Water reservoirs and dams in the EU: complexities and challenges for their sustainable operation within the WEFE (Water Energy Food Ecosystem) nexus

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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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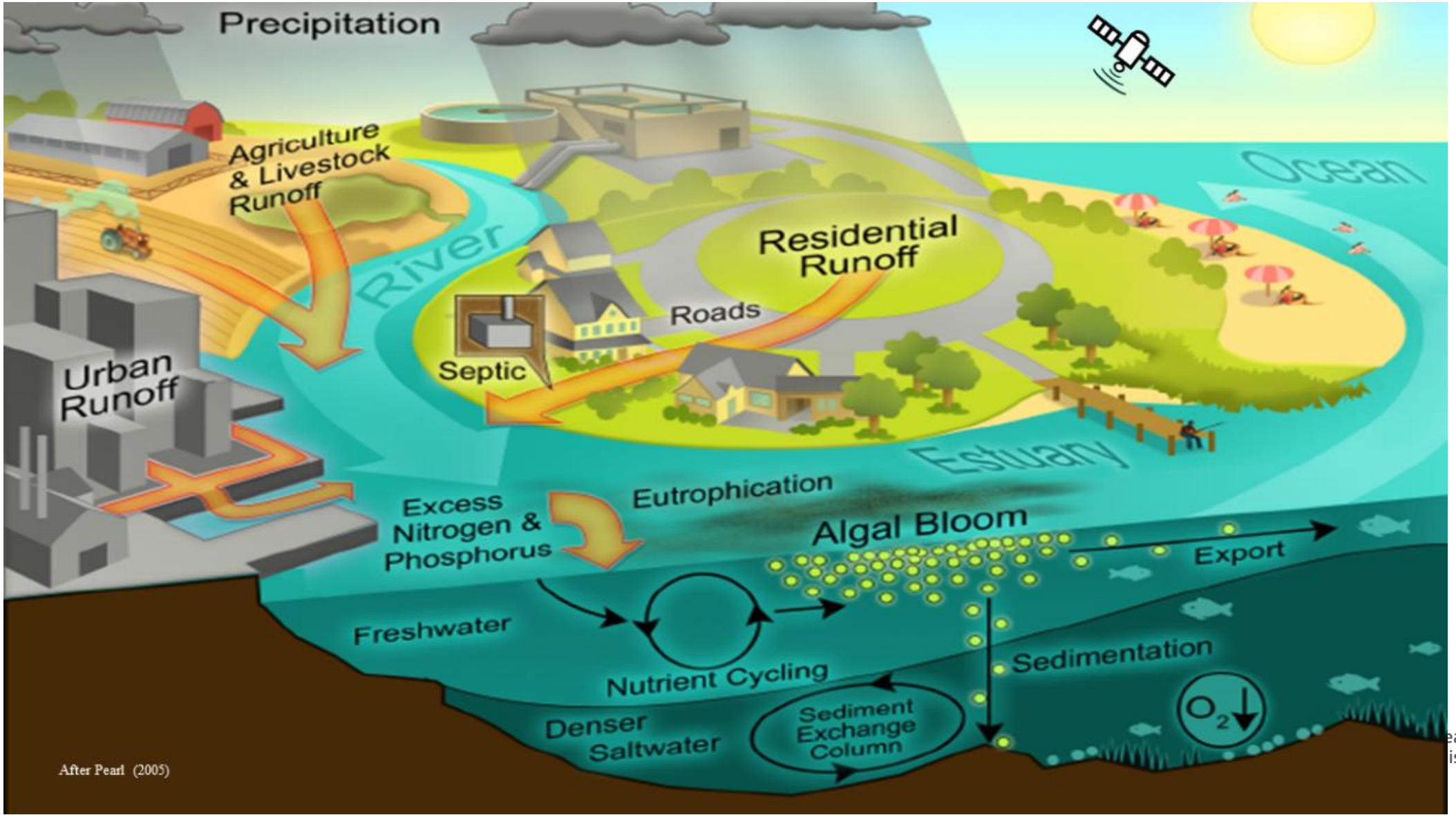
JRC Ocean and Water

Holistic and integrated support: freshwater - coast - sea



The EU Water Acquis (extended)

