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Estimating greenhouse gas emissions from reservoirs in the context of the water, energy, food and environment nexus

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Reservoirs and Nexus

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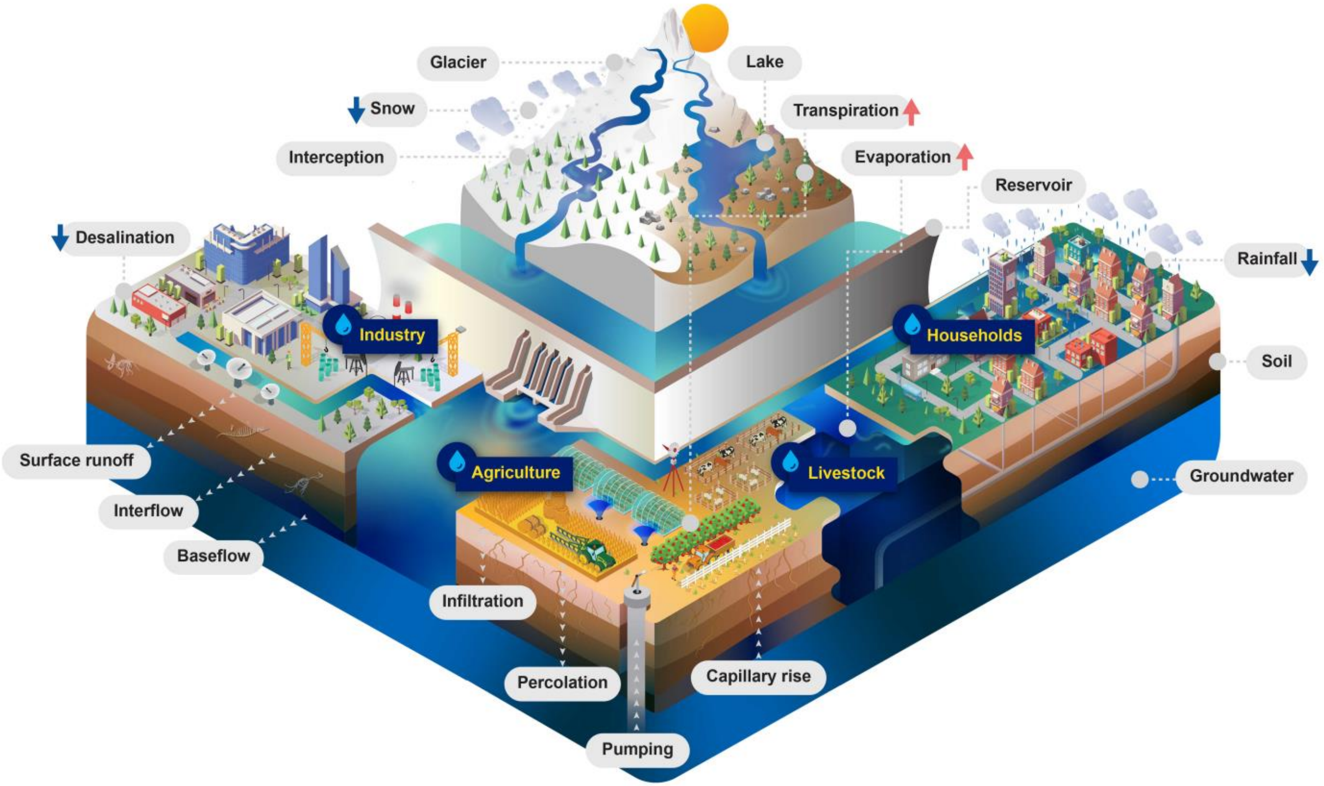

Source: Community Water Model (www.iiasa.ac.at)

- Multiple services – water, energy, food
- Impacts on the environment - positive or negative
- One such impact is on the carbon cycle – GHG emissions (mainly CO_2 and CH_4)
- Important to understand and manage GHG emissions
- Introduce GHG mitigation measures to existing reservoirs; adjust characteristics of planned reservoirs
- Also important for NDC reporting and monitoring of countries
- Roughly, lakes and rivers collectively emit as much CO_2 as the oceans take up.

