Rebound Features of Offshore Wind Farm with Operation & Maintenance Service

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Agenda

- Introduction
- Motivation
- Model overview
- Selected scenarios
- Results & Conclusions

source: wikipedia
(https://en.wikipedia.org/wiki/Offshore_construction)

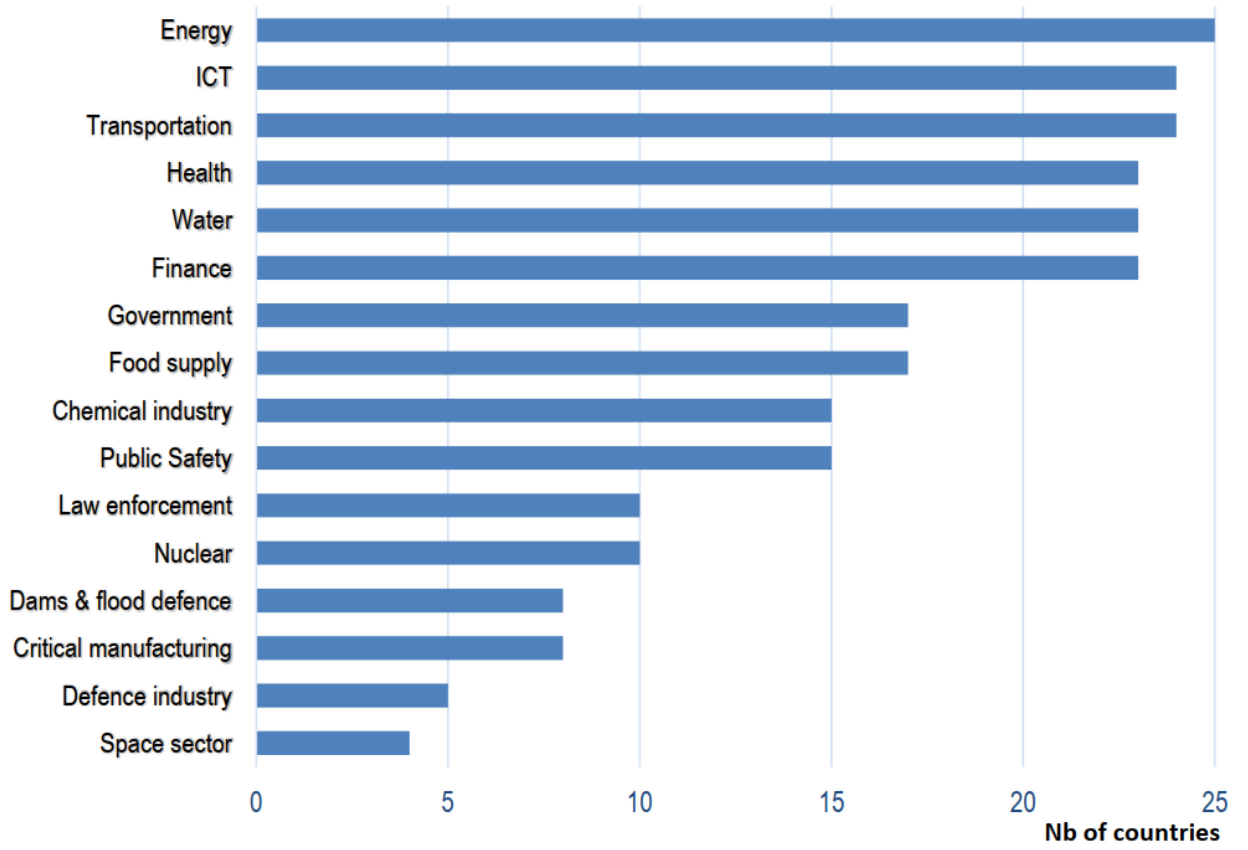
Introduction

What are the critical infrastructure sectors?

"…official definitions of critical infrastructure vary across countries. Some definitions refer to critical infrastructure as infrastructure whose functioning is vital or essential to **economic** and **social well-being**, while others stress their importance for the **functioning of the State or national security**."

Source: OECD Good Governance for Critical Infrastructure Resilience (2019)

