Wind-powered offshore energy hubs supplying offshore oil and gas installations

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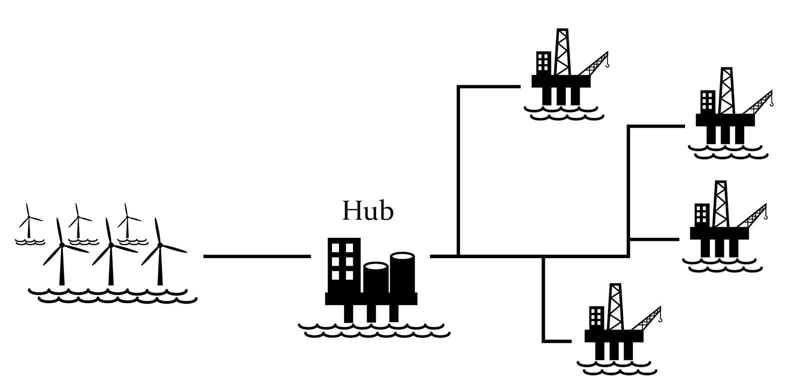
Abstract

Offshore wind power offers the possibility to greatly reduce local CO_2 emissions from offshore oil and gas installations, but variations in power availability must be balanced through energy storage and other generation capacity. This study investigates different energy supply concepts and analyses their feasibility and performance through simulations based on a receding horizon optimisation approach.

Background

- Offshore wind integration with oil and gas installations can give large CO_2 emission reductions by replacing gas turbines
- Economy of scale ⇒ wind farms powering a cluster of installations instead of individual platforms



Offshore hub concepts

Energy supply concepts

Four concepts for providing energy are considered:

C0: Gas turbine generators on each platform (as today)

C1: Wind farm and hydrogen storage on hub, fully isolated system

C2: Wind farm and hydrogen storage on hub, including hydrogen shipments

C3: Wind farm, hydrogen and gas turbines with hydrogen in fuel blend and with CCS on hub

System dimensioning

Energy demand and sizes of the main components in the four concepts (found through repeated simulations) are shown below.

Element	C0	C1	C2	C3
Power demand (MW)	270	270	270	270
Heat demand (MW)	40	40	40	40
Gas turbines (MW)	364	0	150	573
Wind power (MW)	0	900	900	400
Electrolysers (MW)	0	600	600	100
Fuel cells (MW)	0	310	310	0
H2 storage (MSm3)	0	115	20	10
H2 ships (yes/no)	no	no	yes	no

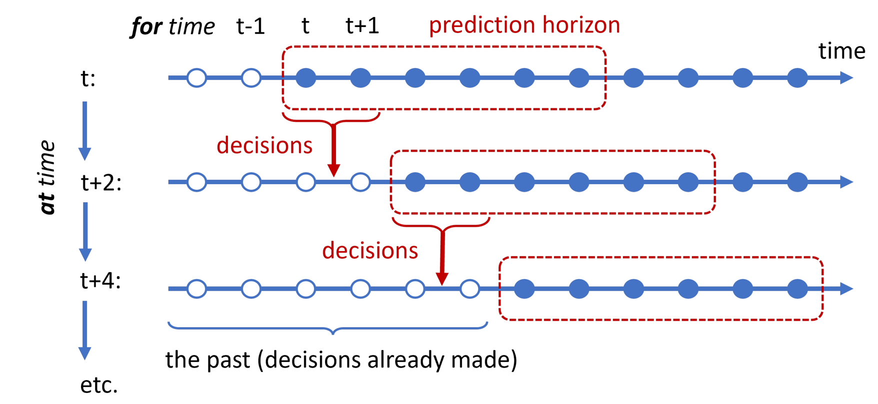
Acknowledgments

This work has received financial support from the Research Council of Norway and industry partners through PETROSENTER LowEmission (grant 296207) and KSP CleanOffHub (grant 326725).

Method

Modelling

- Integrated multi-flow energy system – including flows of multiple energy/matter carriers: electricity, heat, water, oil, gas, hydrogen
- Real-time energy system scheduling – best use of available resources
- Mixed-integer linear programming (MILP) formulation – integer variables representing on-line/offline status for devices such as gas turbines and electrolysers
- Rolling horizon optimisation – scheduling based on predictions for wind power and power demand over a given prediction horizon