Summary

Water reservoirs

Multiple uses

Energy storage

Flood control

Social impact

River fragmentation

Sedimentation

GHG emissions

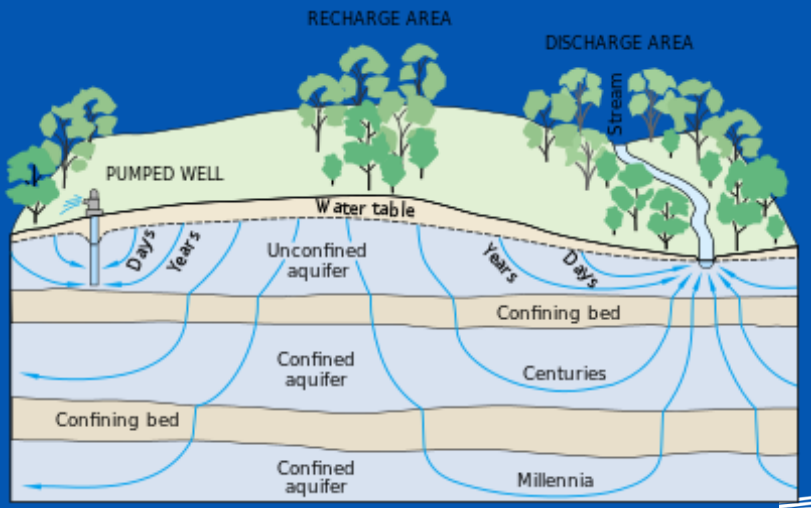
Evaporation

Floating Photovoltaics (FPV)

Environmental impacts

Digital twins

Water reservoirs: types and focus



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Focus of the presentation
Large artificial reservoirs (ICOLD)

Large reservoir: associated to a large dam, i.e.
dam height > 15 m, OR
between 5 m and 15 m and reservoir's volume > 3,000,000 m^3

Water reservoirs for several uses/services (benefits)

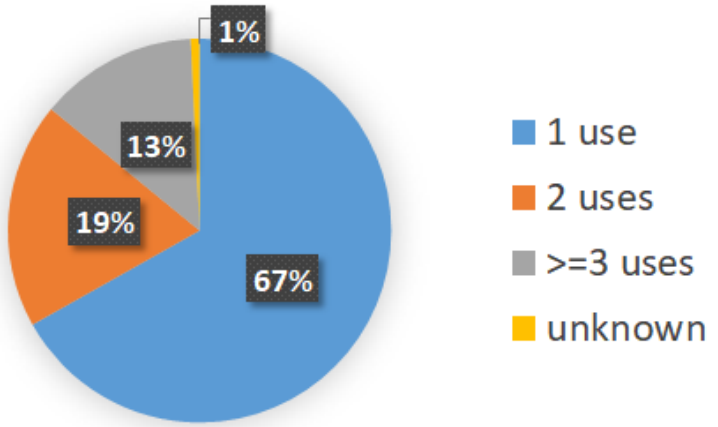
Water reservoirs can be single-use or multiple-uses: the multiple-use ones have different uses: a first use, a second use, etc., in order of priority.

Type of use	Acronym
Irrigation	I
Hydroelectricity	H
Water Supply	S
Flood control	C
Navigation	N
Recreational	R
Other (e.g., firefighting, industrial)	O

Single and multi-purpose reservoirs in the EU

Ref: ICOLD

(a)



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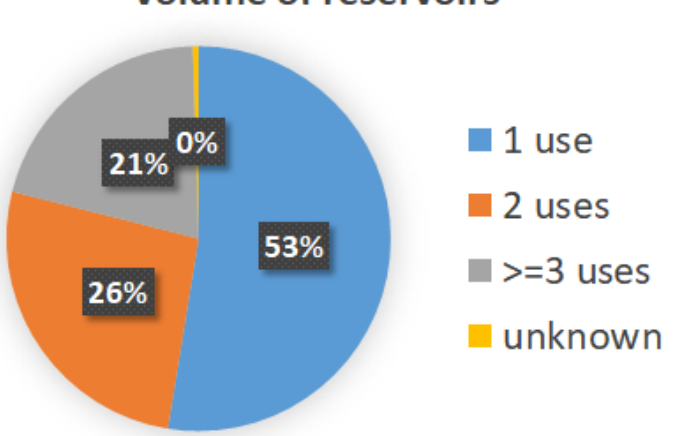

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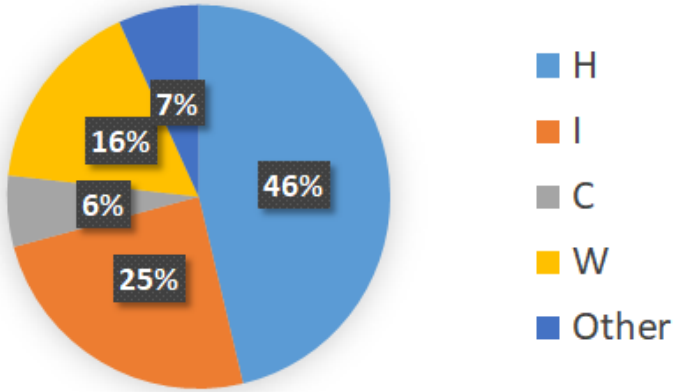

