ETIP HYDROPOWER

ALPHEUS

Augmenting grid stability through Low head Pumped Hydro Energy Utilization and Storage

Boosting Hydropower: Best Practices for Research

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Augmenting grid stability through Low head Pumped Hydro Energy Utilization and Storage

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ALPHEUS
GA: 883553

Project

ALPHEUS was a €5m project funded by the European Union's Horizon 2020 program (883553)

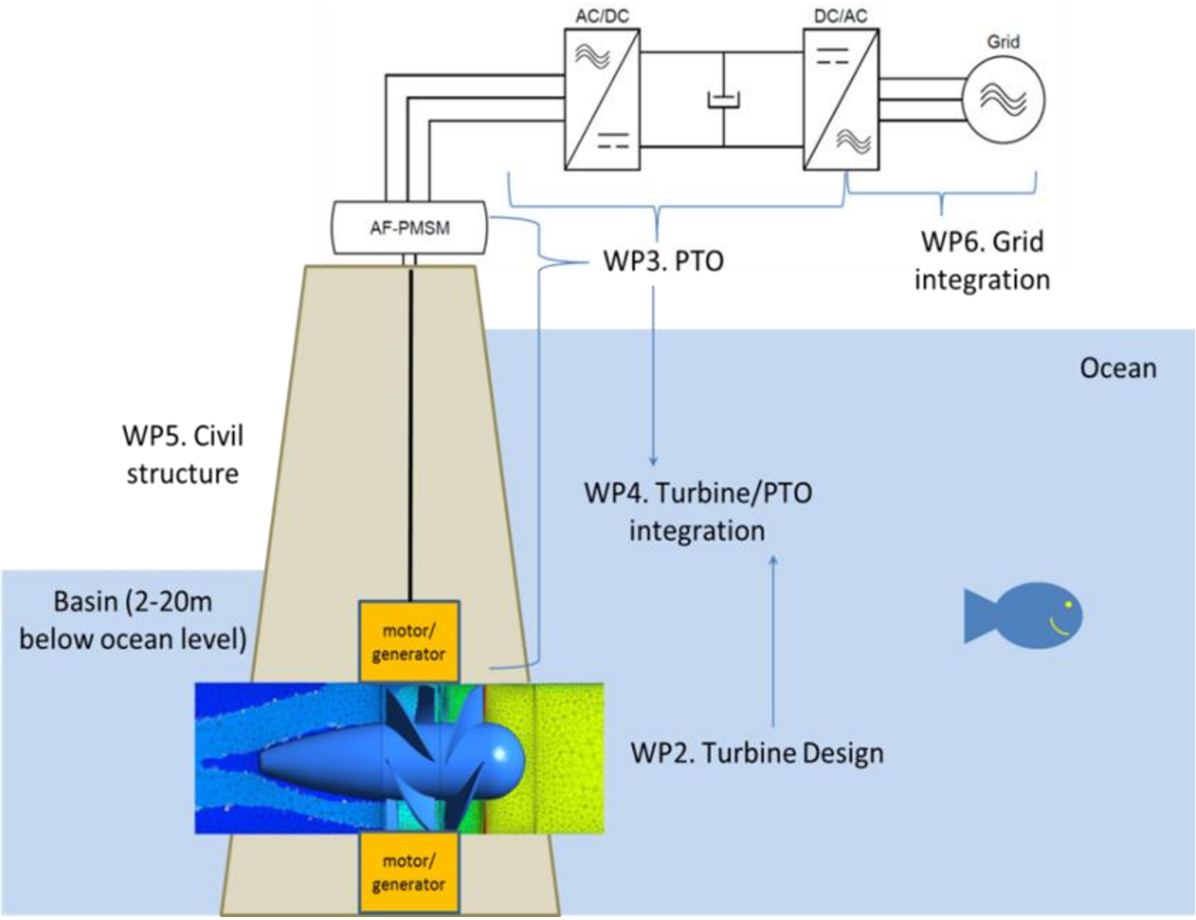
Aim: to improve **reversible pump/turbine (RPT) technology** and **adjacent civil structures** needed to make pumped hydro storage economically viable **in shallow seas and coastal environments** with flat topography.

To accomplish this, we apply **computational simulations and laboratory experiments** to design robustly efficient reversible pump turbines and power take-offs for the low head range.

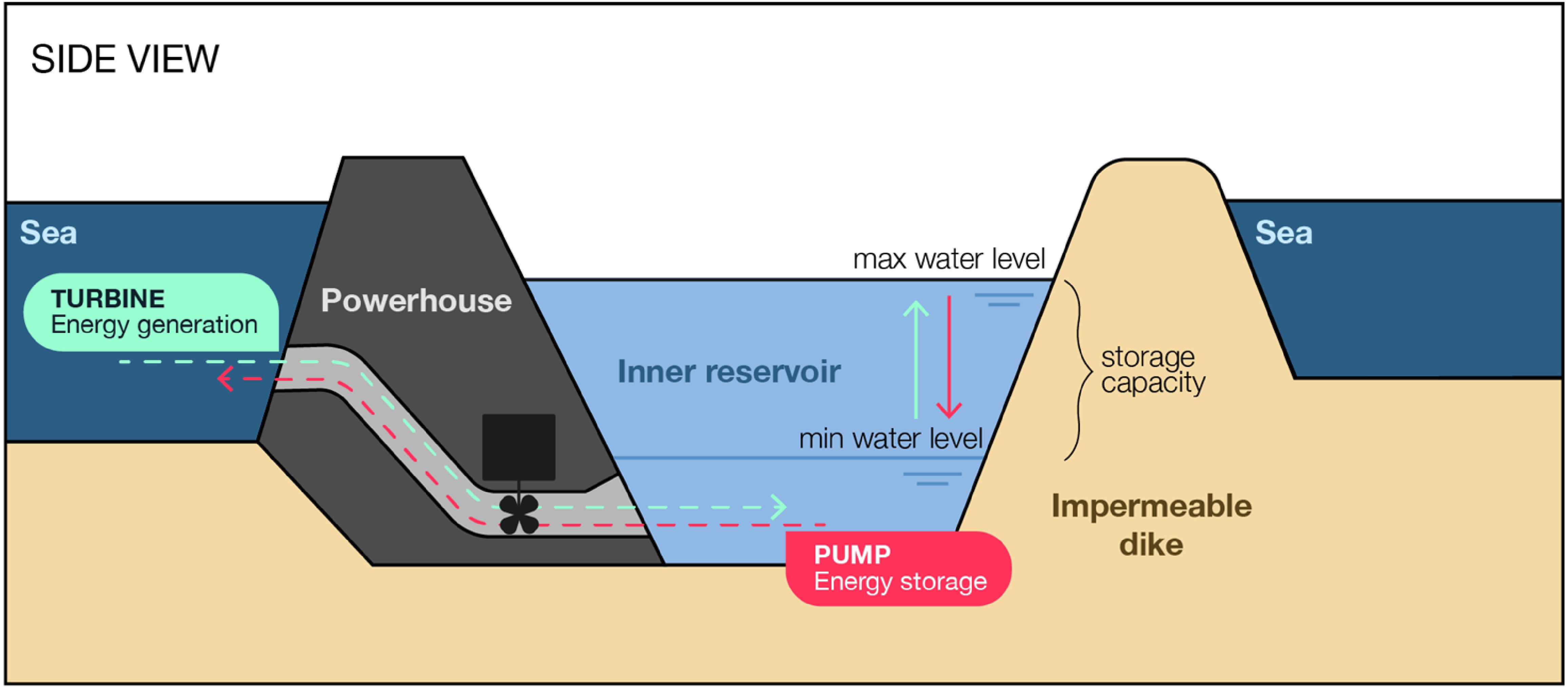
Benefit of ALPHEUS to the hydropower community

