New Energy Coalition — Drivers of Change
university of groningen
Utrecht University

DOSTA — DEVELOPING OFFSHORE STORAGE AND TRANSPORT ALTERNATIVES
NWO

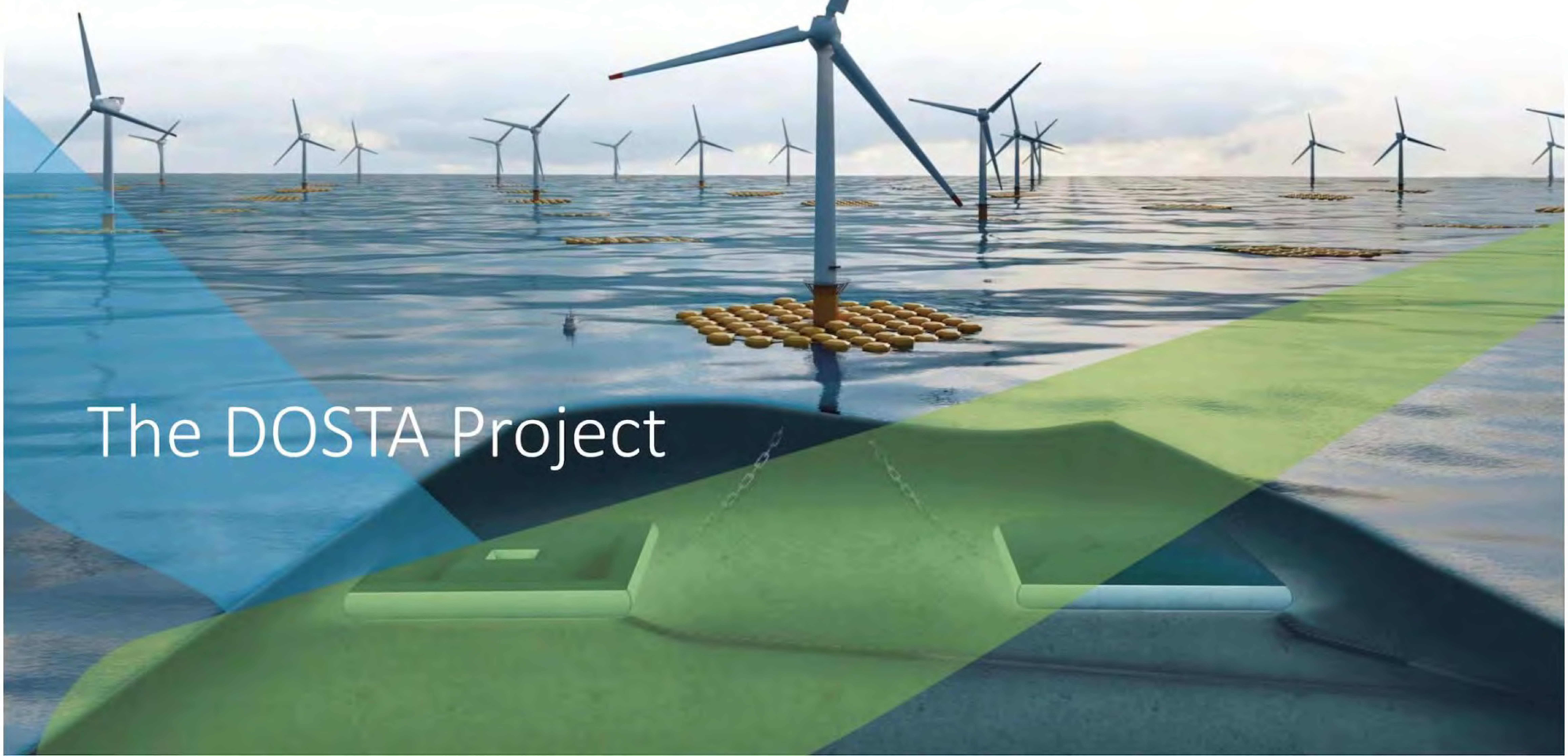
# DOSTA Talks

## Towards the Offshore Energy System of the Future

## Interdisciplinary Insights into Offshore System Integration

NeVER
ebn
Element nl
NGT — Treatment, Transport and Transition of Gas
OCEAN GRAZER
NOGAT — NORTHERN OFFSHORE GAS TRANSPORT
LOYENS & LOEFF — Law & Tax
NAM
SMART PORT
TenneT
TNO
VATTENFALL
SIEMENS energy

DOSTA | DEVELOPING OFFSHORE STORAGE AND TRANSPORT ALTERNATIVES



# The DOSTA Project

# DEVELOPING OFFSHORE STORAGE AND TRANSPORT ALTERNATIVES = *DOSTA*

**BACKGROUND:**

- NWO INITIATED IN 2018 MULTIDISCIPLINARY RESEARCH FOCUSING ON THE NORTH SEA: PHD@SEA

- THE AIM OF PHD@SEA IS TO STIMULATE RESEARCH CONSORTIA TO ADDRESS THE AMIBITION OF THE DUTCH GOVERNMENT TO DEVELOP 75 GW OFFSHORE WIND BY 2050

- DOSTA IS A PHD@SEA PROJECT AND RUNS SINCE 2020

# Who and what is *DOSTA*

**ACADEMIC PARTNERS:**

- UNIVERSITY OF GRONINGEN COVERING THREE ACADEMIC DISCIPLES : SCIENCE, SPATIAL PLANNING AND LAW
- UNIVERSITY OF UTRECHT (COPERNICUS INSTITUTE) COVERNING TECHNICAL / ECONOMIC ACADEMIC RESEARCH

**INDUSTRIAL PARTNERS:**

EBN, ELEMENT NL, LOYENS & LOEFF, NAM, NEVER (DUTCH ENERGY LAW ASSOCIATION), NEC, NGT, NOGAT, OCEAN GRAZER, SMARTPORT, TENNET, TNO AND VATTENFALL

# Objectives of *DOSTA*

**TO ADDRESS THE GOAL TO DEVELOP 75 GW OFFSHORE WIND ENERGY VIA FOUR SEPARATE INTERRELATED RESEARCH TOPICS:**

- MULTISCALE PHYSICS-BASED MODELS OF NOVEL PUMPED-HYDRO OFFSHORE STORAGE TECHNOLOGY

- OPTIMAL SIZING AND OPERATION OF OFFSHORE INFRASTRUCTURE FOR WIND FARMS COUPLED TO HYDROGEN PRODUCTION, STORAGE AND TRANSPORT

- A LEGAL DESIGN FOR NEW OFFSHORE STORAGE AND TRANSPORT INFRASTRUCTURE

- MARINE SPATIAL PLANNING, ENVIRONMENTAL IMPACT AND LOCATIONAL CHOICE

# Research Approach

**TO ACHIEVE AN INTEGRATED BUT MULTIDISCIPLINARY RESEARCH OUTCOME**

- FOUR SEPARATE PHD'S BUT ALSO COMMON RESEARCH OUTCOMES
- ONE OR MORE JOINT ARTICLES
- REGULAR MEETINGS WITH INDUSTRIAL PARTNERS
- INTERNSHIPS
- PUBLIC OUTREACH

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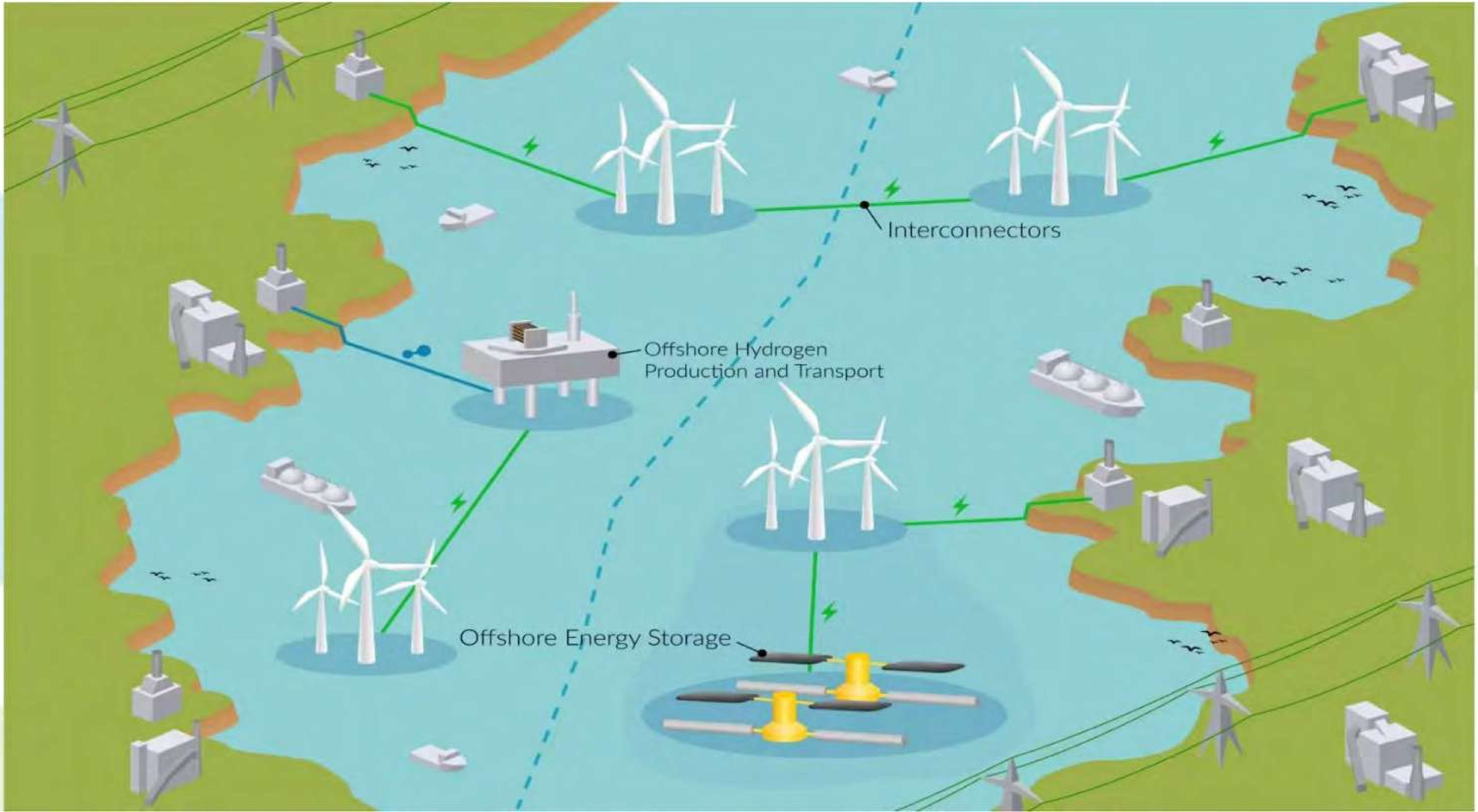

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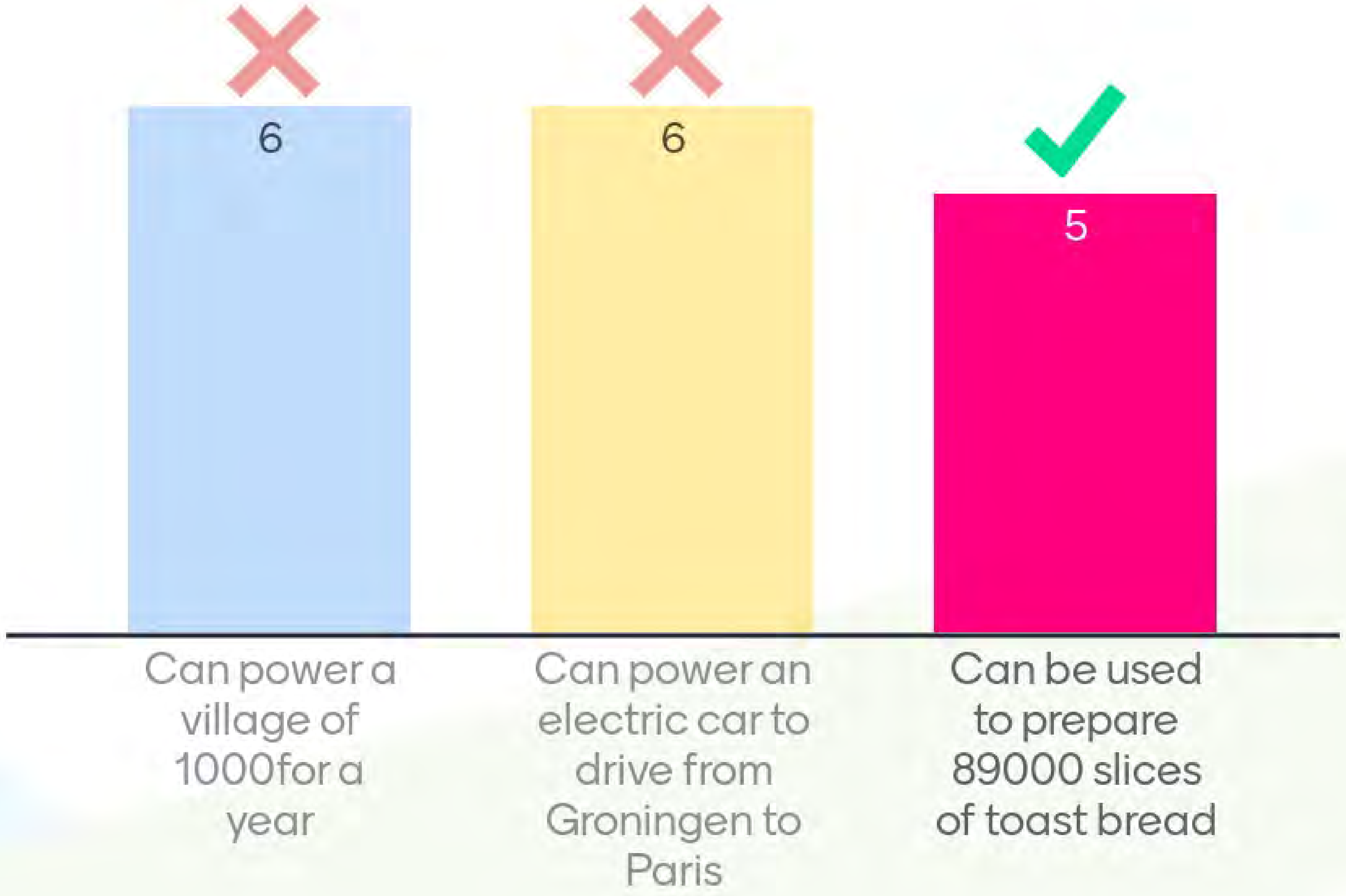
# Developing the Ocean Battery: Unlocking the Potential of Offshore Energy Storage

Robbert Nienhuis
r.m.nienhuis@rug.nl

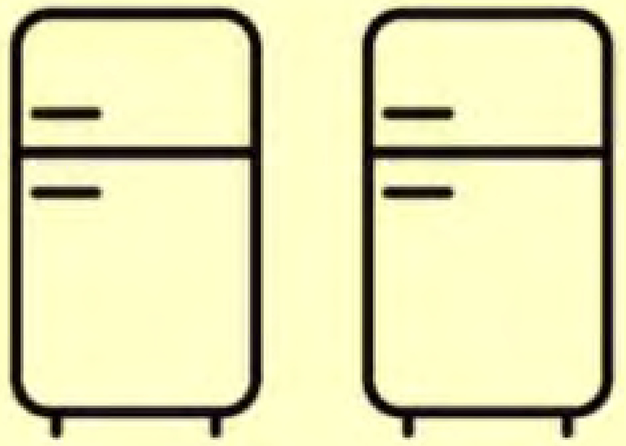
*Faculty of Science and Engineering (FSE)*
*University of Groningen (UG)*

# Instructions

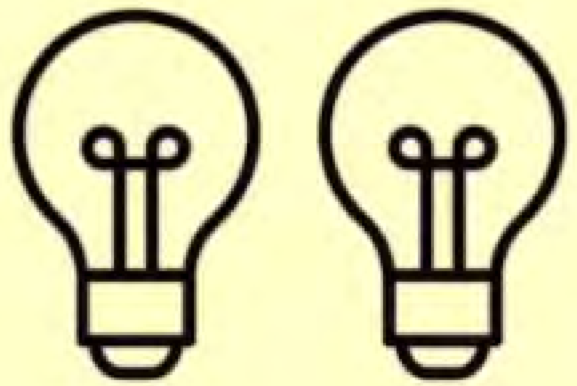
# For the case of energy storage, how much is 1 MWh?



