Congress special session: The role of hydropower in the energy transition process

The role of pumped hydro storage for a green energy transition in Europe

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D.2. Ocean and Water

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The European Commission, DG JRC, Ocean and Water unit

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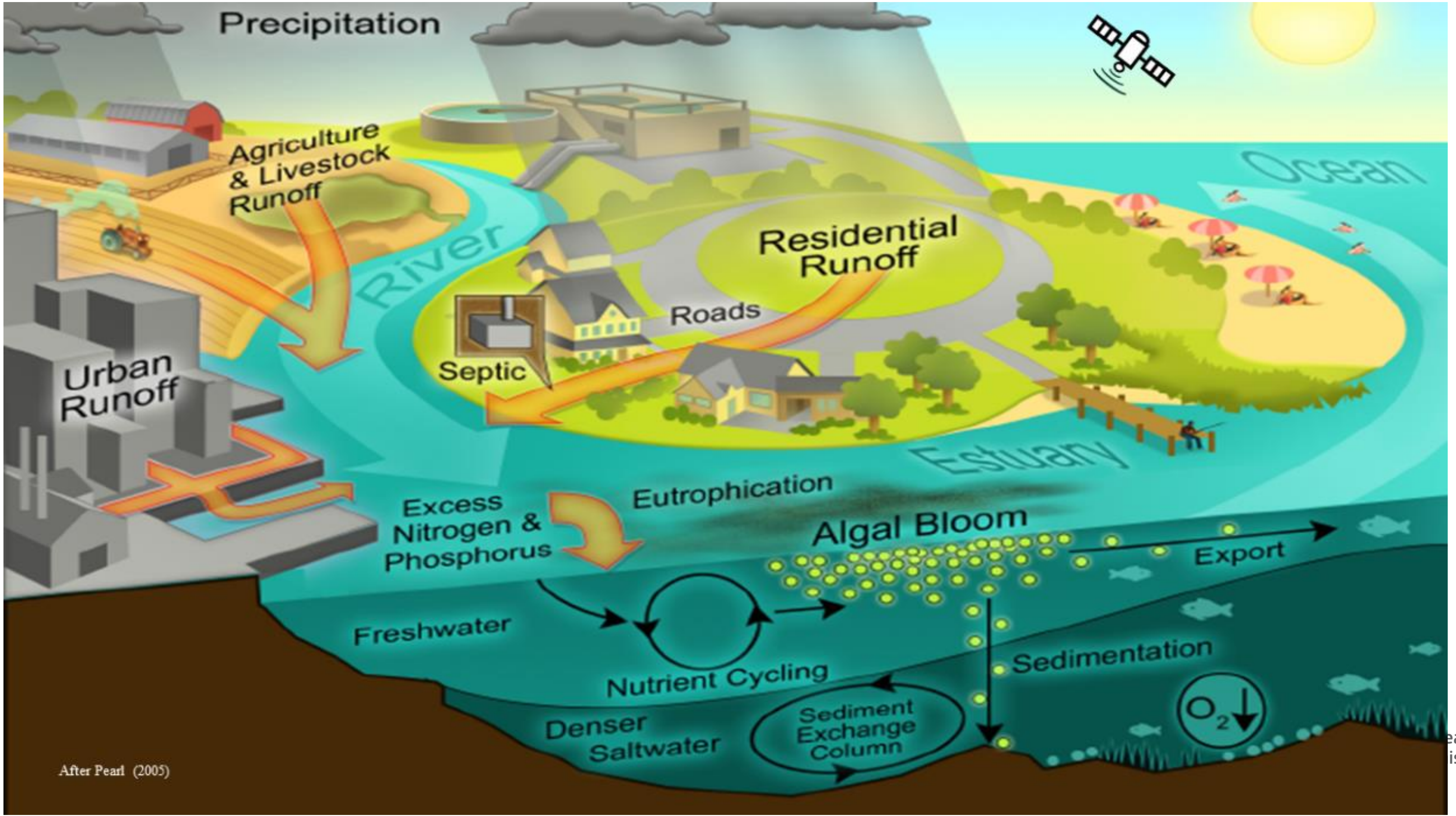
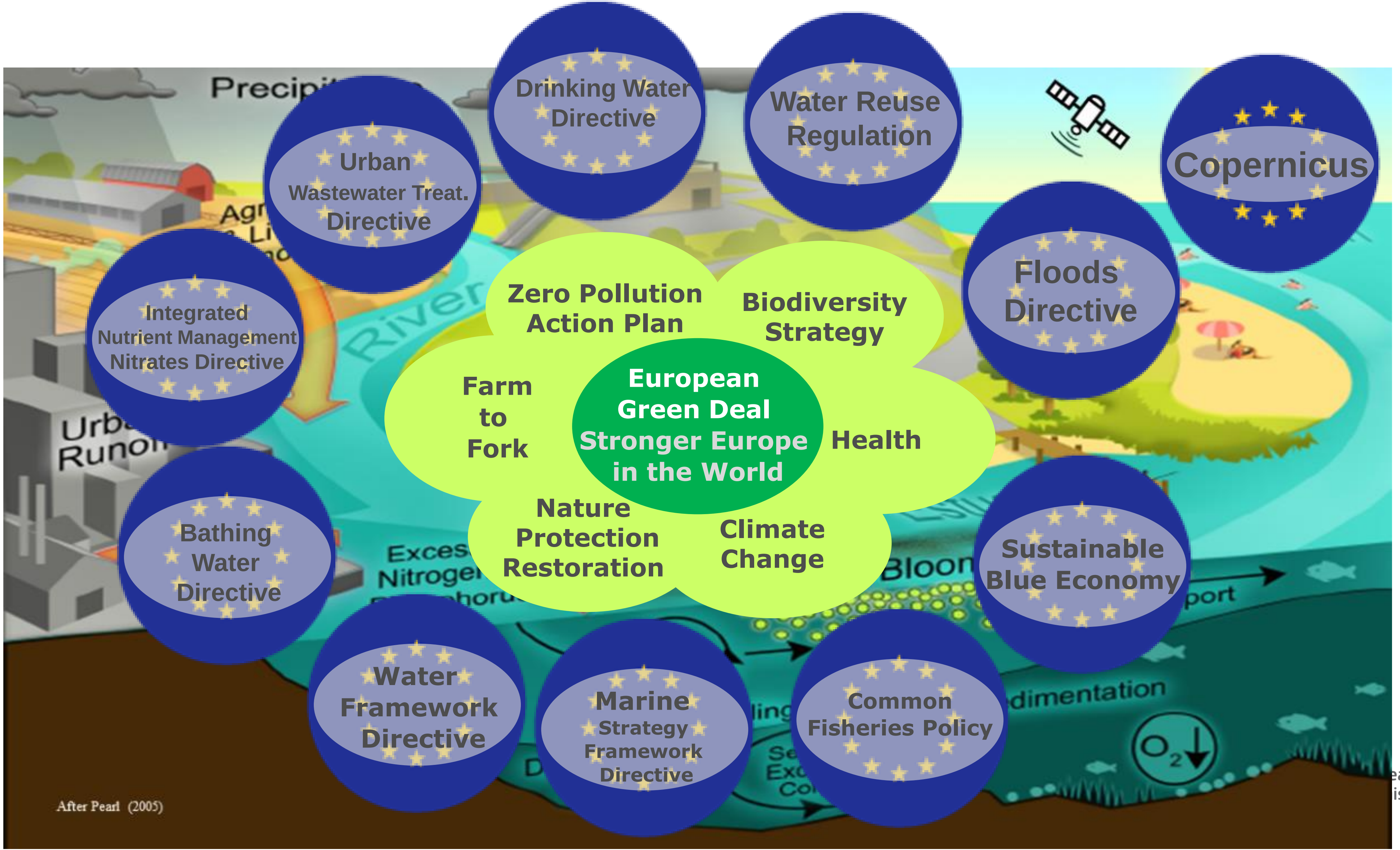
JRC Ocean and Water