Sectors of designated critical infrastructure across OECD countries

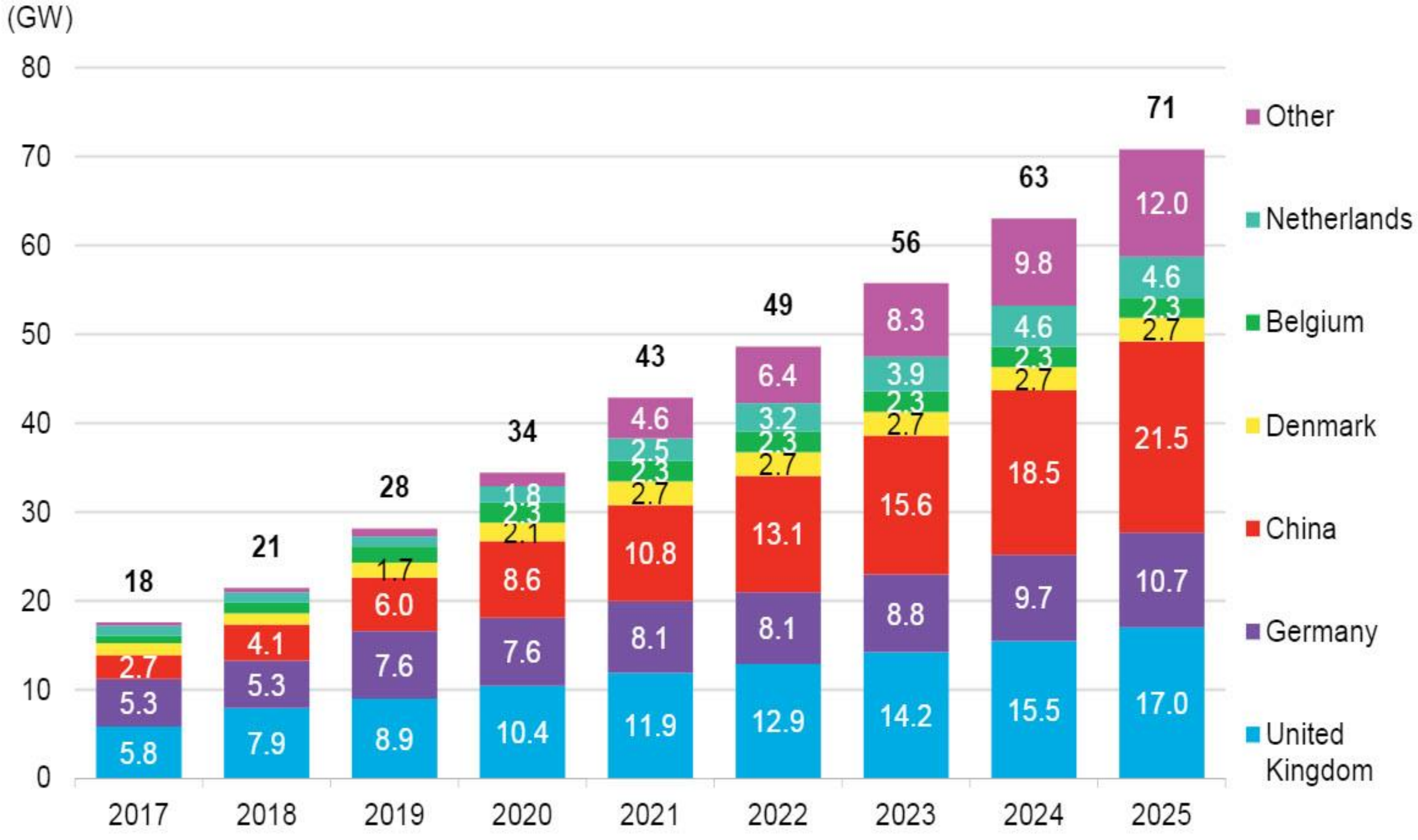


Note: Answers received from 25 OECD countries.
Source: OECD Survey on Critical Infrastructure Resilience and Security (2018)

Motivation

Growing importance

- Germany renounces nuclear energy,
- Reduction of coal consumption,
- Growing importance of wind energy production,
- Reliability of wind power sources should increased.



Global cumulative offshore installation capacities forecast

source: Bloomberg New Energy Finance, 2017

Motivation

Safety and Security Threats

- **Simultaneous failures** of different components or **cascade effects**
- Deliberate and unintentional **ship accidents** during maintenance work
- **Physical attacks** on wind turbines, platforms and maintenance vessels
- **Theft**
- **Cyber-physical** attacks
- **Extreme weather** conditions
- **Aging** and failing components
- ….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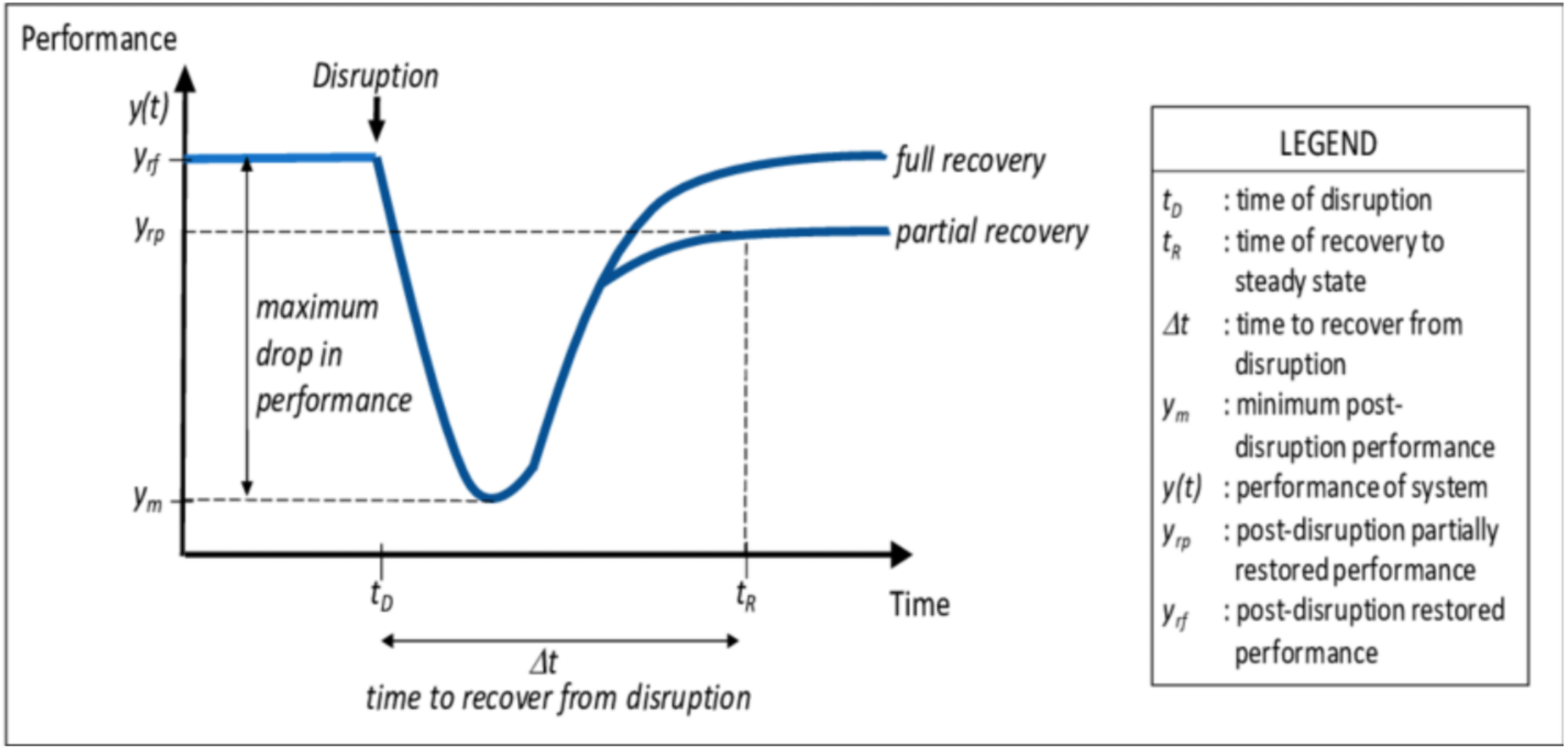
Motivation

