Optimizing jack-up vessel chartering strategies to support maintenance tasks at offshore wind turbines

Vibeke Hvidegaard Petersen, Daniela Guericke, Magnus Stålhane

Agenda

- Problem motivation
- Problem modeling
- Representation of the uncertainties
- Scenarios and decisions
- What is next?

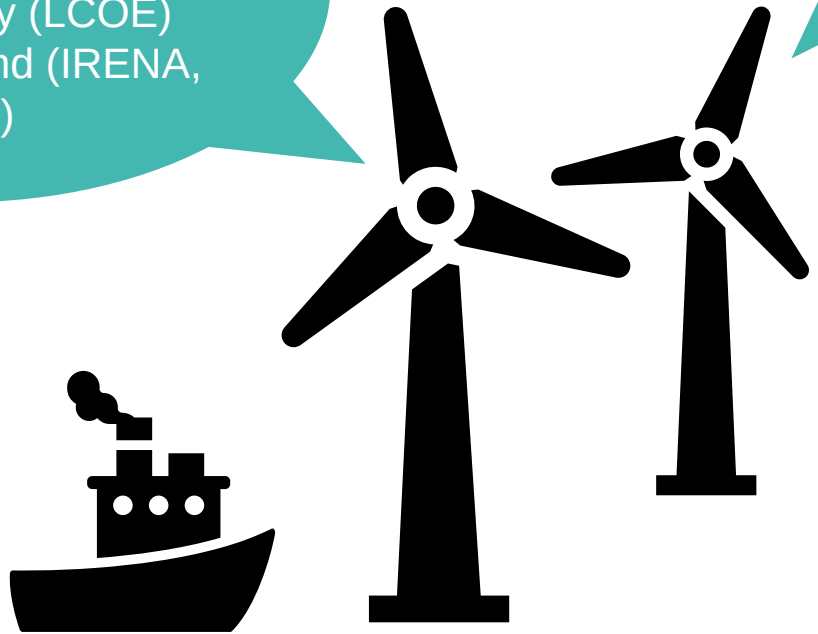
NTNU

Problem motivation

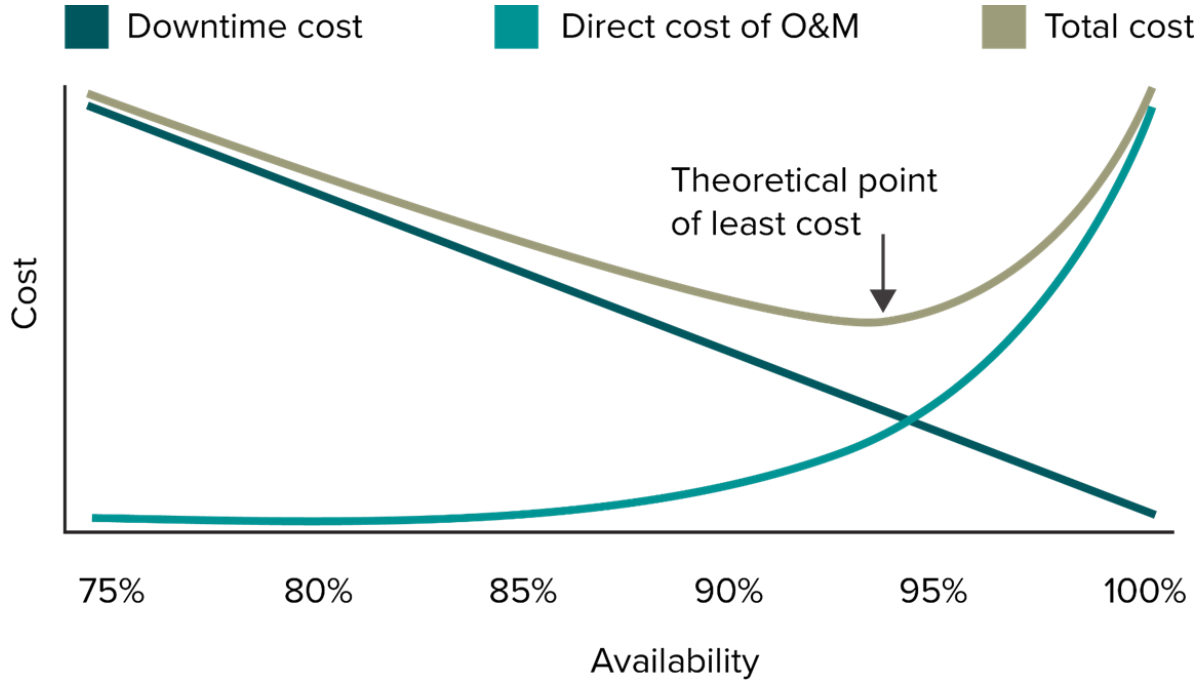
Problem motivation

Maintenance and operations costs account for 16-25% of levelized cost of energy (LCOE) for offshore wind (IRENA, 2020)