Holistic and integrated support: freshwater - coast - sea



The EU Water Acquis (extended)



Sustainability in hydropower

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Hydropower is at the center of a significant debate due to its opportunities as a renewable energy source, as well as its challenges and impacts

Hydropower debate: benefits vs impacts

Renewable energy, energy storage, flexibility

Water management, flood control and water storage (e.g., for irrigation)

Tourism

Market development

Job opportunities

Fish injury

Sedimentation

Fragmentation

Hydropeaking

Flooding upstream

Ecosystem alterations

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Hydropower and policies with different targets

Water Framework Directive: Hydropower as a source of impact

Renewable Energy Directive, REPowerEU: Hydropower as a clean energy technology

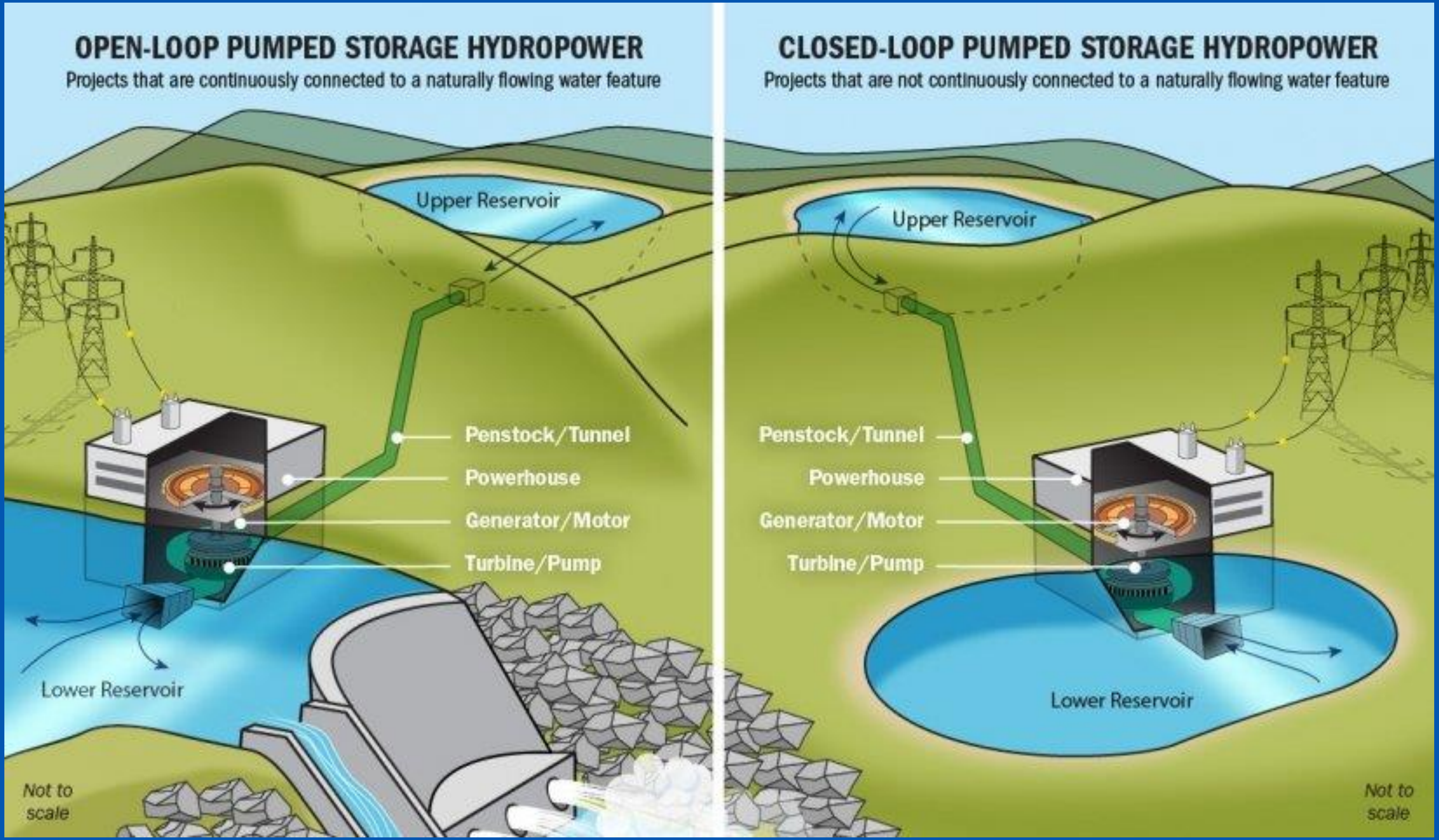
Flood Directive: Reservoirs can be a dangerous interference, but reservoirs can mitigate droughts and can provide water storage

Conflicts can be overcome by sustainable hydropower

Sustainable hydropower needs to achieve a good balance between electricity generation, social benefits and impacts on the ecosystem and biodiversity, developing mitigation solutions and innovative technologies.