Resilience approach

How to minimize drop of performance?
- Redundancy

How to minimize time to recovery?
- Resources
- Reaction time

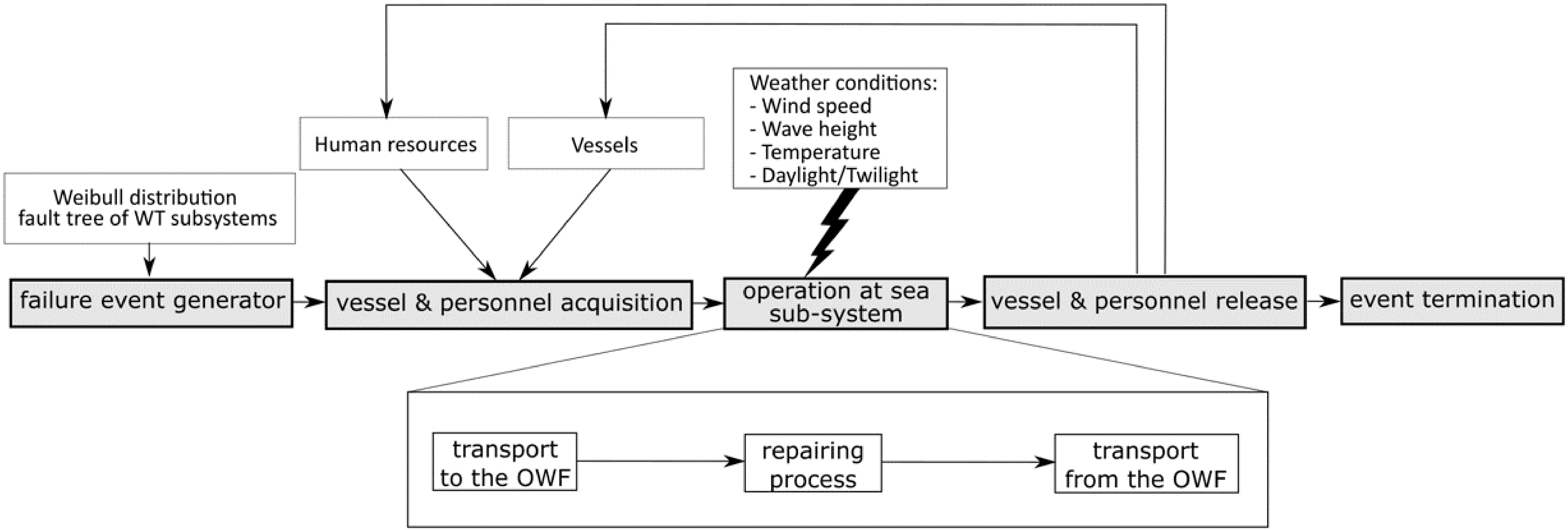


General form of resilience curve for resilience defined as rebound.*

Source: Azad M. Madni et al., Constructing Models for Systems Resilience: Challenges, Concepts, and Formal Methods; Systems 2020, 8(1), 3

* see: Woods, Four concepts for resilience and the implications for the future of resilience engineering, Reliability Engineering and System Safety 2015, Vol. 141, pp 5-9

Simplified overview of the model



Simplified schema of the O&M model as an event-driven simulation

Failure model

- 30 wind turbines (WTs),
- Each WT consists of 19 sub-systems,
- Any failure causes a downtime of a WT,
- Each WT has two different fault trees for different severities,
- Failure ratios adapted from J. Carroll et al.*,
- Weibull distribution for generating failure times:

$$t_1(u) = t_0 + \xi + \lambda(-\log u)^{\frac{1}{\alpha}}$$

where:

t_0 is the current time in simulation,
ξ is a threshold parameter,
λ indicates the scale parameter,
α is the shape parameter.

