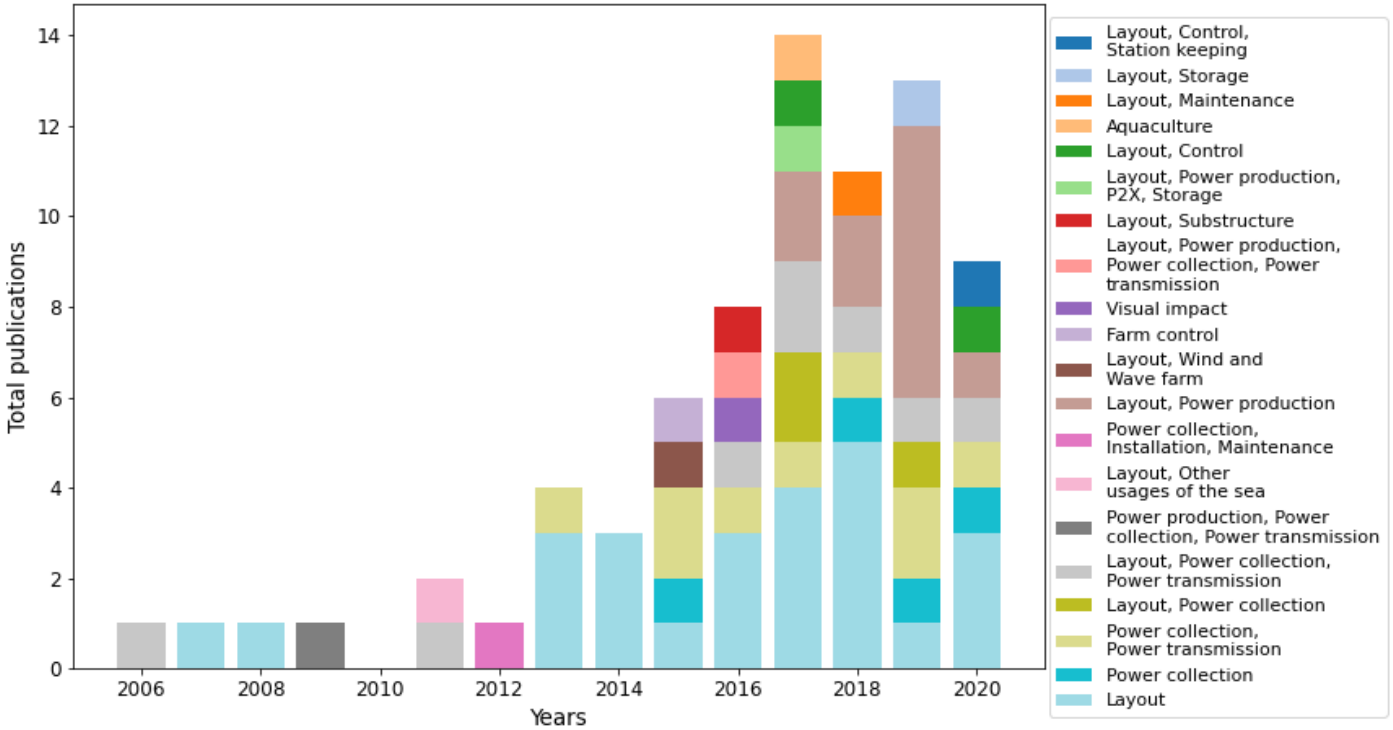
Research trends

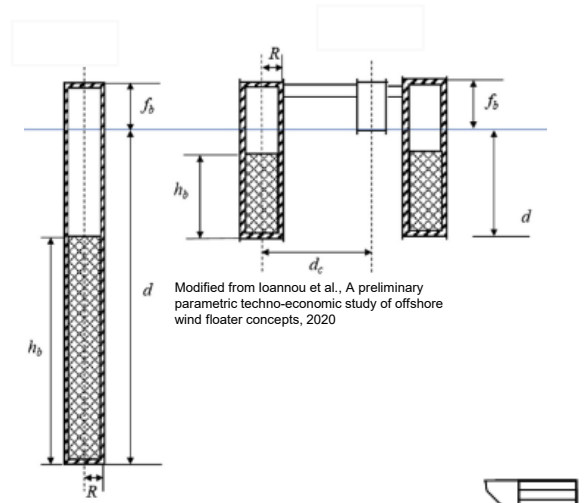
Lack of research works focusing on floating wind farm design