# 1 MWh also…



**2 refrigerators**
run for a year



**2x 60w bulbs**
powered non-stop for a year

**3,600 miles**
driven by an electric car


Groningen – Paris:
Distance: 352.55 mi or 567.38 km
Driving route: 402.98 mi or 648.54 km

# Multiscale Physics-Based Models of Novel Pumped-Hydro Offshore Energy Storage

DOSTA

**D**eveloping
**O**ffshore
**S**torage &
**T**ransport
**A**lternatives

## Setup Project

- 4 year PhD at RUG
- 1 year at Ocean Grazer

university of groningen

OCEAN GRAZER

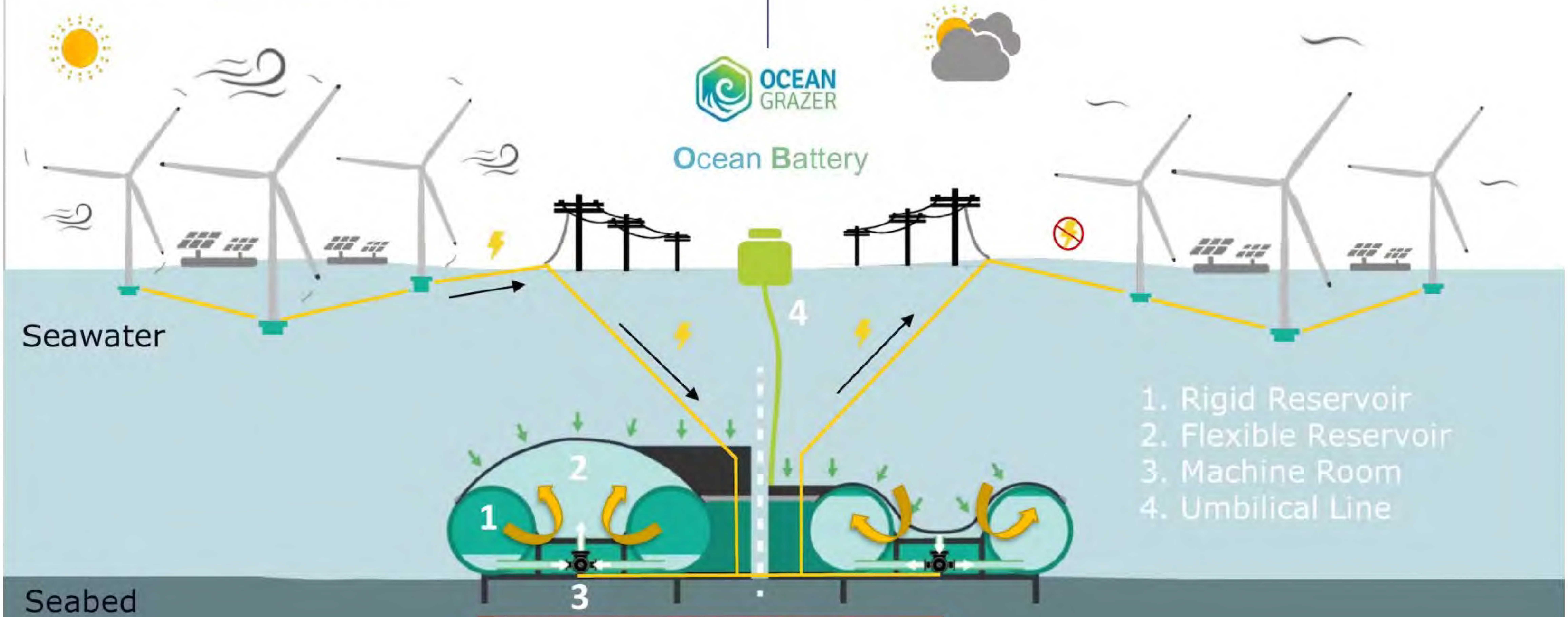
## Research aim

Descriptive model of system behaviour to optimize round-trip efficiency under influence of:

- Isolation and degradation mechanics from the marine-structure interface
- System stability and survivability under internal and external dynamic loading
- Coupling to multi-energy systems, alternative energy carriers in hybrid wind farm systems

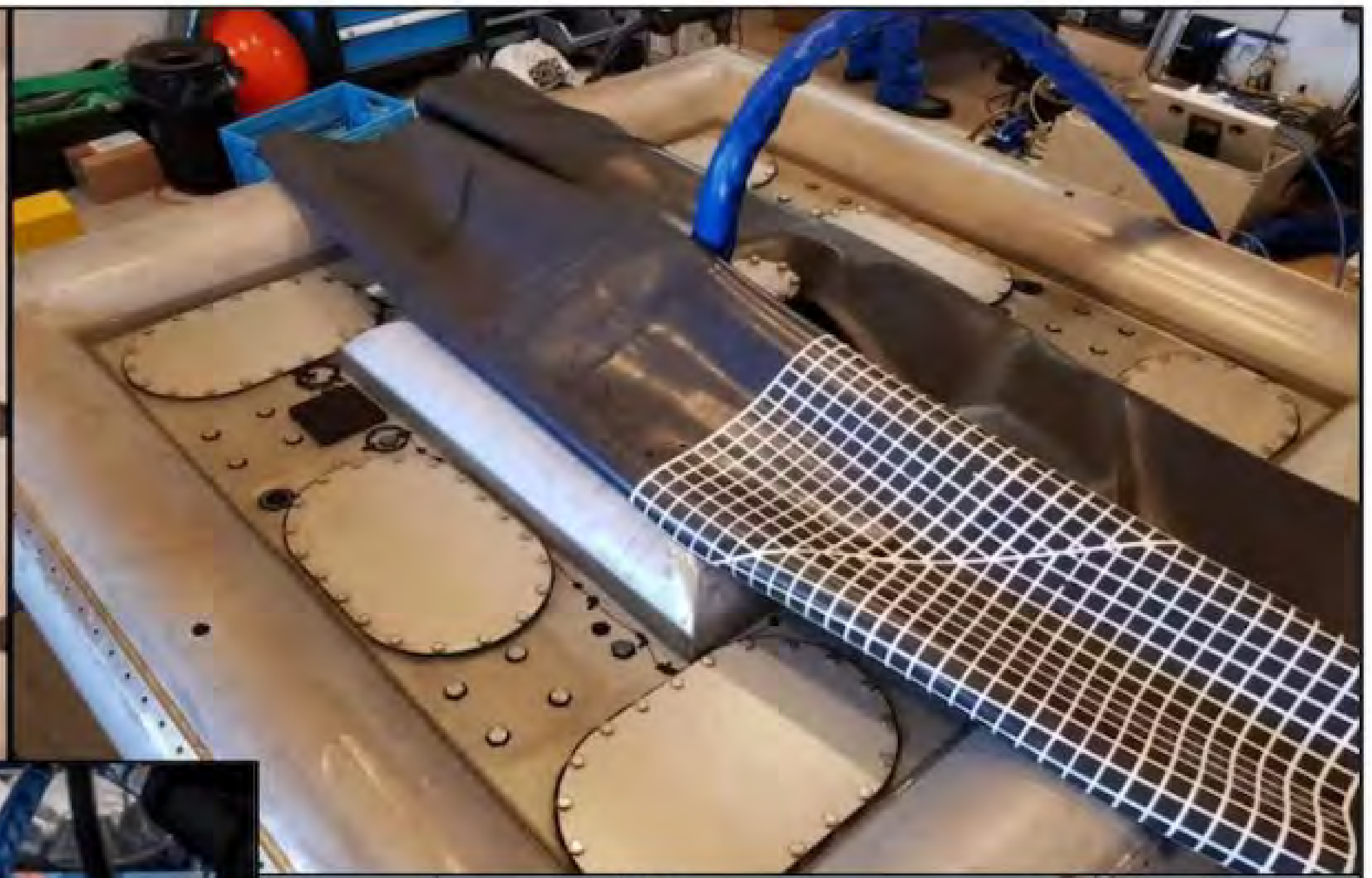
## Table of Contents

# Working Principle




| | |
|---|---|
| **Efficiency Range** | 75 - 80% |
| **Lifetime** | > 25 years |
| **Storage volume** | 8 MWh/unit |