Exemplary list of failures

time (h)	#WT	#sub-system	failure type
614	23	Yaw	1
731	15	Cooling	2
835	3	Gearbox	1
1054	1	Circuit breaker	1
1060	12	Generator	1
1292	30	Yaw	1

* J. Carroll et al., Failure rate, repair time and unscheduled O&M cost analysis of offshore wind turbines, Wind Energy 2016; 19:1107–1119

O&M model

Three types of failures – three types of vessels:

Minor failure – Crew Transport Vessel (CTV),

Major failure – Fast Supply Vessel (FSV),

Major replacement failure – Heavy Lift / Jack-up Vessel (HLV).

source: Damen Shipyards Group

Selected parameters of the O&M vessels

	CTV	FSV	HLV
cruise speed (knots)*	25	20	15
average personnel	3	7	15
average repair time (h)**	7	12	116
distance to OWF	30 km		

* based on existing vessels
** based on J. Carroll et al., Failure rate, repair time and unscheduled O&M cost analysis of offshore wind turbines, Wind Energy 2016; 19:1107–1119

O&M model

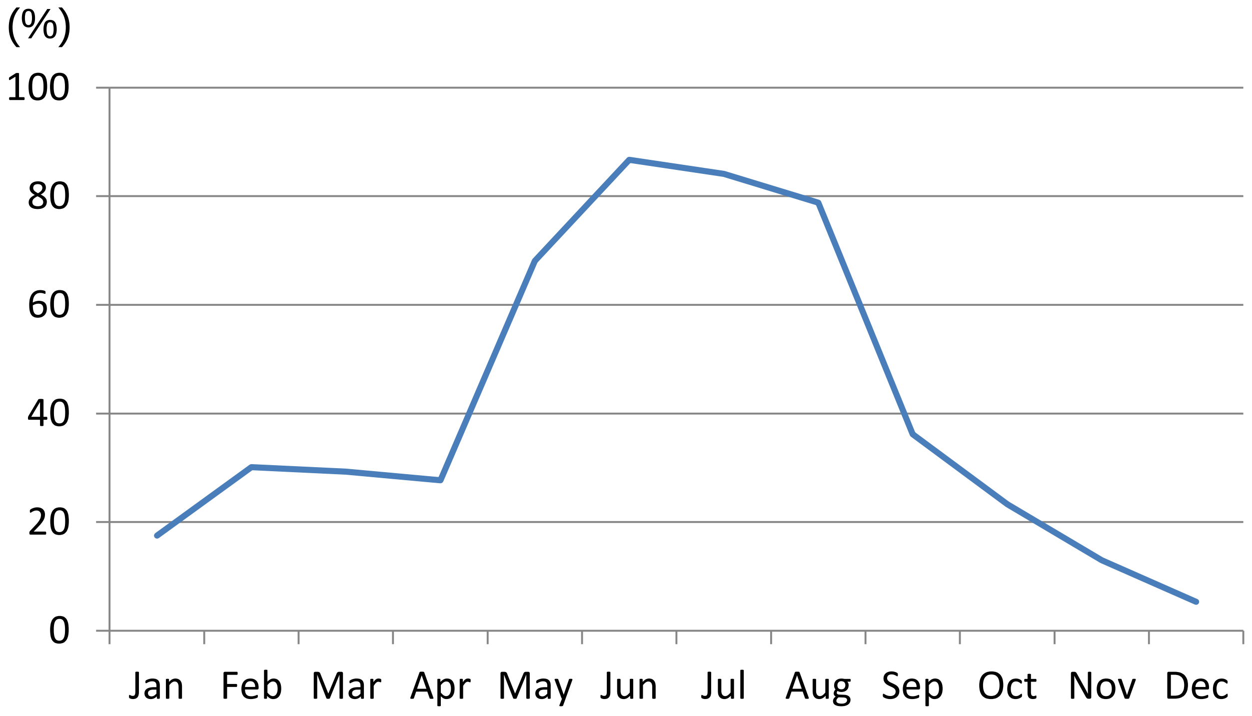
- Our model is not meant to optimize processes,
- Randomness in the model: traveling and repairing times,
- No spare parts logistic, no financial analyses taken into account,
- No mobilization times of vessels,
- 1 year - 1h resolution of weather data,
- Weather influence on vessels operational conditions:

  daylight / twilight / night @58°N latitude,

  wave height < 2.5 m,

  wind speed < 25 ms^{-1},

  temperature > 0° C.



Weather operational conditions for vessels for 2016 at the German Bight area

Selected scenarios

Two selected scenarios of severe weather conditions and following operational windows:

Scenario 1: 08.03.2019 – 28.03.2019

Scenario 2: 22.09.2019 – 03.10.2019

For each scenario the number of CTVs is set to 1, 3 or 5


source: NOAA NDBC

Weather data source:

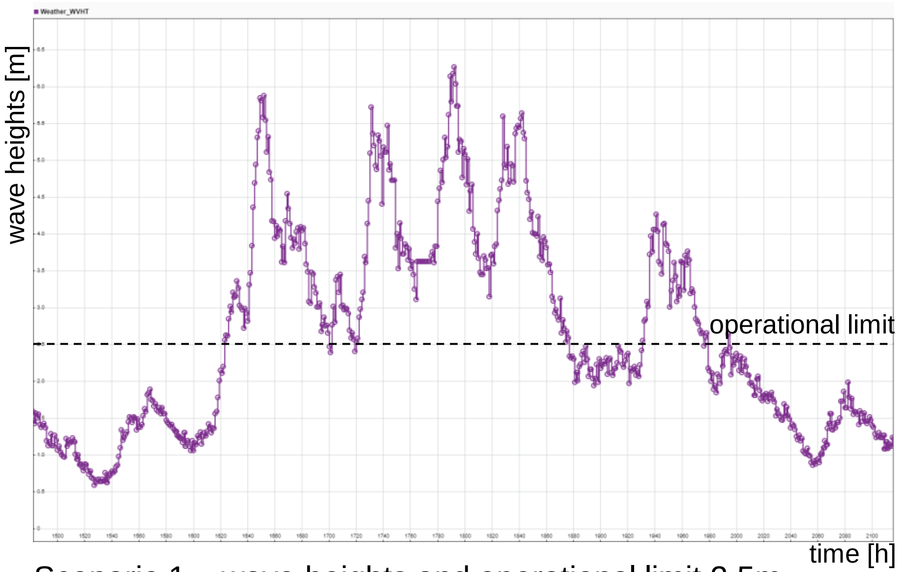
NOAA National Data Buoy Center

3-meter discus buoy w/ seal cage

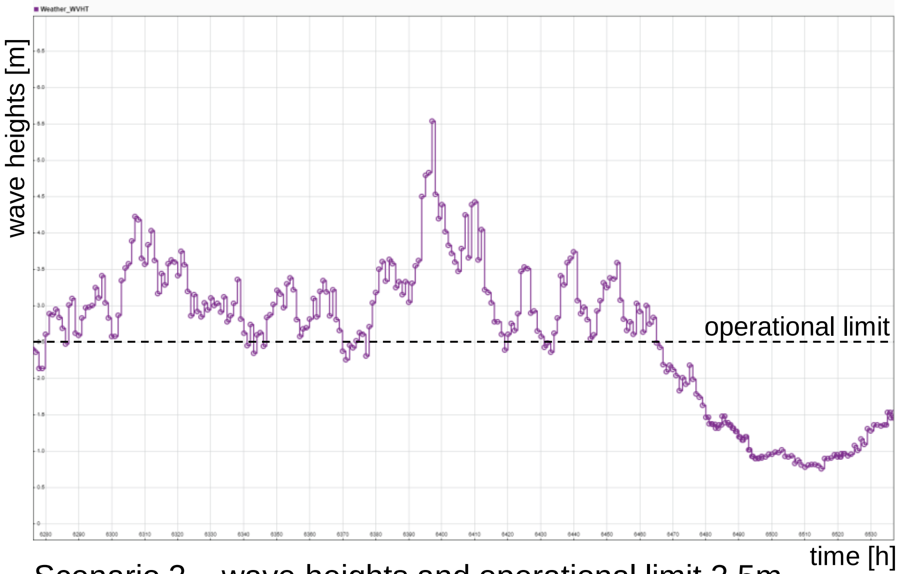
58.270 N 138.019 W

Station 46083 – Fairweather Ground

Weather data for the year 2019



Scenario 1 – wave heights and operational limit 2.5m



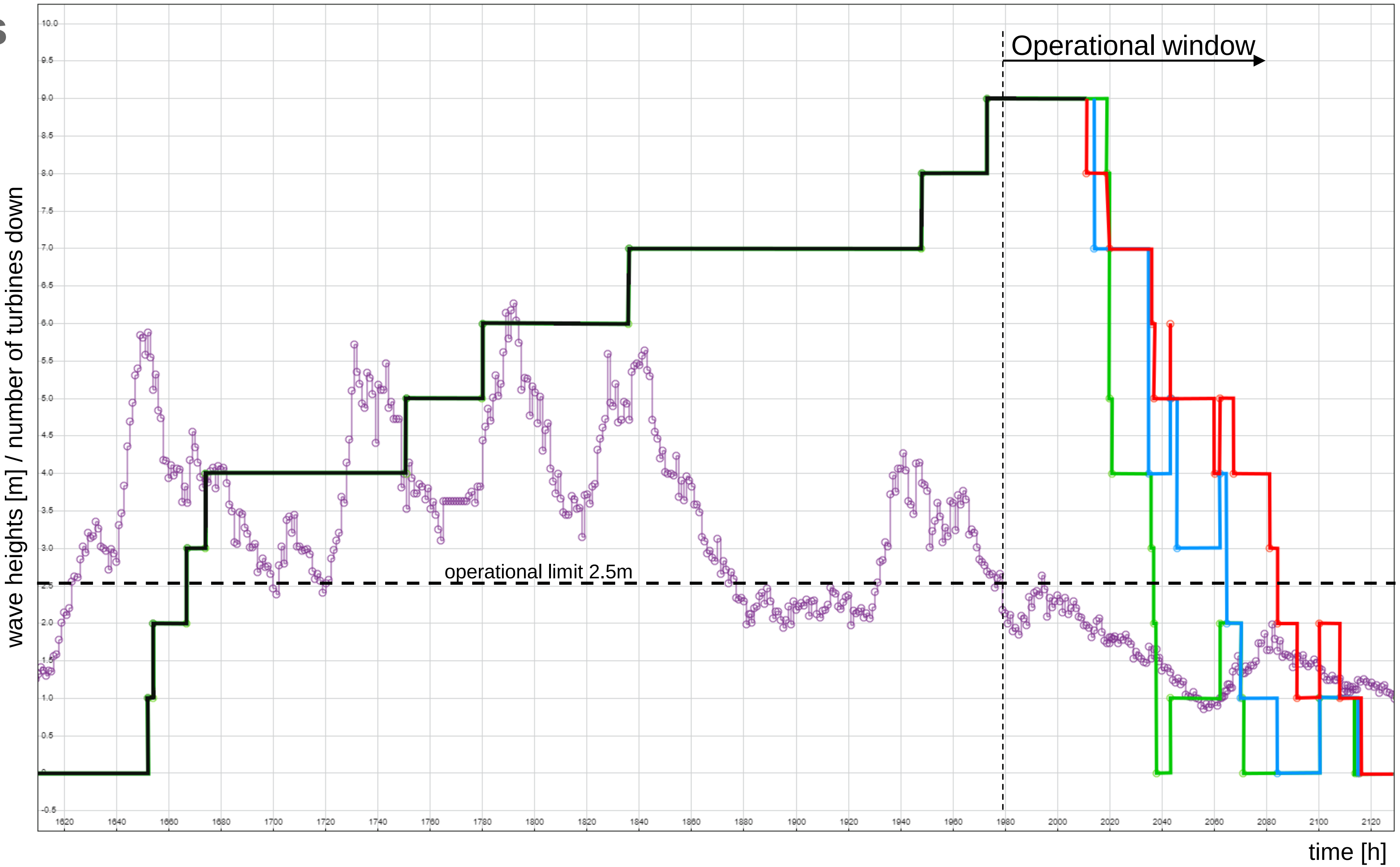
Scenario 2 – wave heights and operational limit 2.5m