There is a wider literature dealing with bottom-founded wind farm design

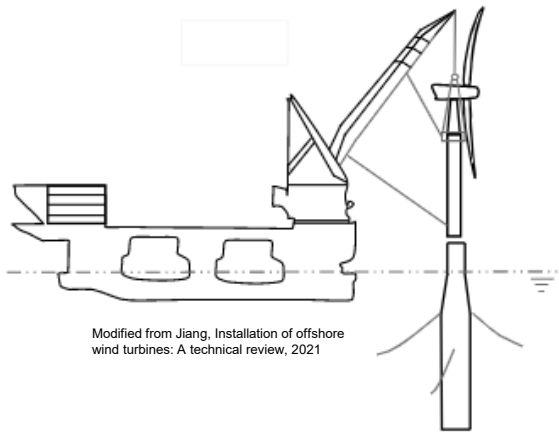
Some interactions will also be of interest for floating wind



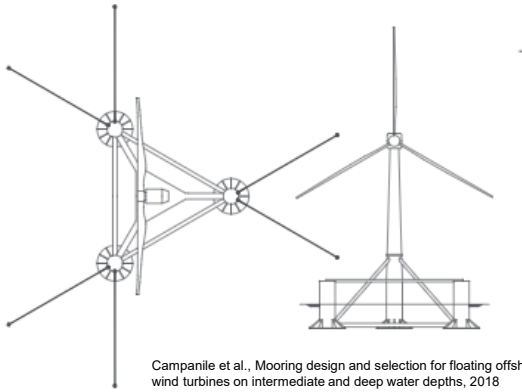
Information can also be collected from the subsystem-specific literature



Modified from Ioannou et al., A preliminary parametric techno-economic study of offshore wind floater concepts, 2020



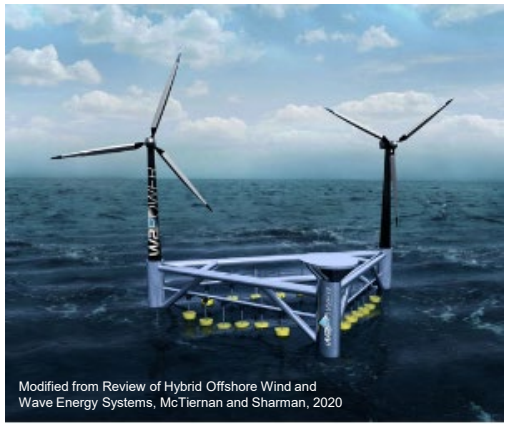
Modified from Jiang, Installation of offshore wind turbines: A technical review, 2021