Today: **Pumped hydro energy storage** is the most mature, environmentally friendly method of large-scale energy storage, but is currently only practical for regions with large topographic gradients available.

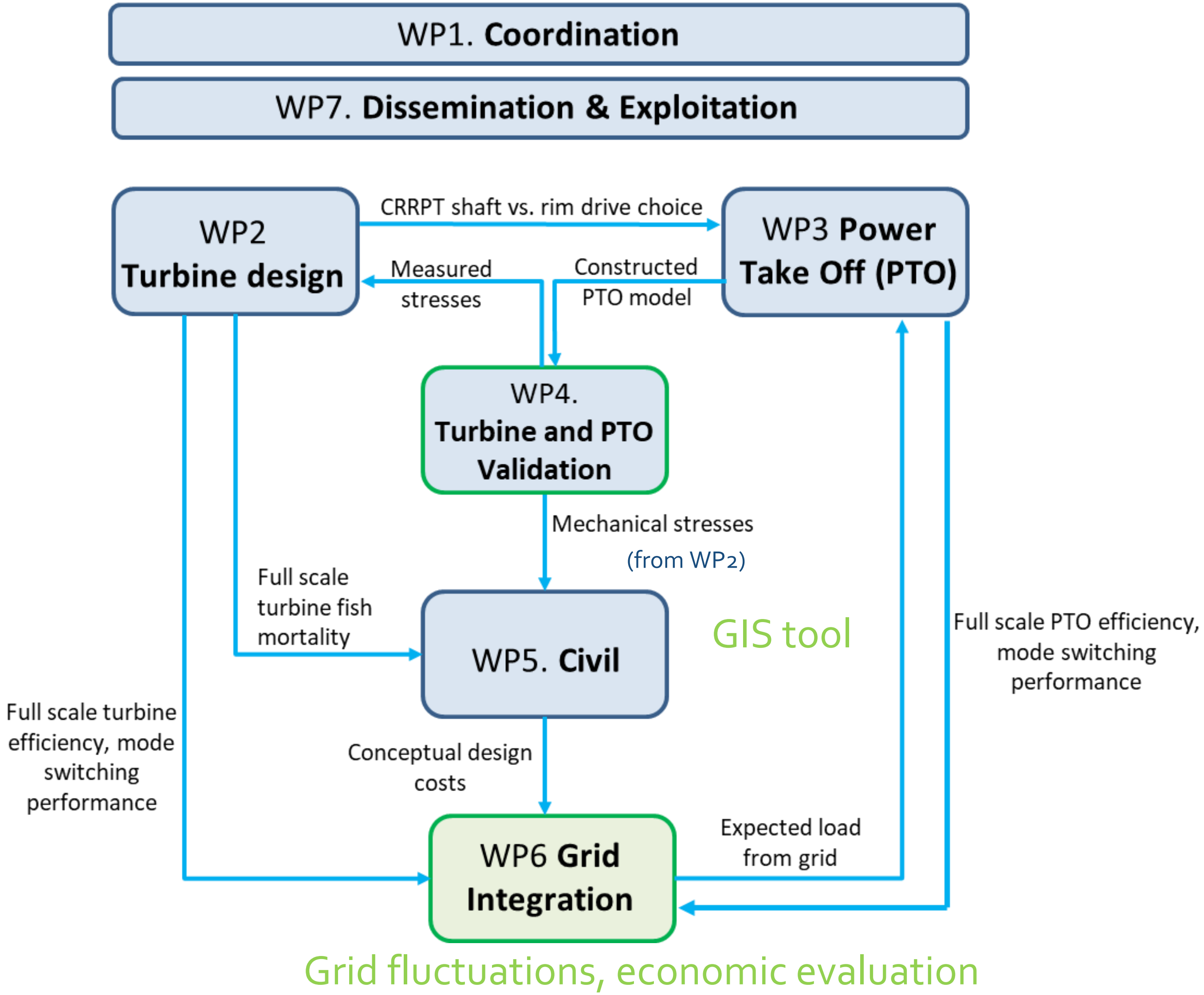
ALPHEUS strives to make pumped hydro energy storage practical for the low elevation countries.