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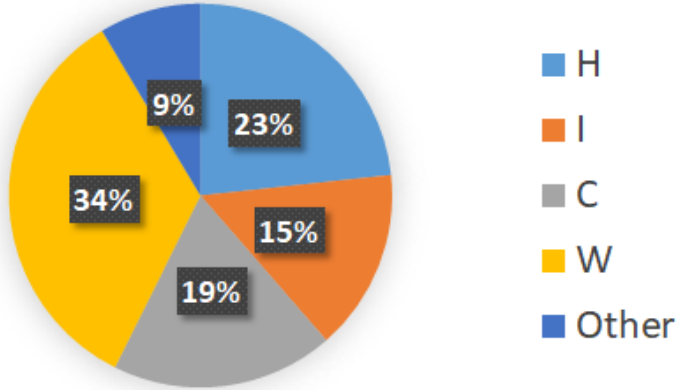

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Energy storage

- GWh of energy stored, electricity that could be generated in one emptying cycle
- Different sources with different data
- Definition: theoretical and technical
- Cascade effect or stand-alone operation

Excluding reservoir hydropower, more than 90% of the remaining energy storage in the world is in PSH (IHA, 2024)

Energy storage

$$E_{s,th,\,I} = \rho g\, H\, V$$

$$E_{s,te,i} = E_{s,th,i} \cdot C_v C_d C_h C_\eta$$

Hydropower type	Theoretical energy storage (TWh)	Technical energy storage (TWh)	Reported energy storage (TWh)
Pumped Storage Hydro	6.6	2.2	1.3 (IHA)
All hydro reservoirs	54.7	23.8	70.8 (ENTSO-E)

Flood control and drought mitigation

Whilst it is difficult to estimate the associated benefits, the multipurpose functions of hydropower reservoirs represent an additional annual economic value of EUR 10 billion to 20 billion, even when neglecting the potential value of avoided damages from flood events (44 billion EUR damages in 2022 in the EU).
IHA estimates that through the water storage function of its reservoirs, the hydropower industry prevents US$131.3 billion in annual GDP losses from drought incidents.

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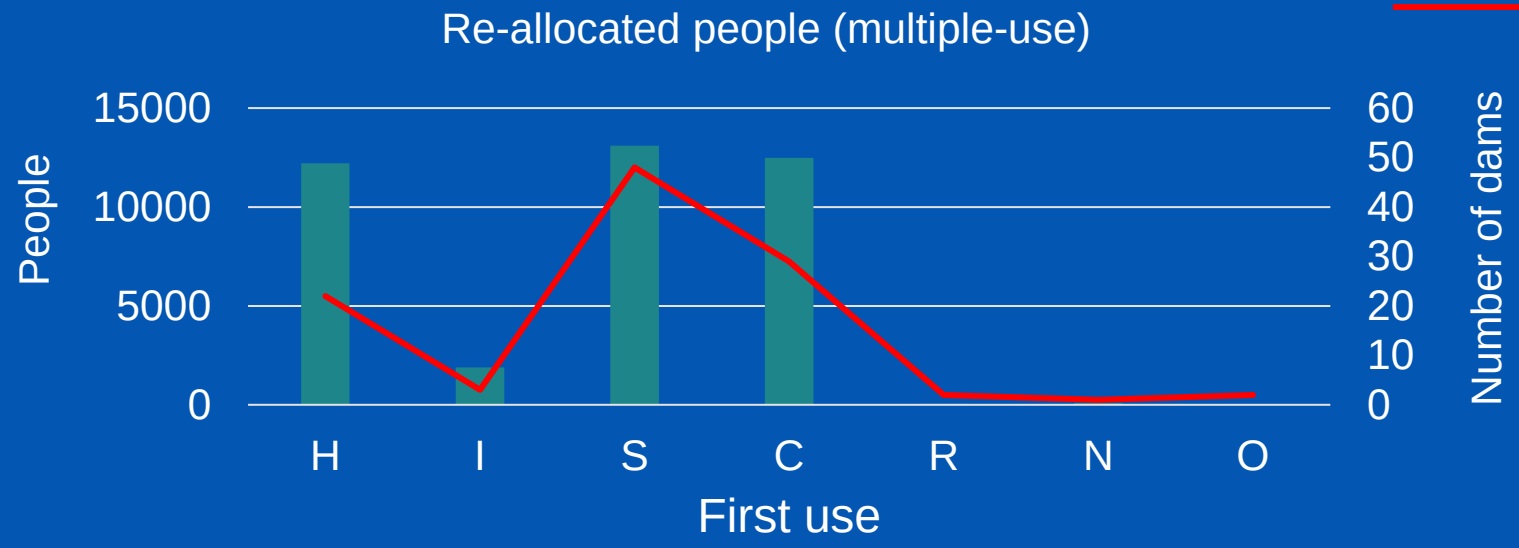
Social impact