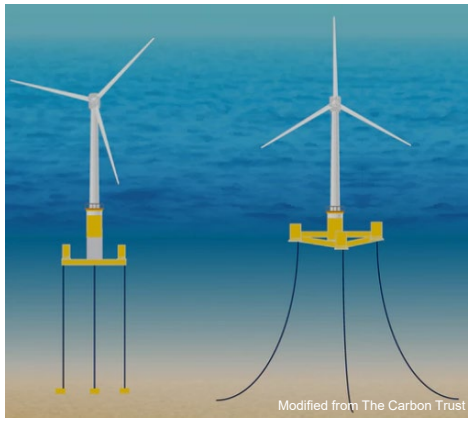


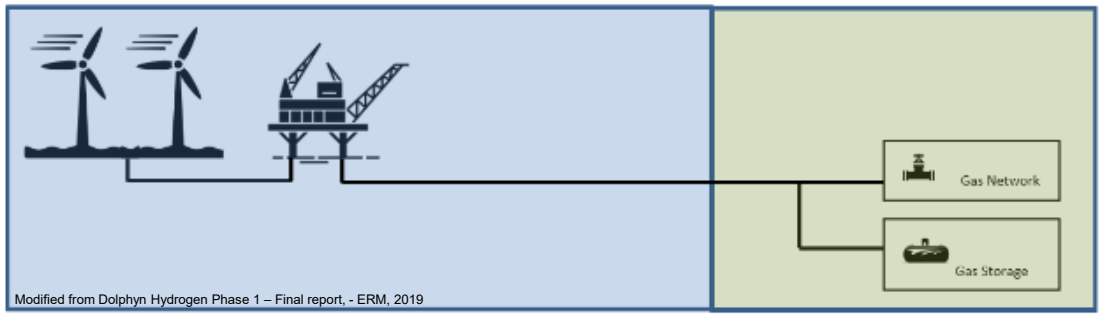
Campanile et al., Mooring design and selection for floating offshore wind turbines on intermediate and deep water depths, 2018

Concepts in floating wind farms

Category	Concepts
Layout definition	
Power production	HAWT, VAWT, Hybrid wind-wave converters, Co-located wind and wave farms
Floating Substructure	Semi-submersible, Barge, Tension-leg platform, Spar