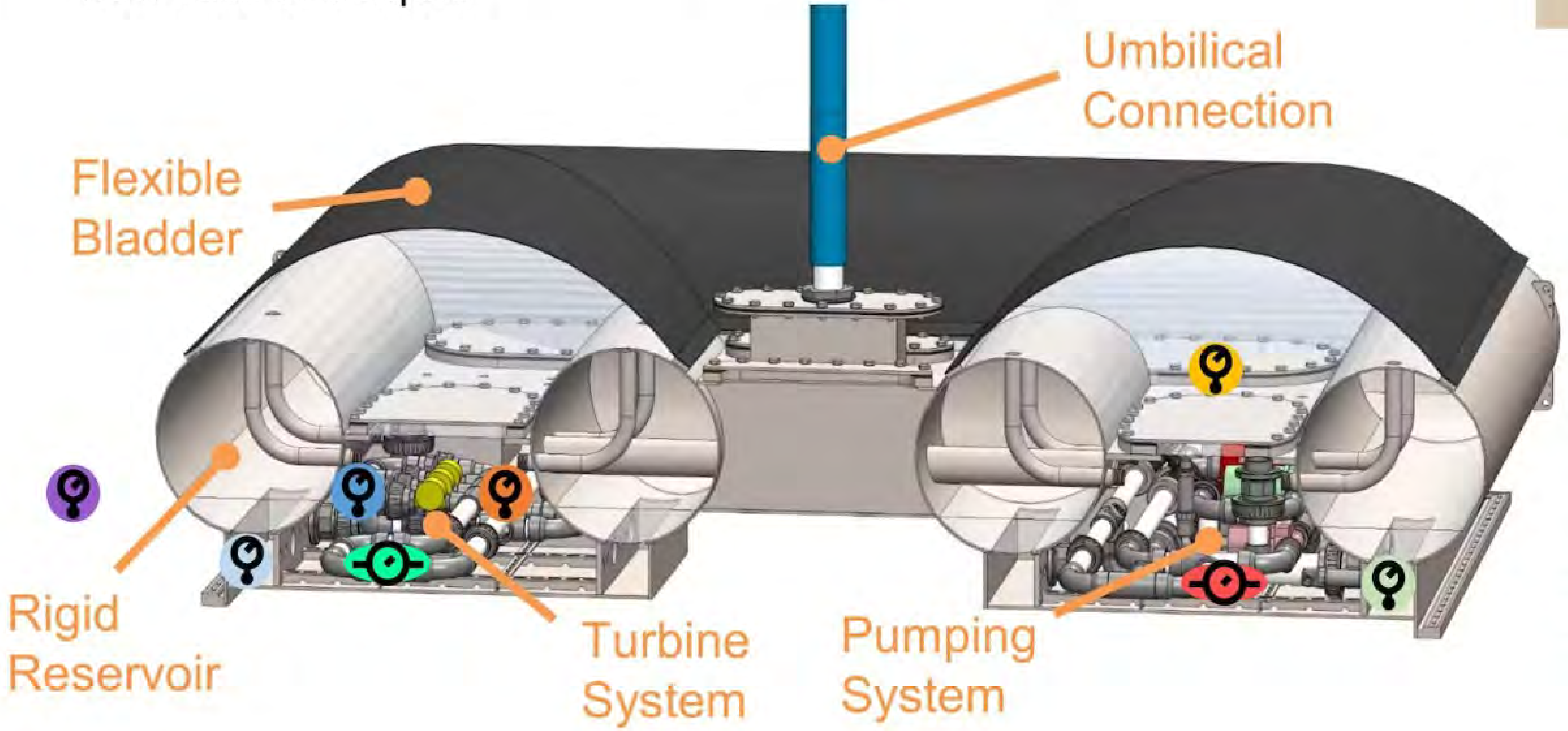
# Ocean Battery Prototype I

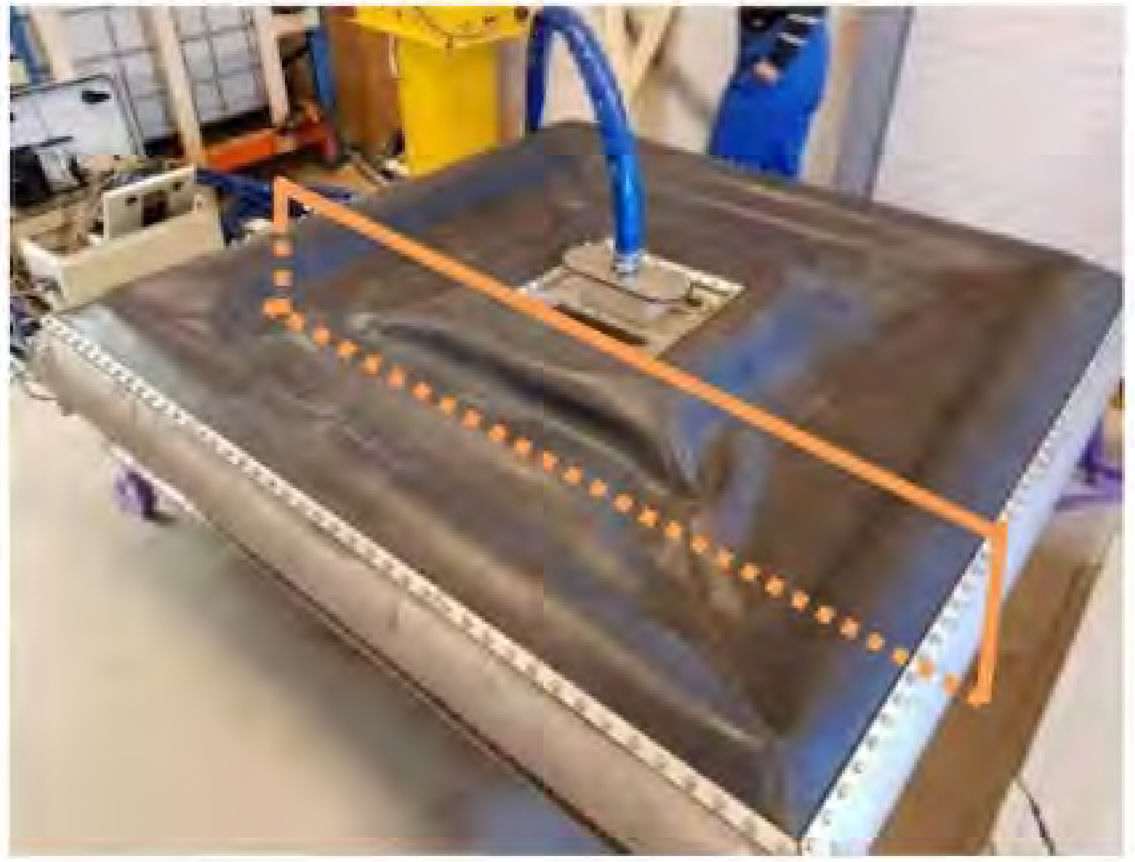


# Ocean Battery Prototype II

**Pressure sensors**
- Used for recording the pressure head in fluid technology systems - [m]

**Flow sensors**
- Used for measuring the volumetric flow rate of a liquid - [L/s]

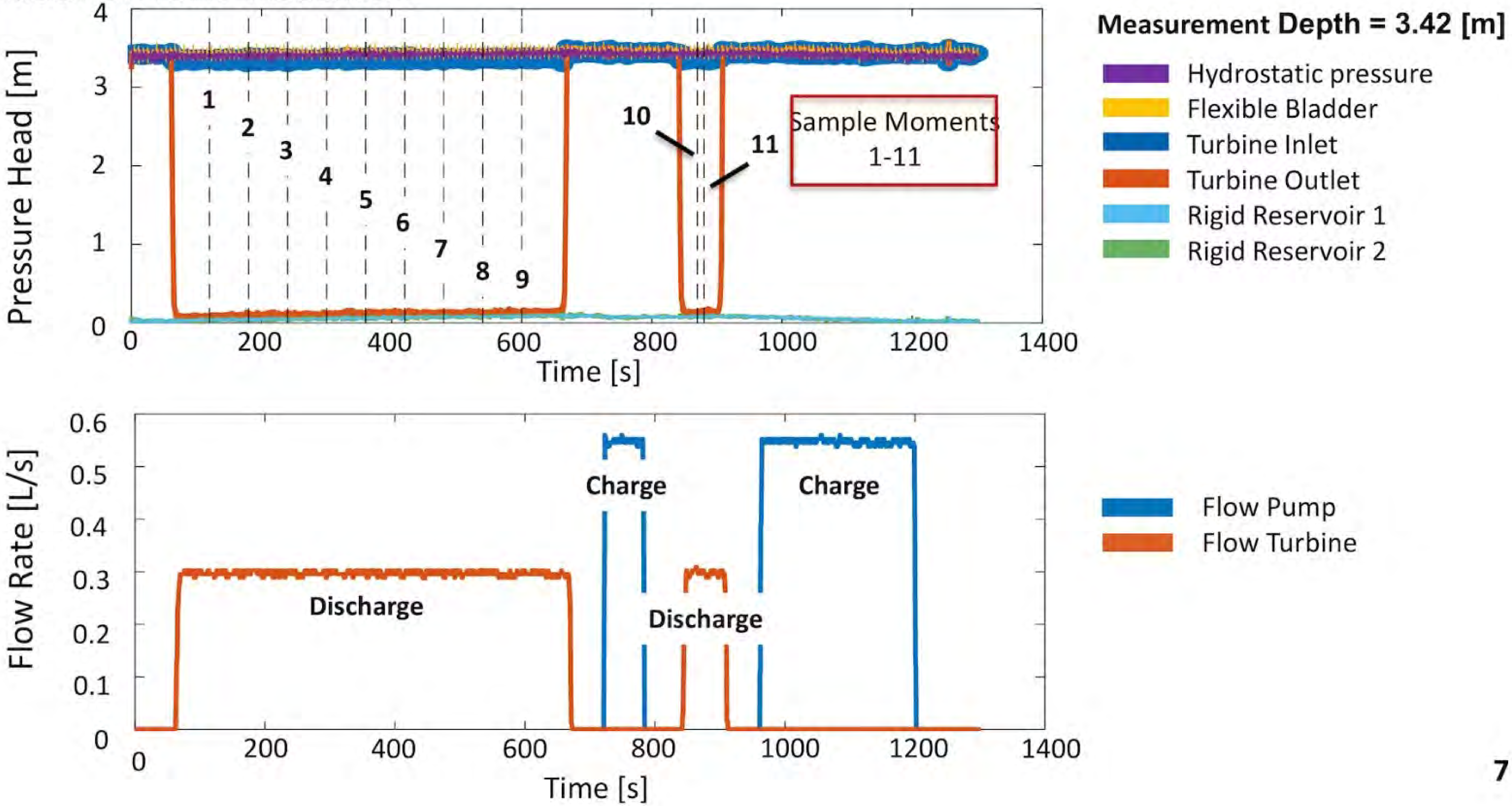


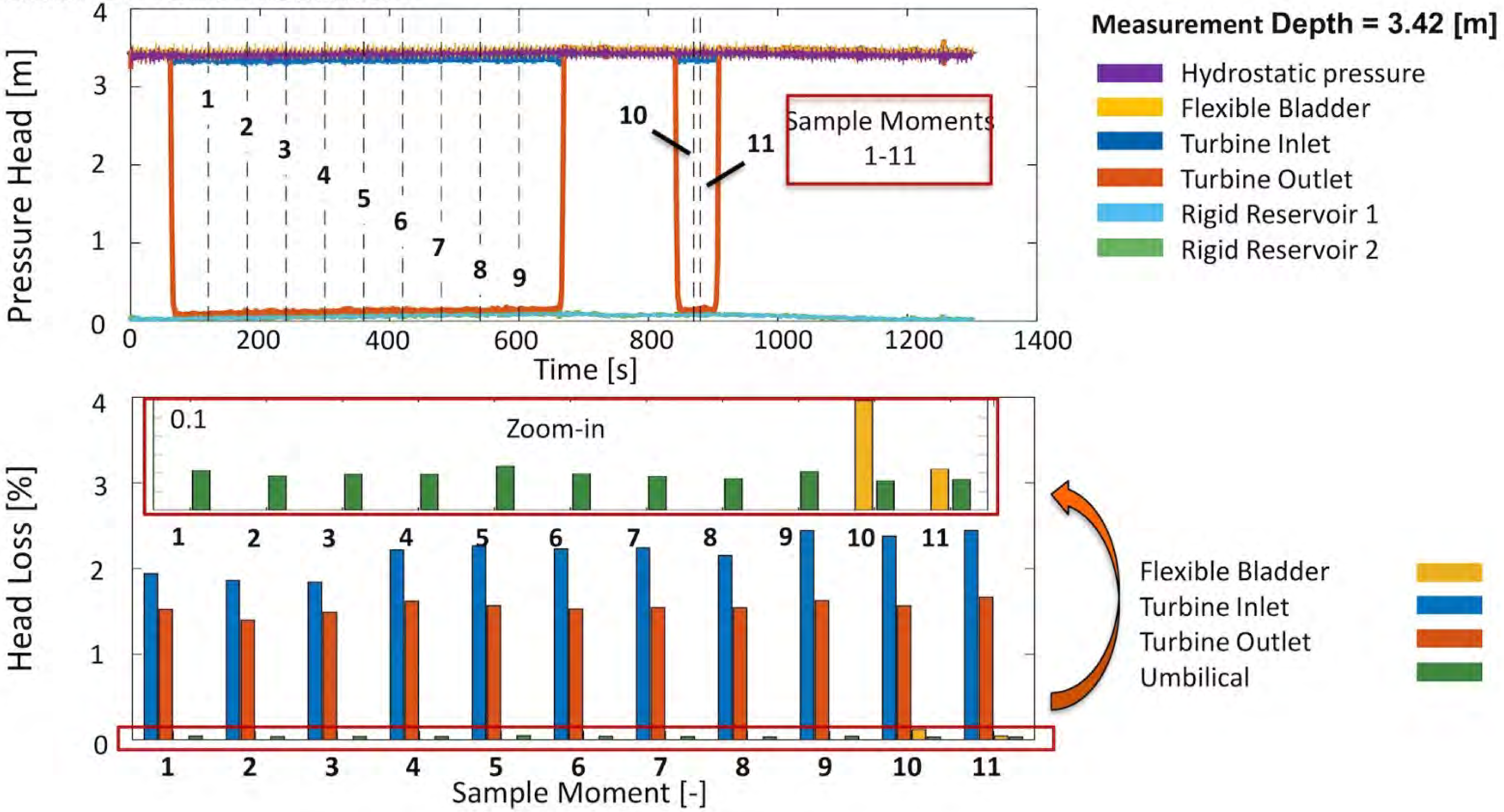
Pressure Sensors
- Hydrostatic Pressure
- Flexible Bladder
- Turbine Inlet
- Turbine Outlet
- Rigid Reservoir 1
- Rigid Reservoir 2