number



H = hydropower
I = irrigation
S = water supply
C = flood control
R = recreation
N = navigation
O = other use

Approx. 2 million people re-allocated at the Three Gorges Dam (China)

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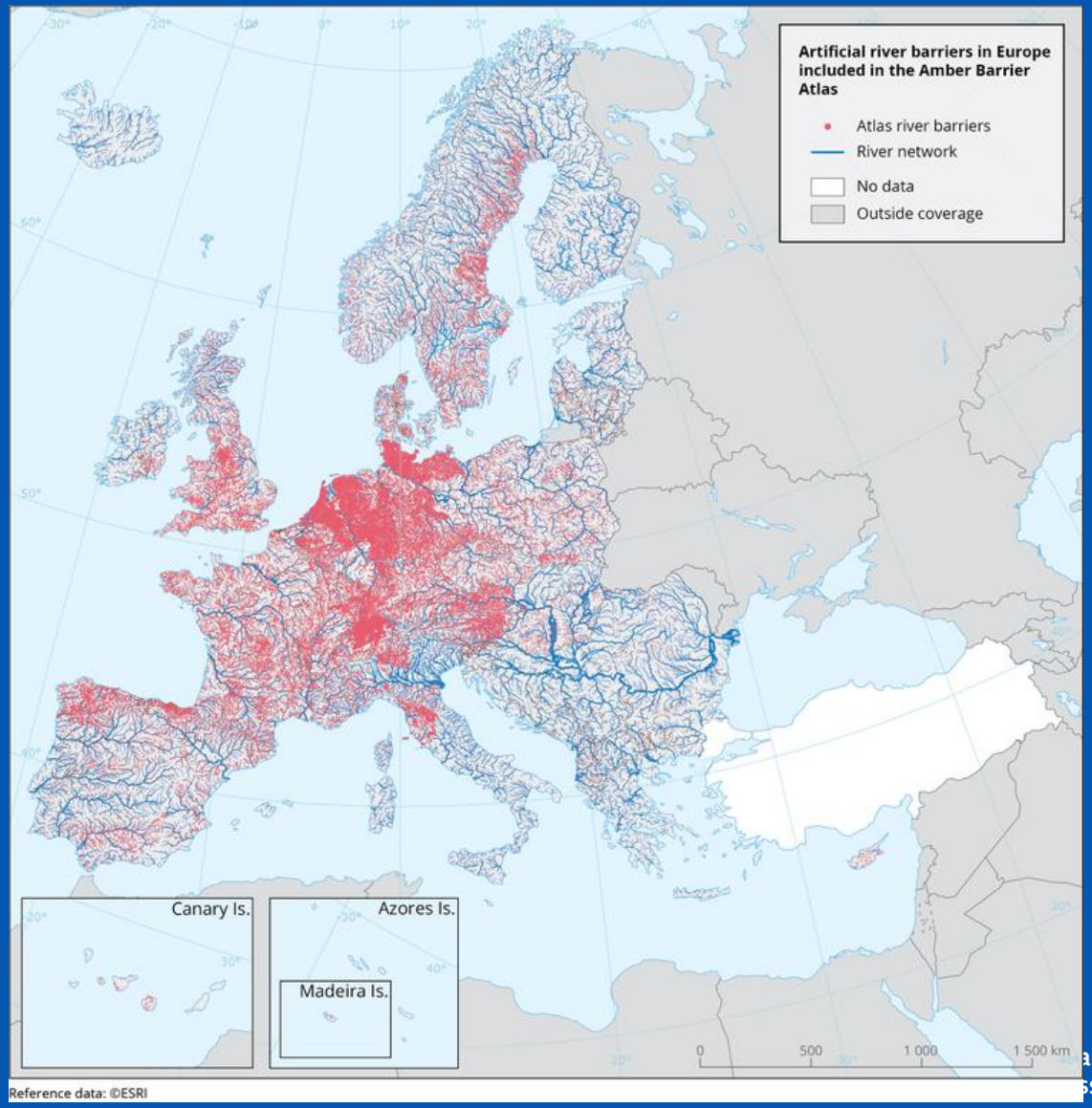
Fragmentation in the EU

450,000 barriers in EU's rivers (AMBER project).