A wind turbine consist of up to 8000 components (IRENA, 2012)

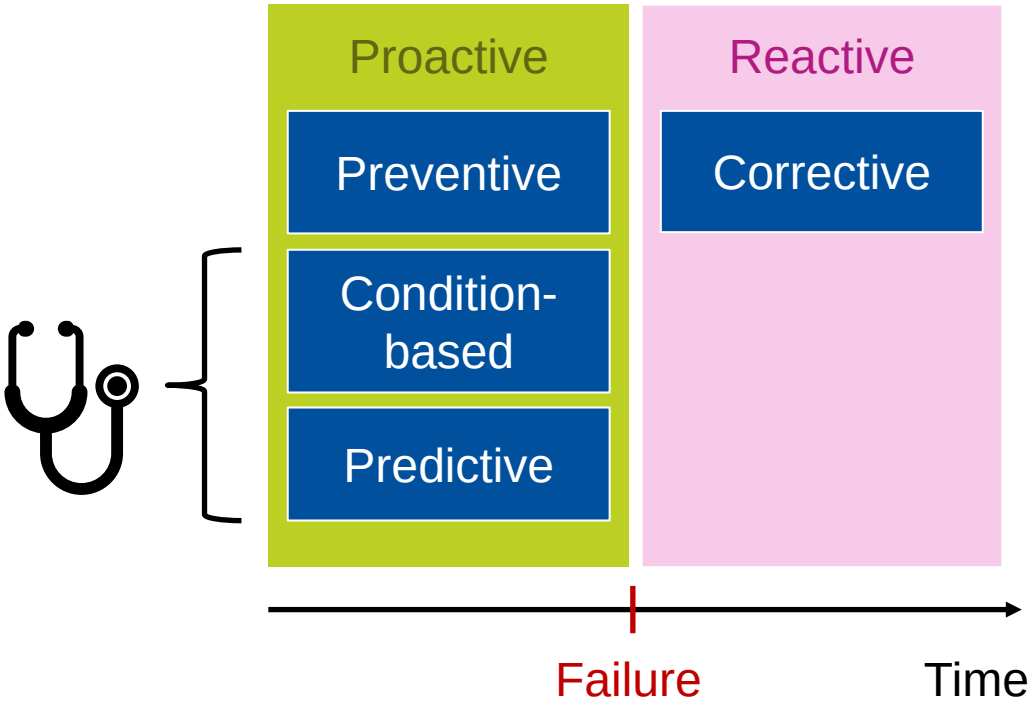


Balancing cost



Philips et al. (2018)