Station keeping	Moorings: Catenary, Taut Anchor: Drag embedment, Vertical-load, Driven pile, Suction pile, Gravity
Power-to-X	Onshore, Offshore centralised, Offshore decentralised
Storage	Onshore, Offshore centralised, Offshore decentralised
Power collection	AC, DC, Pipelines
Power export	HVAC, HVDC, Pipelines
Procurement and manufacturing	
Installation	
Operation and Maintenance	Onsite, At port
Decommissioning	







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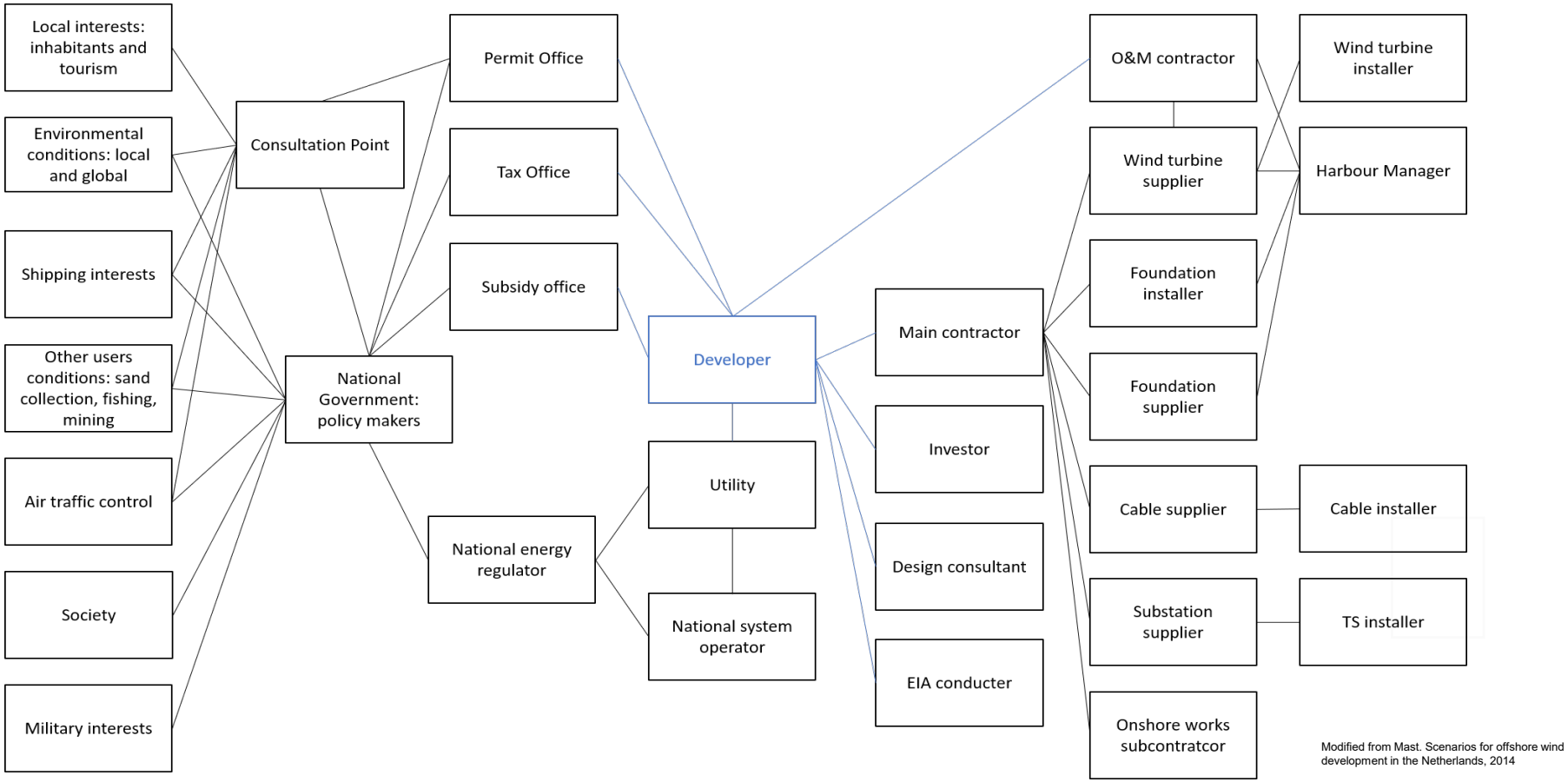
Standpoint