Flow Sensors
- Pump
- Turbine

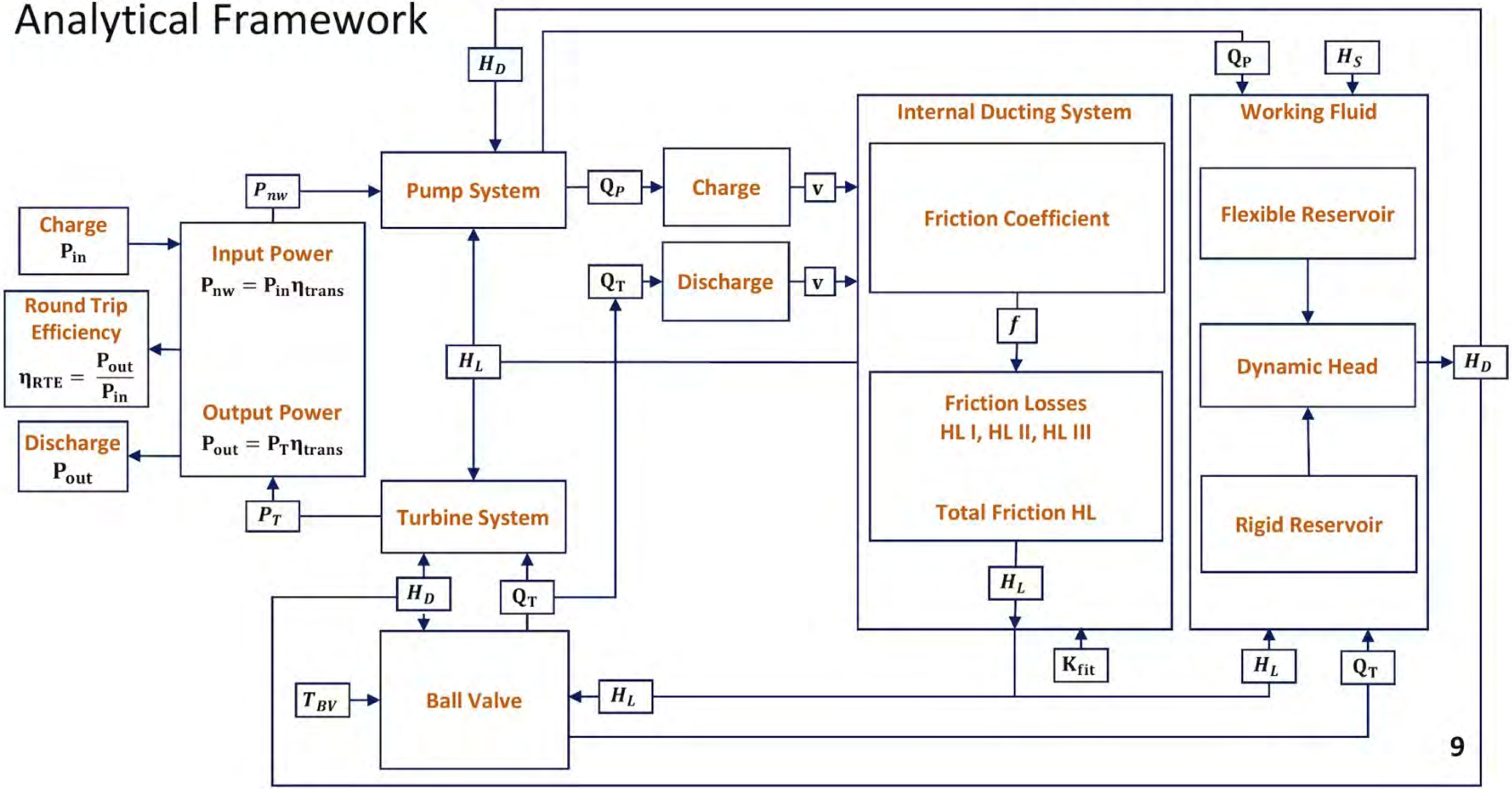
# Measurement Results I



# Measurement Results I

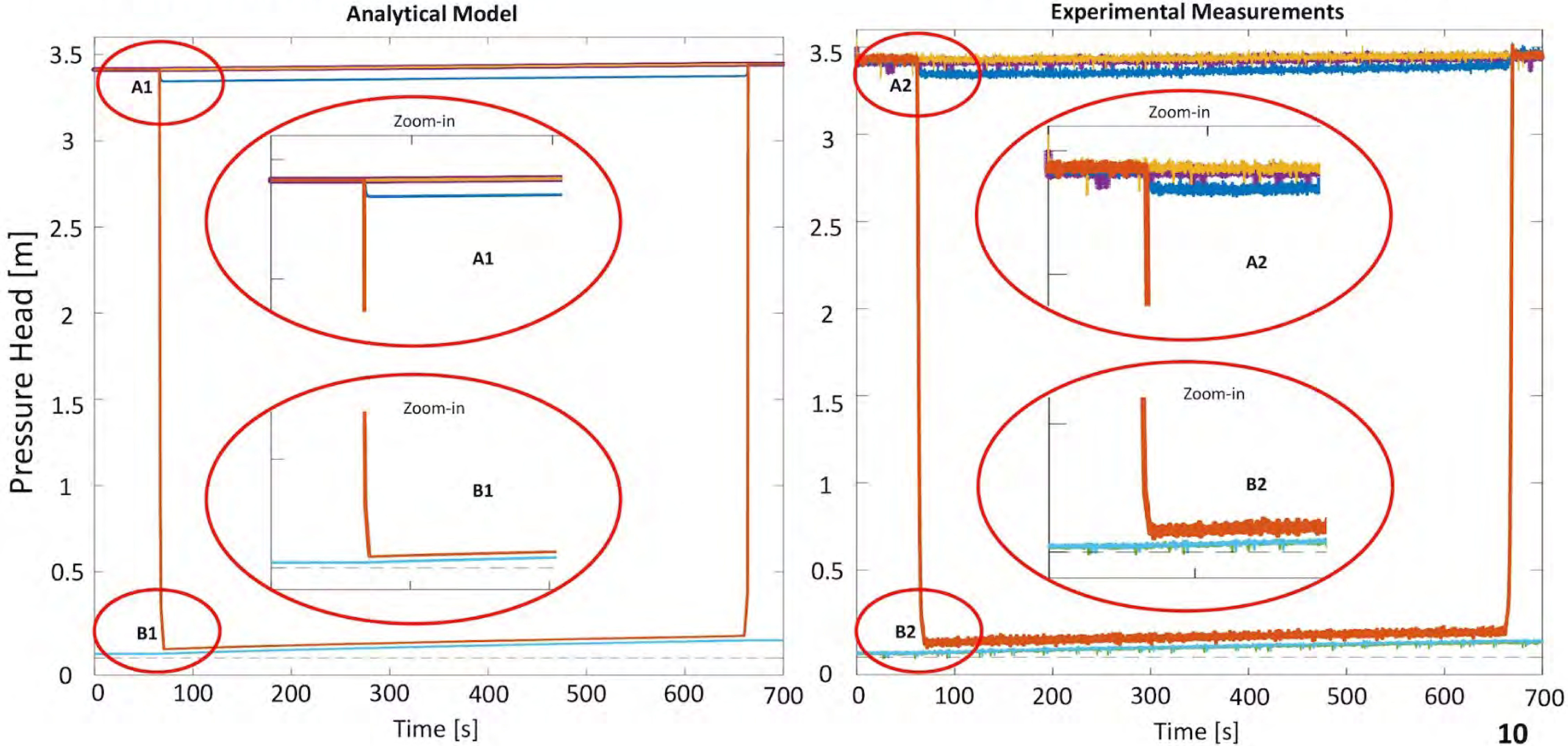


# Analytical Framework

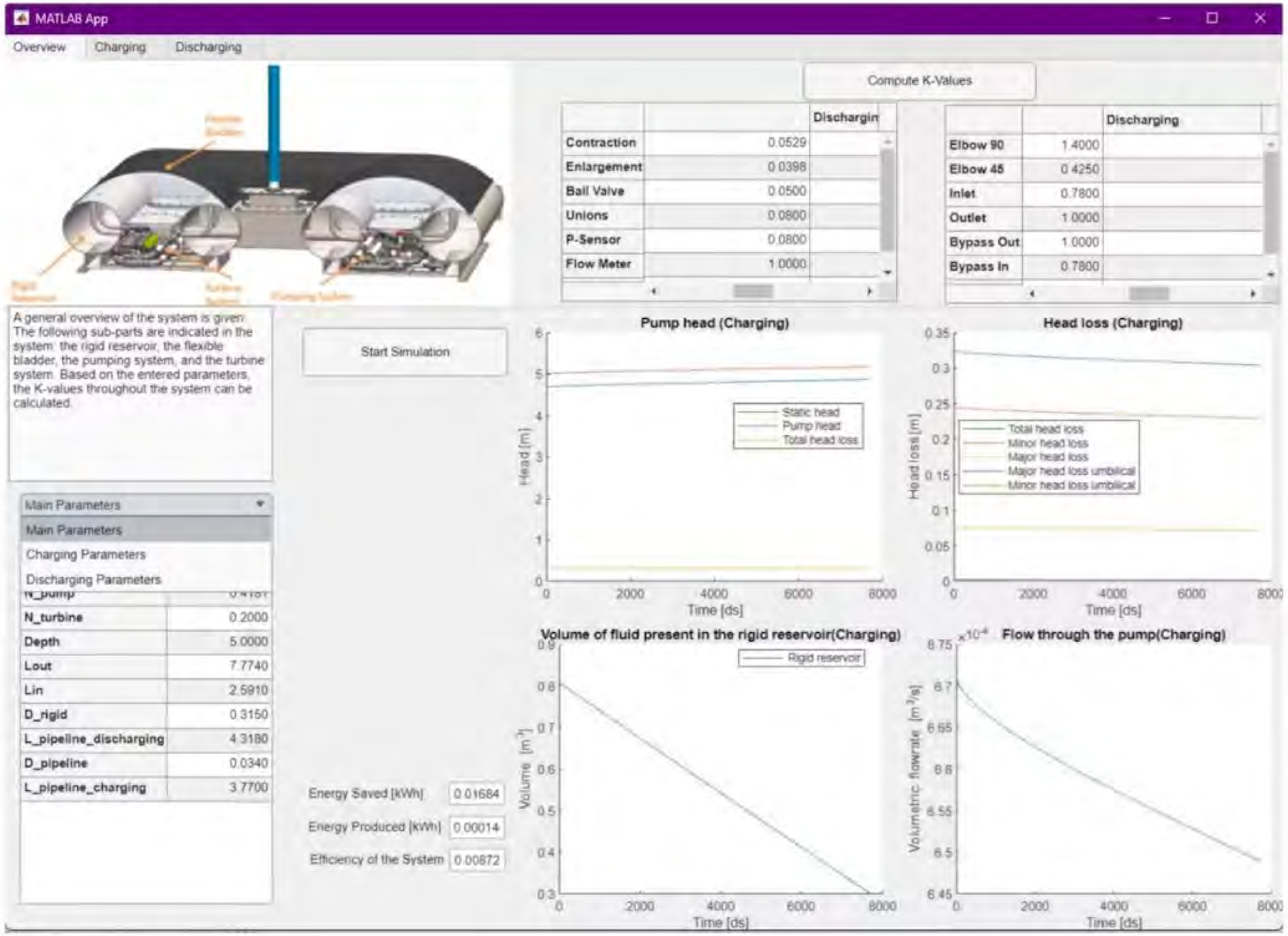


# Model Comparison

**Measurement Case | Depth = 3.42 [m]**



# Digital Twin - GUI




| $S_1$ Section – from sensor p2 to p3 | | |
|---|---|---|
| Fitting Type | Amount # | $K_{min}[-]$ |
| Contraction / Inlet | 1 | 0.27 |
| Bend 90° | 3 | 0.19 |
| Elbow 90° | 1 | 0.90 |
| Flow Sensor | - | - |

| $S_2$ Section – from sensor p3 to p4 | | |
|---|---|---|
| Fitting Type | # | $K_{min}[-]$ |
| Bend 90° | 5 | 0.19 |
| Tee Branch | 4 | 1.80 |
| Turbine Run Through | 4 | 0.40 |
| Elbow 90° | 2 | 0.90 |
| Contraction | 3 | 0.005 |
| Enlargement | 3 | 0.30 |
| S-Bend * | 1 | 0.80 |
| Elbow 90° | 1 | 0.90 |

| $S_3$ Section – from sensor p4 to $p5_T$ | | |
|---|---|---|
| Fitting Type | # | $K_{min}[-]$ |
| Ball valve | 1 | 0 (fully open)<br>5.5 (1/3 closed)<br>200 (fully closed) |
| Elbow 90 Degrees | 2 | 0.90 |
| Enlargement / Outlet | 1 | 0.41 |

* K-value assumed to be two times $K_{45}$

# Efficiency Parameter Overview

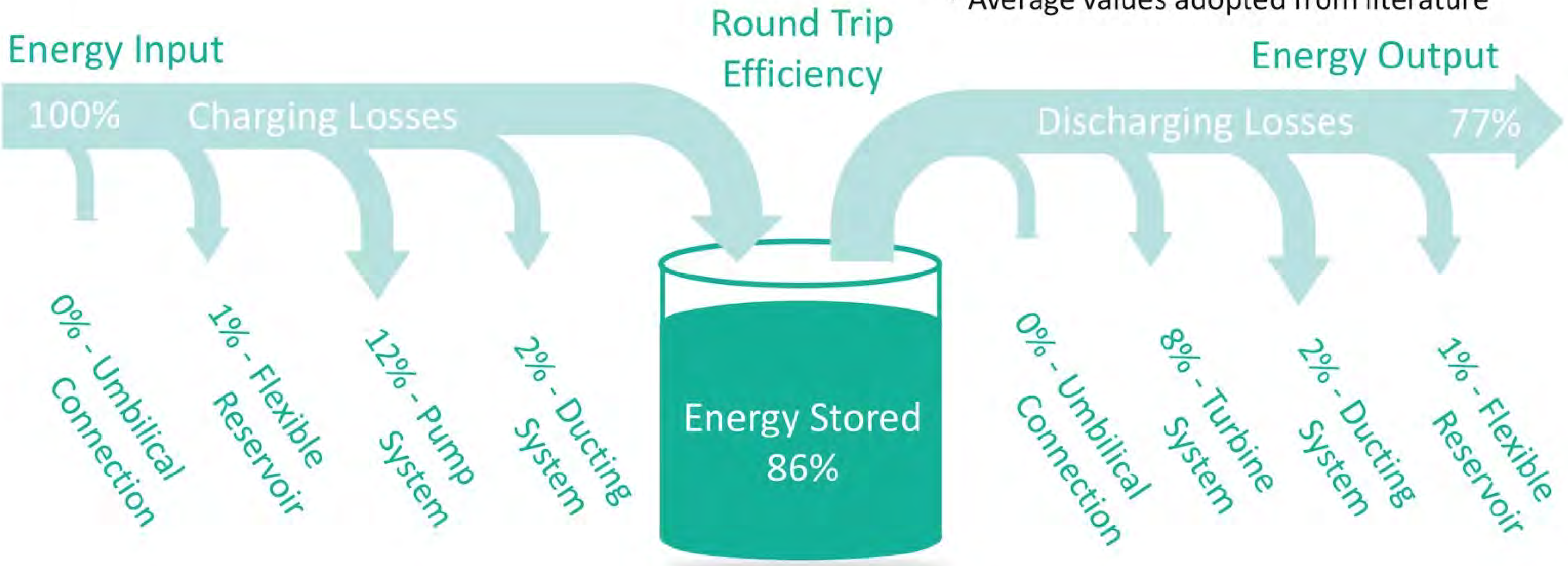
## Round-Trip Efficiency Calculation

- In range with conventional Pumped Hydro Technologies 75 - 80%

## Scaled-up case-study

- Average Pump Efficiency of 88%*
- Average Turbine Efficiency of 92%*
- Total Round Trip Efficiency of 77%

* Average values adopted from literature



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# Any questions?

Robbert Nienhuis

Faculty of Science and Engineering (FSE), University of Groningen (UG)

r.m.nienhuis@rug.nl

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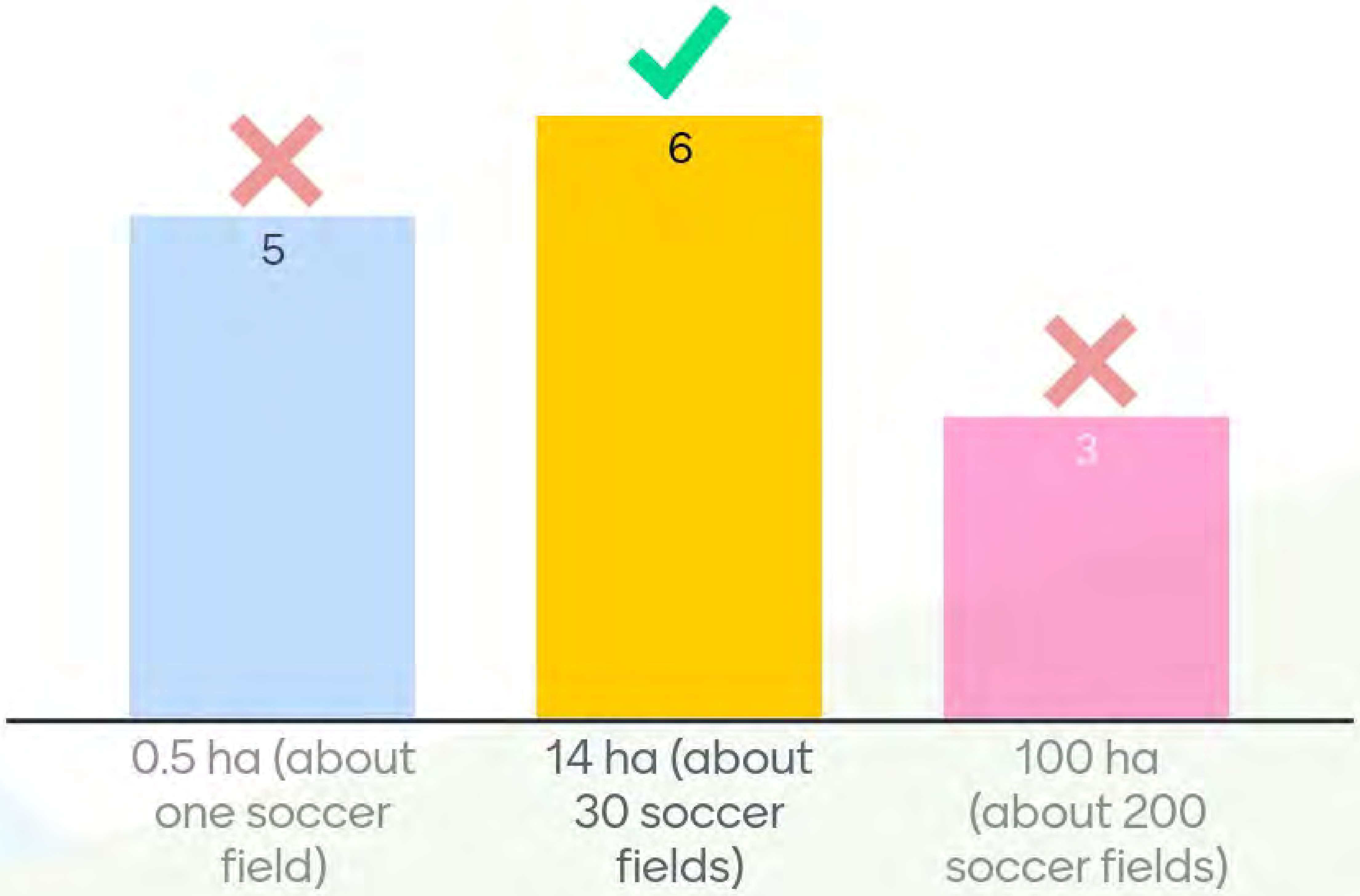
# Harvesting the Wind: Insights into Energy System Optimization