Maintenance strategies



Heavy maintenance

e.g. changing blades or gearbox requires a jack-up vessel

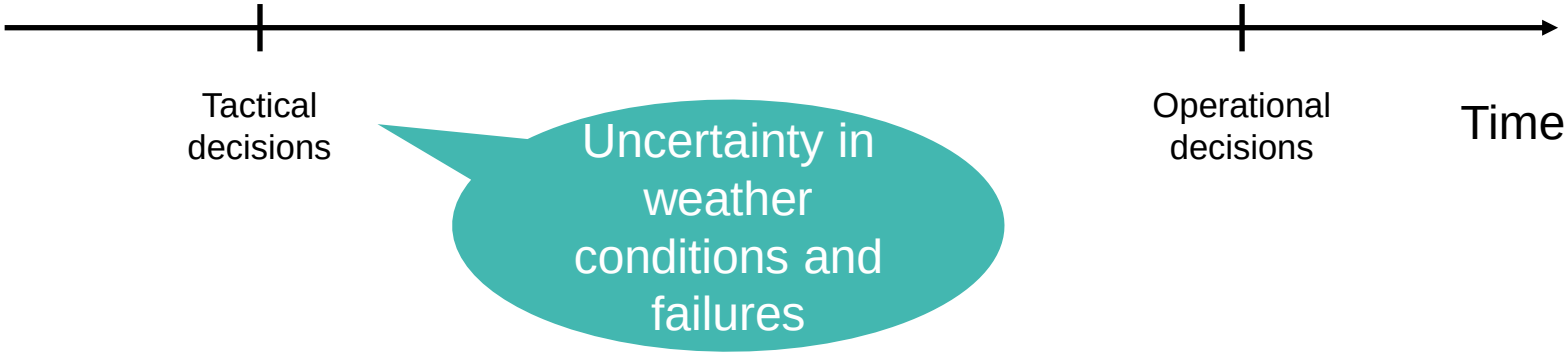
NTNU

Problem modeling

Jack-up vessel chartering problem with sub-assembly ordering

- When and for how long to charter in jack-up vessel
- How many sub-assemblies to order

- Which wind turbines to maintain when



Two-stage stochastic model

First stage

Objective function is to minimize:

- Cost of vessel chartering
- Cost of sub-assemblies

St.

- Bookeeping of chartering period(s)

Second stage

Objective function is to minimize:

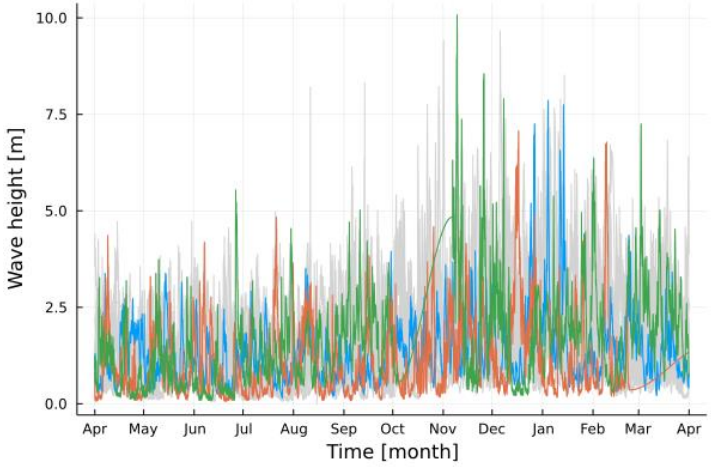
- Downtime cost

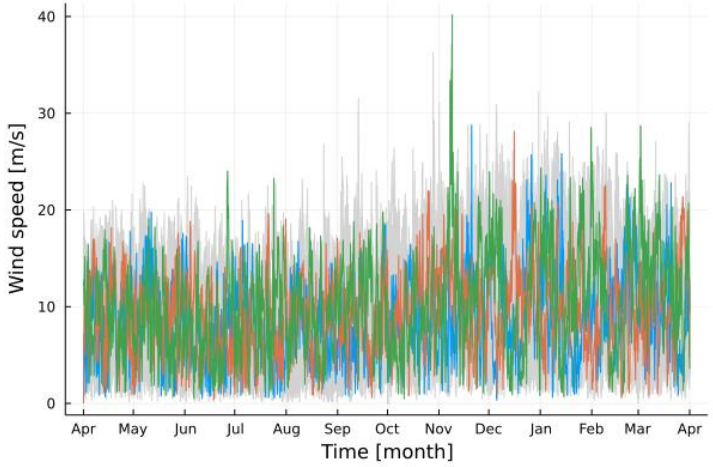
St.

- Assign maintenance tasks to vessel
- No overlapping tasks
- No more tasks than sub-assemblies
- Impose downtime cost if a failed wind turbine is not maintained