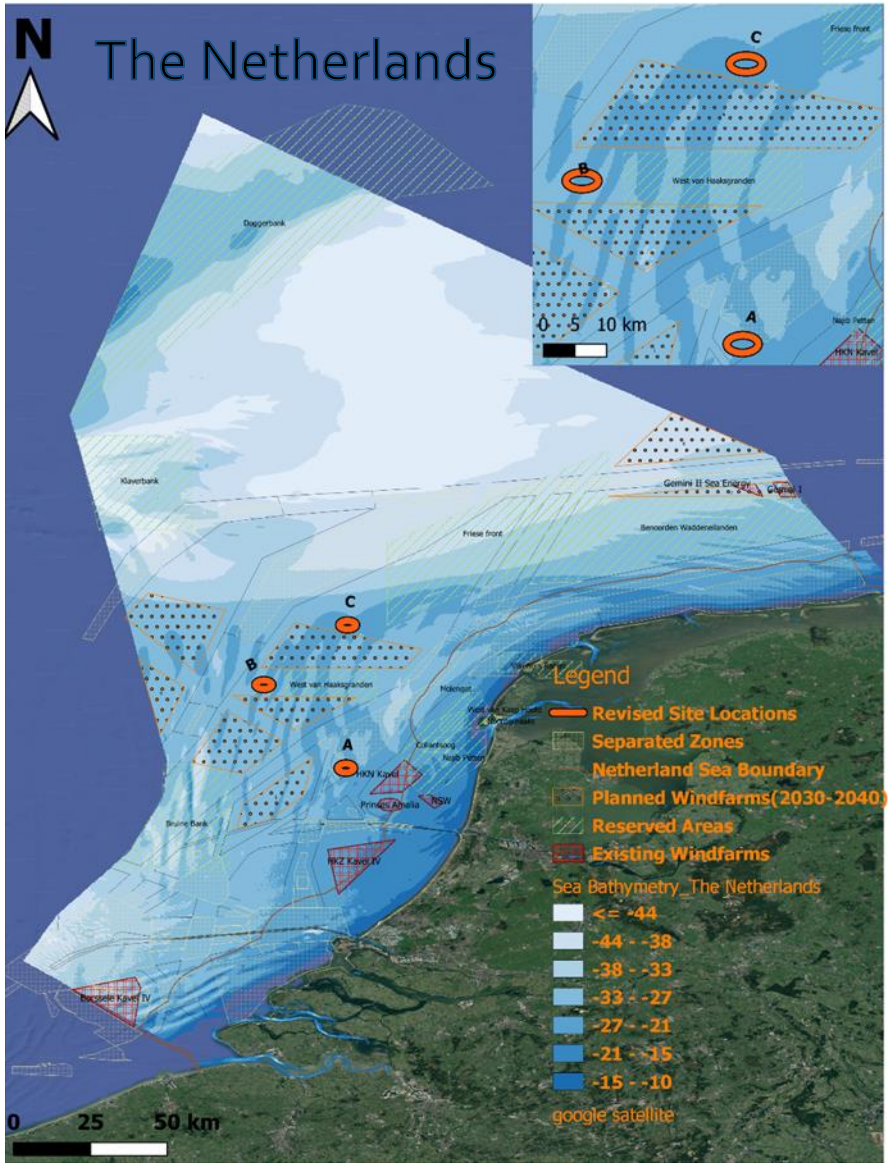
Conceptual design low-head pumped hydro

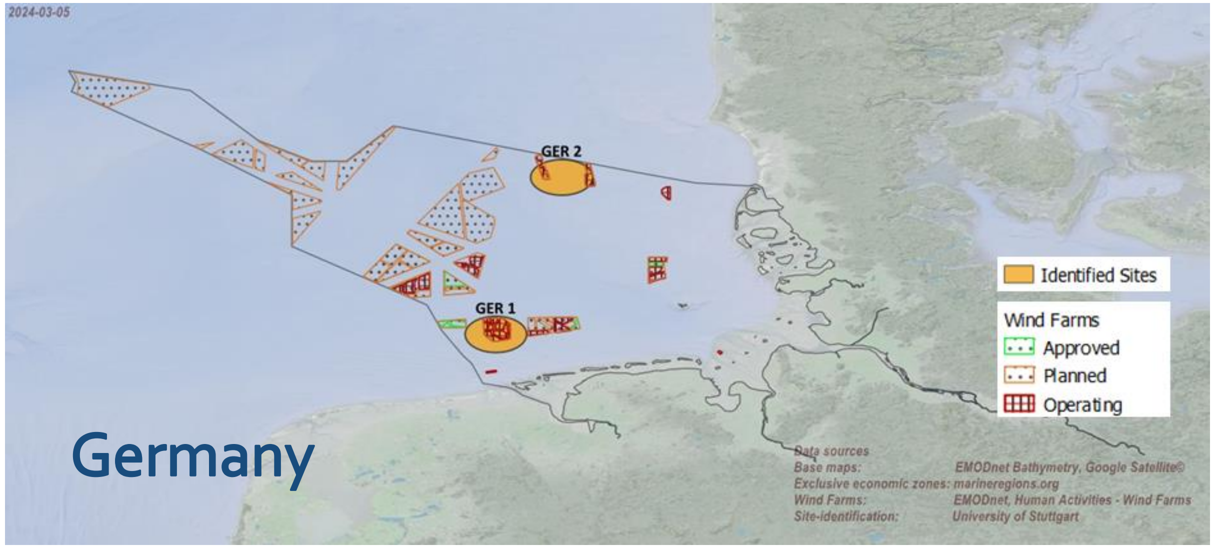


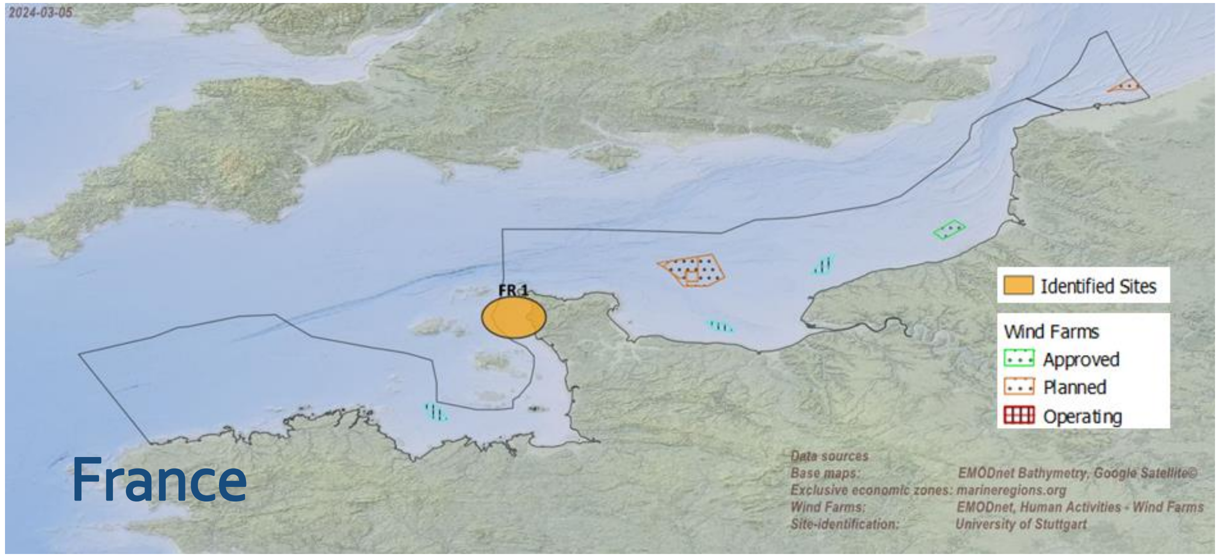
ALPHEUS - Organization



LH-PHES proposed locations



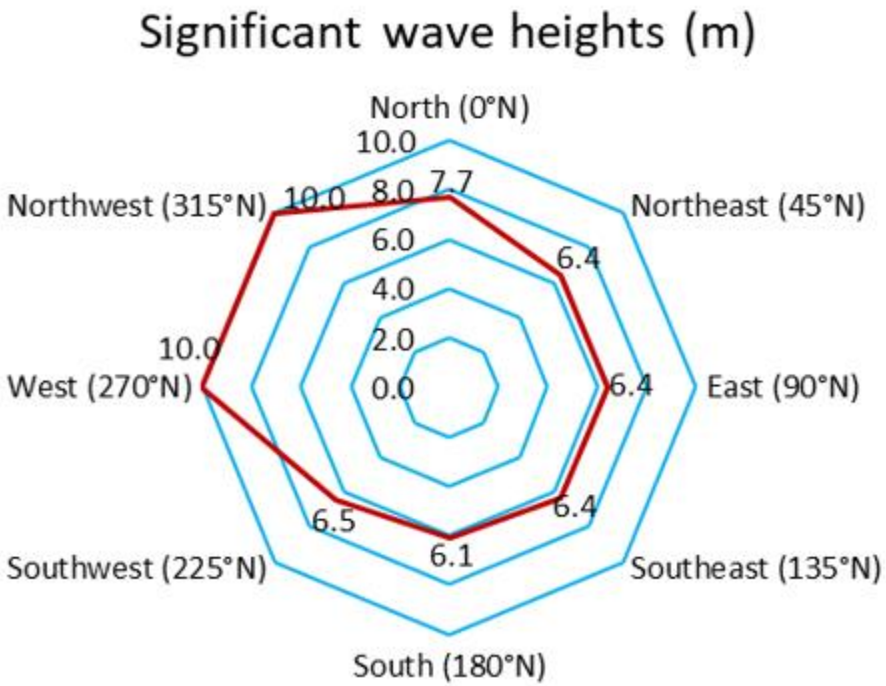




Site selection criteria

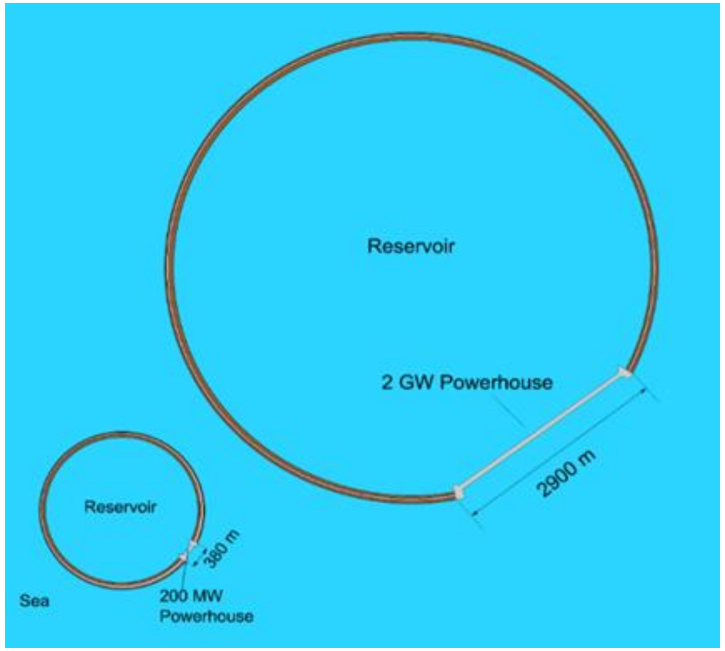
Description	Parameter
Install capacity	200 MW and 2 GW
Storage capacity	2 GWh and 20 GWh
Water level height	20 - 30m
Reservoir shape	Circular
Design wave height	12 m
Turbine type	CR-VS-RPT
Turbine capacity	10 MW
Number of turbines	20 and 200
Reservoir circumference	6 km and 15.7 km
Reservoir diameter	2.5 km - 7.8 km
Design discharge	130 m^3/s