4500 large dams (ICOLD)

25,000 hydropower plants (JRC estimate)



Sedimentation

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

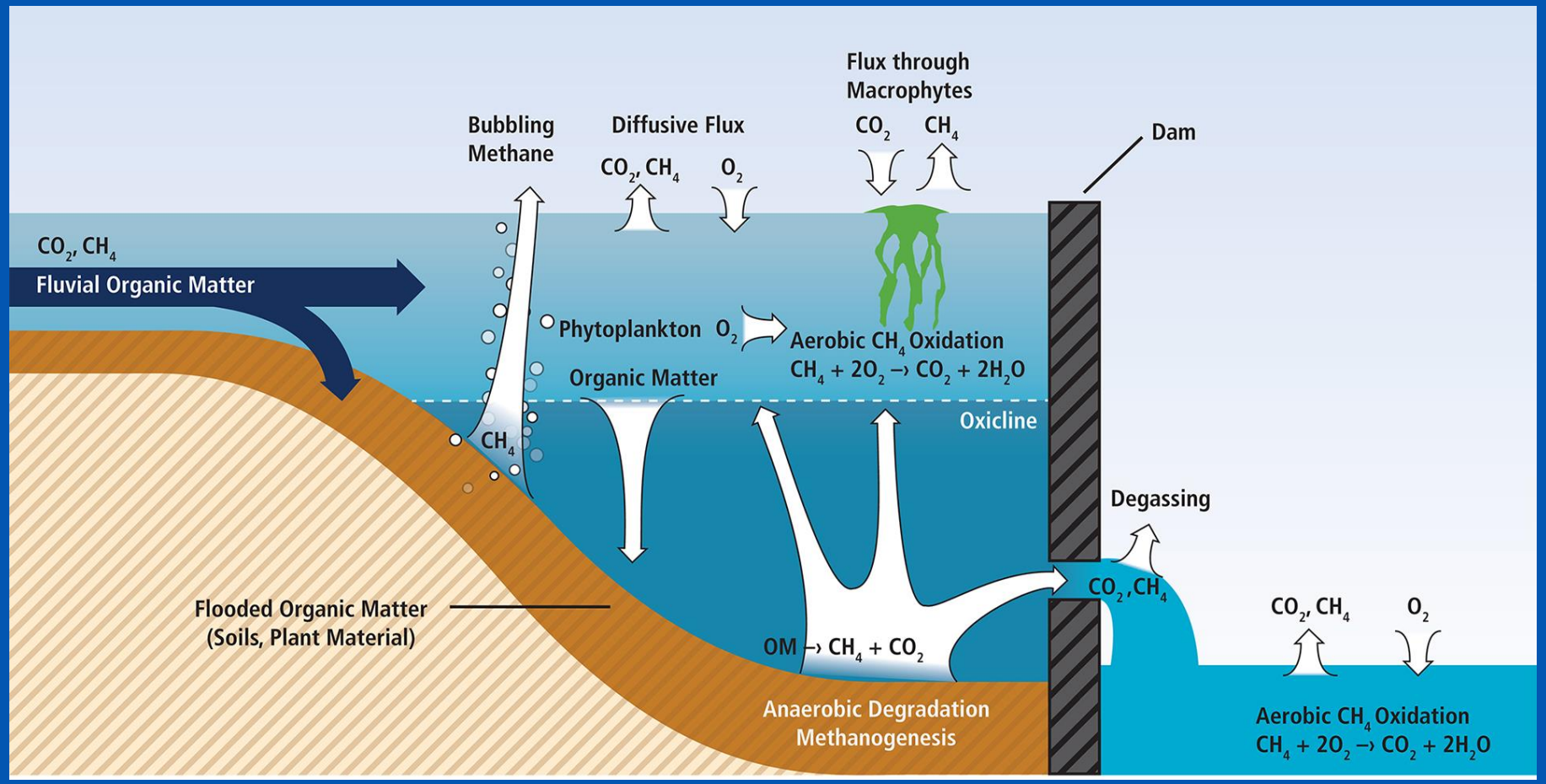
Solutions: dredging, flushing and prevention measures (greening to avoid soil erosion, lateral bypass canals).