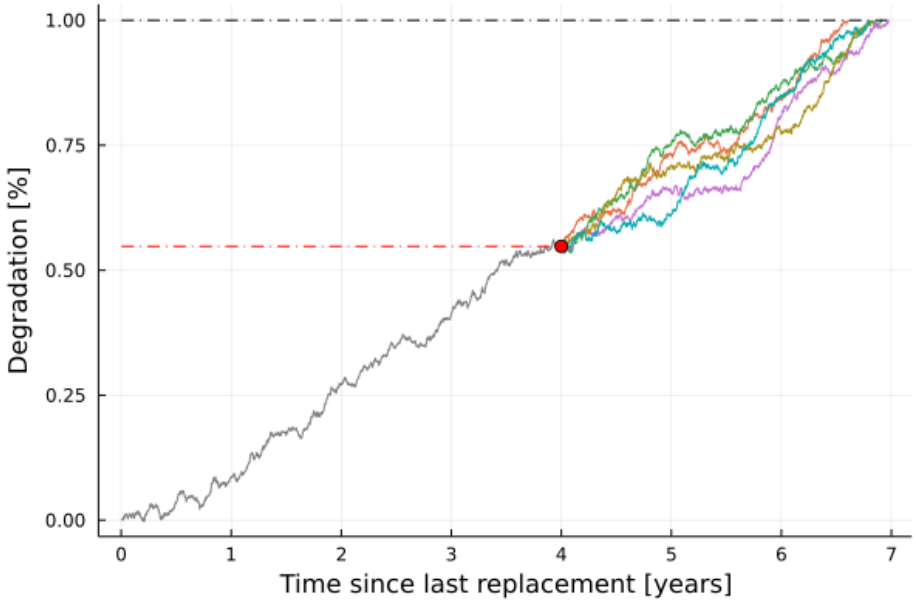
Representation of the uncertainties

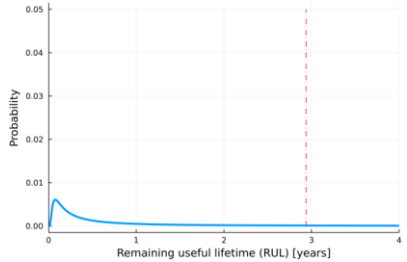
Weather

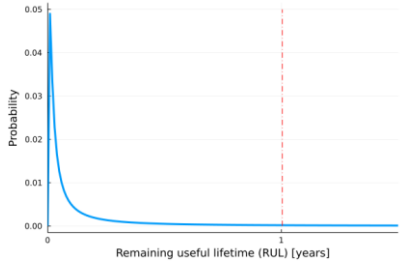

Wave height [m]
10.0
7.5
5.0
2.5
0.0
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
Time [month]


Wind speed [m/s]
40
30
20
10
0
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
Time [month]

Failures


1.00
0.75
0.50
0.25
0.00
Degradation [%]
0
1
2
3
4
5
6
7
Time since last replacement [years]

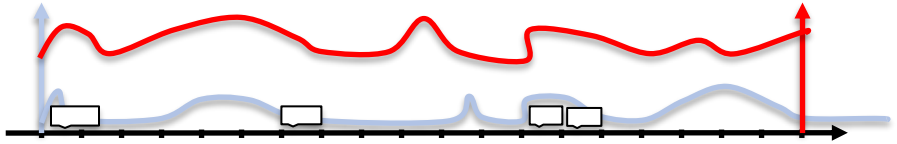

0.05
0.04
0.03
0.02
0.01
0.00
Probability
0
1
2
3
4
Remaining useful lifetime (RUL) [years]


0.05
0.04
0.03
0.02
0.01
0.00
Probability
0
1
Remaining useful lifetime (RUL) [years]