Pumped-storage hydropower

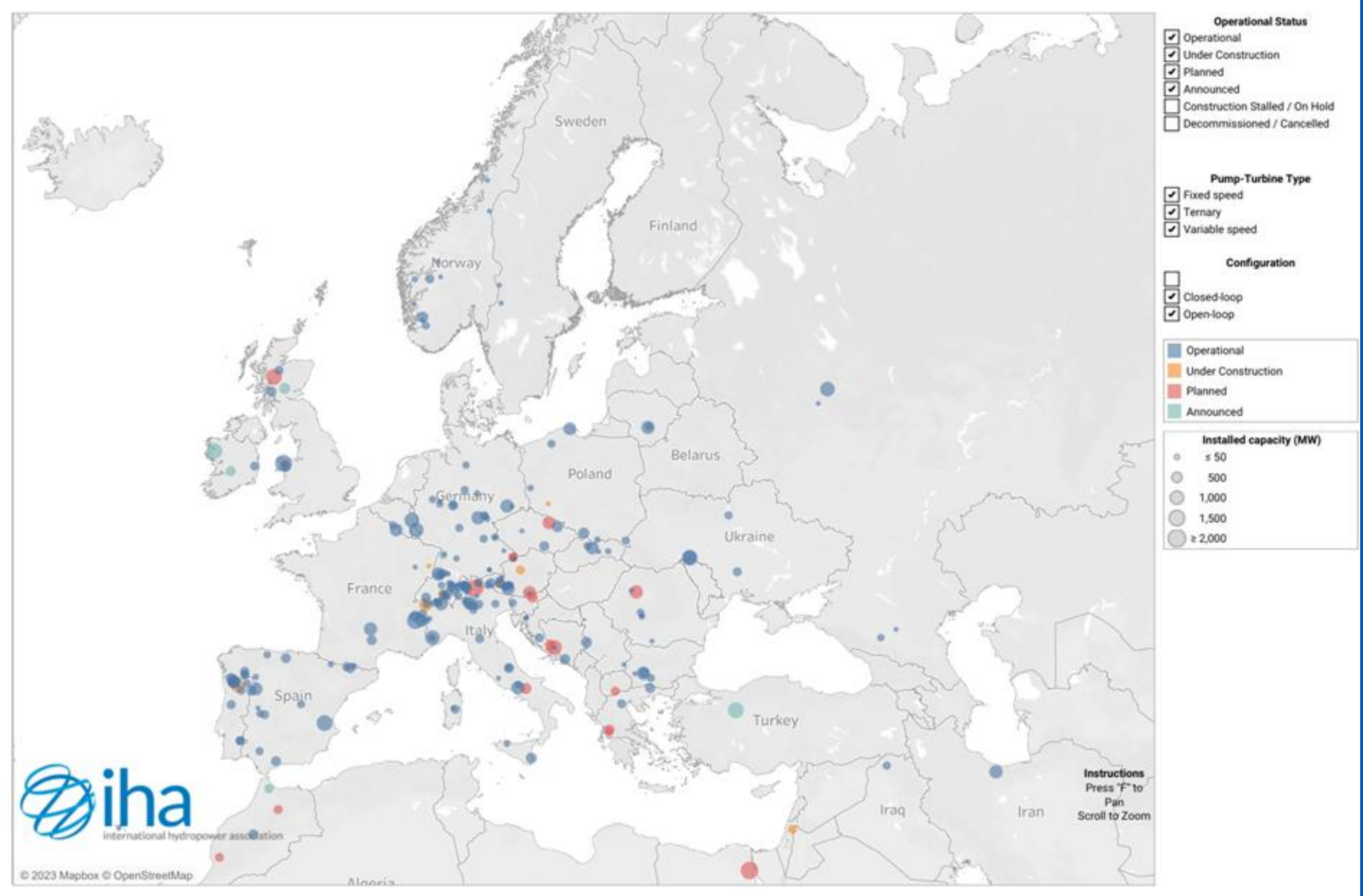
Pumped-storage hydropower plants



The vertical distance between the two reservoirs is called head

Energy storage in RSHP (reservoir-type hydropower) and PSH is the largest source of energy storage today and is the only mature technology for long duration energy storage (IEA, 2023b, World Bank, 2024). Globally, reservoir hydropower has a storage capacity of about 1500 TWh, which is about 170 times more than the global fleet of PSH plants and almost 2200 times more than the Li-Ion battery capacity of both stationary and automotive applications (IEA 2021). Excluding reservoir hydropower, more than 90% of the remaining energy storage in the world is in PSH (IHA, 2024)

PSH in the EU



Installed power in the EU: 46 GW, more than a quarter of the global installed capacity (IHA, EUROSTAT), 1300 GWh of technical energy storage

Sustainable Water&Energy storage, and PSH, solutions:
Focus on the EU

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How to increase energy storage capacity, and improve operation, of existing PSH?

A large-scale European perspective

Some options in the following slides.

Modernisation and flexibility increase of existing PSH

Increasing generation

+40 TWh/y of annual energy generation potential (Quaranta et al., 2021) (>+11%) by:

- *Digitalization of the operation.*
- *Replacement of electro-mechanical equipment*.
- *Waterways and penstocks*.

Increasing flexibility

- *As above, but especially:*
- *Variable speed turbines*
- *Short-circuit operation*
- *Optimisation at part-load operation*
  → X-FLEX Hydro

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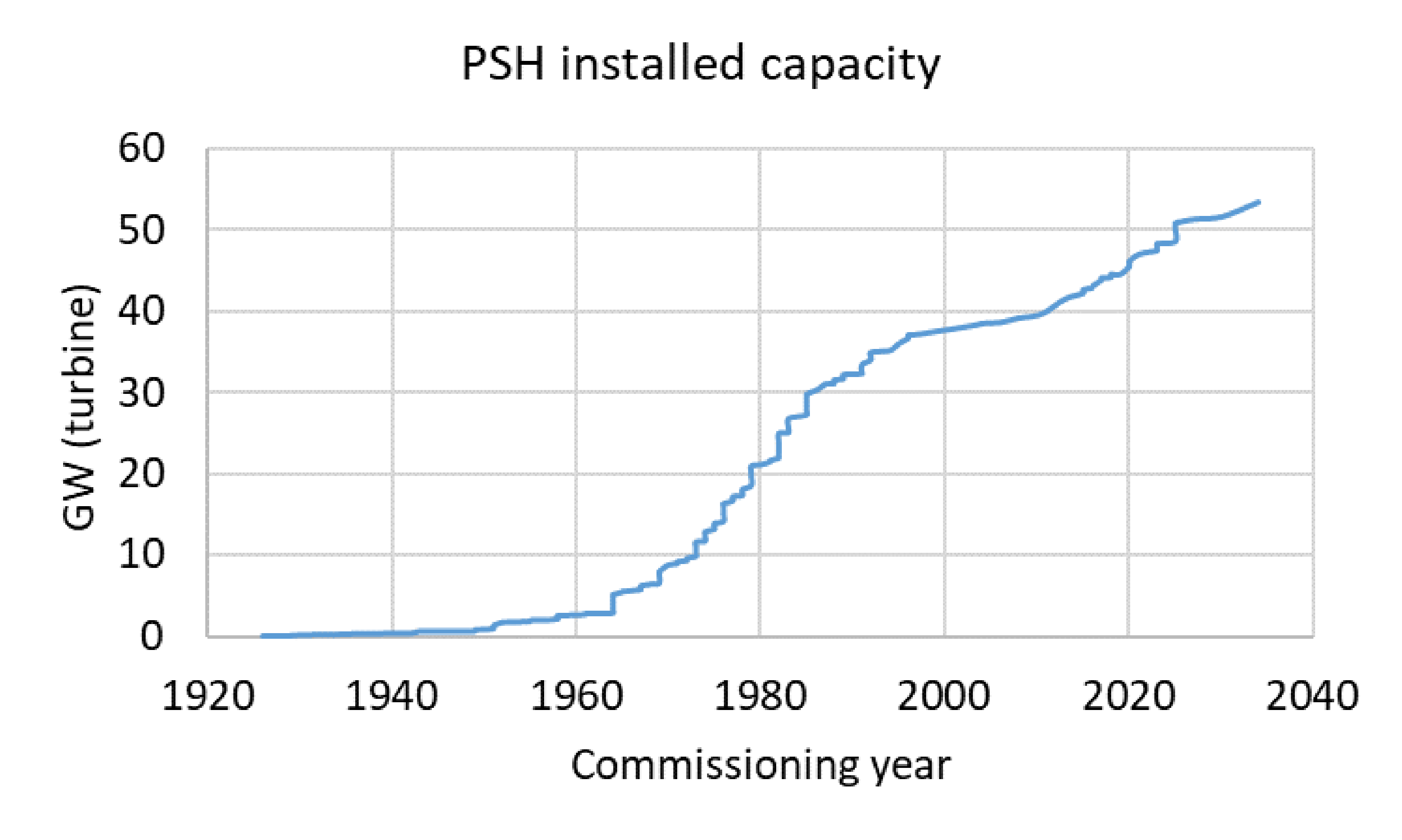
Age of PSH in the EU