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

Plastics

Fig. 1. Accumulation of floating debris behind the Three Gorges (Sânxiá) HPP dam on the Yangtze River, China [4].

GHG emissions



Solutions: capture mechanisms for degassing methane, vegetation removal before flooding, sedimentation control.

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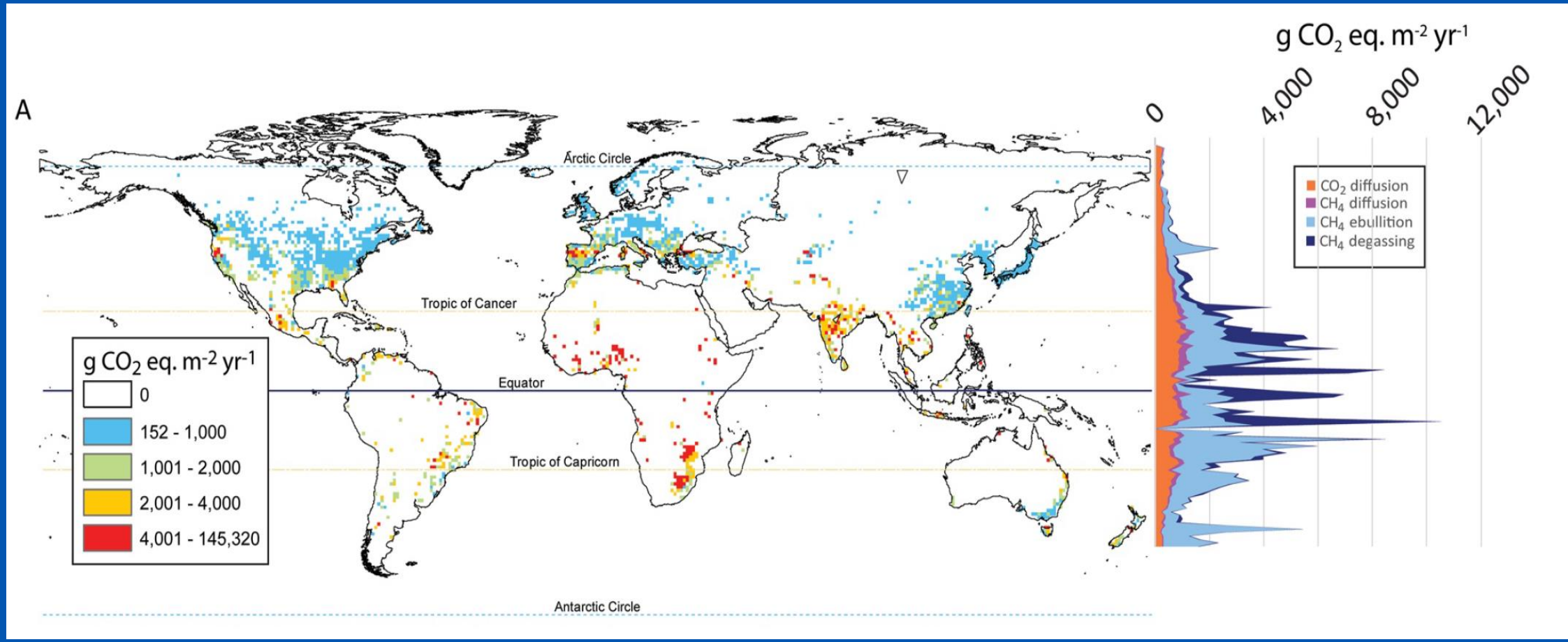

Harrison et al., 2021,

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Evaporation

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Floating Photovoltaics (FPV)