Estimating GHG Emissions from reservoirs

- Reservoir systems may be either sources or sinks of GHGs
- Depends on location, hydrology, configuration, operation etc.
- GHGs need to be estimated at different stages of development
- Challenges:
  - Field sampling
  - Use of regional averages
  - Modelling
- Tools to estimate GHG emissions without field sampling

  e.g., G-res tool (www.hydropower.org/gres-tool)

  Offered by the International Hydropower Association (IHA)

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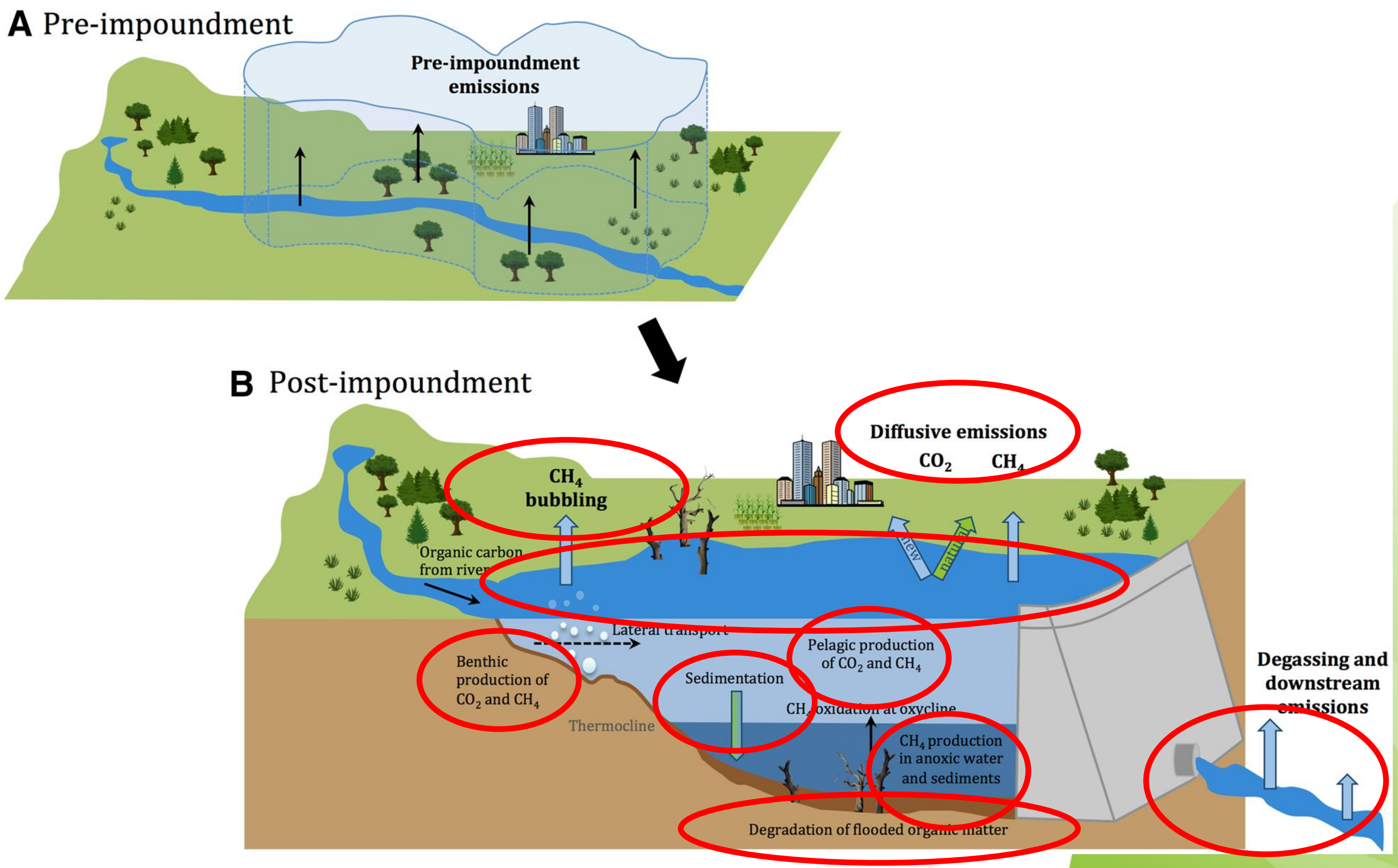
Estimating GHG Emissions from reservoirs