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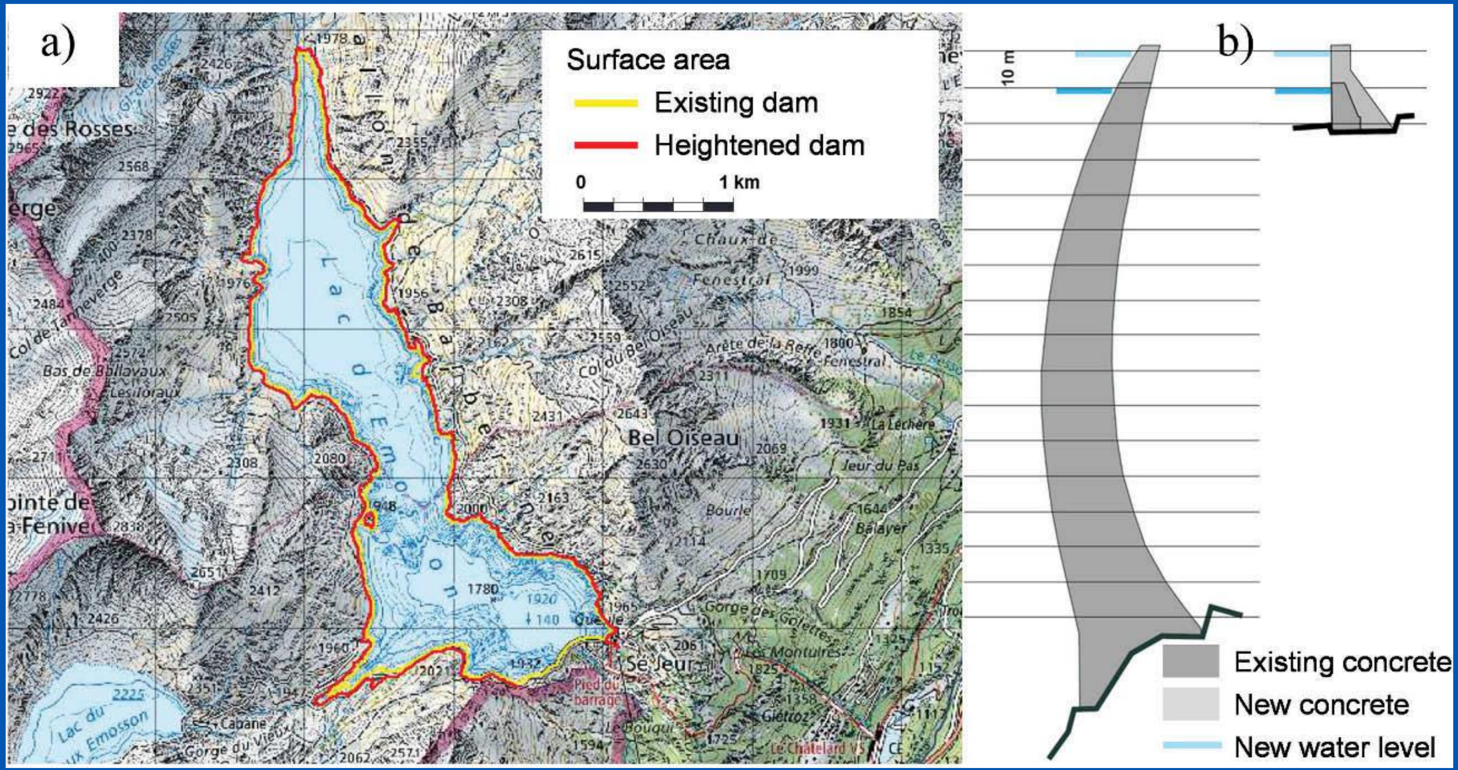
Dam heightening



Fauriel et al. (2023).
+30% (= +2 TWh) in Switzerland

De-sedimentation

Annual sediment inflow into the EU's reservoirs: approx. 0.7% of the reservoirs' volume.

Solutions: dredging, flushing and prevention measures (greening to avoid soil erosion, lateral bypass canals).

2-8 billion EUR/year dredging cost in EU reservoirs

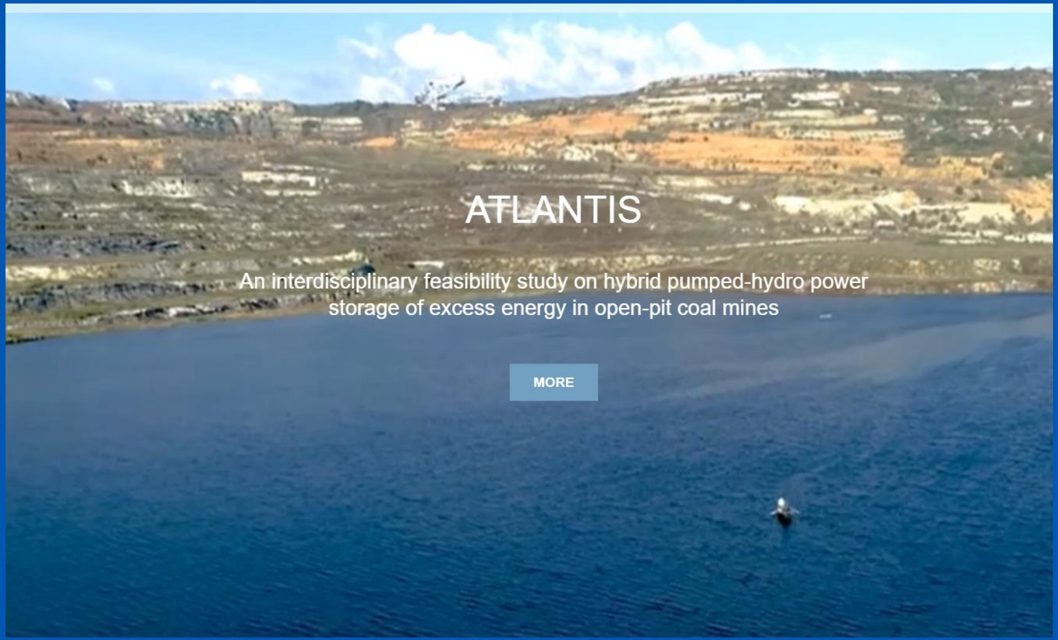
https://www.sciencedirect.com/science/article/pii/S095965262304341X

Is it possible to build new PSH without damming rivers?