The Netherlands

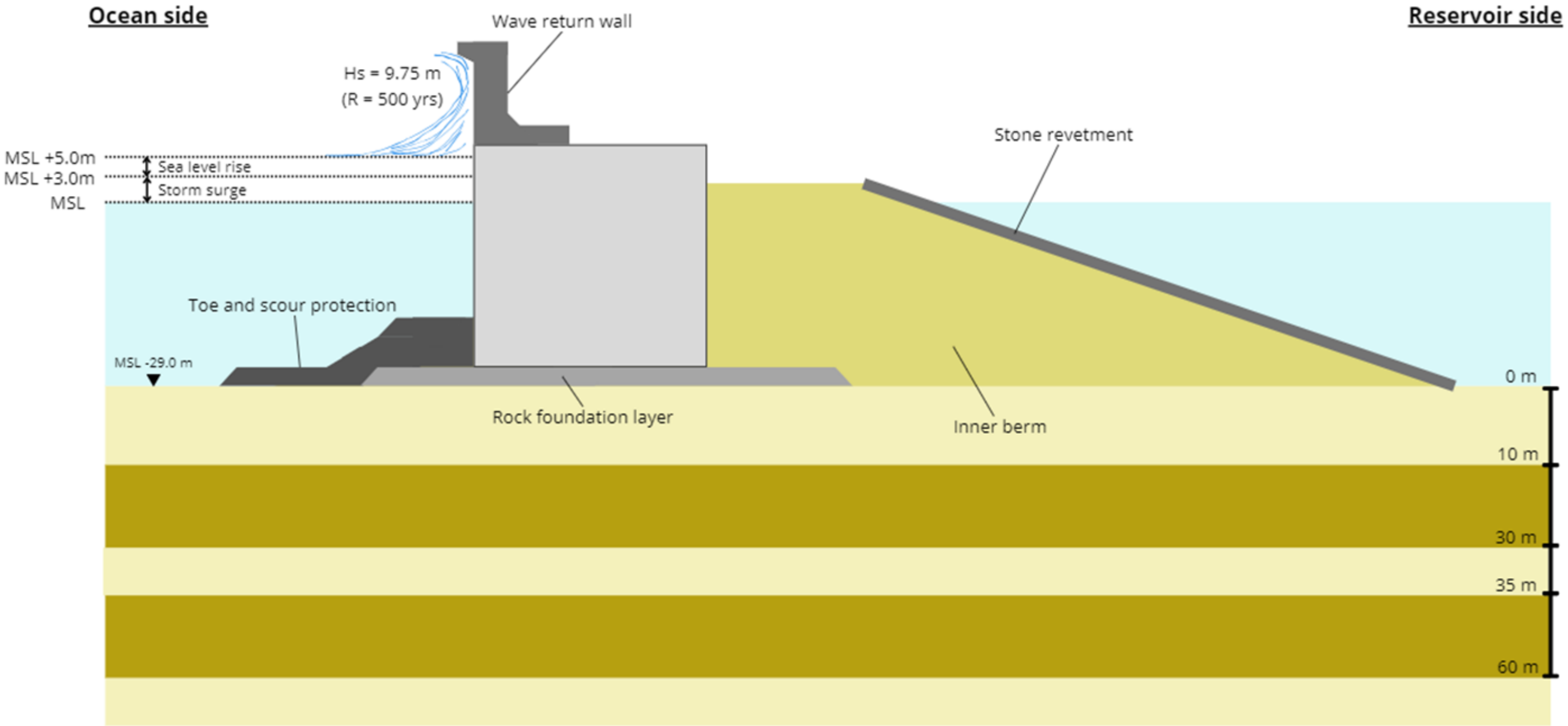


Significance of the wave impact (Wave data at the IJ-Ver location on the Dutch continental shelf)

Ring dam conceptual design



Sizes of the 2 GWh and the 20 GWh PHES -top view



The sectional view of the Ring dam

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Dam Caisson Construction and Transportation Methods

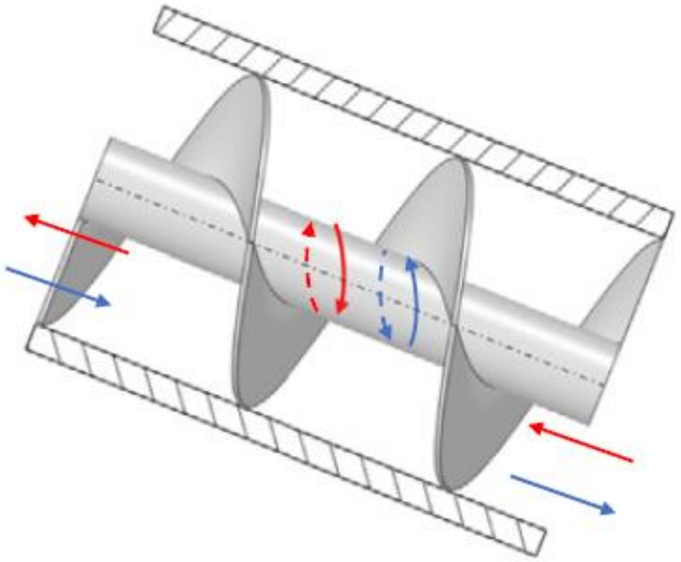
Giant Gantry and moving pre-fabricated caisson to the floating dock (Reference: Antbuildz | The Construction of Mega Tuas Port)

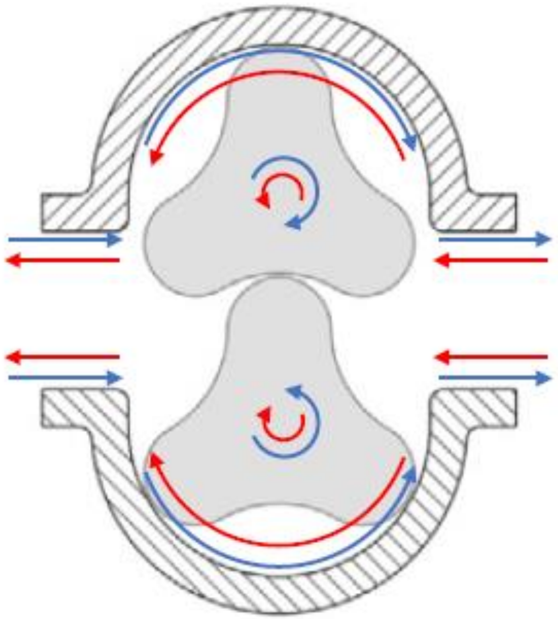
Floating Dock (Reference: Antbuildz | The Construction of Mega Tuas Port)