Selected scenarios

Scenario 1
08.03.2019 – 28.03.2019

Number of turbines down for:
- 1 CTV
- 3 CTVs
- 5 CTVs

Wave heights:
- [m]

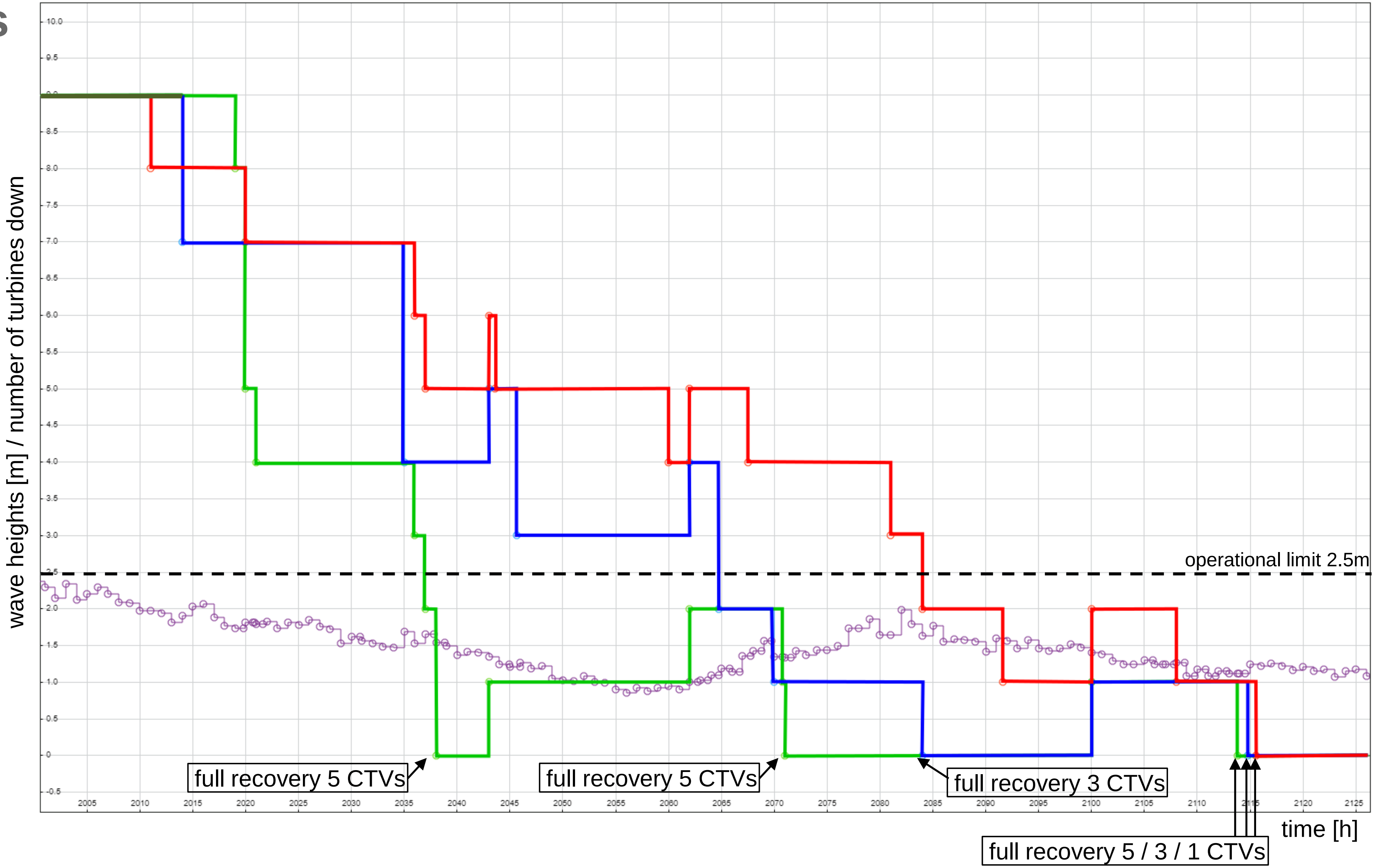


Selected scenarios

Scenario 1 – rebound feature
08.03.2019 – 28.03.2019

Number of turbines down for:
- 1 CTV
- 3 CTVs
- 5 CTVs

Wave heights:
- [m]