A large-scale European perspective

Some options in the following slides.

PSH in abandoned mines



Weber et al. (2024).
+7 TWh in the EU (3 TWh the most economic sites)

https://www.sciencedirect.com/science/article/pii/S0960148124001782

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Reservoir interconnection

Gimeno-Gutiérrez and Lacal-Arántegui (2015)

Potential (GWh)	20 km	10 km	5 km	3km	2 km	1 km
Theoretical	14238	3593	886	319	76	5

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Is it possible better operate PSH and the overall energy system?

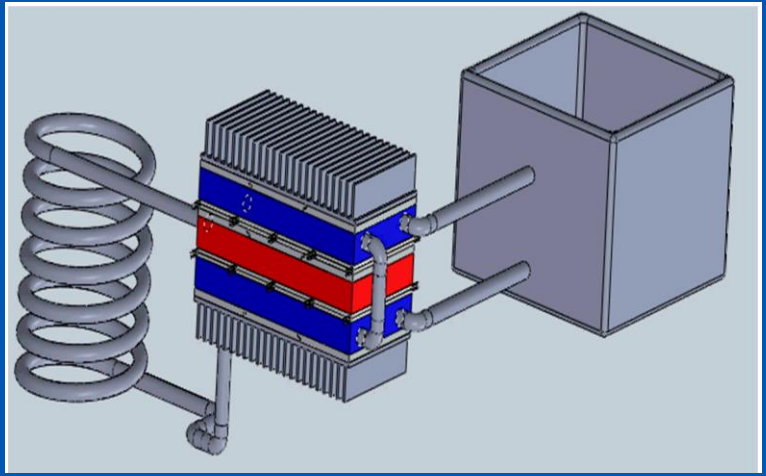
A large-scale European perspective

Some options in the following slides.

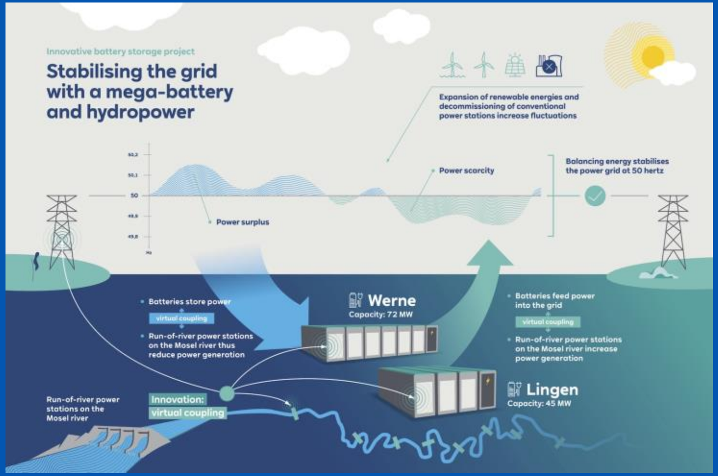
Hydropower and hybridization with other energy technologies

Photovoltaics

Wind



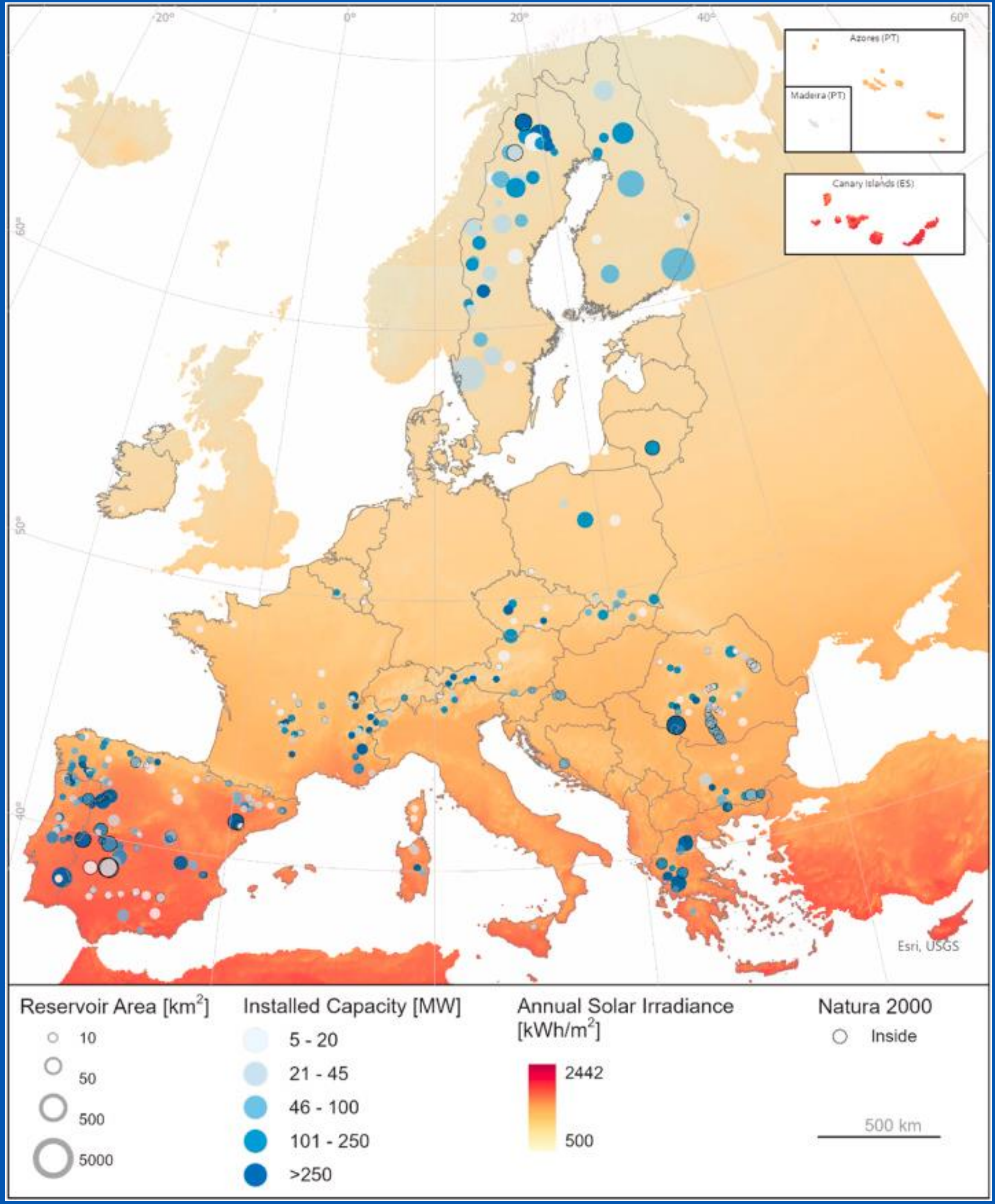
Heat extraction



Batteries

Hybridisation with Floating Photovoltaics (FPV)