Net GHG footprint = (Post impoundment emissions – Pre impoundment emissions+ Emissions from Construction)



Source: Prairie et al. 2018

Changes:

- The shape of the system
- Land cover
- Hydrology
- Expose new source of organic matter (e.g., soil carbon)
- Create new zone potentially conducive to CH_4 formation
- More GHG production in the water column
- More sedimentation
- More GHG production in sediments
- More GHG emissions

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Pre-Impoundment Emissions

Based on:

- **Reservoir area (km2)**

- **Land cover of the impounded area**

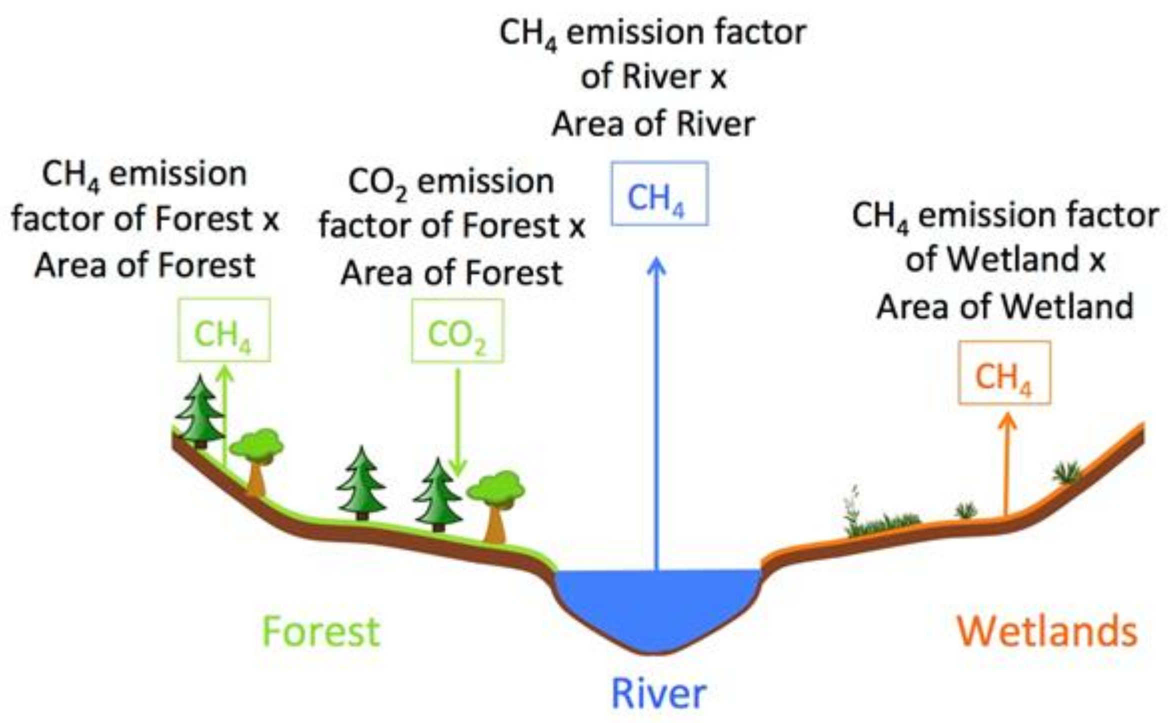
  % of Wetland, Forest, Croplands, Water Bodies, Shrubland/Grassland, Settlements, Bare Areas, Permanent Snow/Ice