Selected scenarios

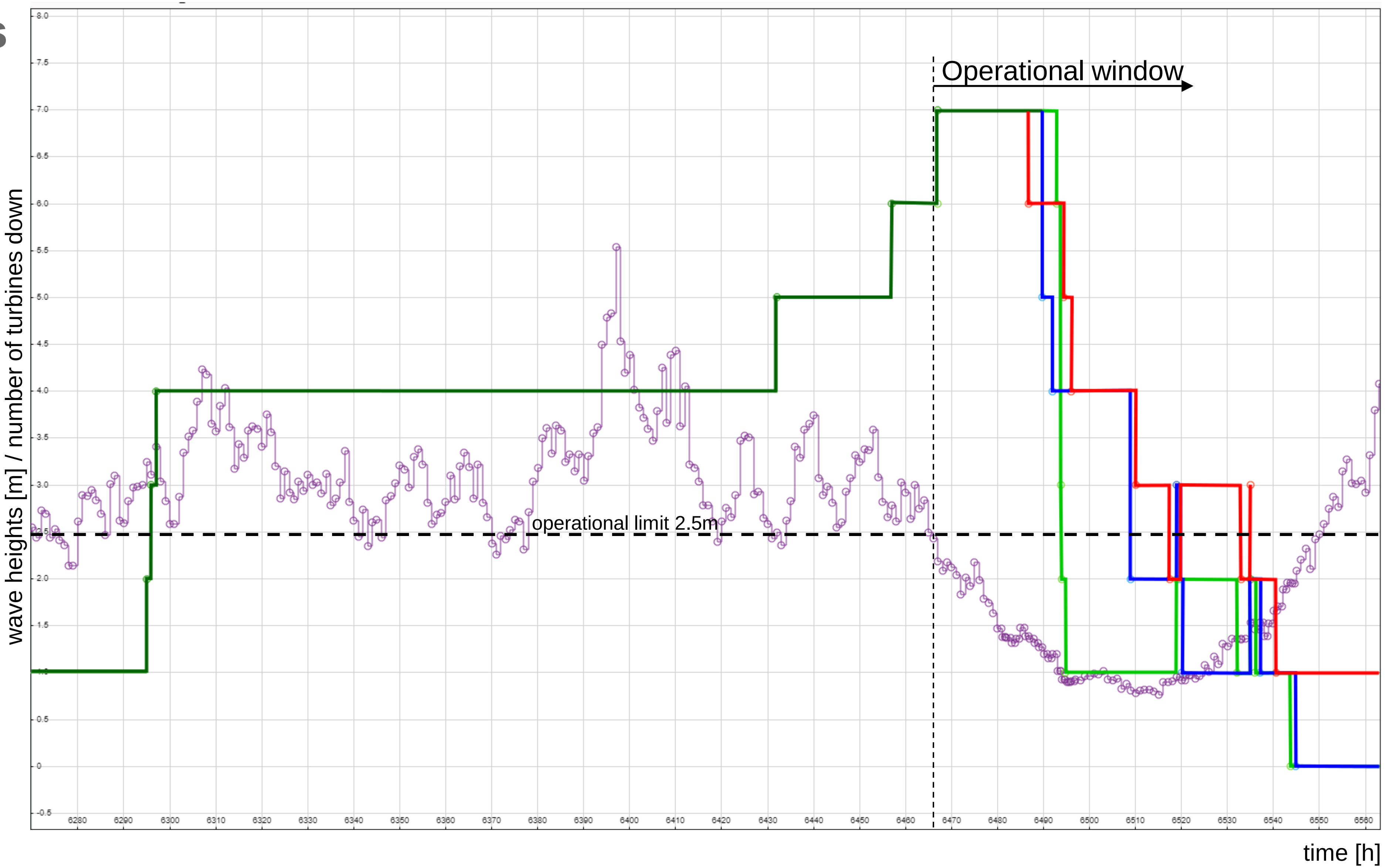
Scenario 2
22.09.2019 – 03.10.2019

Number of turbines down for:

- 1 CTV
- 3 CTVs
- 5 CTVs

Wave heights:

- [m]



Selected scenarios

Scenario 2 – rebound feature
22.09.2019 – 03.10.2019

Number of turbines down for:
- 1 CTV
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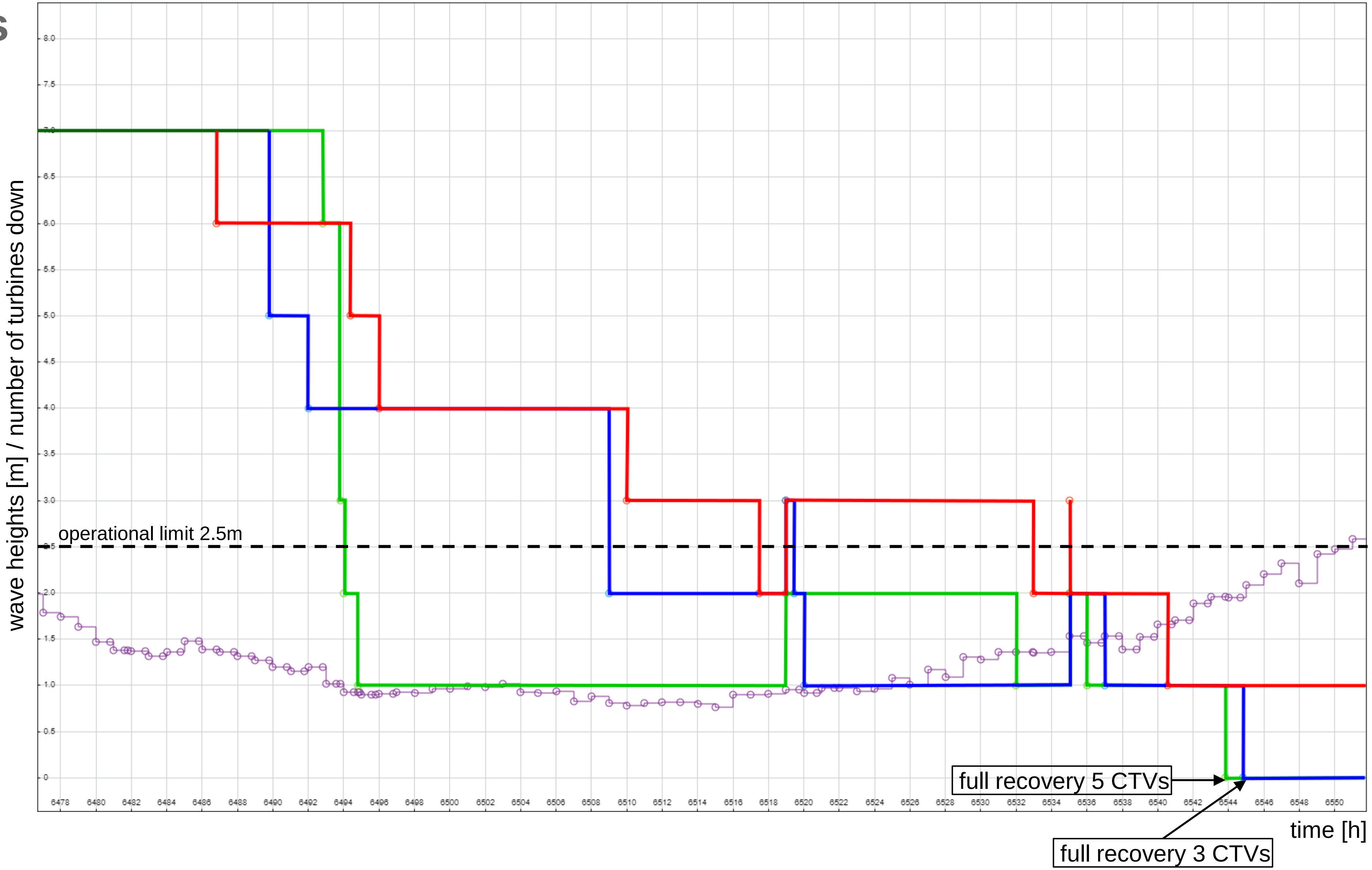
- 5 CTVs