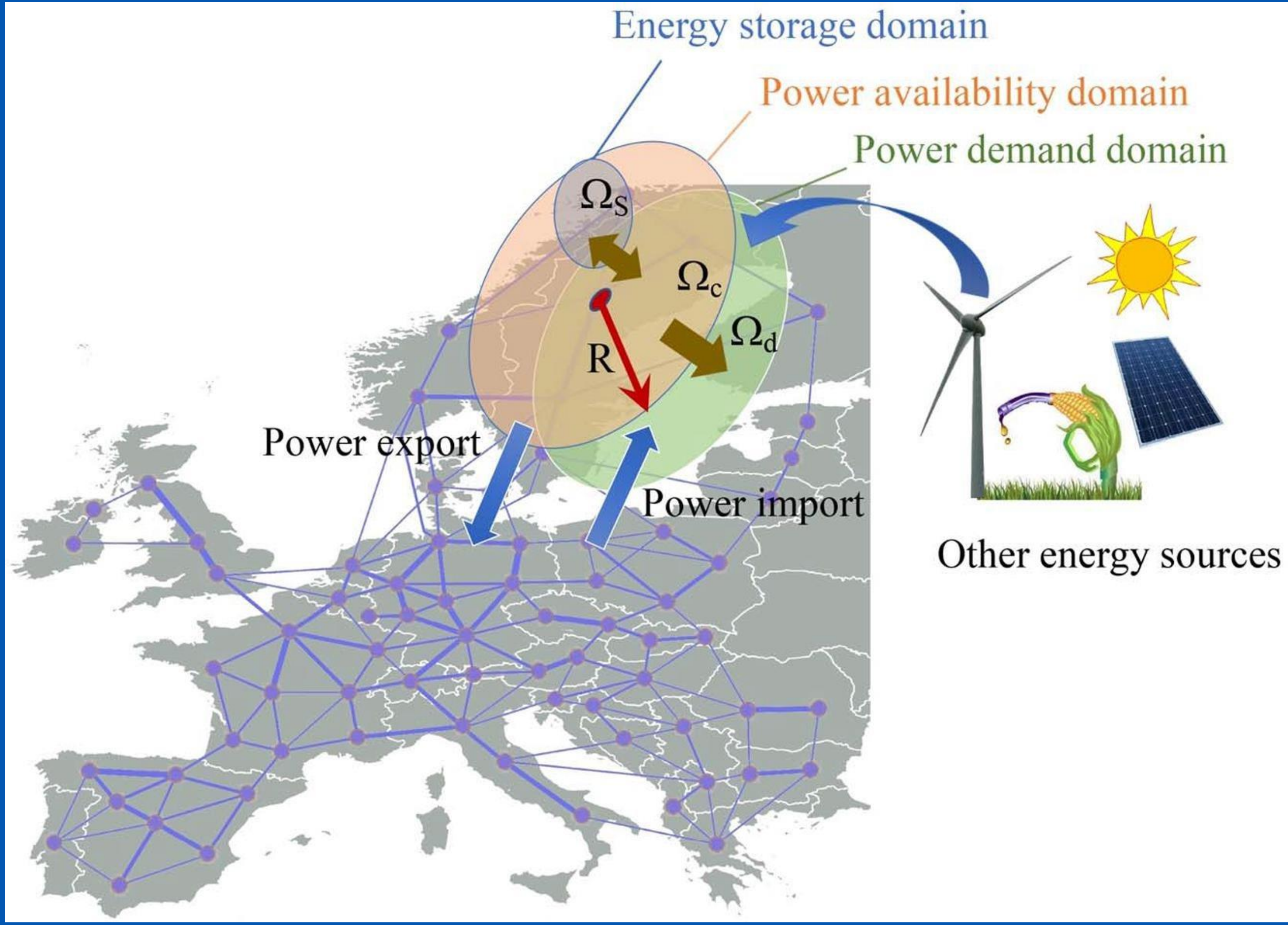
FPV potential



•Using <15% of EU's reservoir area investigated in the paper, FPV output ~50% of the hydropower generation.

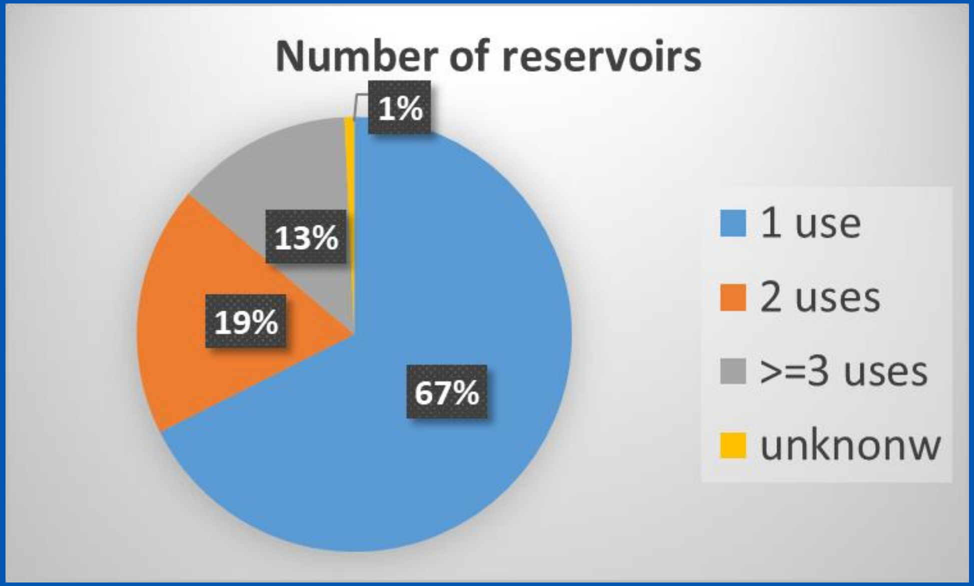
•A 10% reservoir's area coverage with FPV results in 1717.8 Mcm annual water savings (+300-400 GWh/y).
(Kakoulaki et al., 2022)