- Several actors involved in the design of floating wind farms
- Their involvement and interest in distinct design phases and subsystems is different
- We adopted the standpoint of the developer



Modified from Mast. Scenarios for offshore wind development in the Netherlands, 2014

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Design Structure Matrix

- Use a Design Structure Matrix to visually portrait them
- DSM provide a simple and flexible tool to visualise the interconnections between subsystems in complex design problems

		i	1	2	3	4	5	6	7	8	9	10	A
Power plant design	*i*	⊗											
Layout definition	1		⊗			1	1	1					1
Power production	2	2		⊗	2	2	2	2					2
Floating substructure	3			3	⊗	3	3		3	3	3	3	
Station keeping	4	4				⊗	4				4		
Power collection	5					5	⊗				5		5
Power export	6						6	⊗					6
Procurement and Manufacturing	7								⊗				7
Installation	8									⊗			8
Operation and Maintenance	9										⊗		9
Decommissioning	10											⊗	10
LCoE	A	A											⊗

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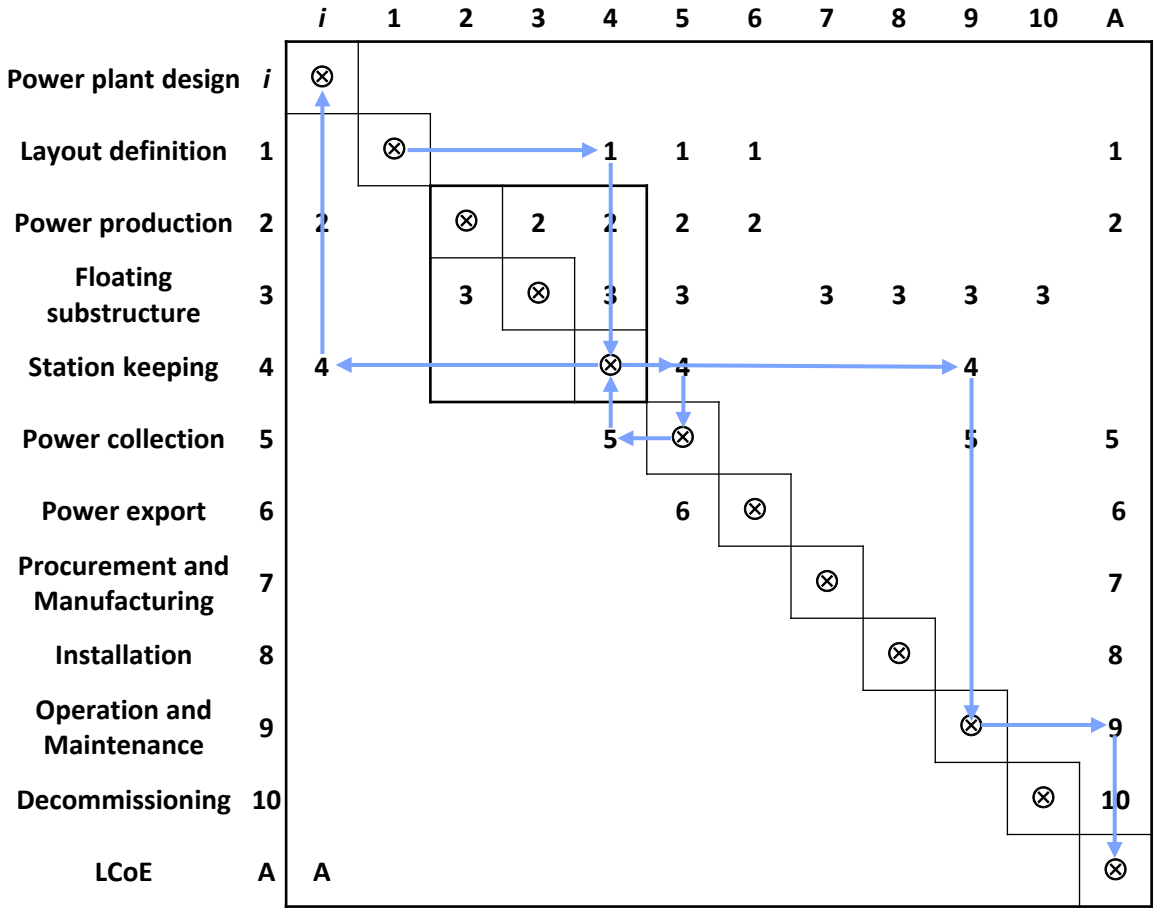

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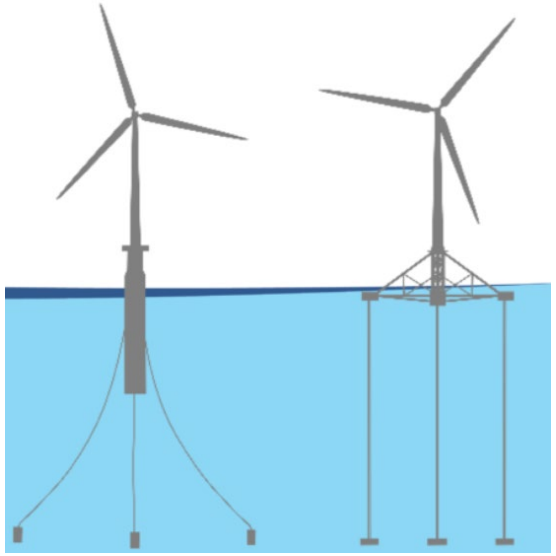
Couplings: Power production – Substructure

Modified from: World's first floating wind farm has started production, Equinor,. 2017