  Soil type (Mineral vs Organic)

- **Climate**

  Tropical, Subtropical, Temperate, Boreal

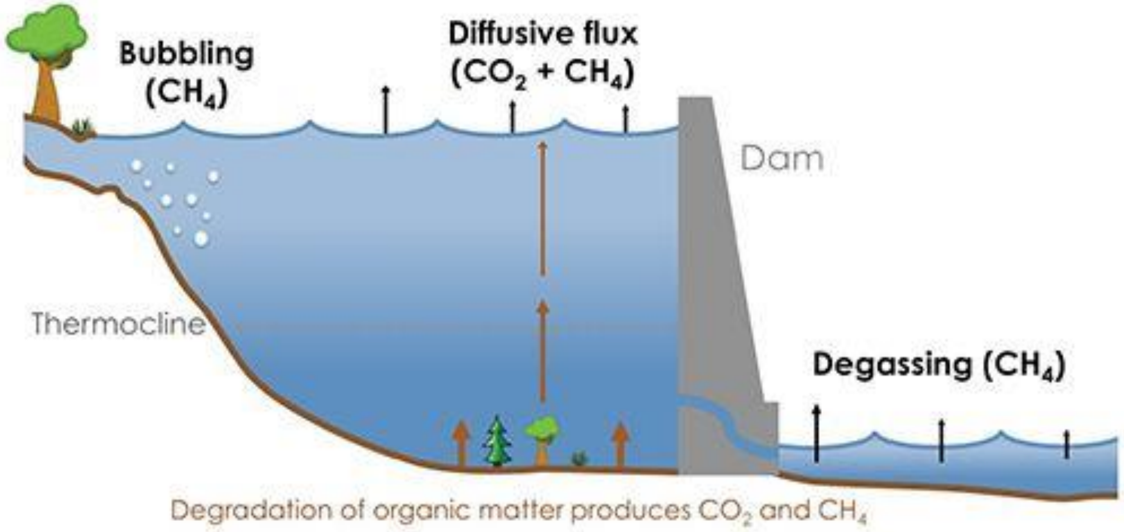
- **CO_2 and CH_4 emission factors (from IPCC) + CH_4 emission from waterbodies**



Source: G-res technical documentation

Post-Impoundment Emissions

- Methane (CH_4) Bubbling Emissions in the littoral zone
- Diffusive Carbon Dioxide (CO_2) and Methane (CH_4) Emissions from the surface
- Methane (CH_4) degassing emissions



Source: International Hydropower Association (IHA)

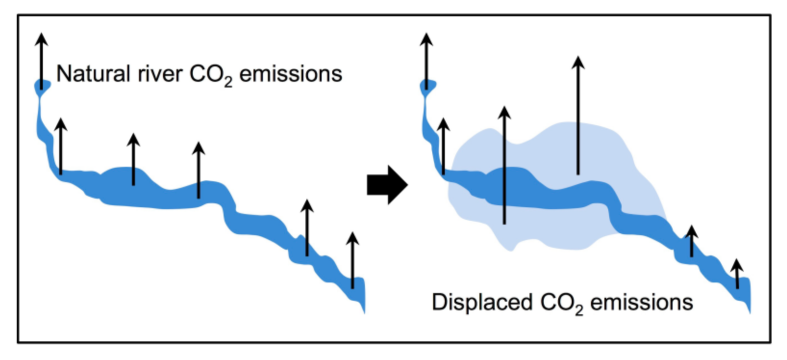
What is Influencing GHG Emissions from reservoirs?