Oogeso tool

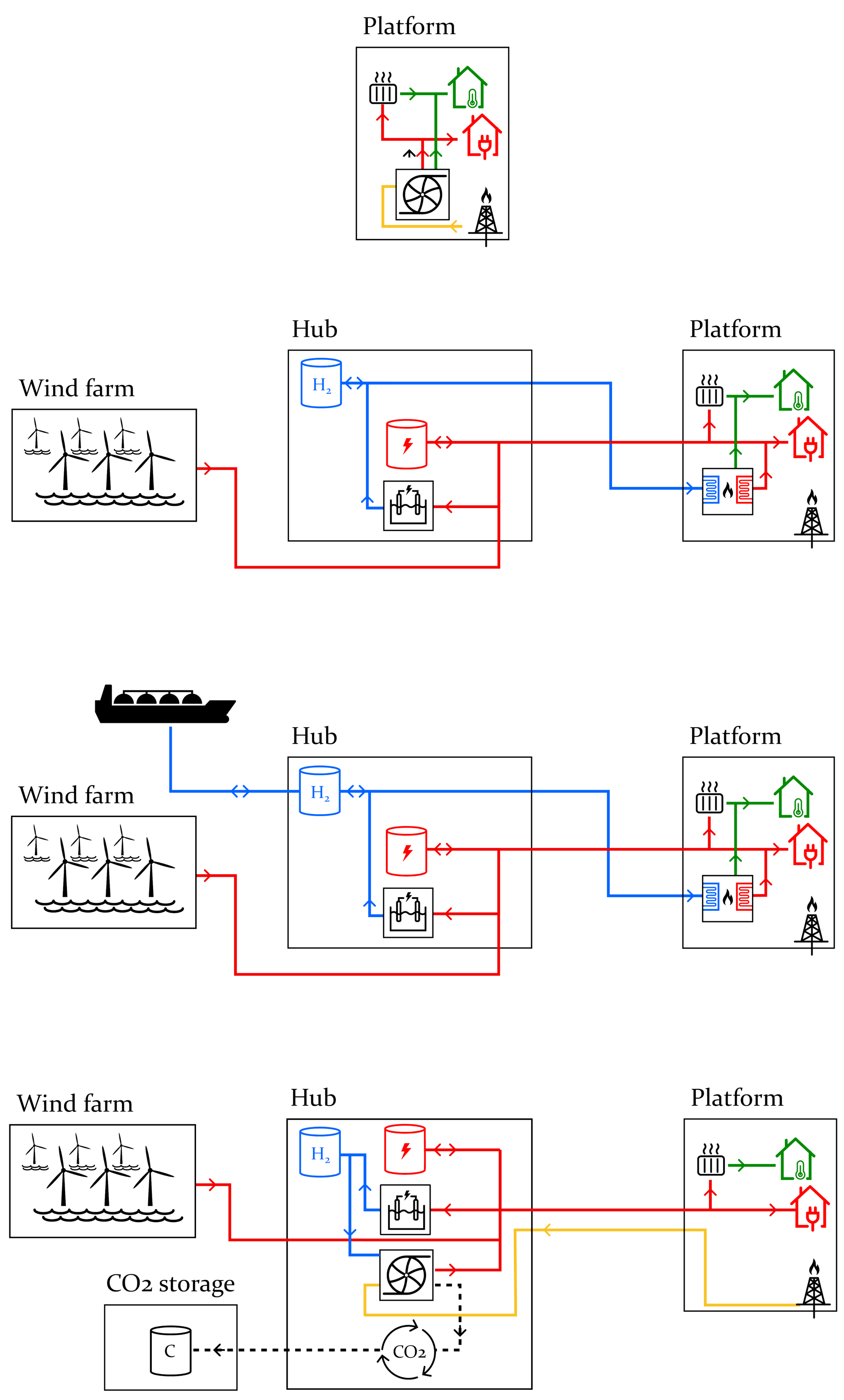
The *Offshore oil and gas energy system optimisation* (Oogeso) tool is an open-source Python package that implements the above modelling approach and is used for:

- Realistic simulation of energy system behaviour
- Check feasibility of chosen design alternatives
- Quantify performance by computation of key performance indicators

Code: https://github.com/oogeso/oogeso

Case study

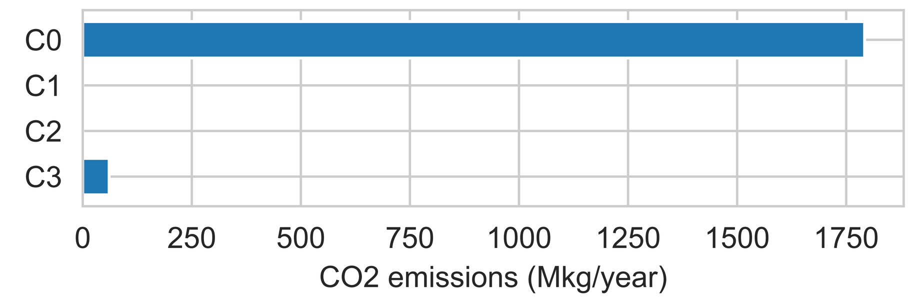
Concepts C0–C3 (from top to bottom):