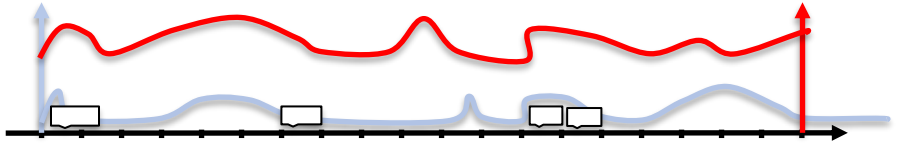
Scenarios and decisions

Scenarios

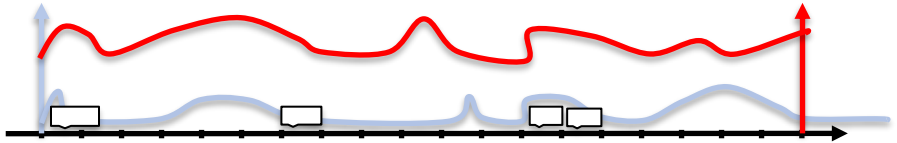
Scenario 1



Scenario 2



Scenario n

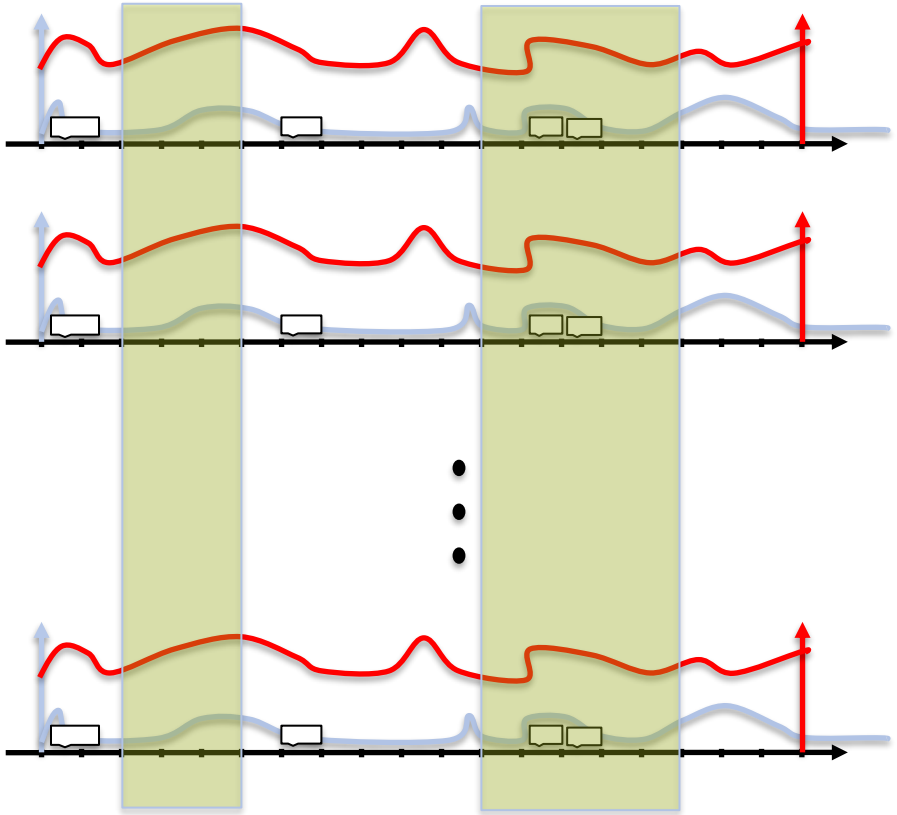


Scenarios and first stage decisions

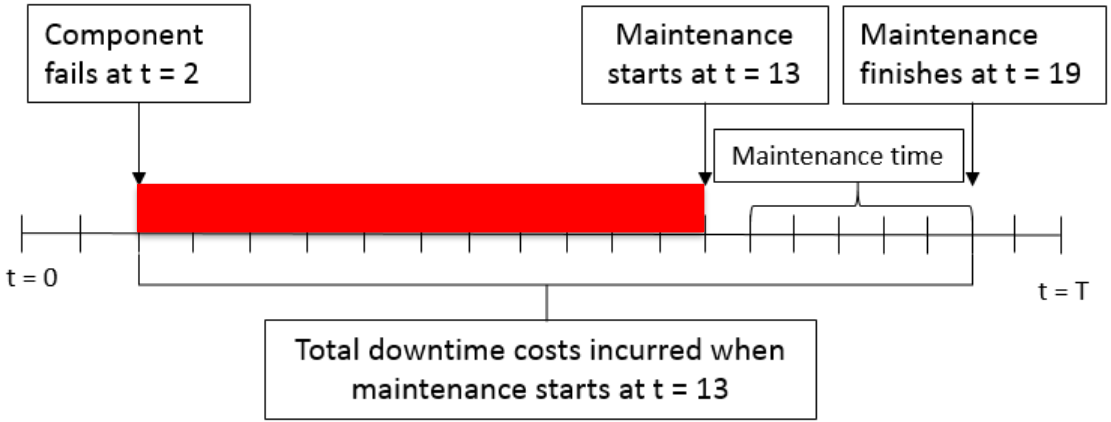
Scenario 1

Scenario 2

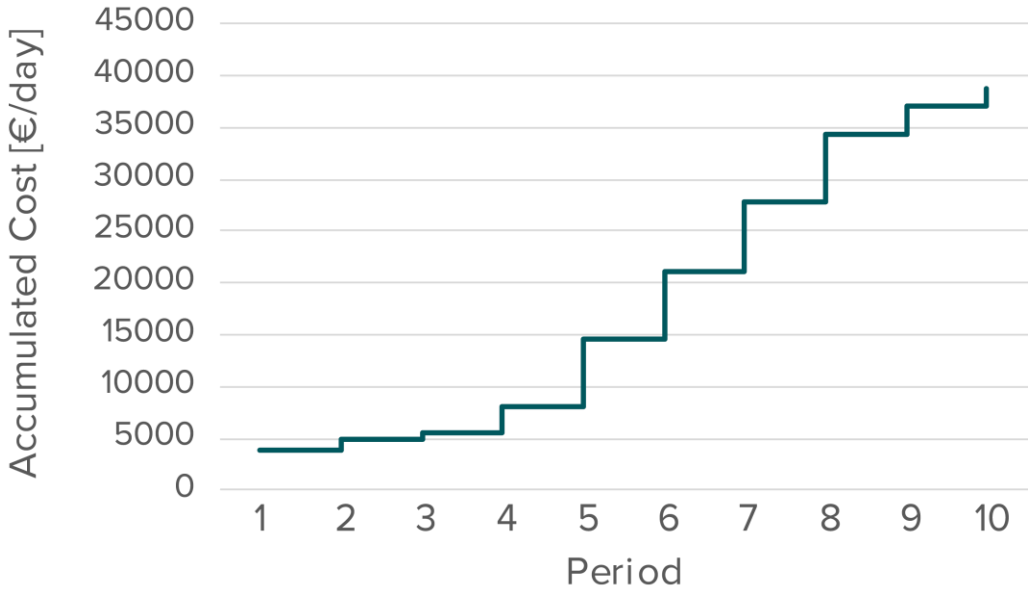
Scenario n