- **Water residence time (WRT):** average time a water molecule spends in the reservoir
- More time for processes in the reservoir than in the river

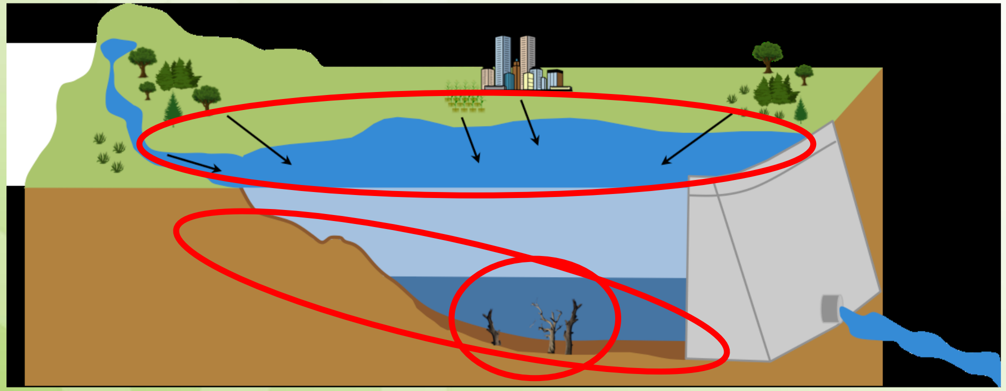
- **Phosphorous**: mainly from the catchment
- The higher the WRT, the higher the Phosphorous concentration
- Limiting factor for aquatic metabolism

- **Carbon:** new carbon mainly from the flooded soil
- Limiting factor for carbon processing

- **Above ground biomass:** only a small fraction of new carbon



Source: G-res training material



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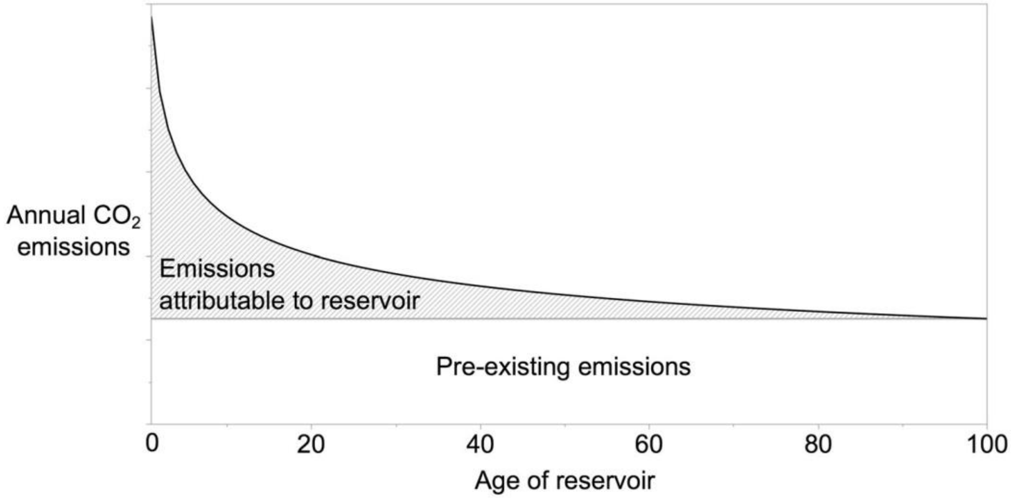
What is Influencing GHG Emissions from reservoirs?