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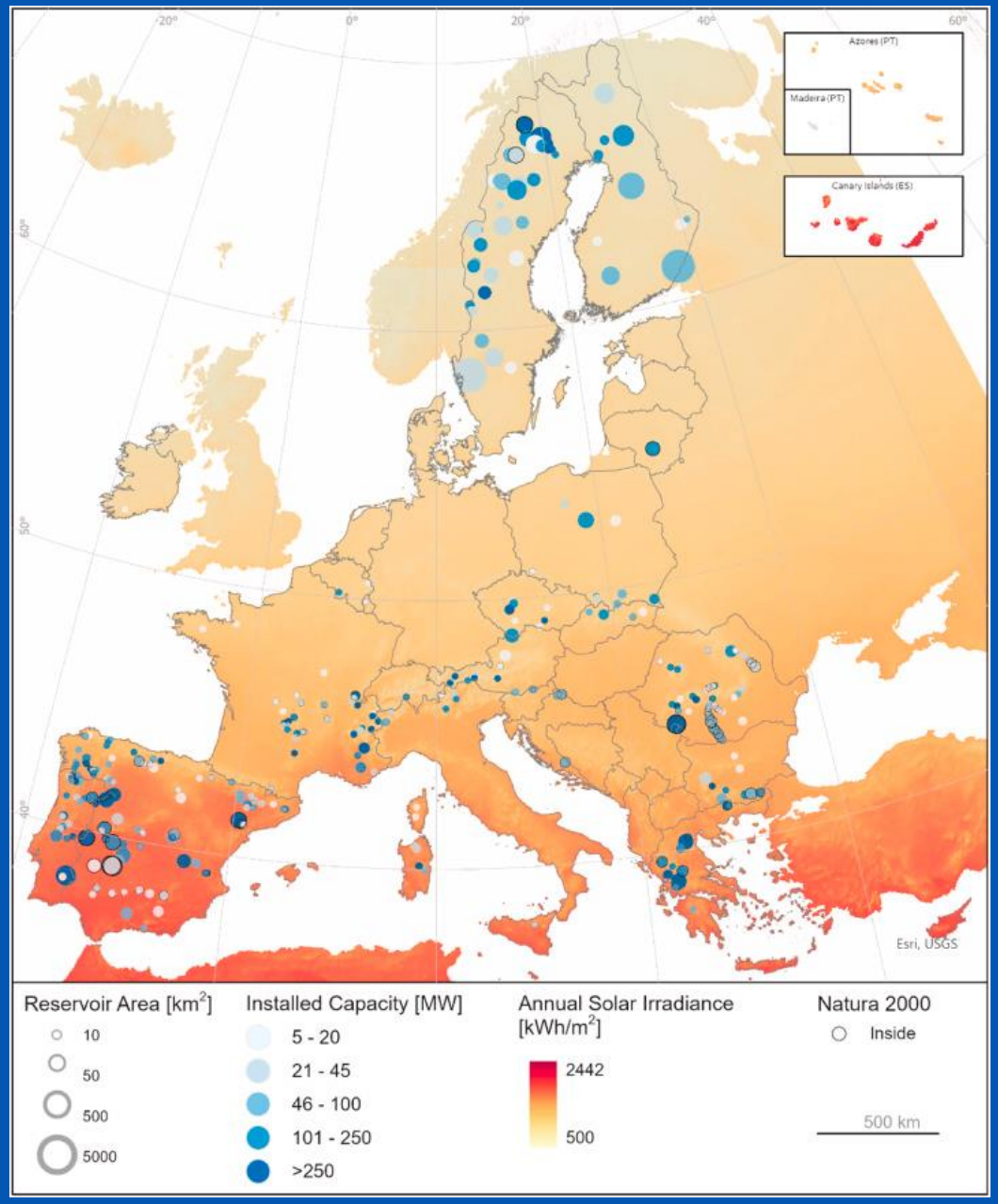
FPV potential



- 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)

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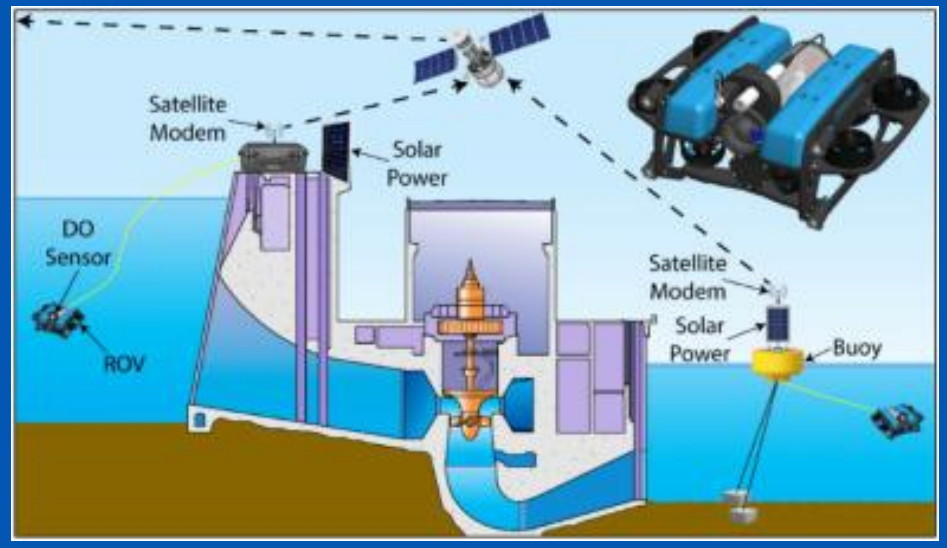
Impacts on the hydrology and on ecosystems