Jan Wiegner

Copernicus Institute of Sustainable Development, University Utrecht

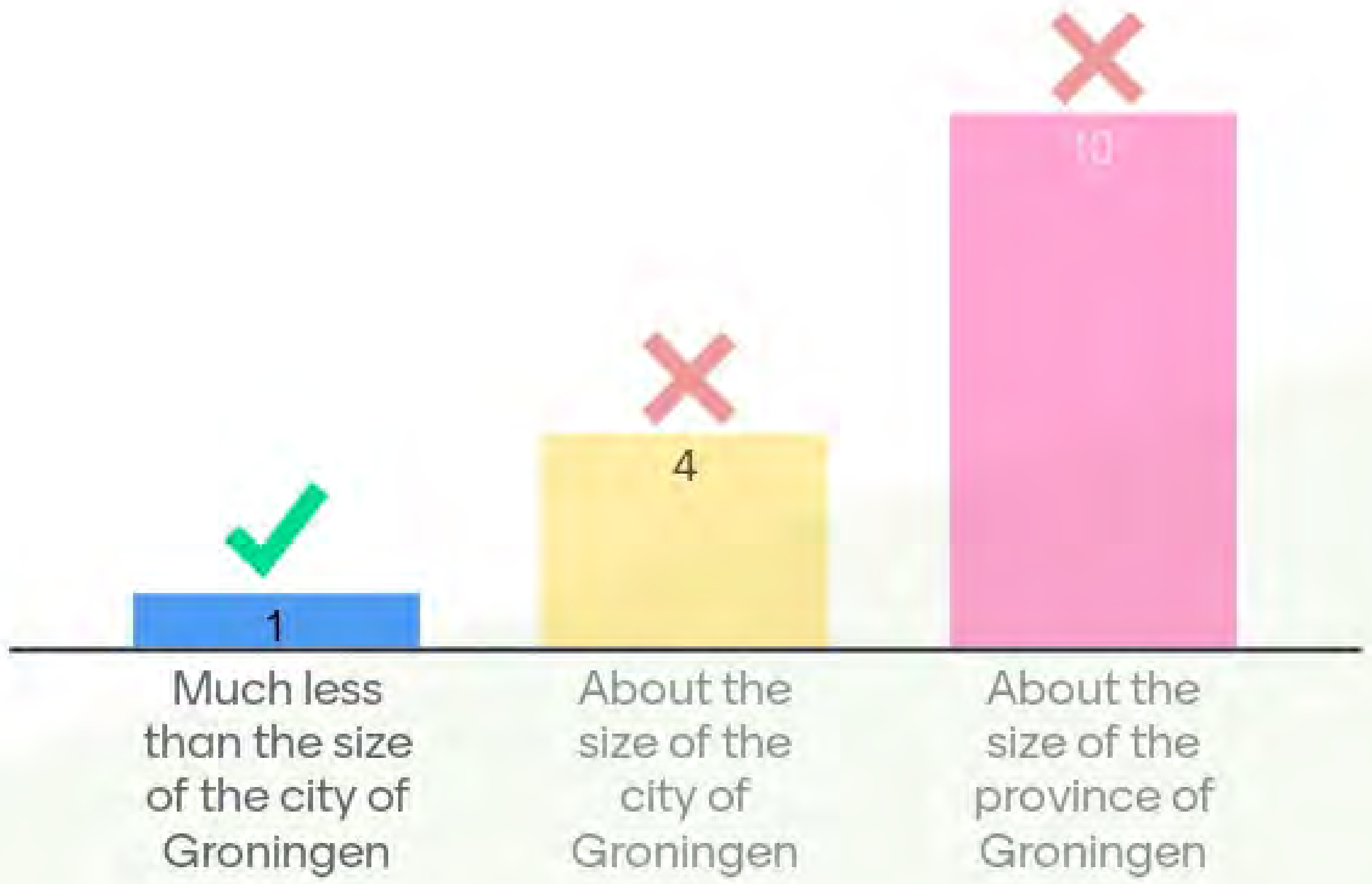
j.f.wiegner@uu.nl

# What is the area requirement for 1GWe of electrolysis?



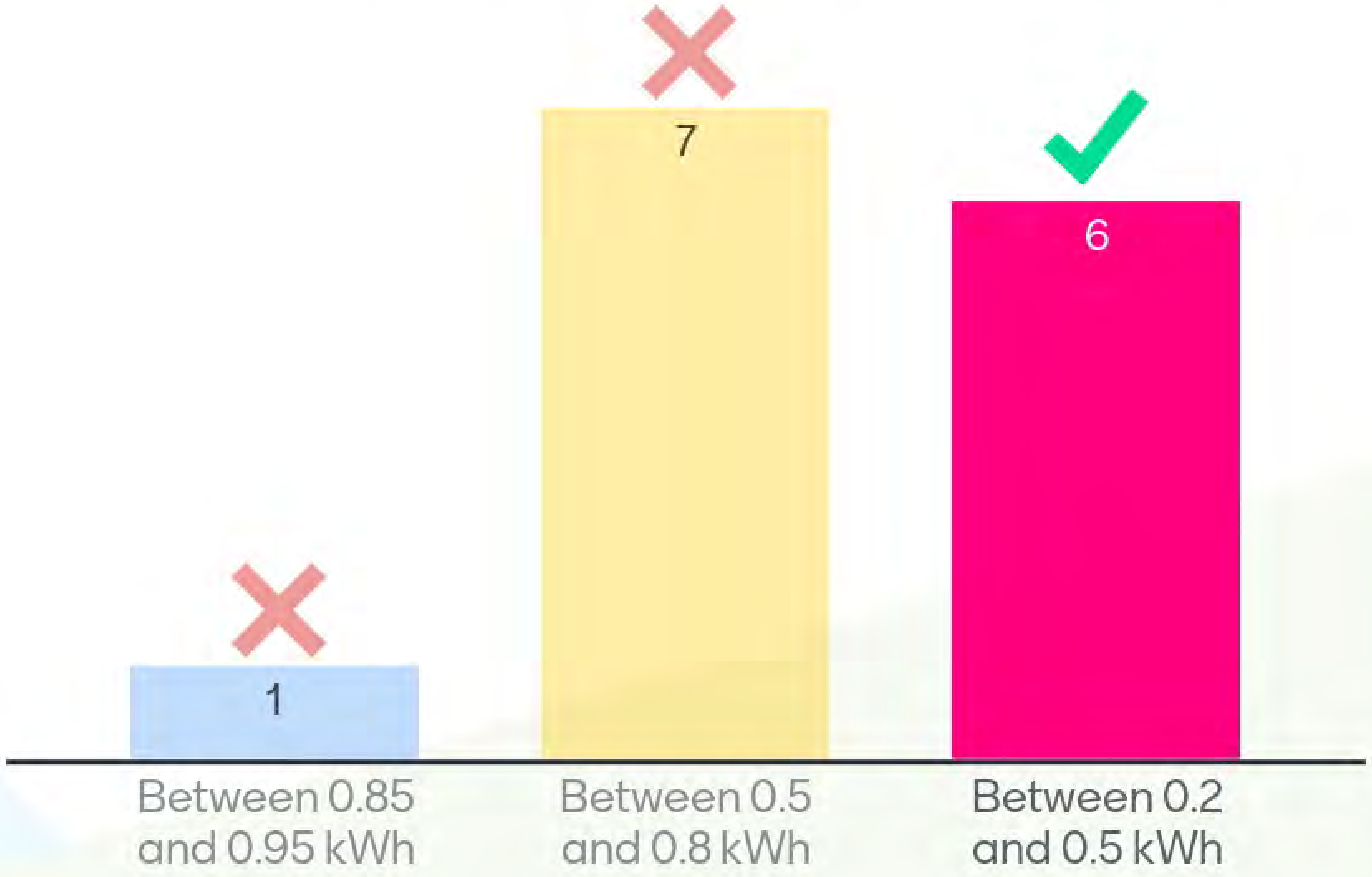
# Area Requirements of Electrolysis

# What is the area requirement for supplying about 20 million tons of hydrogen with electrolysis (estimated H2 production Europe in 2030)?



# Area Requirements of Electrolysis

# How much electricity can be fed back to the grid after conversion to hydrogen?



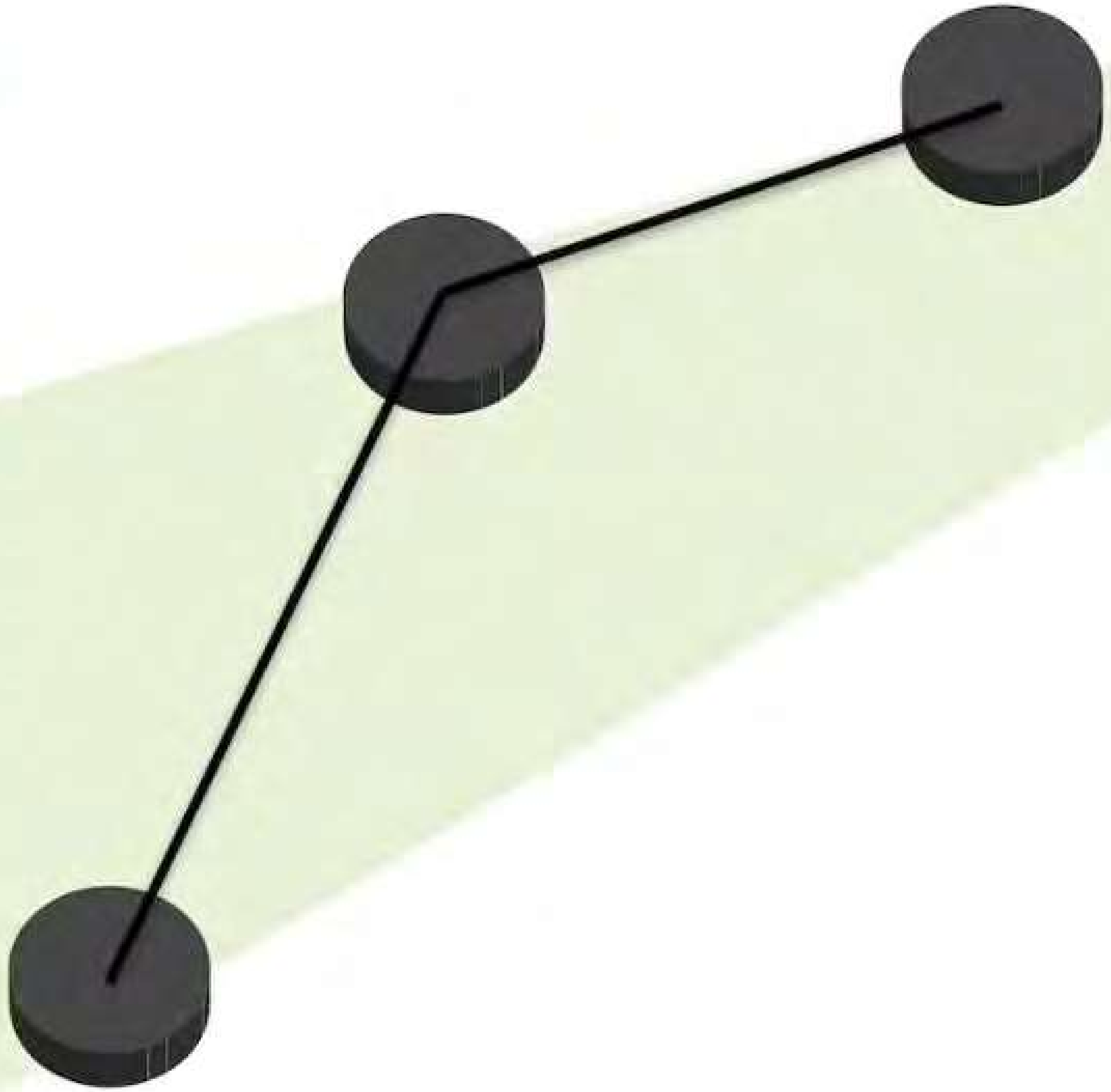
# Efficiency of Electricity-Hydrogen-Electricity Storage

- *How much electricity can be fed back to the grid after conversion to hydrogen?*
  - Between 0.85 and 0.95 kWh
  - Between 0.5 and 0.8 kWh
  - **Between 0.2 and 0.5 kWh**

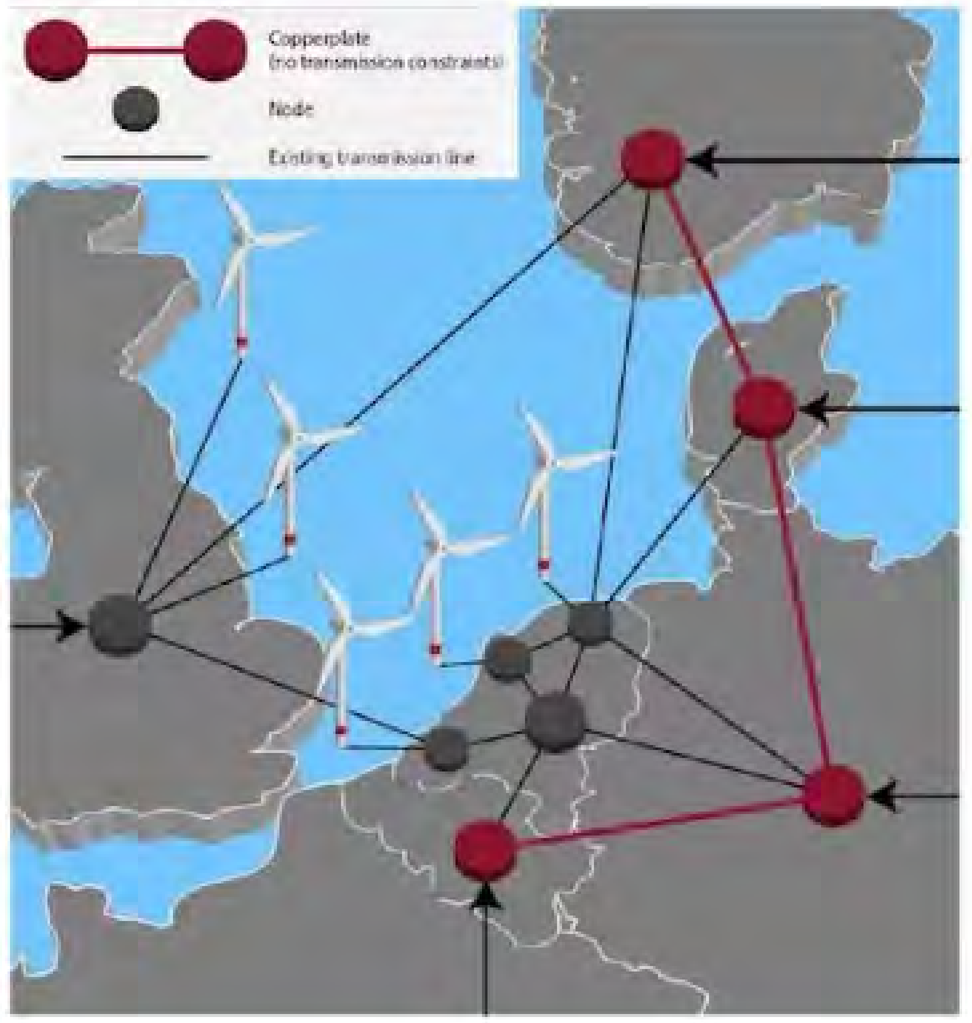
# How many DC meshed grids exist worldwide?

0 — 3 — > 10

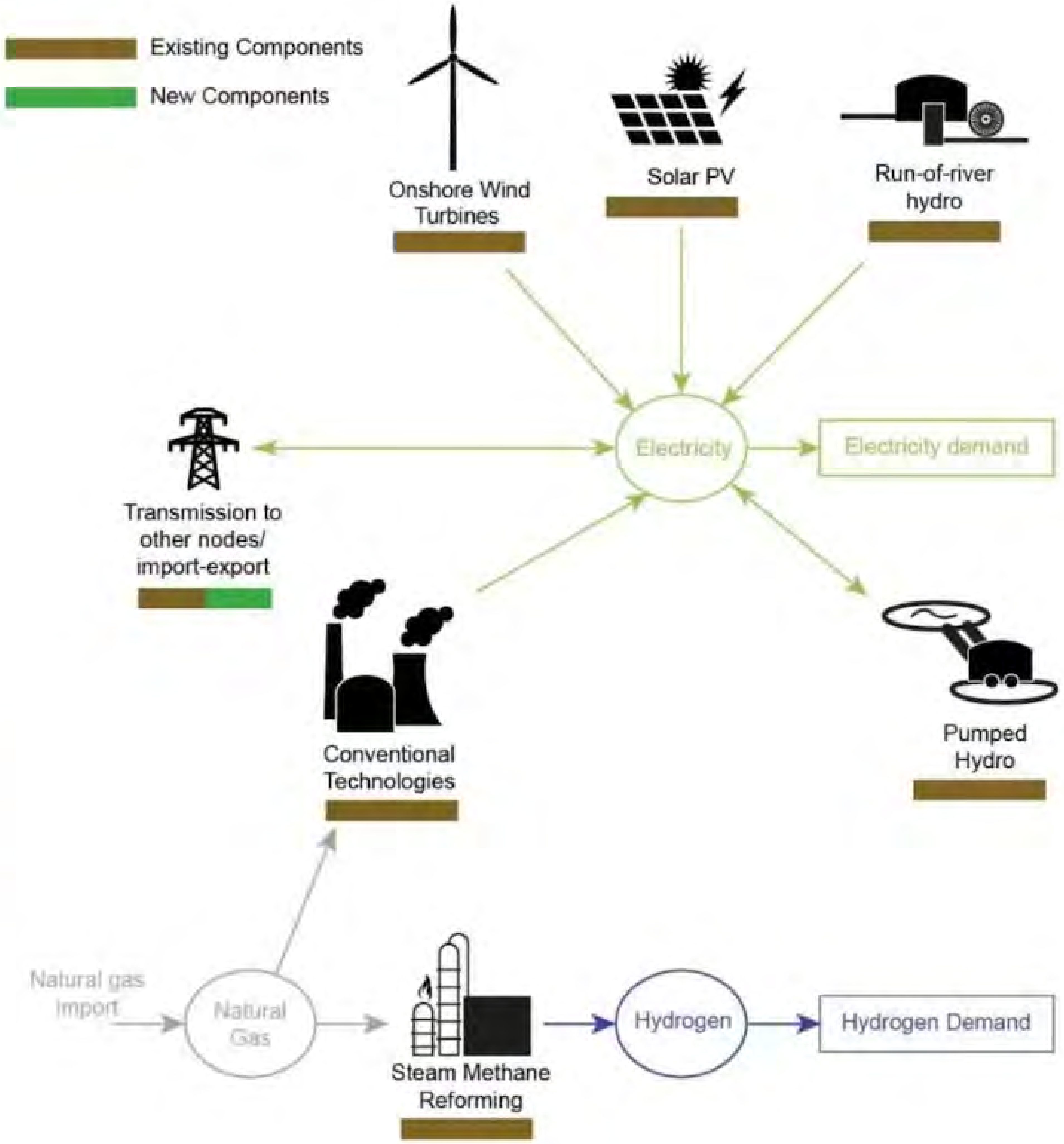
- *How many DC meshed electricity grids exist worldwide?*
  - None
  - **3 with only 3 terminals**
  - Over 10