Results

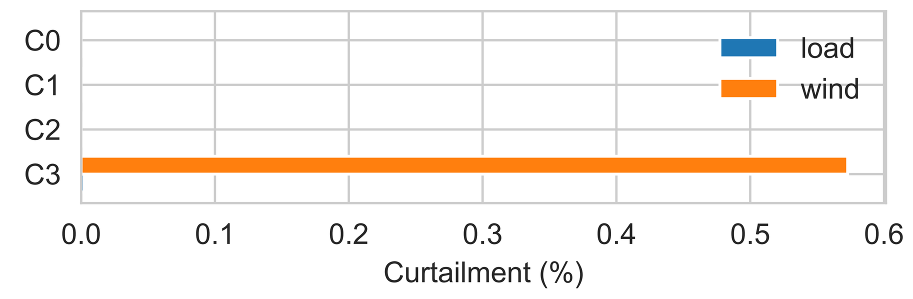
CO_2 emissions

CO_2 emissions are eliminated in C1 and C2, and drastically reduced in C3 (non-zero because carbon capture is not 100%).



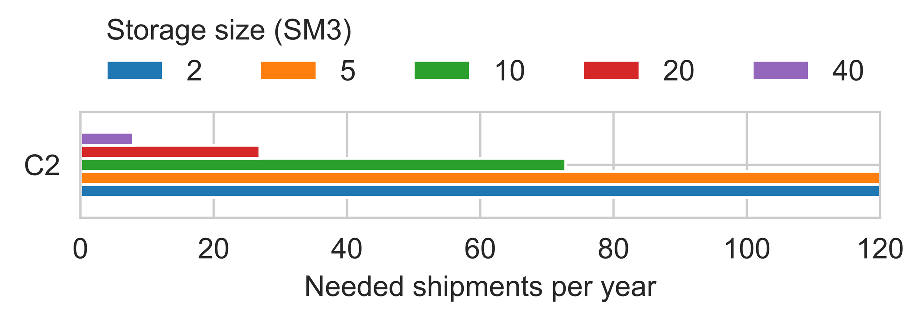
Wind and load curtailment

Curtailment levels are acceptable: No load curtailment in any of the cases, and only a small amount of wind power curtailment in C3.

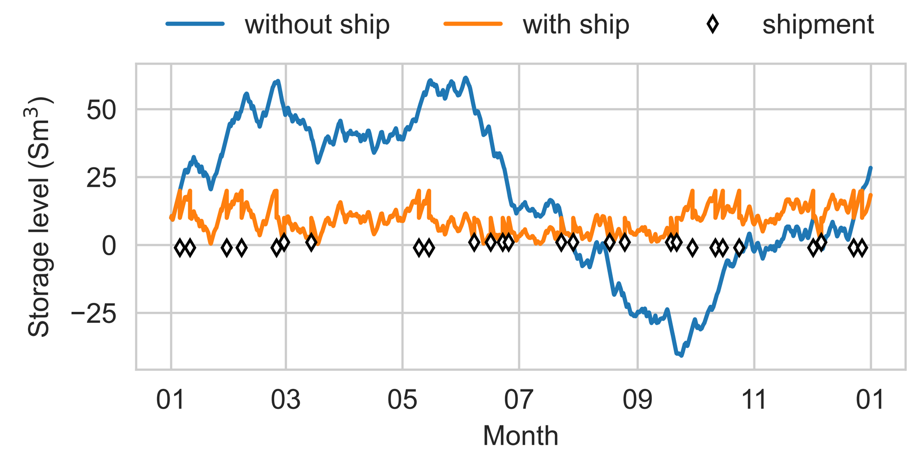


Hydrogen storage and shipments

By allowing shipments of hydrogen, the storage size can be reduced. With storage size 20 Sm3, and ship capacity of 10 Sm3, 27 shipments are needed per year, either to fill or tap the storage.



Seasonal fluctuations in wind power necessitate large storage capacity in autonomous system. This can be greatly reduced if hydrogen transport to/from the offshore hub is considered.



Conclusion

- Different concepts for offshore energy systems with wind power as the main energy supply can eliminate or greatly reduce CO_2 emissions.
- Hydrogen shipments can reduce seasonal storage capacity otherwise required in autonomous system.
- Costs need to be considered to identify the best option.

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