Modified from EDPR

Modified from: Quest Floating Wind Energy, LCC 2018



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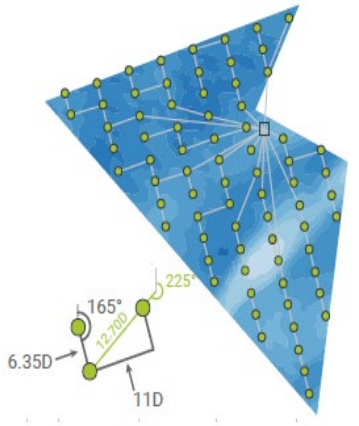
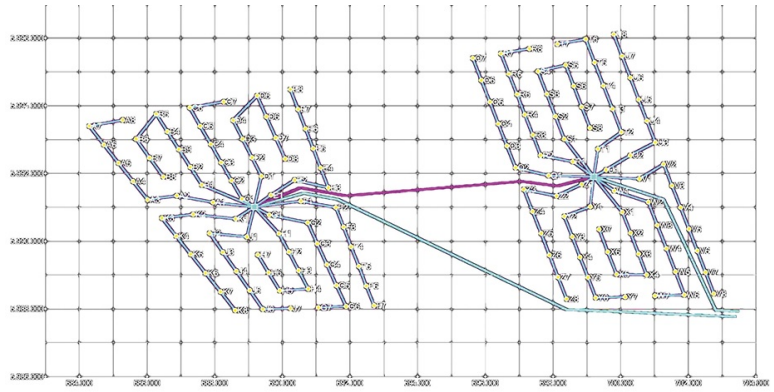
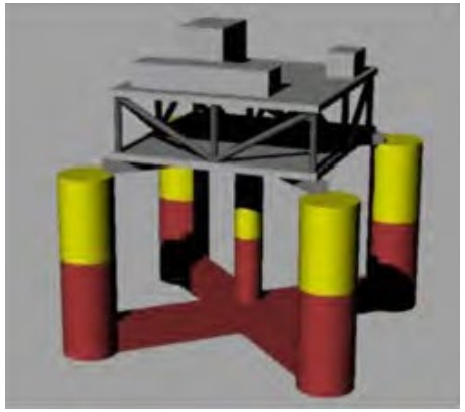
Couplings: Layout definition – Power collection and export



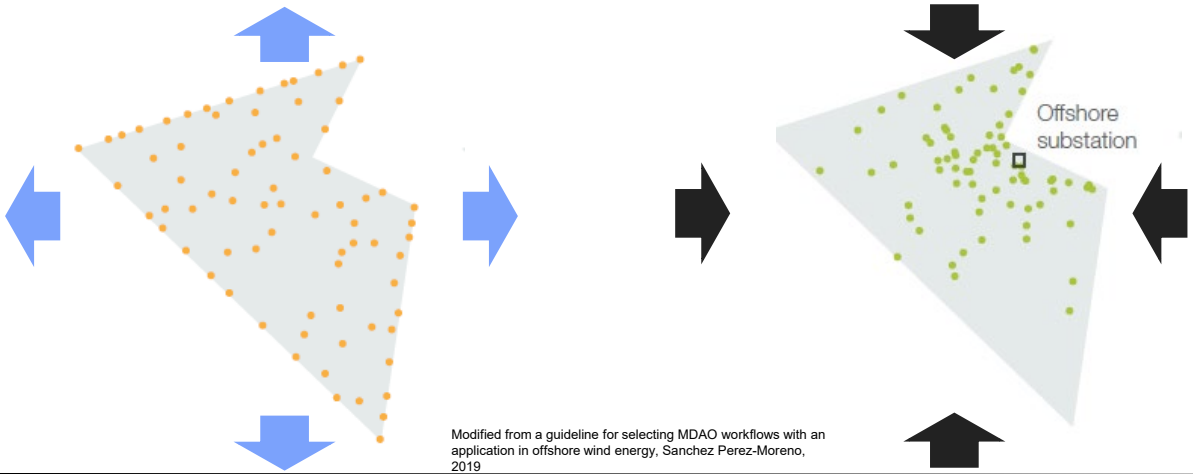
Multidisciplinary design analysis and optimisation of a reference offshore wind plant, Sanchez Perez-Moreno et al., 2018