- Impacts on the hydrology,
- Impacts on water temperature, biological activity and biota
- Impacts on oxygen content
- Fish migration
- Hydropeaking and thermopeaking

Solutions: mitigation measures (Environmental flow), compensation measures (e.g., greening to improve biodiversity), real-time control and operation (next slide), aeration mechanisms, selective withdrawals

Digital twin of reservoirs and digital solutions

- Up to + 1% of hydropower efficiency
- Up to +10% of annual revenue and -10% of spills in hydropower reservoirs
- Up to +10% of energy generation in cascade reservoir hydropower
- Better inflow forecast
- Better reservoir management
- Dam safety
- Environmental monitoring (sediments, water quality, oxygen,..)

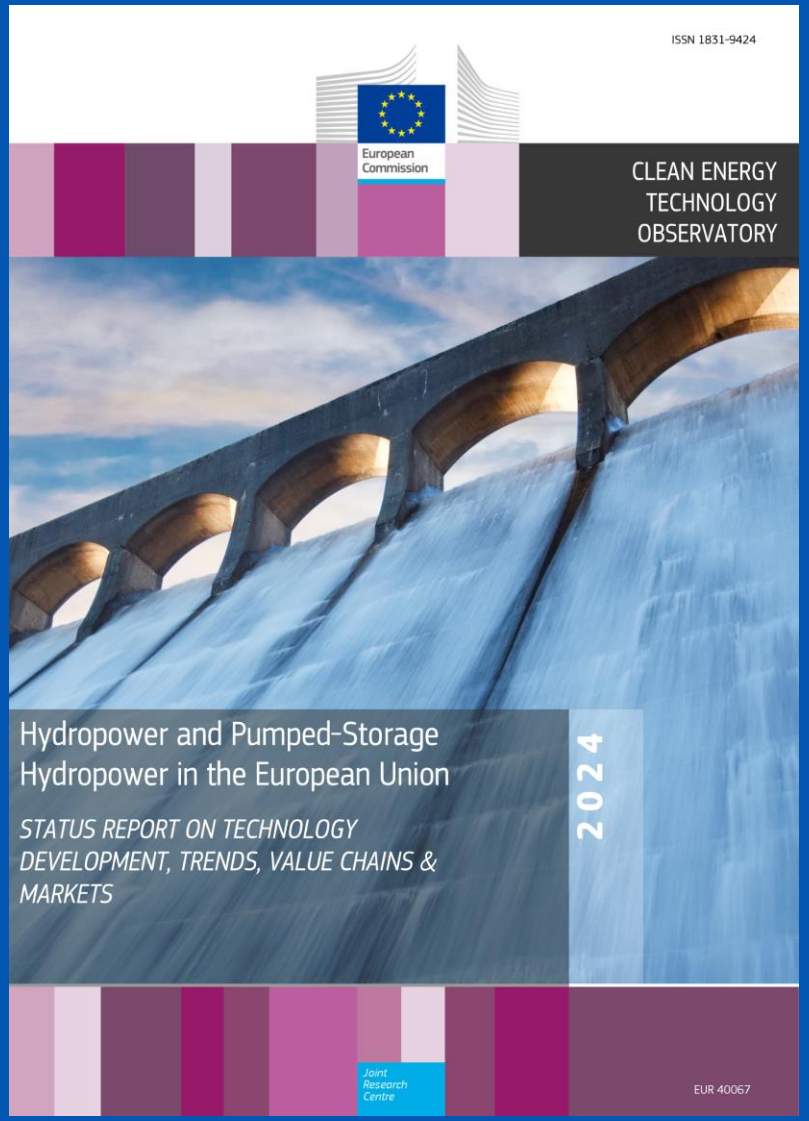


https://www.sciencedirect.com/science/article/pii/S0048969723011051

Conclusions and questions at EU level

- Complex topic within the WEFE (and society and climate) nexus
- Water reservoirs come with benefits, but also with costs and impacts

- How much water storage do we need?
- Which types of reservoirs should be built (underground res., dams, aquifer recharge, urban greening,..)?
- Where new reservoirs should be built?
- Which are the innovative solutions (de-sedimentation, digitalization, GHG capture, new dam construction methods,..)?
- How costs and revenues should be allocated/shared among the different water uses? How conflictual uses can be overcome?
- Which is the role of small reservoirs?



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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