

Sectoral Project

**Implementing the
Recommendations of the World
Commission on Dams**

**Background paper on
reservoir emissions with climate impact**

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Summary

Research on the climate impacts of reservoirs is still at an early stage. Nevertheless, a discernible trend is that hydropower stations generally emit smaller amounts of greenhouse gases than equivalent fossil-fuelled power stations. The exception is when the inundated biomass is very large (e.g. forests) and the reservoir comprises warm, shallow waters with a large surface area. Under these conditions, which occur largely in tropical regions, large amounts of methane can be emitted. In specific cases, the climate impact here can be worse than with conventional power stations.

Climate impact of reservoirs

State-of-the-art in research

There are few scientific findings on the greenhouse gas balance of reservoirs. Extensive measurements have so far only been conducted in Brazil, Canada and French Guyana with no measurements for the Mediterranean region. It is extremely difficult in particular to estimate pre-flooding emissions, as most measurements have been taken at existing reservoirs so comparative data is missing. Another problem is that the multifaceted and intricate carbon cycle has not been completely understood as a whole. Complex interactions in the individual case make it difficult to quantify carbon dioxide emissions and carbon absorption, as the dispute about accounting for carbon sinks (biomass) in the national greenhouse gas balance clearly shows.

Reservoir emissions and their impact

Essentially, carbon dioxide (CO_2) and methane (CH_4) are the relevant gases with reservoirs. CO_2 is generated by the decomposition of organic materials under aerobic conditions and CH_4 is produced by decomposition processes under oxygen-deficient conditions. These anaerobic conditions can occur at deeper water levels, particularly in shallow, warm waters (respiration rate). The adverse climate impact of a unit weight of methane is approx. 21 times greater than that of carbon dioxide.

The primary cause for emissions is the decomposition of organic matter in the reservoir, which stems from:

- Biomass inundated by reservoir filling (This can be entire forests!)
- Continuous influx of biomass from the catchment area
- New biomass produced in the reservoir (aquatic plants, respiration of organisms)
- Decomposition of inorganic and organic soil components

Emissions differ by time and place. As a rule, they are very high shortly after flooding (decomposition of flooded biomass) and decline slowly over time till they reach a steady level. Methane emissions can also be much higher in shallower than in deeper waters. Selective measurements cannot therefore simply be extrapolated for the whole surface.

Flooding a forest is tantamount to clearing it. A carbon sink is lost, which contributes to an absolute increase of greenhouse gases in the atmosphere. If the biomass in the reservoir decomposes under oxygen-deficient conditions methane can be emitted, which worsens the greenhouse effect considerably.

To estimate net emissions, methane emissions before flooding and CO_2 emissions through the decomposition of new biomass or biomass influx must be subtracted from the total amount. The latter does not increase the total CO_2 content in the atmosphere as the decomposition of this biomass is offset by the formation of new biomass (which binds CO_2 again), closing the carbon cycle.

Estimating greenhouse gas emissions from reservoirs:

(emissions (CO₂ + CH₄) – (CH₄-emissions of ecosystem before flooding) – (CO₂ emissions through biomass influx and new biomass produced in the reservoir) = net emissions.

These emissions must be viewed over a period of about 70 years (lifespan of hydropower station).

Additional factors such as emissions in constructing a power station (need for life cycle assessment), removal of sediment with carbon deposits or possibly the reservoir's function as a carbon sink (as with seas) do not play a very significant role in the whole picture. They are, however, repeatedly cited in the discussion on this. Some authors also adduce the so-called leaching effect and demand that account must be taken of the activities of the resettled population (e.g. clearance for new settlements).

Put simply then, we can say the following:

Depending on the volume and carbon content of the inundated biomass, considerable emissions of greenhouse gases can occur, which contribute to an absolute increase of these gases in the atmosphere. The greenhouse effect escalates particularly if the biomass decomposes under a high respiration rate. In this case a large amount of methane is produced. Oxygen-deficient conditions occur in warm shallow waters.

As compared with fossil-fuelled power stations the emissions must be set against the power generated. Accounting for all the current scientific uncertainties, there is therefore a discernible trend:

Large shallow reservoirs in tropical regions with inefficient power stations can be more damaging to the climate than efficient gas power stations with the same capacity.

A recurrent yardstick applied in international discussion is the ratio between power capacity/flooded area (W/m²).

An oft-cited rule of thumb: If the power generated per unit area is less than 0.1 W/m², an efficient fossil-fuelled power station can be less damaging to the climate. If this figure is above 0.5 W/m², we may assume that the hydropower station has a lower greenhouse effect. This figure can be applied as a rough guide, particularly in tropical regions. Major factors such as the volume of flooded biomass and the climatic conditions are, however, ignored. Both factors must always be considered in any exact estimate of the impacts of a reservoir on the climate.

Initial measurements confirm this hypothesis. Calculations at reservoirs in Boreal areas (here Canada) have shown that the greenhouse gas emissions/power capacity ratio is ten times smaller than that of fossil-fuelled power stations. Measurements at reservoirs in tropical regions with low power station capacity were higher. They can exceed emissions from modern gas power stations. The published figures, however, vary greatly and are very unreliable. It is thus difficult to arrive at a generalized estimate. In very few cases has the decline in emissions after the first years of flooding been included in calculations. This can result in large margins of error in estimates.

Recap

As reservoirs always flood biomass, their anticipated emissions should always be assessed in planning. Planners must always aim at high power capacity per unit area (W/m^2). In tropical regions, the biomass should be cleared from the reservoir basin before inundation. Logging a forest prior to flooding and using the timber for building houses, for example, can reduce reservoir emissions considerably.

CDM & reservoir dams

Hydropower projects can generally be registered as CDM projects if they meet the criteria for all CDM projects. Certificates of emission reduction (CERs) can then be acquired. At present, 7 hydropower projects (>10MW) have been proposed for appraisal by the World Bank Prototype Carbon Fund (PCF) or the Dutch CERUPT programme (as at October 2002). While most experts agree on the climatic benefits of electricity generation in most dams, the problem under the CDM scheme is that they are not 'additional' projects. CDM prescribes that tradeable CERs can only be acquired for projects where additional efforts are undertaken to reduce greenhouse gas emissions.

A CDM project activity is additional if anthropogenic emissions of greenhouse gases by sources are reduced below those that would have occurred in the absence of the registered CDM project activity. (Marrakesh Accords)

The interpretation of this provision by the CDM Executive Board will in future be decisive for the number of hydropower projects that can be accepted under CDM. Most of the current dam projects now proposed (incl. Bujagali) were already under construction. They would therefore be built anyway and can hardly be seen as meeting the 'additional' criterion. According to figures from industry, 1700 large-scale hydropower projects throughout the world have been proposed for construction and it is impossible to say how many are eligible for CDM.

Sources

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