Second stage decision – when to fix a given failure

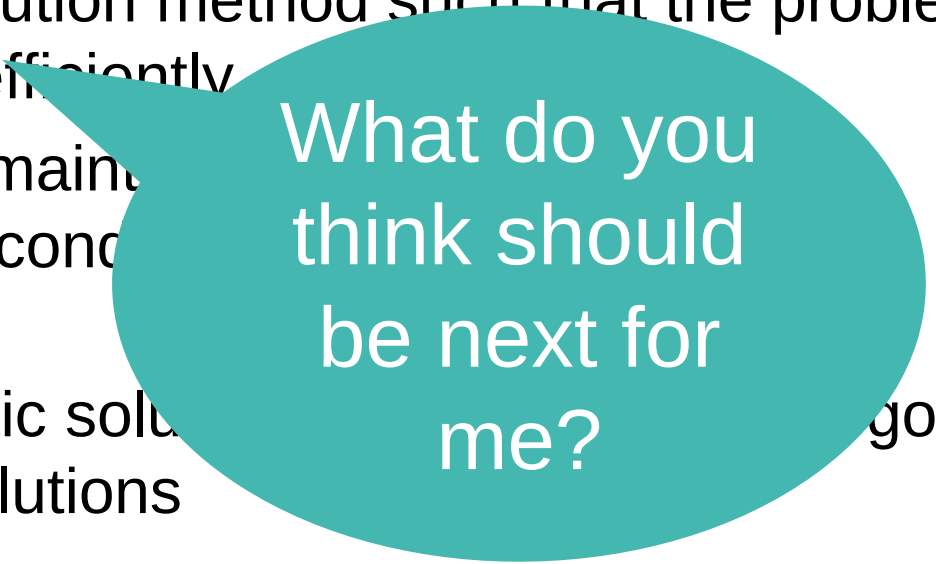


Downtime costs – depends on wind speed



What is next?

- Ensure realistic modeling and realistic data
- Work on the solution method such that the problem can be solved efficiently
- Test predictive maint… preventive and cond… strategy
- Develop heuristic solu… good near-optimal solutions