Modified from Gemini offshore wind farm www.geminiwindpark.nl/



From Concept Design of Floating Substation for a 200 MW Wind Farm for the Northeast U.S., Shelley et al., 2020



Modified from a guideline for selecting MDAO workflows with an application in offshore wind energy, Sanchez Perez-Moreno, 2019

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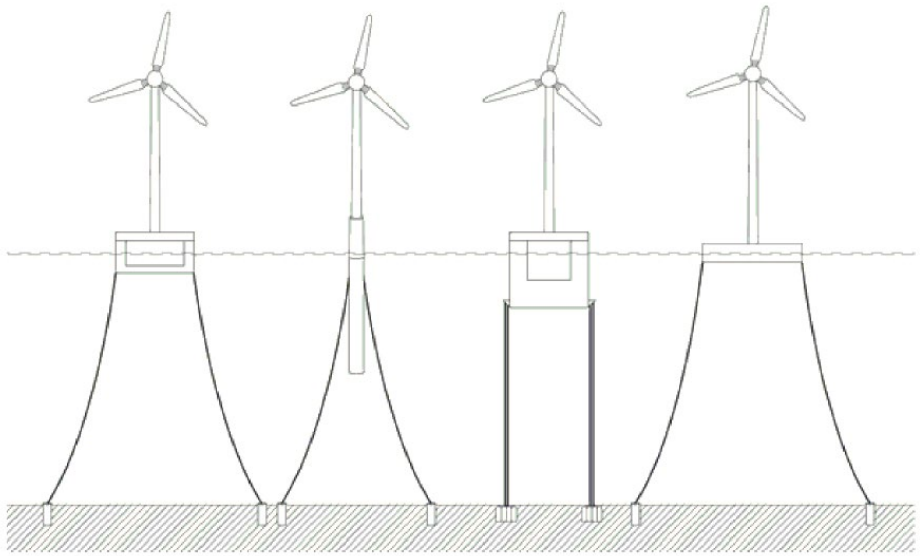
Couplings: Platform – Manufacturing – Installation – O&M

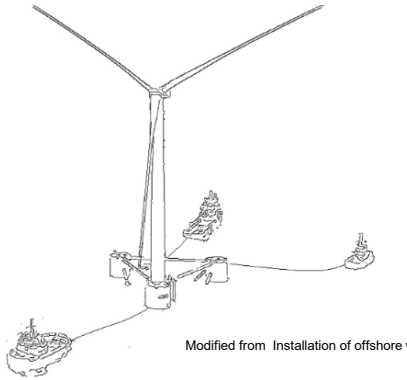


From DNVGL-ST-0119 Floating wind turbine structures, DNV GL, 2018

Manufacturing complexity factor

	Steel	*Concrete*
Spar buoy	1.31	1.54
Barge	1.66	1.64
Semi-submersible	1.81	1.99

Modified from A preliminary parametric techno-economic study of offshore wind floater concepts, Ioannou et al., 2020



Modified from Installation of offshore wind turbines: A technical review, Jiang, 2021

Installation simplicity

Spar buoy	+/-
Tension leg platform	-
Semi-submersible	+

Modified from improvements in the O&M modelling of floating offshore wind farms, Rinaldi et al., 2020

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Thank you!

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[5] A Multi-Objective Optimization Framework for Offshore Wind Farm Layouts and Electric Infrastructures, Rodrigues et al., 2016

[6] Multidisciplinary design analysis and optimisation of a reference offshore wind plant, Sanchez Perez-Moreno et al., 2018

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[8] A systems engineering vision for floating offshore wind cost optimization, Barter et al., 2020

[9] The Design Structure System: A Method for Managing the Design of Complex Systems, Steward, 1981

[10] Applying the design structure matrix to system decom-position and integration problems: A review and new directions, Browning, 2001

* STEP4WIND overview from STEP4WIND: Bridging the gap between academic research and industrial development of floating offshore wind farms, Axelle Viré, FOWT 2020, 9 Sep. Marseille

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