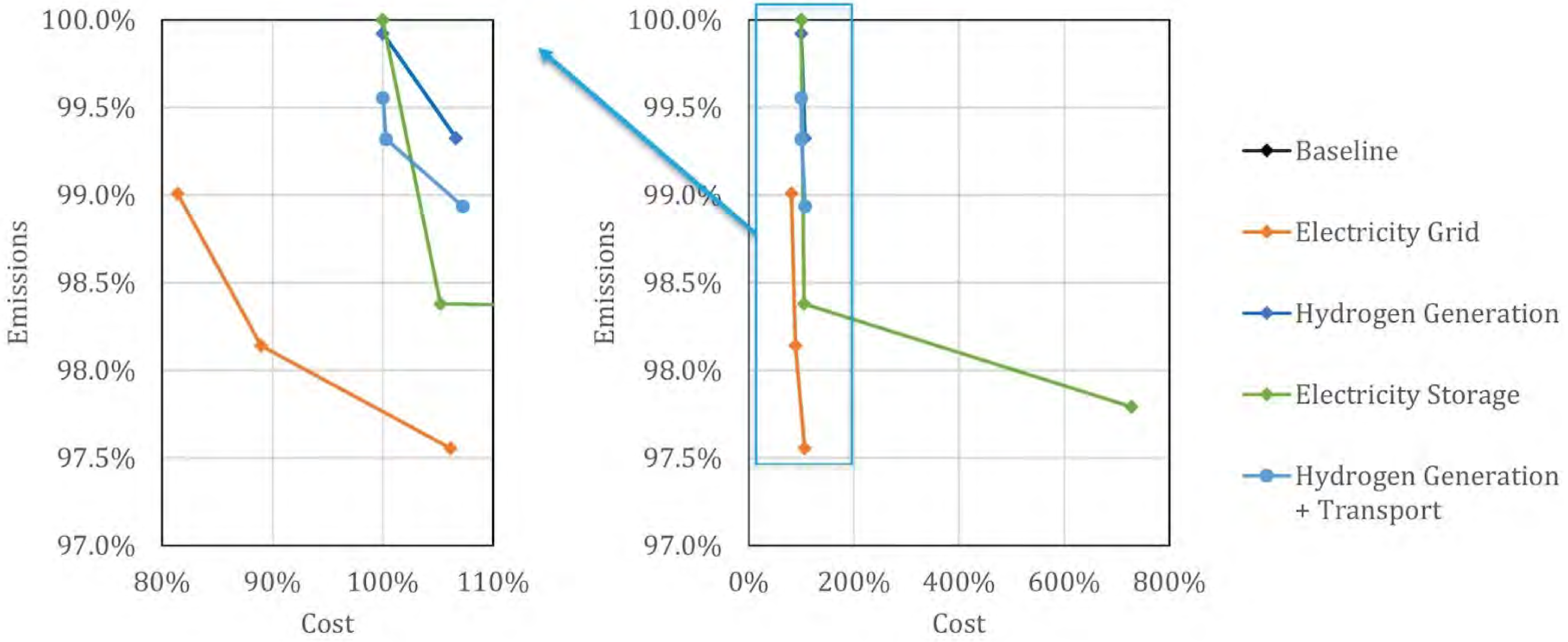
# Electricity Grid expansion



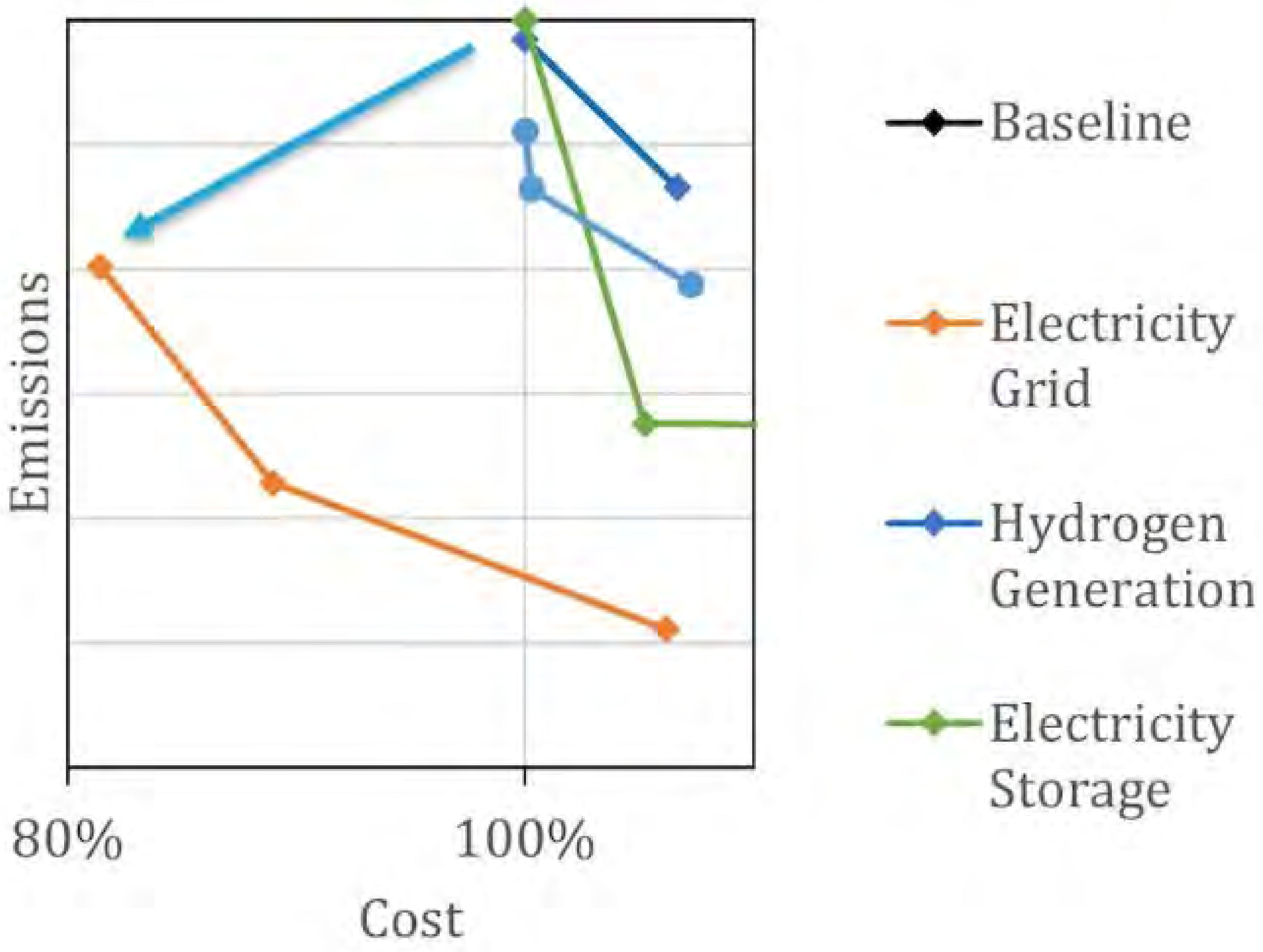

| Decision Variables | Additionally: size and location of additional grid capacities |
|---|---|



# Electricity Grid expansion



# Electricity Grid expansion




- *Best measure to reduce BOTH cost and emissions*
- *'no regret' measure: This can reduce both: emissions and costs*
- *Grid expansions help to:*
  - Make storage capacitity in other countries available
  - Spatially diversify the renewable portfolio of the whole system

# Coffee Break

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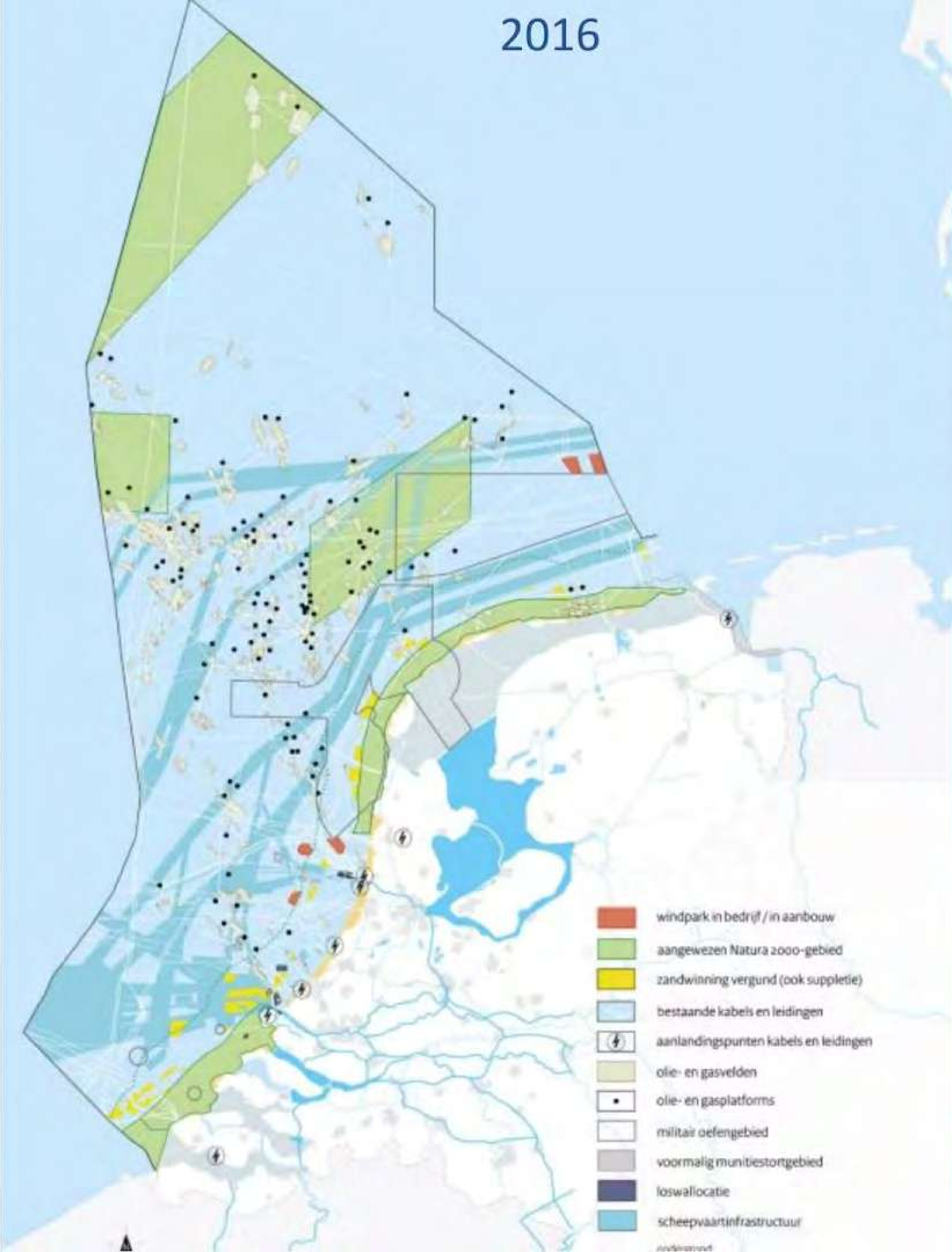
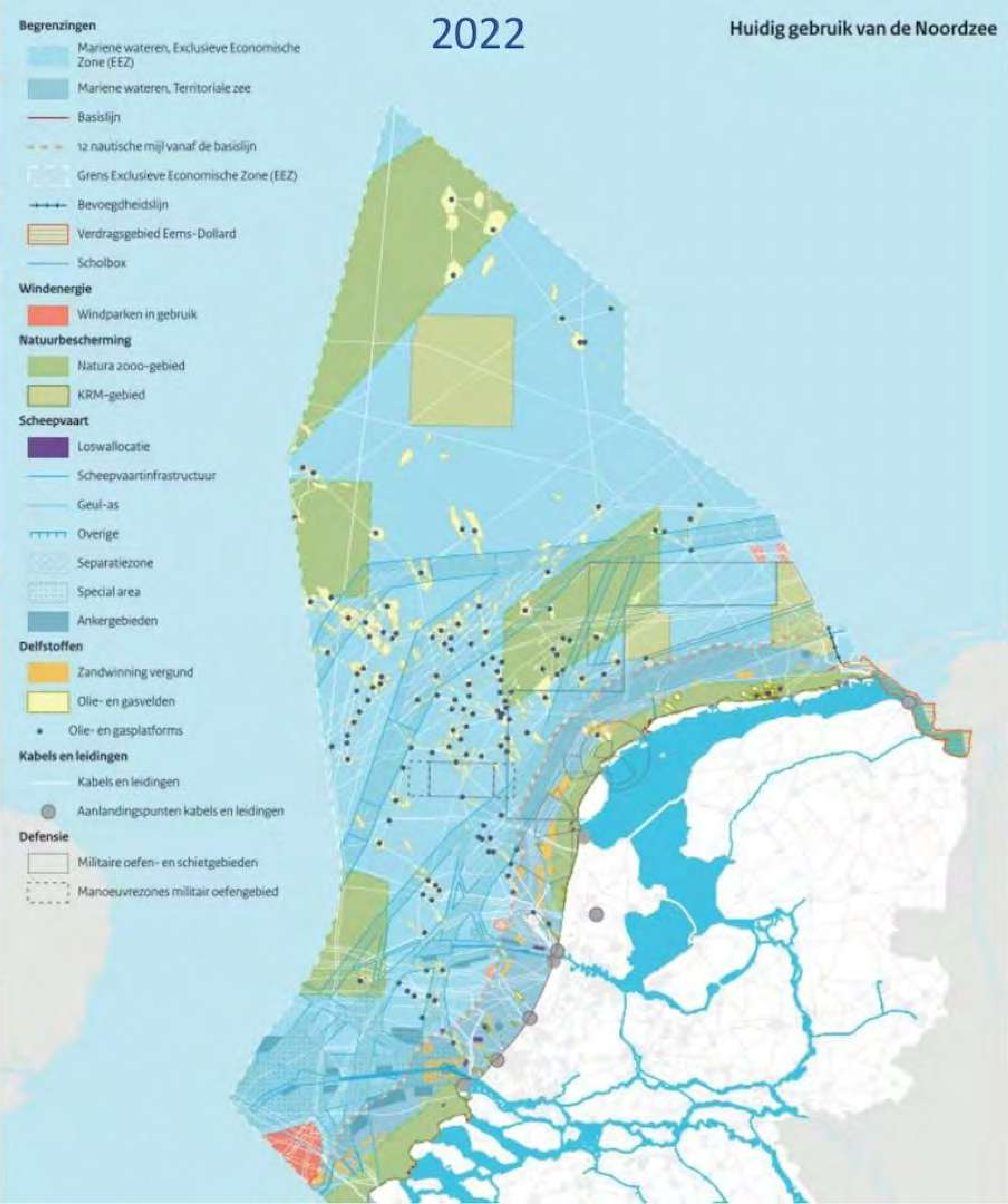
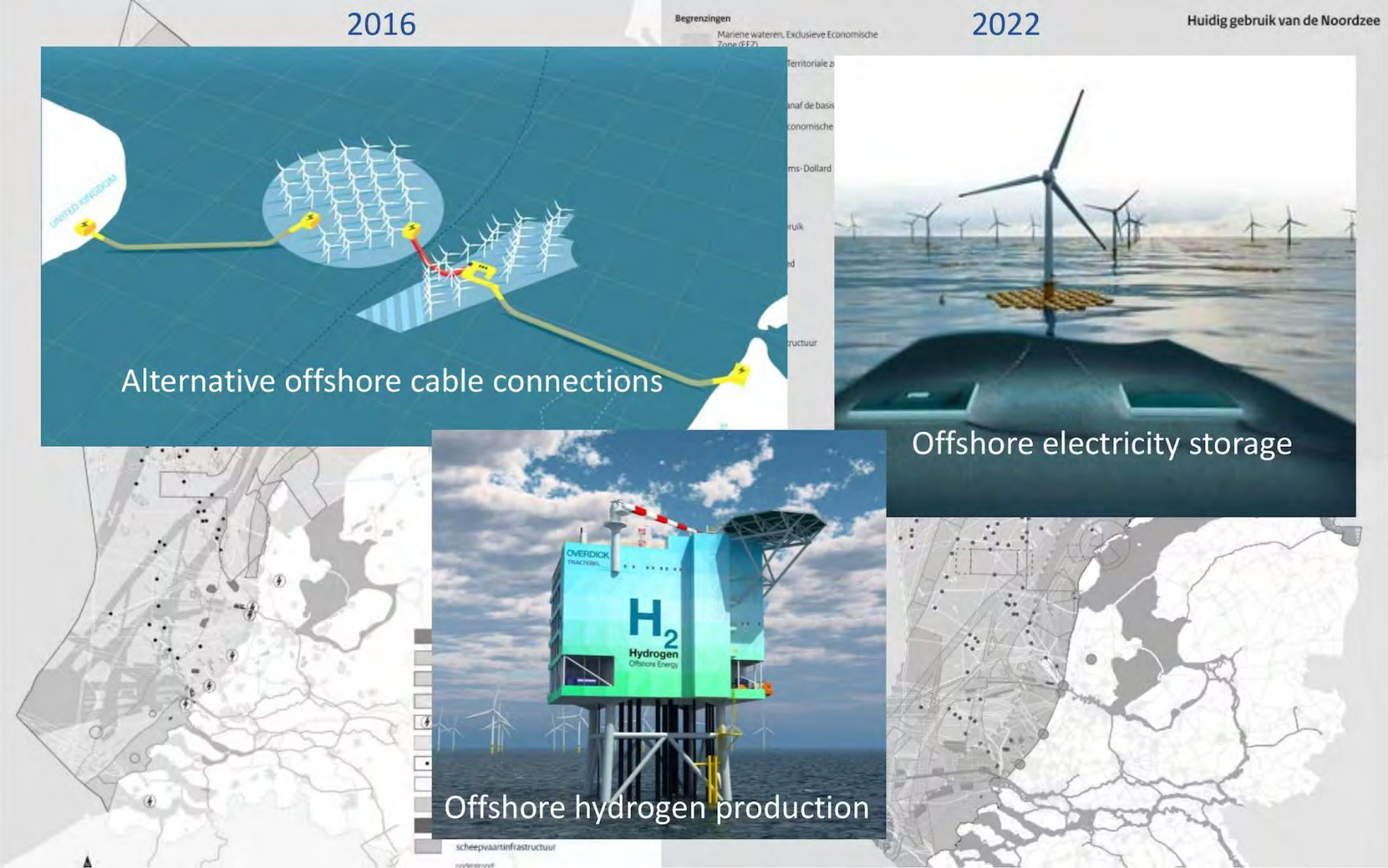
# Governance implications for a new offshore energy system