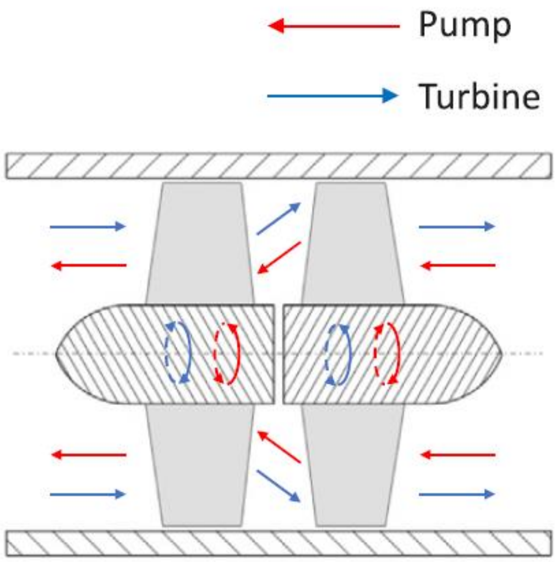
Caisson transportation using tug boats

Caisson transportation using semi-submersible vessel

Pump-turbines for low-head solution





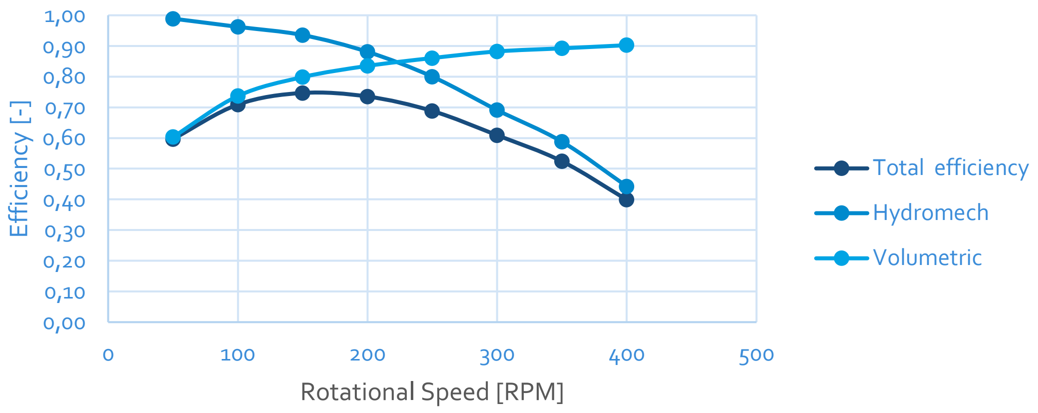


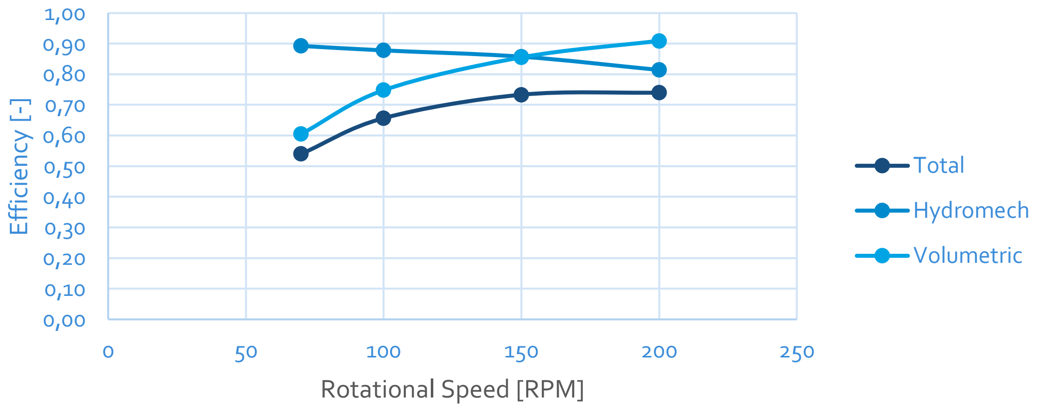
Archimedes screw system

Positive Displacement system

Counter-rotating system