References

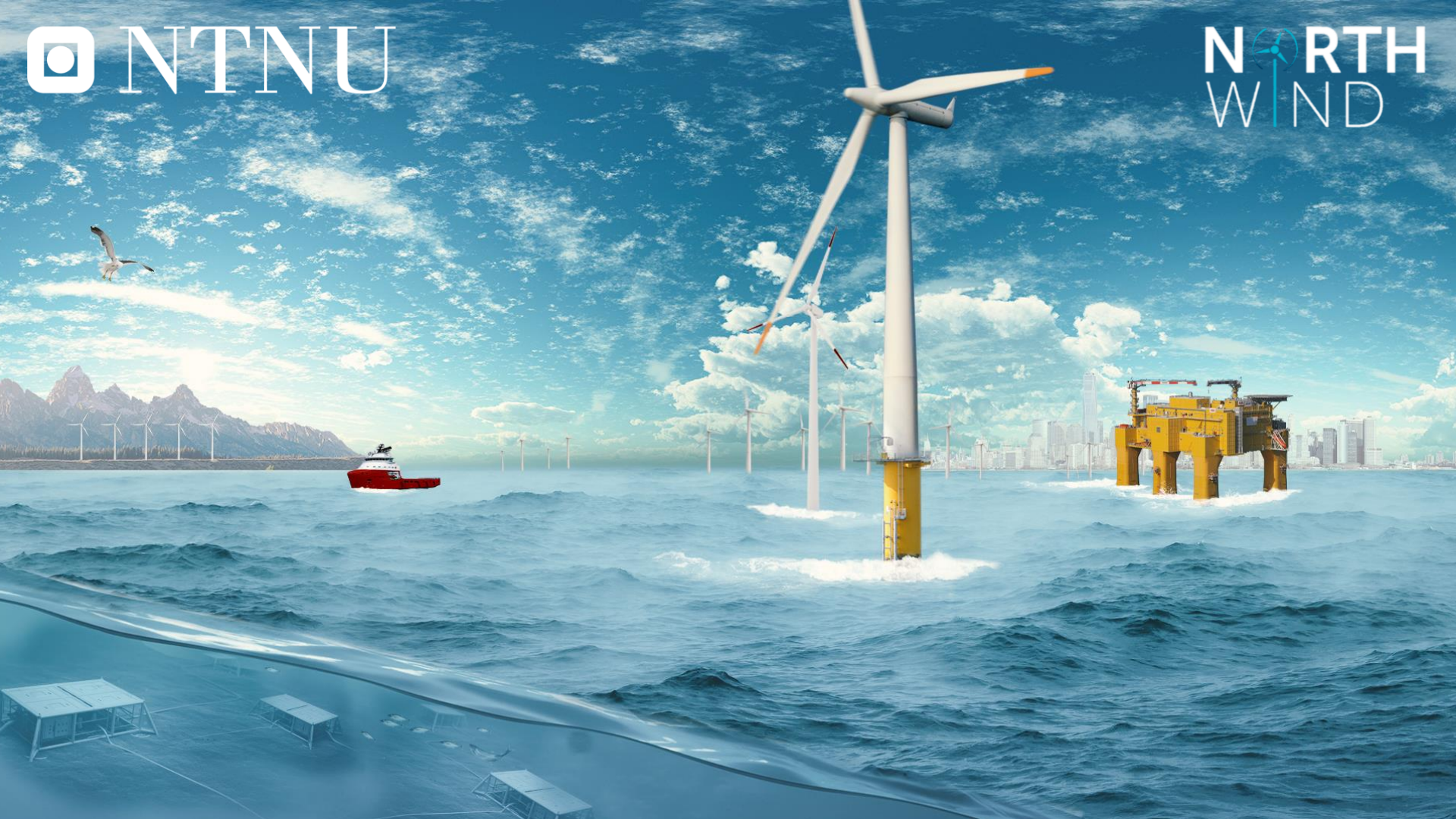
IRENA (2012). “Renewable Energy Technologies: Cost Analysis Series”. url: www.irena. org/Publications.

IRENA (2020). “Renewable Energy Technologies: Cost Analysis Series”. url: www.irena. org/Publications.

Laporte, Gilbert and François V Louveaux (1993). “The integer L-shaped method for
stochastic integer programs with complete recourse”. In: Operations Research Letters
13.3, pp. 133–142

Philips, Joe et al. (2018). A Guide to UK Offshore Wind Operations and Maintenance. Tech. rep.
September. GL Garrad Hassan.

Stålhane, Magnus, Kamilla Hamre Bolstad, et al. (2021). “A dual-level stochastic fleet size and mix problem for offshore wind farm maintenance operations”. In: INFOR: Information Systems and Operational Research 59.2, pp. 257–289


NTNU
NORTH WIND