Juul Kusters
j.e.h.kusters@rug.nl


2016
windpark in bedrijf / in aanbouw
aangewezen Natura 2000-gebied
zandwinning vergund (ook suppletie)
bestaande kabels en leidingen
aanlandingspunten kabels en leidingen
olie- en gasvelden
olie- en gasplatforms
militair oefengebied
voormalig munitiestortgebied
loswallocatie
scheepvaartinfrastructuur


2022
Huidig gebruik van de Noordzee
Begrenzingen
Mariene wateren, Exclusieve Economische Zone (EEZ)
Mariene wateren, Territoriale zee
Basislijn
12 nautische mijl vanaf de basislijn
Grens Exclusieve Economische Zone (EEZ)
Bevoegdheidslijn
Verdragsgebied Eems-Dollard
Scholbox
Windenergie
Windparken in gebruik
Natuurbescherming
Natura 2000-gebied
KRM-gebied
Scheepvaart
Loswallocatie
Scheepvaartinfrastructuur
Geul-as
Overige
Separatiezone
Special area
Ankergebieden
Delfstoffen
Zandwinning vergund
Olie- en gasvelden
Olie- en gasplatforms
Kabels en leidingen
Kabels en leidingen
Aanlandingspunten kabels en leidingen
Defensie
Militaire oefen- en schietgebieden
Manoeuvrezones militair oefengebied


2016
2022
Huidig gebruik van de Noordzee
Begrenzingen
Mariene wateren, Exclusieve Economische
UNITED KINGDOM
Alternative offshore cable connections
Offshore electricity storage
OVERDICK
H2
Hydrogen
Offshore Energy
Offshore hydrogen production
scheepvaartinfrastructuur

# Planning (space for) an energy transition

Governance is an essential part of the system integration discussion:

- For strategic decision-making on desirable futures
- For establishing enabling rules and regulations
- For finding optimal locations

# Planning (space for) an energy transition

Governance is an essential part of the system integration discussion:

- For strategic decision-making on desirable futures *WHAT?*
- For establishing enabling rules and regulations *HOW?*
- For finding optimal locations *WHERE?*

# Marine Spatial Planning in the Netherlands

Coordinating ministry: Ministry of Infrastructure and Water Management

Other responsibilities with:

- Ministry of Economic Affairs and Climate
- Ministry of Interior and Kingdom Relations
- Ministry of Agriculture, Nature and Food Quality

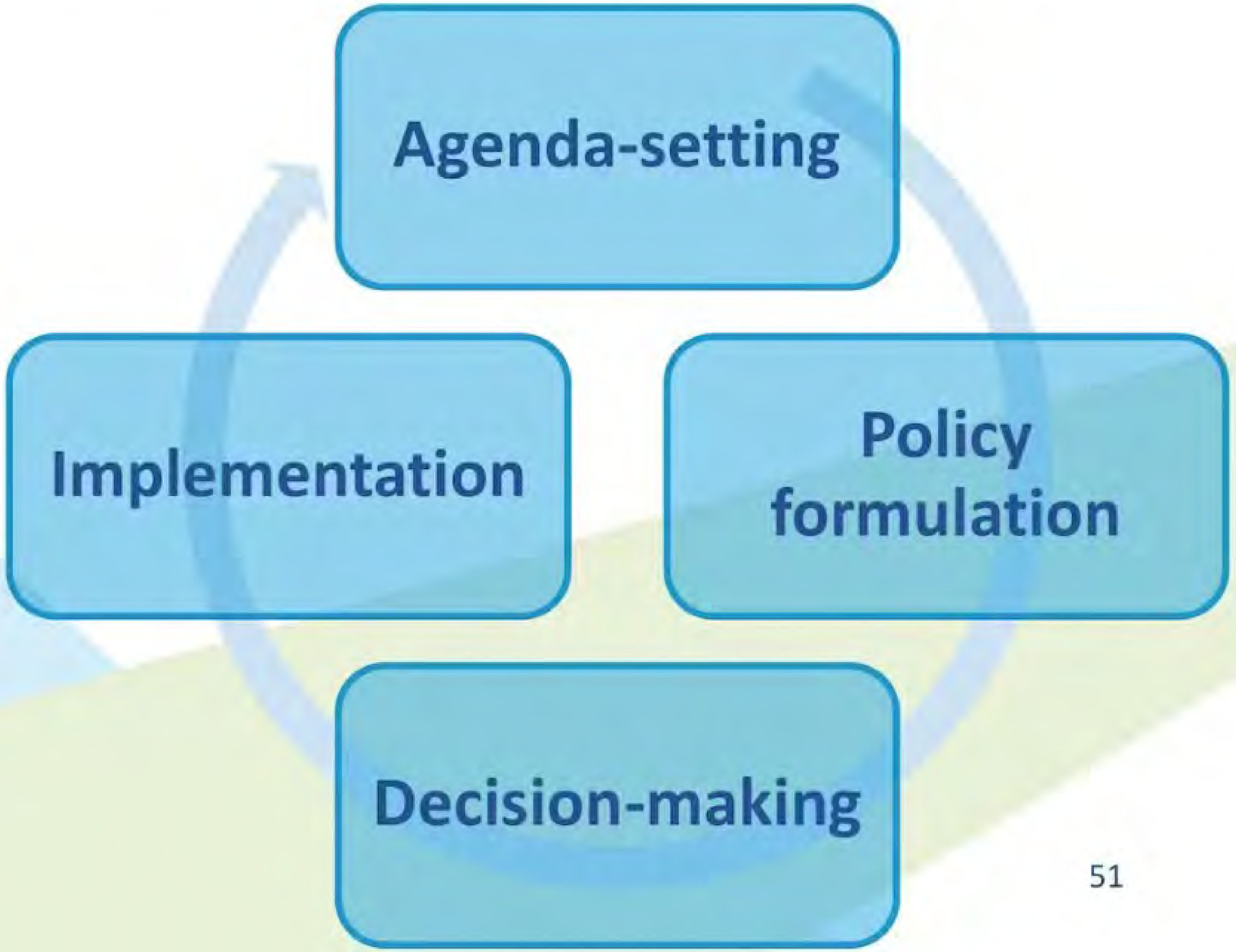
.... *and more*

New plan every 6 years

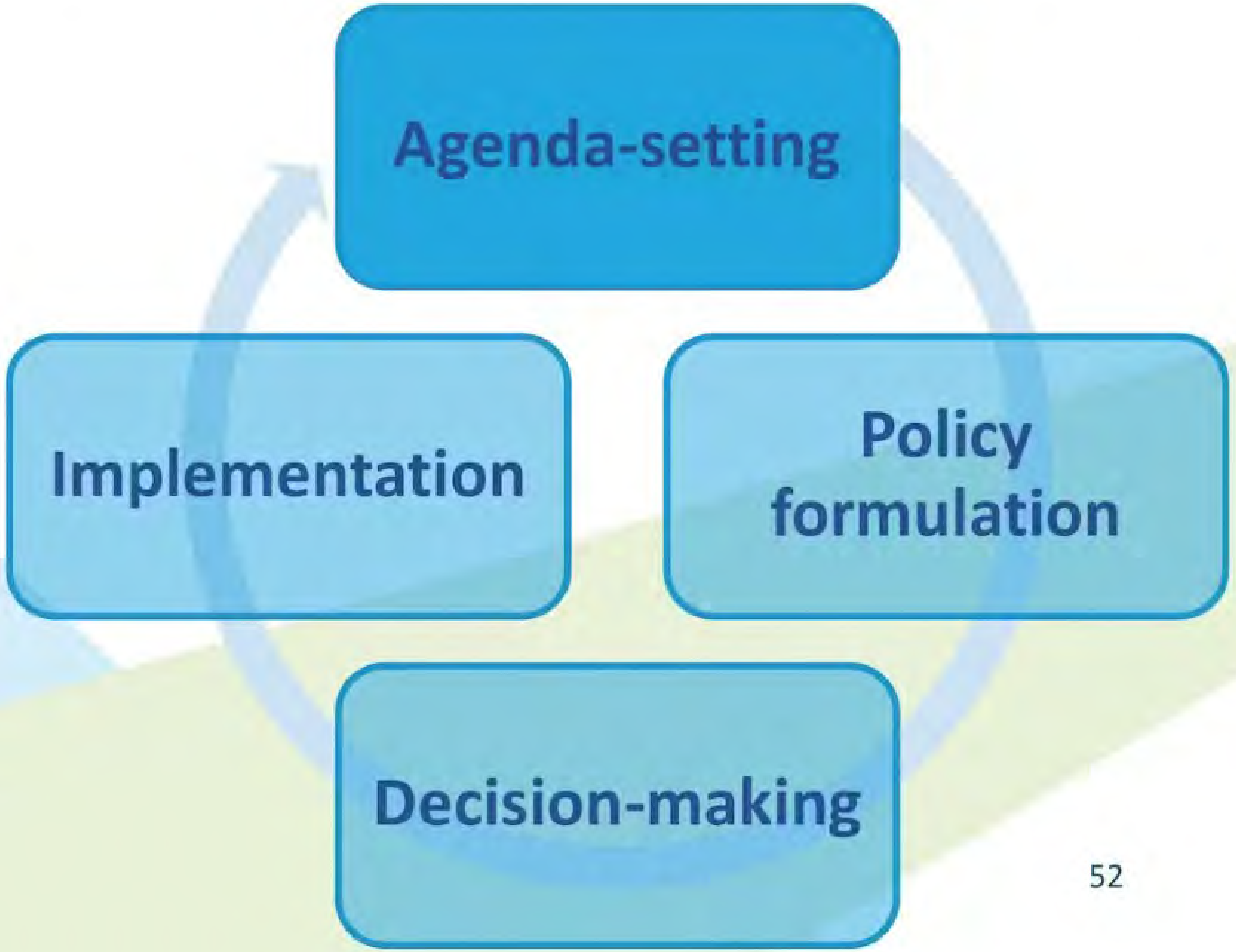
# Three large challenges

- Energy transition → up to 72 GW of offshore wind energy by 2050
- Food transition → sustainable and profitable fisheries sector
- Nature transition → recovering the status of the marine environment

# A planning process in its simplest form



# A planning process in its simplest form



# 1. Agenda-setting

Topics may emerge on the agenda through:

- Stakeholder participation in policy-making
- Close industry-government relations
- Various stakeholder networks

NOORDZEEOVERLEG

CoP Noordzee

# 1. Agenda-setting

Development of innovative technologies is hindered by:

- Powerful stakeholders shaping the debate
- Short-term orientation of policy
- Lack of rules and regulations

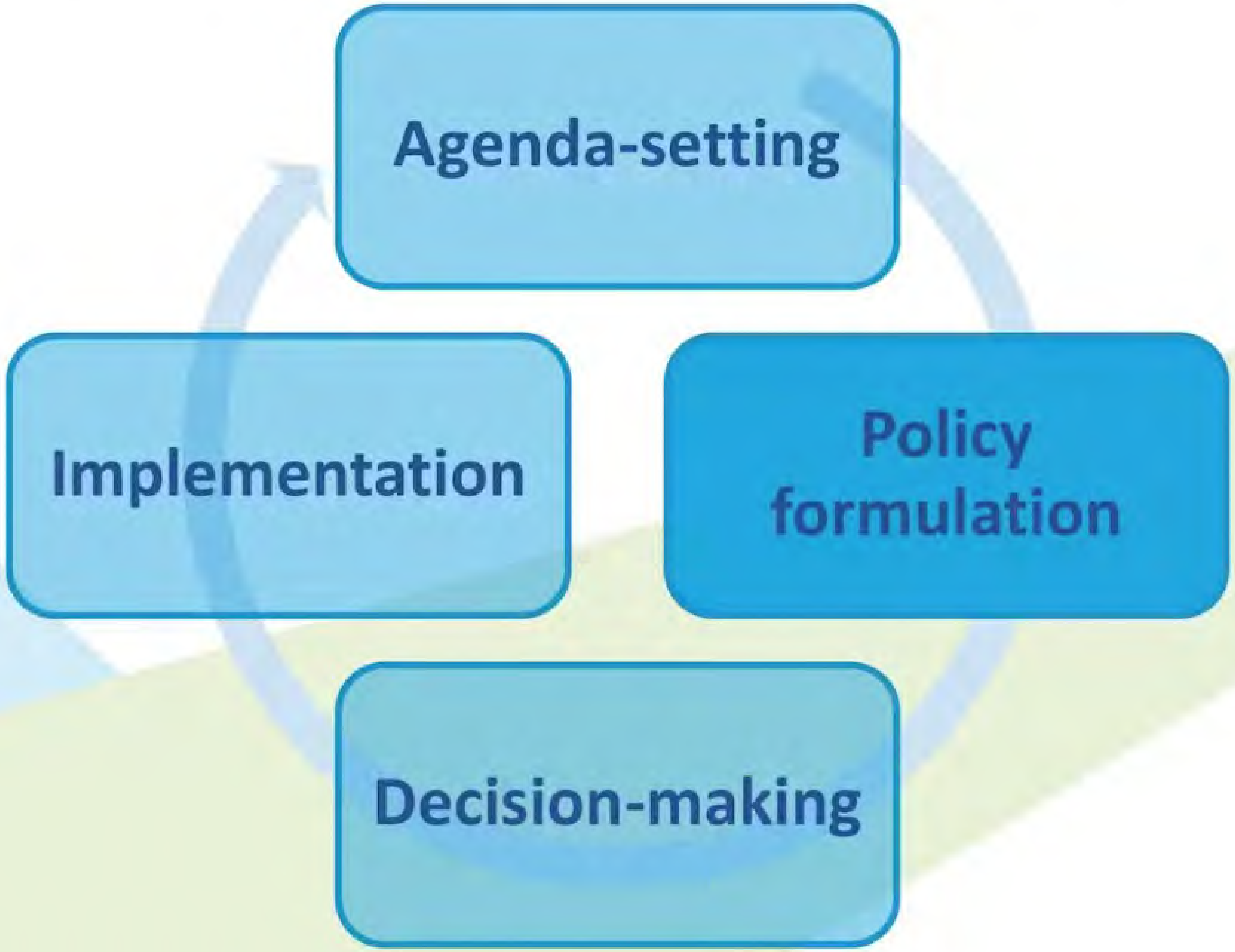
# 1. Agenda-setting

Development of innovative technologies is hindered by:

- Powerful stakeholders shaping the debate
- Short-term orientation of policy
- Lack of rules and regulations

**SO: Need for a future-oriented MSP process offering long-term guidance.**

# Formulating the marine spatial plan



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# 2. Policy formulation – environmental assessment

Strategic Environmental Assessment (SEA) aims to integrate environmental considerations into the formulation of policies, plans and programs.