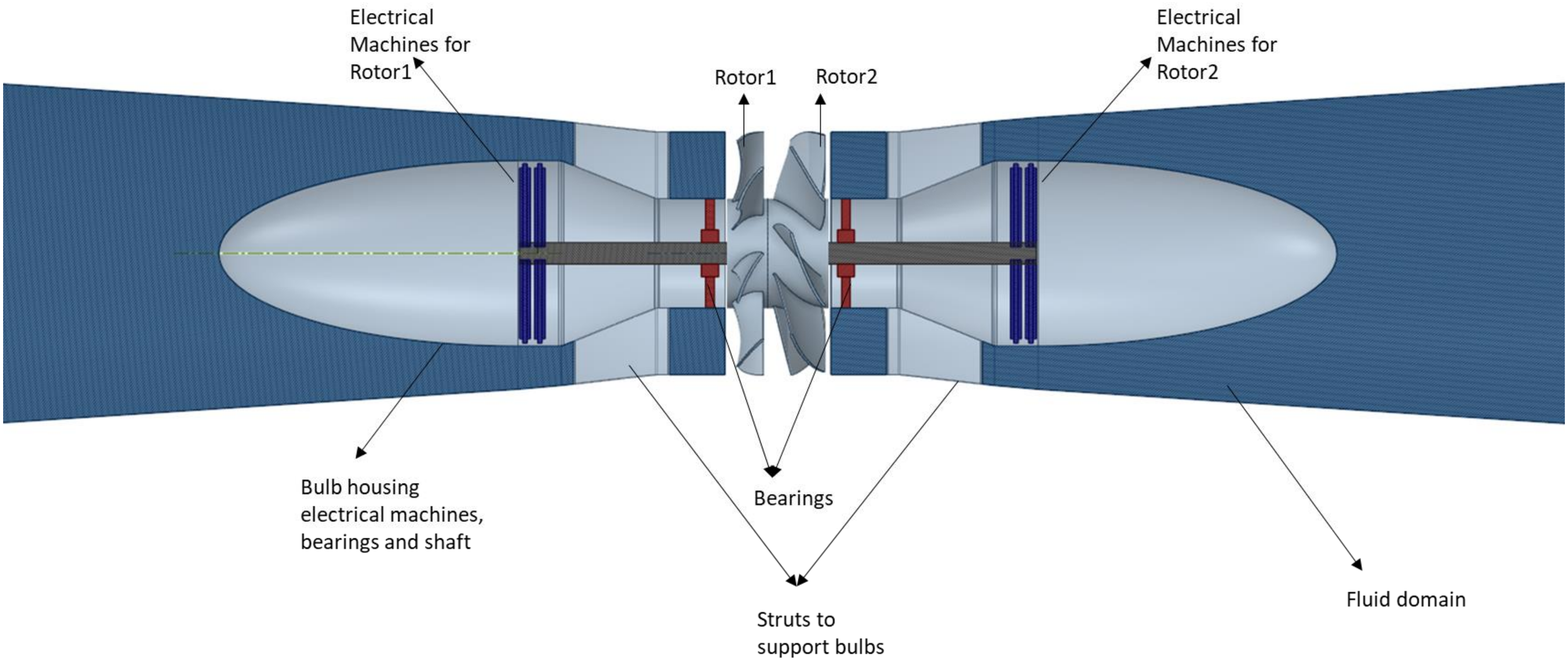
Positive-displacement RPT – 30 kW model



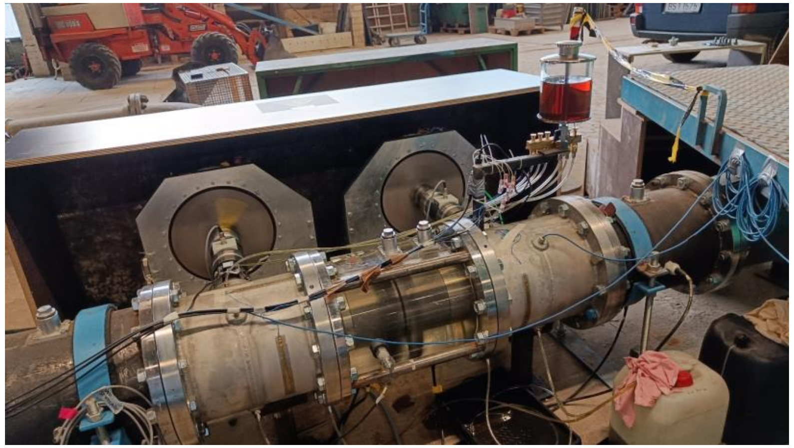


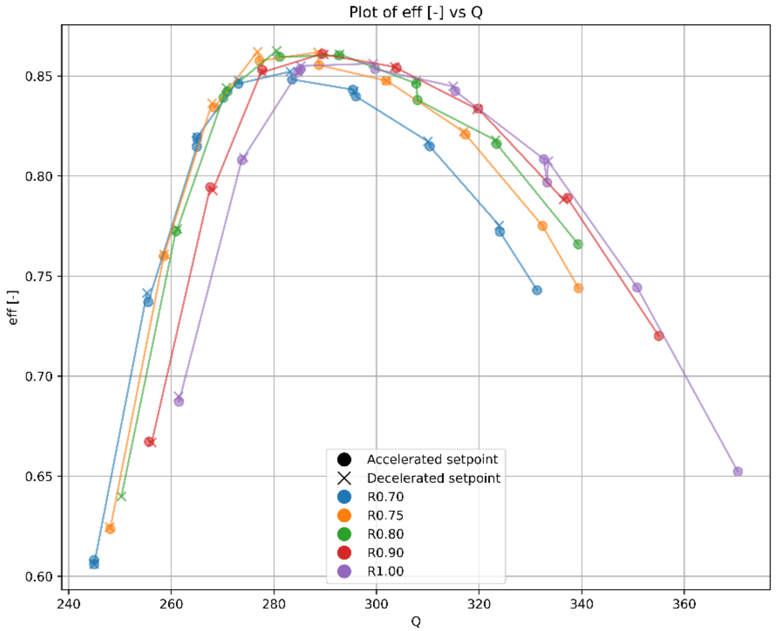
- VERY sensitive to debris in the water. Grit in the supply water easily jammed between the lobes and casing.
- Lower efficiency
- Cavitation and structural vibrations for operating conditions > 200 rpm