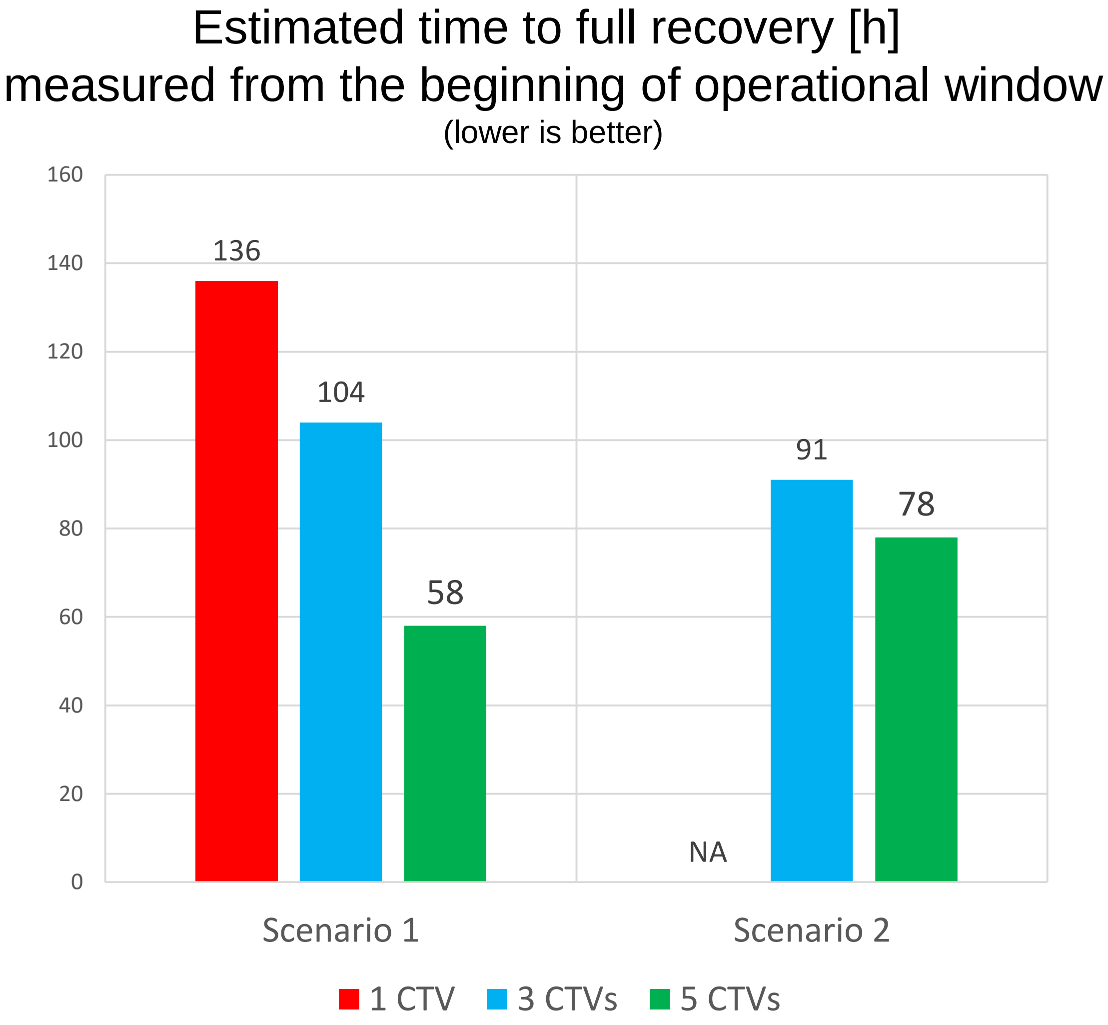
Wave heights:
- [m]



Results & Conclusions

General conclusions:

- The number of maintenance vessels has impact on the system recovery feature,
- Slow recovery process may lead to accumulation of failures,
- Energy provision is dependent on wind force therefore we need to take full advantage of operational windows (especially at harsh weather conditions).



Results & Conclusions

How to minimize drop of performance?

- Redundancy

The common counteract measure in terms of resilience – redundancy of resources, is not an efficient factor to protect the OWF system against drops of performance. In presented case the number of vessels doesn't affect the performance in severe weather conditions.

How to minimize time to recovery?

- Resources
- Reaction time

Redundancy of resources in the case of recovery has a significant impact on the OWF system.

Possible high importance of implementing fast, short-time charter options for O&M purposes.

Thank you

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