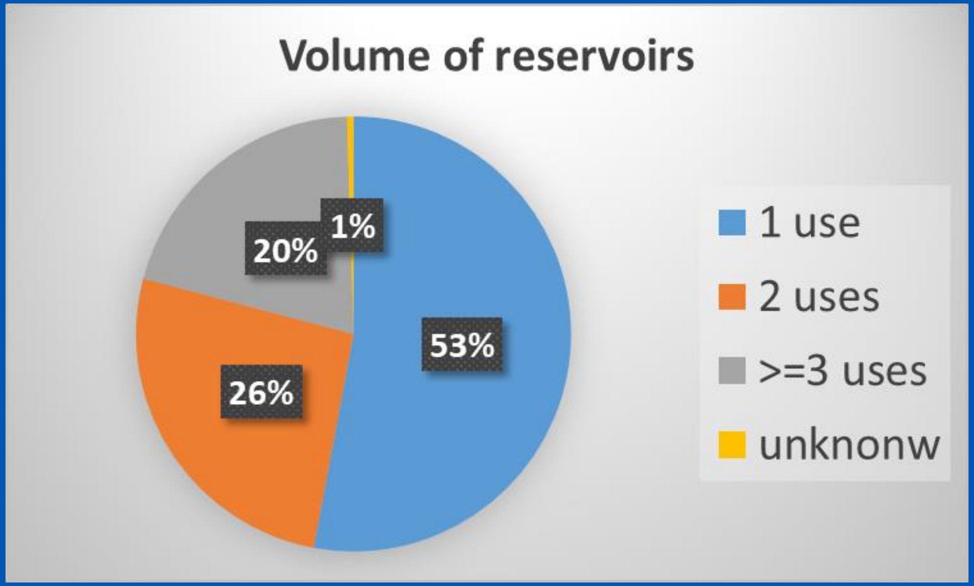
Grid expansion and continental interconnection



Worman et al. (2024).
200 TWh reduction of energy storage demand over 5 years

PSH systems as multi-purpose and water management systems





Single and multi-purpose reservoirs in the EU (+CH)
Ref: ICOLD

Total volume is 280 billion m3

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New green-field PSH

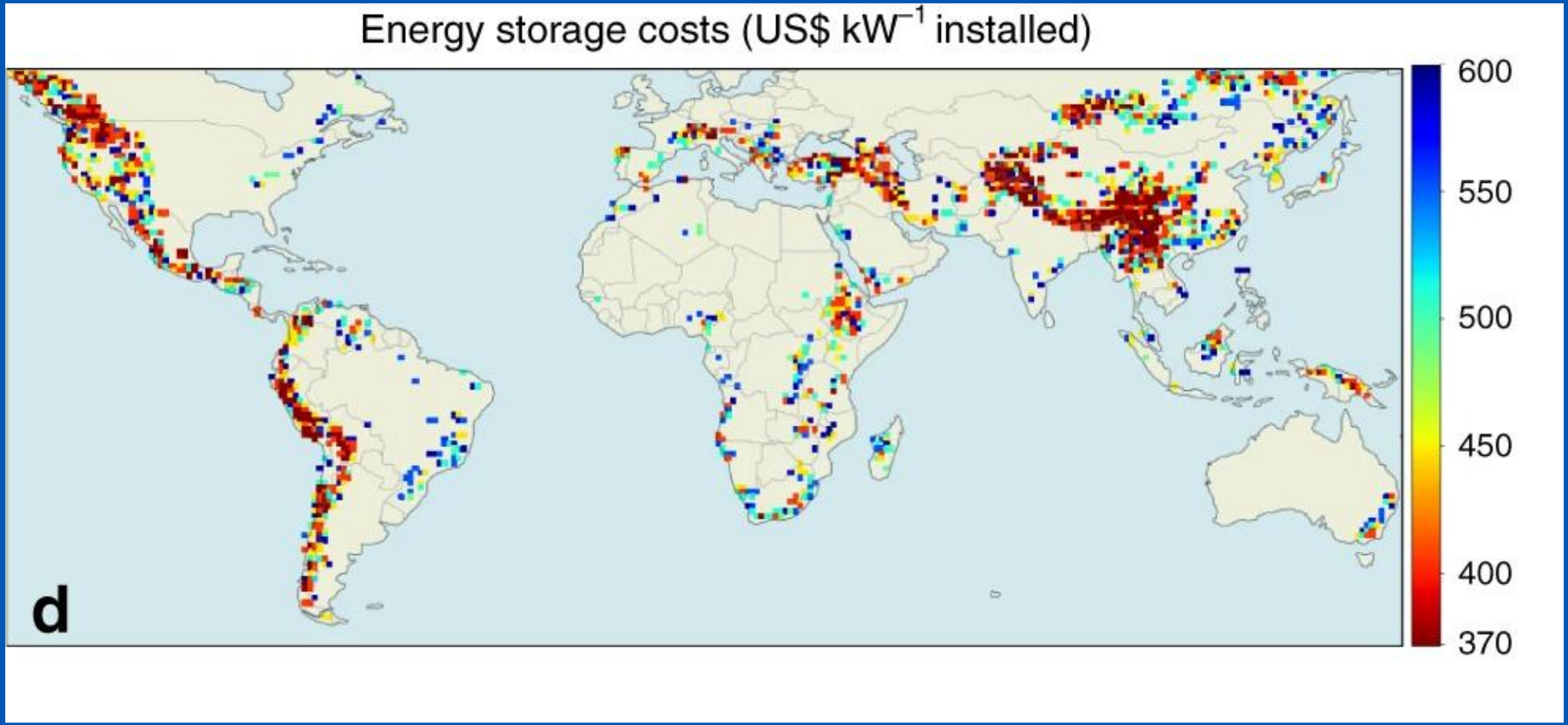
Some options in the following slides.

Potential of closed-loop PSHs

Stocks et al. (2021): 300 TWh (the cheapest sites are 25 TWh)

Lowest costs sites are shown in red with yellow representing sites with twice the capital cost.

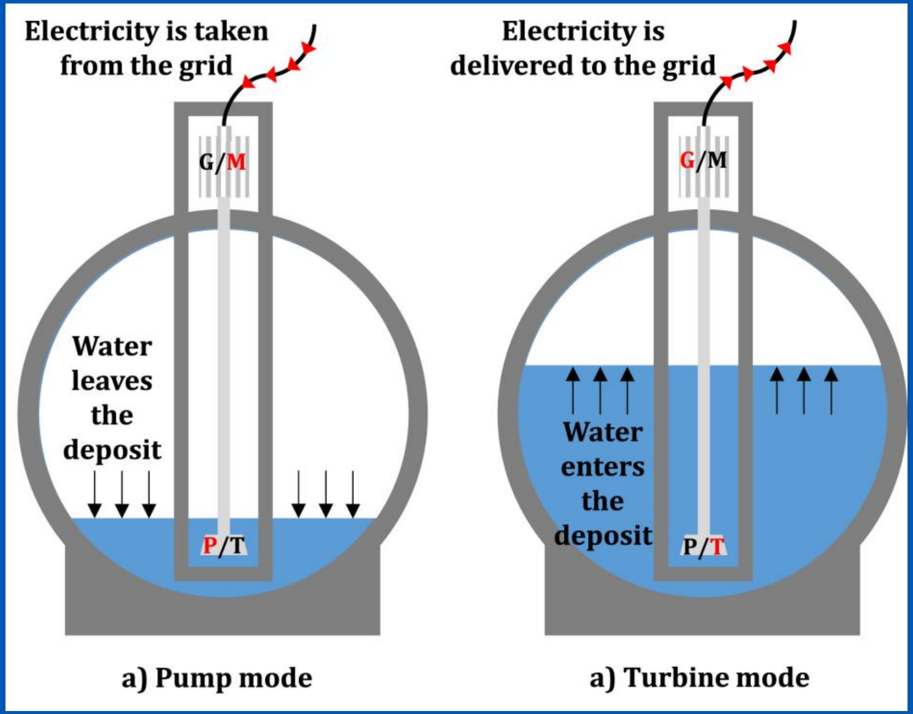
Potential for open-loop seasonal PSHs



Hunt et al. (2020).