Conceptual design – Counter-rotating RPT

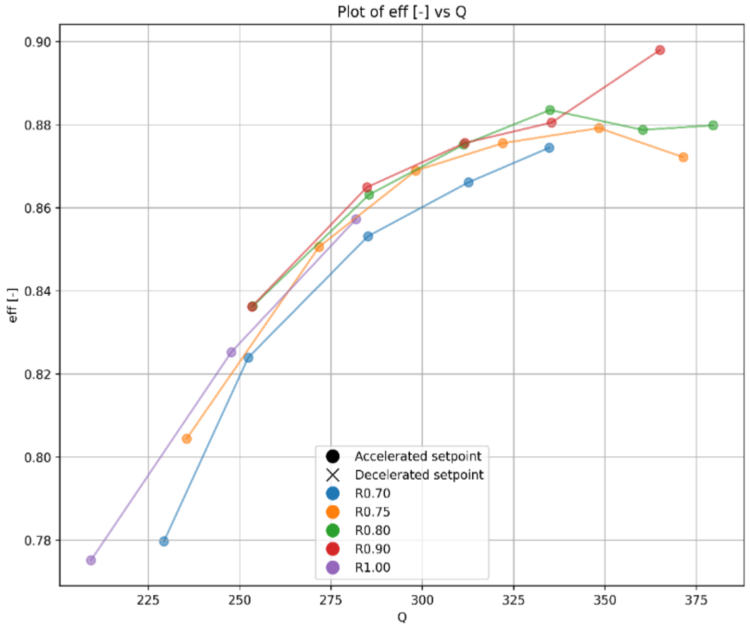


Counter-rotating RPT - 30 kW model



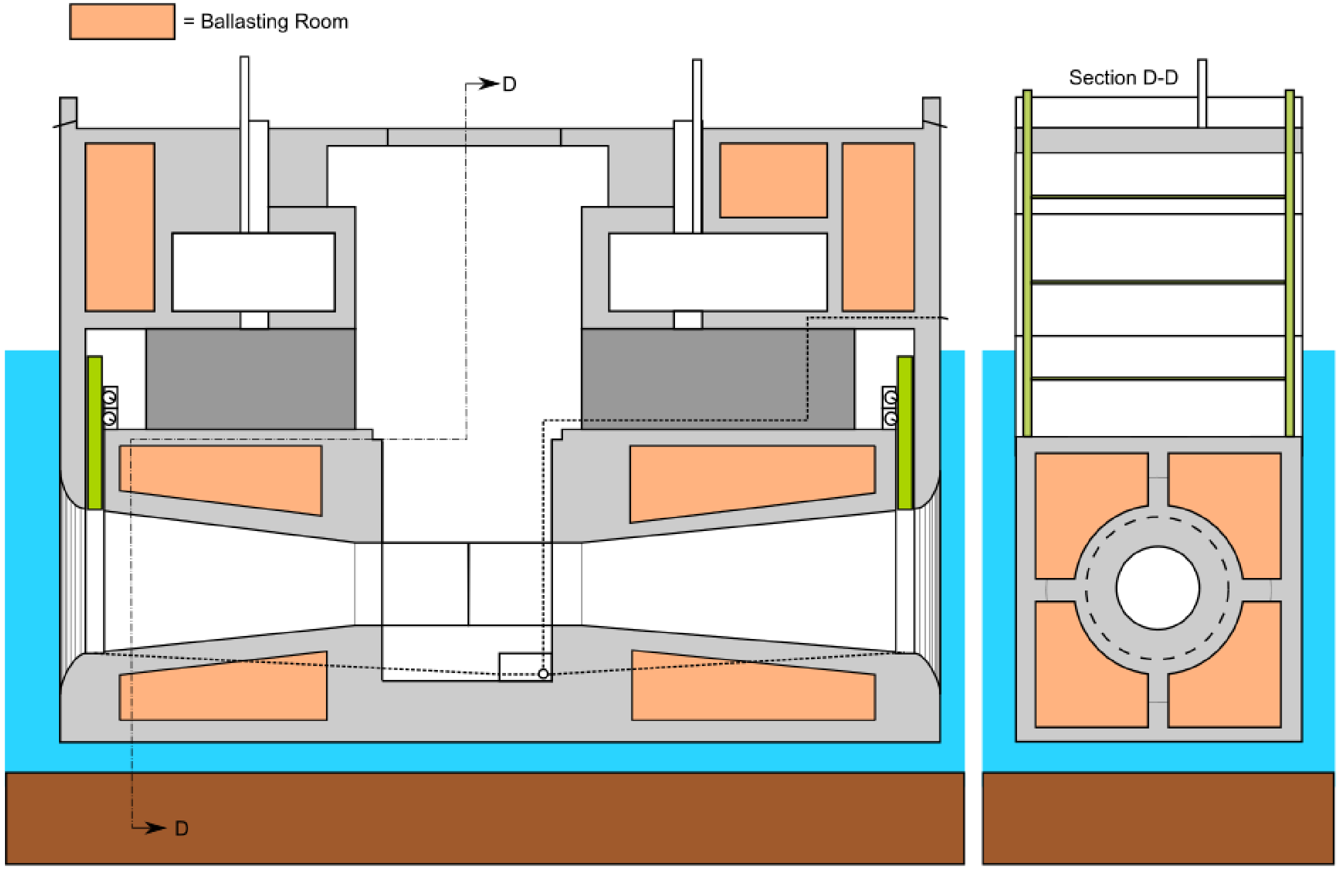


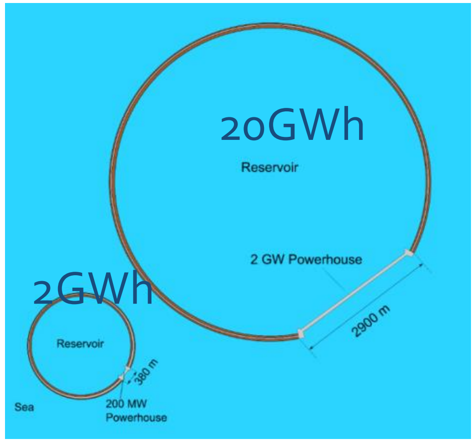
Turbine mode

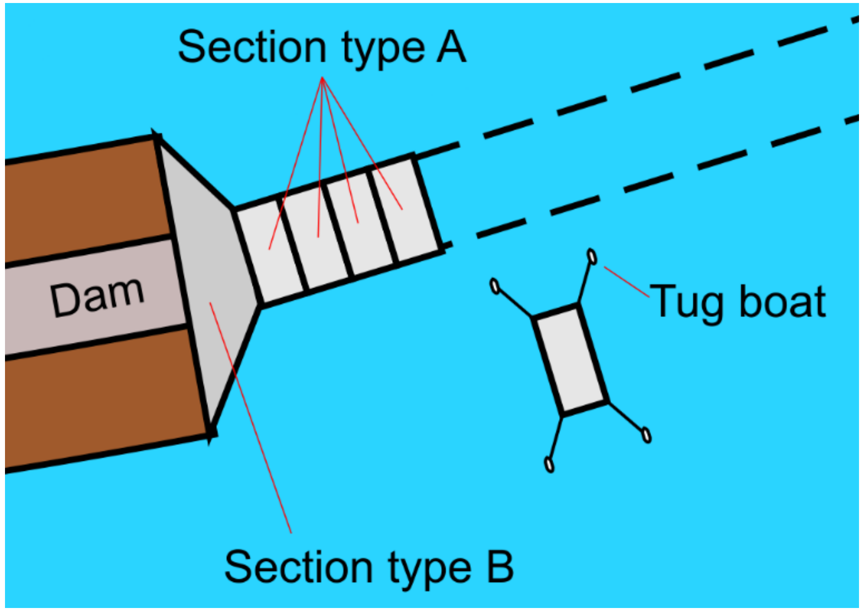


Pump mode

Powerhouse design







Construction and O&M costs

Storage capacity	20 GWh
Power capacity	2 GW
Empty or fill time	10 hours
Lifetime	100 years
Discount rate	5%
Roundtrip efficiency	70%
O&M costs	€ 117 million/year

Source: Irene Souto Blázquez

Capex	5,5 bn €
Specific costs	2.75 Mio €/MW
LCOS	190 €/MWh

Food for thought: Offshore PHS business case

Technology	LCOS	Global Warming Potential[a]	Abiotic Depletion Potential (use of metals etc.)[a]
Conventional PHS	€ 80 – 200 / MWh	33,6 kg CO_2-eq / MWh[b]	-
Lithium-ion batteries	€ 200 – 400 / MWh	27,3 kg CO_2-eq / MWh	1,94 kg Sb-eq / GWh
Hydrogen	€ 200 – 1900 / MWh	44,3 kg CO_2-eq / MWh	1,64 kg Sb-eq / GWh
Offshore PHS	€140 – 260 / MWh	32,7 kg CO_2-eq / MWh	1,34 kg Sb-eq / GWh

[a] Calculated for the scenario that all stored energy originates from offshore wind energy [Bonamusa, 2023]
[b] For conventional PSH the same 70% roundtrip efficiency has been assumed. With 80% roundtrip efficiency the GWP becomes 32,7 kg CO2-eq / MWh

- Offshore PHS economically competitive with Li-ion batteries and hydrogen
- Offshore PHS has similar CO2-eq emissions as batteries, but 26% less than hydrogen
- Offshore PHS results in 31% less depletion of (rare) materials compared to batteries and 18% less than hydrogen

➔ **Offshore PHS technically, economically and environmentally (?) feasible**

ALPHEUS Conclusions

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- The North Sea has plentiful sites for low head offshore PHS.
- Civil technologies are already well-developed and mature.
- Electro-mechanical technologies have been developed at model scale, and show promising efficiencies, up to 80% round trip.
- Total round-trip efficiency >70%.
- Low head offshore PHS LCOS is slightly higher than conventional PHS, but lower than Li-Ion.
- Low head offshore PHS Global Warming Potential is similar to Li-Ion, but has a much lower abiotic depletion potential than Li-Ion.
- Low head offshore PHS can generate revenues for grid balancing on timescales from minutes to days.

Thank You!