- **Reservoir age**

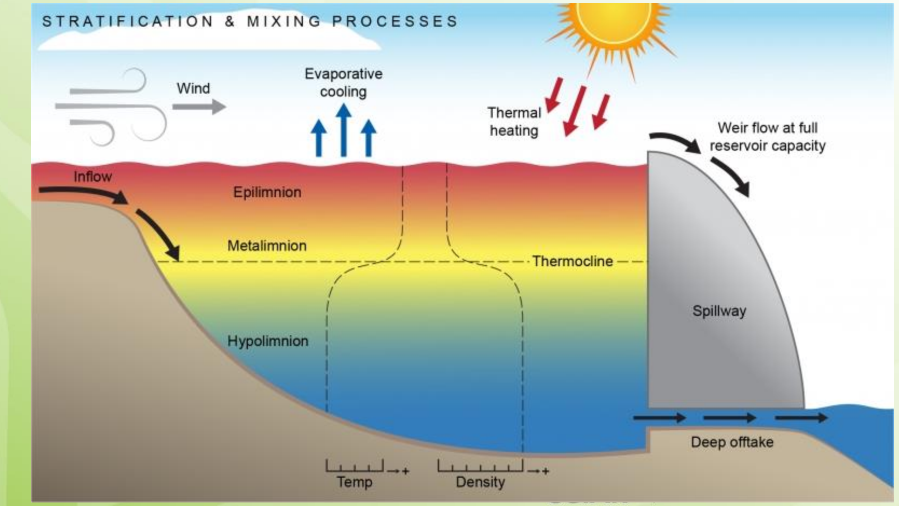


Source: Prairie et al. 2017

- **Temperature**

↑ **Temperature =** ↑ **Aquatic metabolism =** ↑ **GHG Production**

- **Thermal stratification**: Creation of a density barrier limiting the movement of nutrients and gases: the **thermocline**



Source: UNSW Water Research Laboratory

Datasets used in developing the GHG Emission model in the G-res tool

GIS variables	Units	Source	Supplemental information
Mean monthly and annual air temperature	°C	Global Climate database (Hijmans et al., 2005)	Average for the period 1950-2000
Climate		Rubel and Kottek, 2010 Köppen-Geiger climate classification	4 categories compatible with the emission factor of IPCC (2006): - Tropical - Subtropical - Temperate - Boreal
Annual precipitation	mm yr^{-1}	Global Climate database (Hijmans et al., 2005)	Average for the period 1950-2000
Mean Annual runoff	mm yr^{-1}	Fekete et al., 2000	
Mean monthly and annual wind speed	m s^{-1}	NOAA (GLOBE Task Team et al., 1999)	
Population density	person km^{-1}	CIESIN, 2005	
Soil carbon content of the inundated catchment area	kgC m^{-2}	SoilGrids - global gridded soil information (Hengl et al 2017)	Surface layer of the soil only (0-30 cm)
Land coverage	%	ESA-CCI 2014-2017	9 categories: refer to section 2.2.6 below
Reservoir mean global horizontal radiance	kWh $m^{-2}d^{-1}$	SSE (NASA 2008)	See Annex III to convert to Cumulative global horizontal radiance (kWh m^{-2} $period^{-1}$).

Model based on combining field assessment data of 223 reservoirs in different regions of the world with literature and other global datasets.

The G-res tool also provides the use of the Google Earth Engine facility to assess pre-impoundment land cover.

Source: G-res technical documentation

Emissions from Global Reservoirs

Comparison of GHG emissions for 480 hydropower reservoirs in different parts of the world

Source: Ubierna et al. 2022

	Net GHG emissions ($gCO_2eq/m^2/yr$)	Net GHG emissions intensity (gCO_2eq/kWh)	Net GHG emissions intensity allocated to hydro (gCO_2eq/kWh)
Minimum	−607.76	−921.52	−921.52
Q1	227.23	9.46	5.45
Median	334.43	43.09	22.72
Mean	617.34	277.36	170.03
Q3	605.25	185.22	98.71
Maximum	11,000.18	10,536.28	4294.54

Comparison of Average Lifecycle GHG Emissions for different sources of power generation

Source	Emission intensity (gCO2-eq/kWh)
Reservoir hydropower	23
Wind	12
Nuclear	12
Solar	48
gas	490
coal	820

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Source: Ubierna et al. 2022

Summary

- The type and amount of GHG emissions from reservoirs depend on a number of factors ranging from the reservoir size, land cover, climate and the type of operation.

- Need to make emission estimates on a case-by-case basis

- Free online tools are available to make reasonable estimates of emissions from reservoirs without expensive field sampling

- Useful for planning new reservoirs and mitigating the impact from existing reservoirs.

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Summary

- **Potential mitigation measures:**
  - Installing aerating devices
  - Altering reservoir operating levels
  - Adding intakes above the thermocline to prevent degassing
  - Converting methane emissions to energy

Thank You!

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