Two central elements

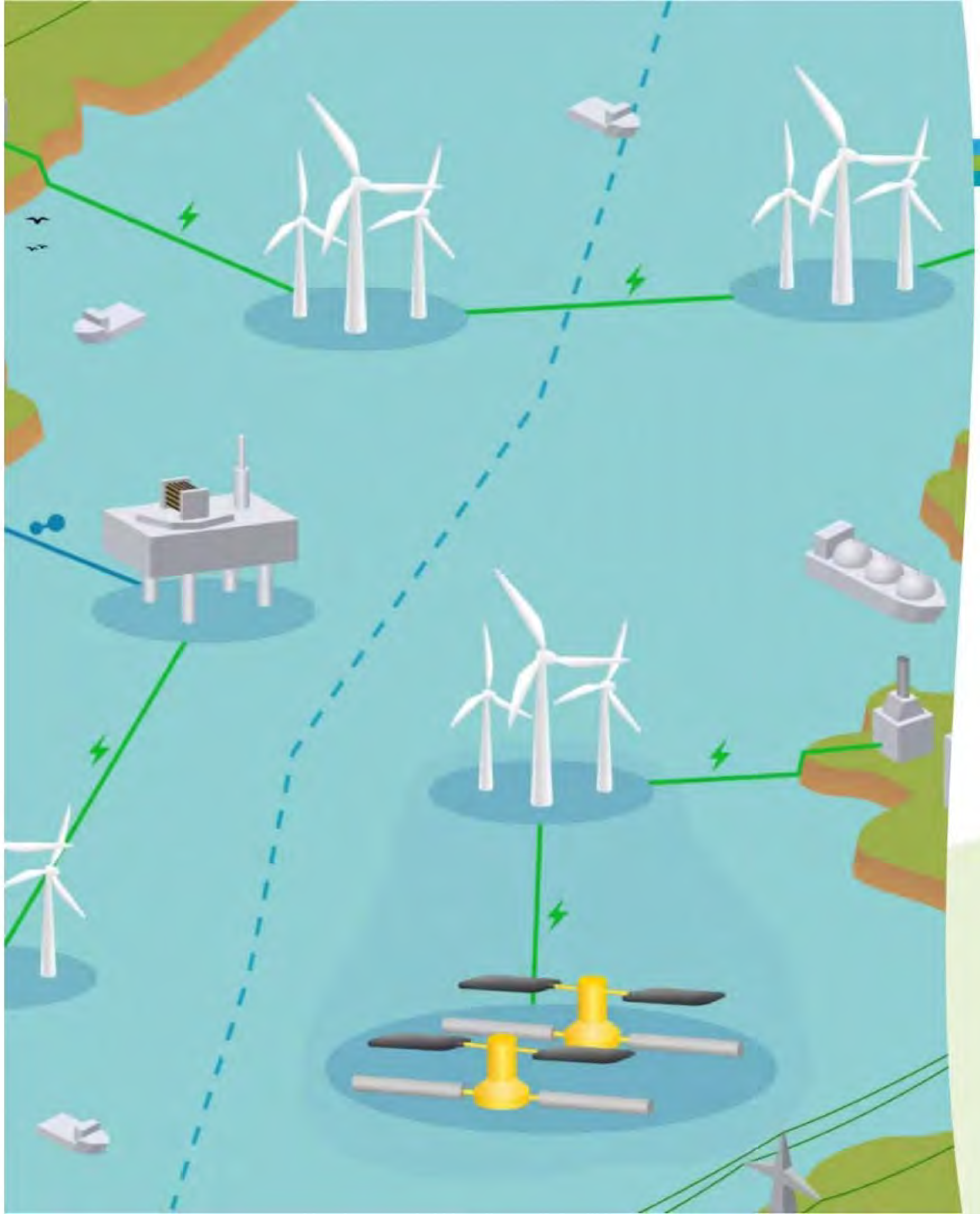
- Identify **cumulative** effects
- Develop and assess **alternative** approaches for meeting goals

# 2. Policy formulation – environmental assessment

However:

- Limited understanding of the marine ecosystem.
- Cyclical nature of MSP process

In the Netherlands, SEA is utilized to bring together existing sectoral North Sea policies, **rather** than exploring alternative options.



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# Main takeaways

Marine Spatial Planning is about more than just maps and spatial allocation.

**What** and **how** questions are equally important!

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# Any questions?

Juul Kusters – Department of Spatial Planning and Environment, Faculty of Spatial Sciences, University of Groningen

j.e.h.kusters@rug.nl

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# Legal Considerations for Offshore System Integration: Obstacles and Solutions

Liv Malin Andreasson
l.m.andreasson@rug.nl

# Offshore Wind Energy Roadmap

with cable routes from the offshore grid


# Facts and Figures of Offshore Wind Energy Roadmap 2023

## At a glance

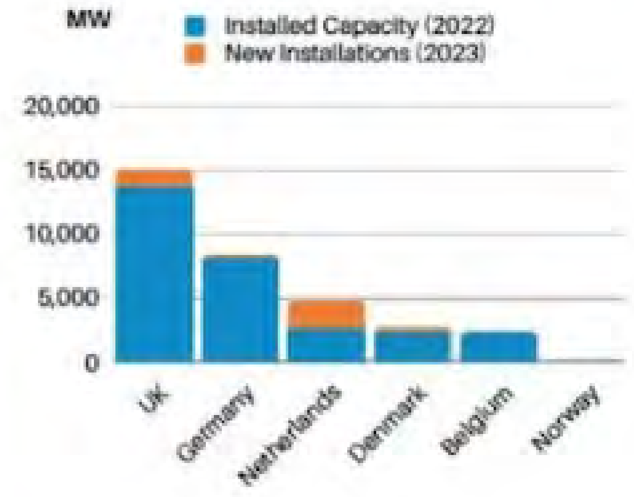
Under the Offshore Wind Energy Roadmap 2023, successful tenders in three designated offshore wind zones have been completed. These are: Borssele (Sites I & II, III & IV, and V) between 2016 and 2018, Hollandse Kust (zuid) in 2018 and 2019 and Hollandse Kust (noord) V in 2020.

## Key figures *(by end of 2023)*

**4.7 GW**
offshore wind capacity

**15.8 %**
expected share of offshore wind generation in total electricity consumption

**3,500 MW**
offshore connection, in standardised concept of 700 MW per connection by TenneT

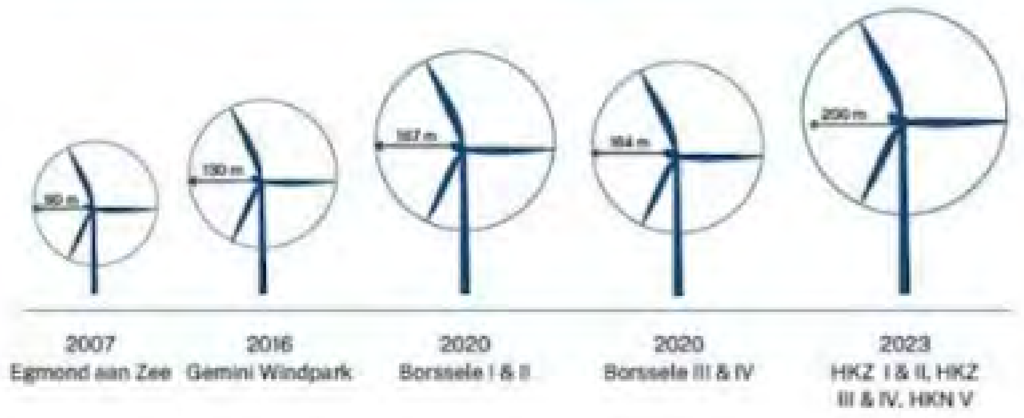



## KEY DRIVERS


## ACHIEVEMENTS

1. Pre-bid costs and risks for offshore wind developers significantly reduced thanks to implementation of a one-stop shop approach.
2. Cost saving of around €7 billion for Borssele, and the world's first zero-subsidy offshore wind farm – Hollandse Kust (zuid) Sites I & II.
3. Nature Inclusive Design – ecology-friendly measures integrated as a basic condition for offshore wind development.
4. The capacity of individual Dutch offshore wind farms increased seven fold, up from 110 MW for Egmond aan Zee in 2007 to 760 MW for Hollandse Kust (noord).
5. Connection costs for offshore wind farms have been reduced and development time for projects is down to just 3-4 years (from 7-10 years previously).

## TURBINE DEVELOPMENT



## Legal Design for New Offshore Storage and Transport Infrastructure

Identify legal obstacles and propose legal solutions to facilitate the development of offshore storage and transport infrastructure

- Alternative cable connections
- Electricity (pumped) storage
- Hydrogen production and transport

Research Question: Which legal solutions are required to enable large-scale offshore wind energy developments by providing alternatives for bringing large quantities of offshore renewable energy to the market?

# Offshore Energy System Integration

- **Existing laws** pertaining to **offshore energy activities** in the Netherlands regulate each category of offshore energy activities specifically
- **Difficult to ascertain which rules apply** to new types of offshore energy activities and their interlinkages

- **'Energy system integration'** entails linking previously separate players, energy carriers and adjacent sectors of the energy value chain through innovative methods into one large energy system

- **(Q)** How has the Netherlands used its powers to regulate offshore energy activities?

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# Current Dutch Legislation

| Legal framework | Scope of application |
|---|---|
| **Mining Act** of 31 October 2002 (Mijnbouwwet) | establishes rules for the exploration and extraction of minerals and mining-related activities<br>→ **Applicable offshore** |
| **Wind Energy at Sea Act** of 24 June 2015 (Wet windenergie op zee) | establishes rules for offshore wind energy<br>→ **Applicable offshore** |
| **Water Act** of 29 January 2009 (Waterwet) | establishes rules for the management and use of water systems<br>→ **Applicable offshore** |
| **Electricity Act** of 2 July 1998 (Elektriciteitswet) | establishes rules for the generation, transmission and supply of electricity<br>→ **Limited applicability offshore** |
| **Gas Act** of 22 June 2000 (Gaswet) | establishes rules for the transport and supply of gas<br>→ **Limited applicability offshore** |

# Legal Obstacles: New Energy Storage and Transport Options

| Energy storage and transport options | Need for legislative changes |
|---|---|
| **Alternative Offshore Cable Connections** | • Need to amend the relevant provisions of the the Wind Energy at Sea Act and the Electricity Act*<br>• Need to ensure that the relevant provisions of the Electricity Act* are applicable offshore |

*see next slide for the forthcoming Energy Act

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# Legal Obstacles: New Energy Storage and Transport Options

| Energy storage and transport options | Need for legislative changes |
|---|---|
| **Alternative Offshore Cable Connections** | • Need to amend the relevant provisions of the the Wind Energy at Sea Act and the Electricity Act*<br>• Need to ensure that the relevant provisions of the Electricity Act* are applicable offshore |
| **Offshore Hydrogen Production and Transport** | • Need to amend the relevant provisions of the Mining Act and the Gas Act<br>• Need to adopt specific provisions on hydrogen production and transport (either in existing legislation or in a new dedicated hydrogen legislation) |

*see next slide for the forthcoming Energy Act

DOSTA | DEVELOPING OFFSHORE STORAGE AND TRANSPORT ALTERNATIVES

# Legal Obstacles: New Energy Storage and Transport Options

| Energy storage and transport options | Need for legislative changes |
|---|---|
| **Alternative Offshore Cable Connections** | • Need to amend the relevant provisions of the the Wind Energy at Sea Act and the Electricity Act* <br> • Need to ensure that the relevant provisions of the Electricity Act* are applicable offshore |
| **Offshore Hydrogen Production and Transport** | • Need to amend the relevant provisions of the Mining Act and the Gas Act <br> • Need to adopt specific provisions on hydrogen production and transport (either in existing legislation or in a new dedicated hydrogen legislation) |
| **Offshore Electricity Storage** | • Need to implement the new EU rules on energy storage and amend the relevant provisions in the Electricity Act* <br> • Need to ensure that the relevant provisions of the Electricity Act* are applicable offshore |

*see next slide for the forthcoming Energy Act

# Forthcoming Legislation

- The **Energy Act** (Energiewet) is a proposed new Act to replace the current Electricity Act and Gas Act and to prepare Dutch energy legislation for the energy transition
- The Energy Act implements the EU Electricity Directive (Directive 2019/944) and the EU Electricity Regulation (Regulation 2019/943) from the Clean Energy Package into Dutch legislation
- One of the objectives of the Energy Act is to strengthen the legal framework for energy system integration

**(P) lacks explicit reference to offshore energy system integration**

## Key Takeaways

- The legal situation for new energy storage and transport options is uncertain as current laws lack appropriate and/or necessary provisions; to some extent, provisions in relevant laws are not applicable offshore
- Necessary to either adopt specific provisions (or laws) regulating new energy storage and transport options or to move from sector-specific laws for offshore energy activities to a general legal framework for offshore energy activities

# Thank you for your attention

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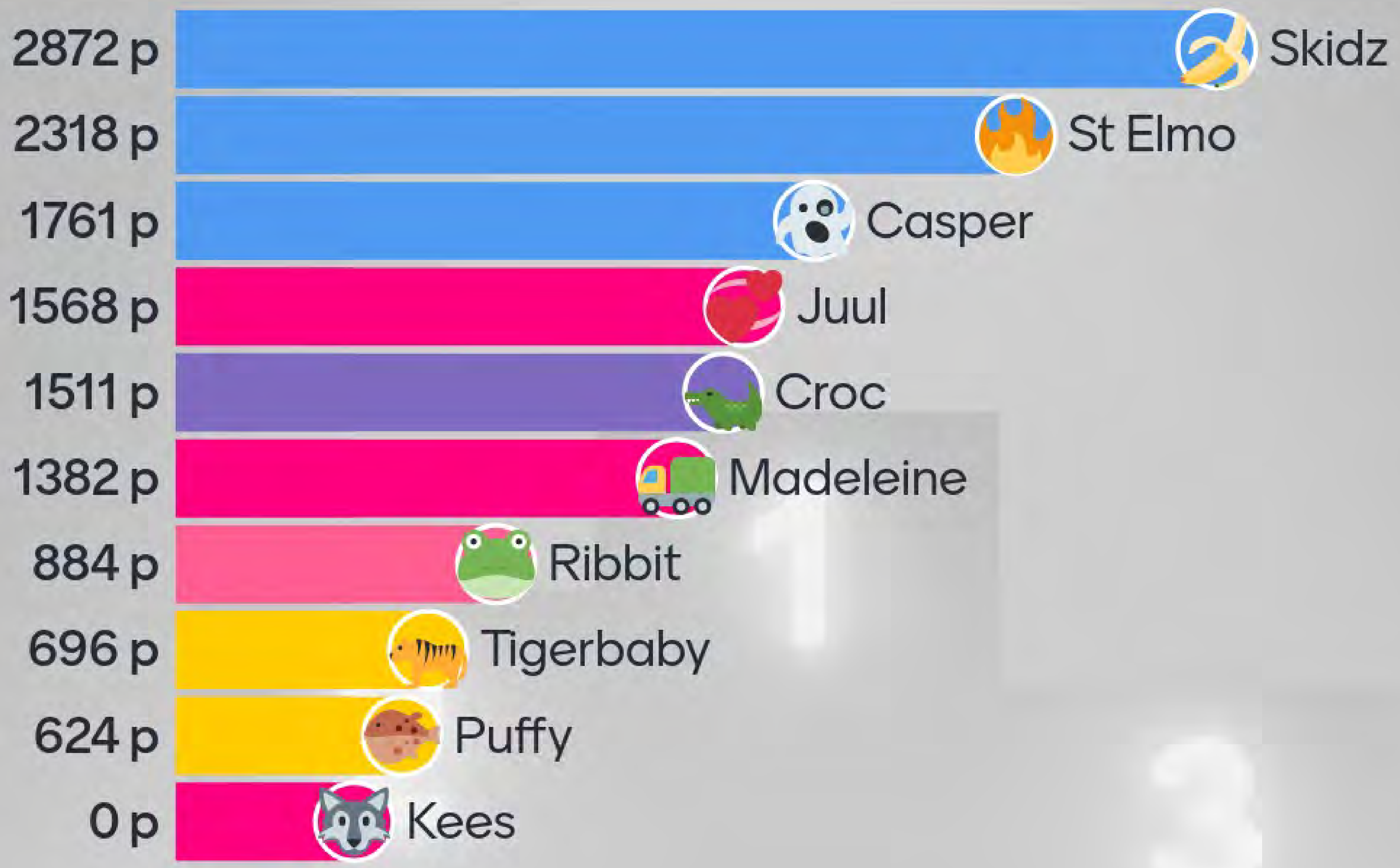
# Leaderboard



Thank you!
Questions?