The cheapest sites were found to represent 10-14 TWh

Ocean energy storage



On the sea bed

PSH using the ocean

Sustainable hydropower potential

How to develop new hydropower in a sustainable way without damming new rivers?

Some options in the following slides.

Modernisation/Refurbishment

+40 TWh/y -> + 11%

References: Quaranta et al., (2021), and Quaranta and Muntean, (2023)

- *Digitalization of the operation.*
- *Replacement of electro-mechanical equipment*.
- *Waterways and penstocks*.

Improving:

- generation, flexibility
- Sustainability and safety
- Resilience to climate changes
- Water resources management

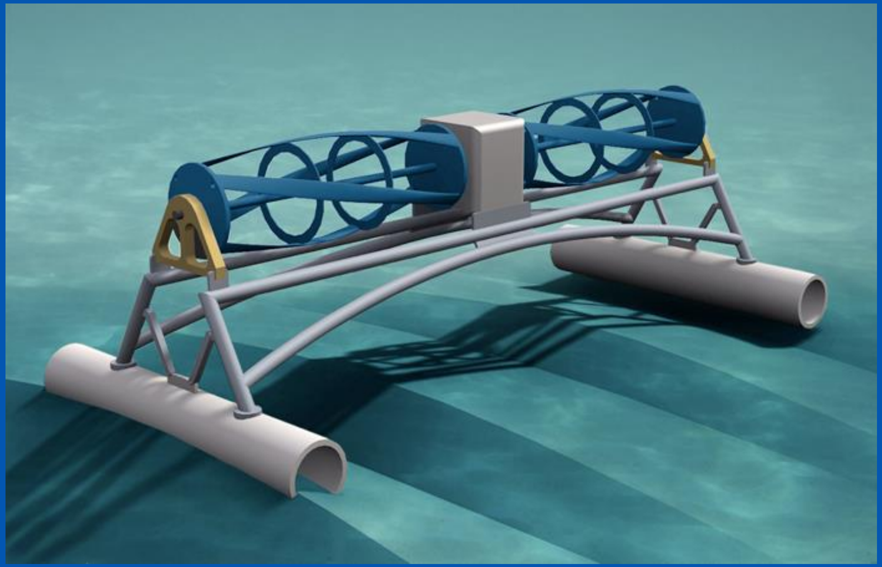
Hydropower potential in historic low head sites (e.g. water mills

+ 8 TWh -> +2.5%
Reference: Quaranta et al., (2022)

Hydrokinetic turbines

+3 TWh/y -> + 1%

References: Quaranta et al., (2022), Quaranta and Muntean, (2023)



Hydropower in WDNs and WWTPs

+3.1 TWh/y->0.8%

Reference: Quaranta et al., (2022)

Water Distribution Network (WDN), Wastewater Treatment Plant (WWTP)

Key personal references

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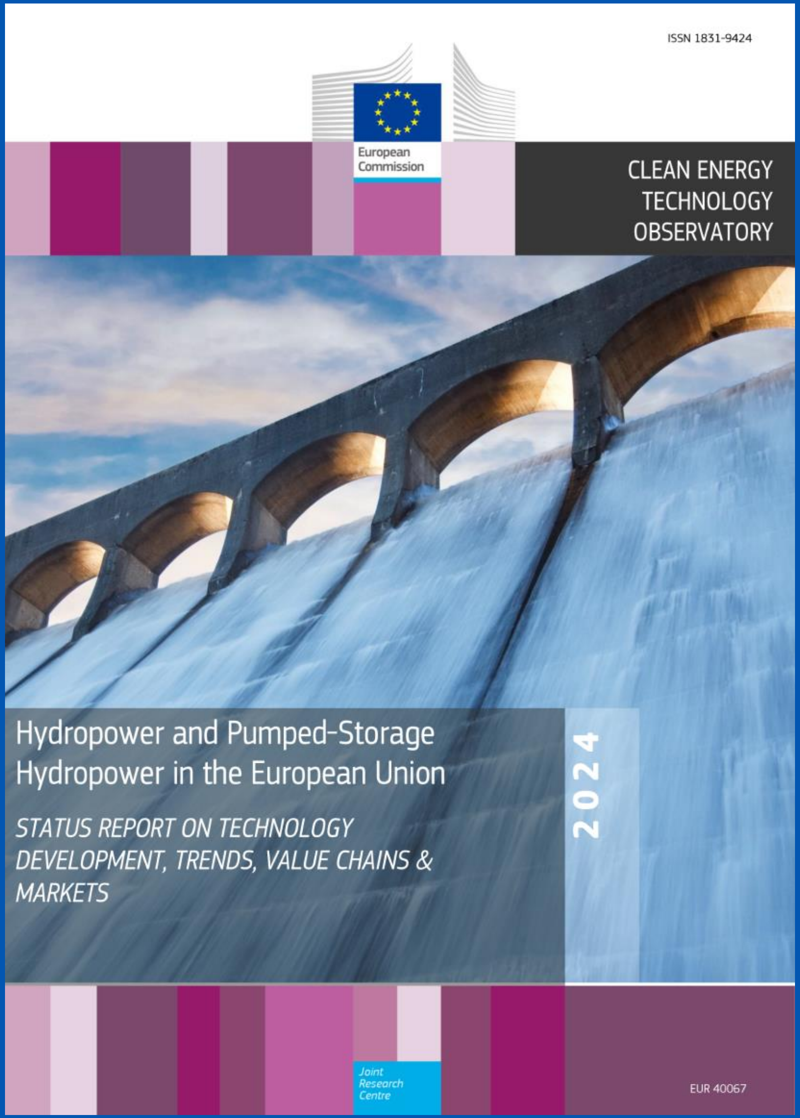

The *technology state-of-the-art and future developments and trends* section builds on the:

- technology readiness level
- Installed capacity and electricity production
- Technology costs
- Public and private R&I funding
- Patenting trends
- Scientific publication trends
- Impact of EU R&I

The *value chain analysis* maps the situation of the technology with regard to the:

- Turnover
- Gross Value Added
- Environmental and socio-economic sustainability
- EU companies
- Employment
- Energy intensity and labour productivity
- EU production

The *EU position and global competitiveness* analyses the EU position in the global market according to the:

- Global and EU market leaders
- Trade, imports and exports
- Resources efficiency and dependence

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Thank you

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