International Rivers Network
Linking Human Rights and Environmental Protection

Frequently Asked Questions: Greenhouse Gas Emissions from Dams

May 2007

What is the contribution of dams to global warming?

According to the most detailed estimate available, done by Ivan Lima and colleagues from Brazil's National Institute for Space Research (INPE), the world's large dams emit **104 million metric tonnes of methane** annually from reservoir surfaces, turbines, spillways and rivers downstream (1). This implies that dam methane emissions are responsible for at least **4% of the total warming impact of human activities.** No one has yet calculated the total climate impact of dams, which would include releases of carbon dioxide and nitrous oxide.

How do emissions from dams compare to those from other sources?

According to the estimates of the INPE researchers, dams are the largest single anthropogenic source of methane, being responsible for 23% of all methane emissions due to human activities. Methane is a much more potent heat-trapping gas than carbon dioxide, although it does not last as long in the atmosphere.

The most recent assessment of the Intergovernmental Panel on Climate Change states that methane has a warming impact 72 times higher than carbon dioxide if measured over 20 years, and 25 times higher measured over 100 years. Using these IPCC "global warming potential" (GWP) estimates means that one year's methane emissions from large dams, as estimated by Lima, have a global warming impact over 100 years equal to that of **2.6 billion tonnes of carbon dioxide.** (Under the Kyoto Protocol, countries estimate their total warming impact using the 100 year GWPs). Over 20 years, the warming impact of annual large dam methane emissions is equivalent to **7.5 billion tonnes of carbon dioxide**. By comparison:

- Global CO_2 emissions from fossil fuel burning (2004): 26.6 billion tonnes (2)
- US CO_2 emissions from fossil fuel burning (2005): 6 billion tonnes (3)
- EU-15 emissions from fossil fuel burning (2003): 3.3 billion tonnes (4)
- Global CO_2 emissions from coal (2003): 9.6 billion tonnes (5)
- US CO_2 emissions from coal (2005): 2.1 billion tonnes (3)
- US CO_2 emissions from road transport (2005): 1.7 billion tonnes (3)
- Global CO_2 emissions from aviation (2002): 0.5 billion tonnes (6)

How do dams emit greenhouse gases (GHGs)?

The "fuel" for the methane, carbon dioxide and nitrous oxide emitted by dams is the rotting of the vegetation and soils flooded by reservoirs, and of the organic matter (plants, plankton, algae, etc.) that flows into, and is produced in, reservoirs over their lifespan. The gases are released at the reservoir

surface, at turbines and spillways, and downstream of the dam. Greenhouse gases are also produced by various other dam-related impacts including the fossil fuels and building materials used during dam construction; land clearing for resettlement sites, transmission lines and access roads; and the expansion of irrigated agriculture (an important cause of methane emissions). The trapping of sediments in reservoirs may act as a carbon sink; it may also indirectly increase the concentration of carbon dioxide in the atmosphere by reducing the amount of river-borne sediments available to fertilize oceanic plankton, which are important consumers of carbon dioxide.

Which dam-related processes have the highest warming impact?

Most of the global warming impact of dams is due to methane emissions at spillways, turbines and downstream. Methane is produced at the reservoir bottom. As it rises toward the surface most of the methane is oxidized in the water to carbon dioxide, a much less powerful greenhouse gas. But when methane-rich deep water is released at the dam the pressure acting upon it suddenly drops and most of its dissolved methane is released directly into the atmosphere. This degassing occurs according to the chemical principle of Henry's Law and is a similar process to the fizzing of a newly opened bottle of Coke. The INPE researchers estimate that 95% of dam methane emissions are from spillways, turbines and downstream.

Which reservoirs have the highest warming impact?

The thermal, chemical and biological conditions in tropical reservoirs mean that their methane emissions are one or more orders of magnitude higher than those from reservoirs elsewhere. Large, shallow tropical reservoirs have the highest emissions.

How do large hydro plant emissions compare with fossil fuel power plants?

Large hydropower reservoirs in the tropics can have a higher global warming impact per kilowatt-hour generated than fossil fuels, including coal. Philip Fearnside, of Brazilian government research institute INPA, estimates that in 1990 the warming impact of hydropower dams in the Amazon was equal to that of between 3 and 54 natural gas plants generating the same amount of energy.

What is the importance of distinguishing between net and gross emissions?

Ideally, a calculation of the warming impact of reservoirs should be based upon net emissions. This requires adjusting measurements of gross emissions at the reservoir surface and dam outlets to allow for whatever sinks and sources of greenhouse gases existed in the reservoir zone before submergence, the uptake of carbon through photosynthesis of plants and plankton in the reservoir, and the impact of the reservoir upon the pre-dam flows of carbon throughout the wider watershed. It is particularly difficult to assess the net impact of dams upon carbon dioxide fluxes, and net carbon dioxide emissions may be significantly smaller than gross emissions. However because reservoirs produce such huge amounts of methane relative to background fluxes, the difference between net and gross methane emissions is not likely to be significant. The INPE methane estimates are for gross emissions.

Do the INPE calculations include all large dams?

A large dam is defined by the International Commission on Large Dams (ICOLD)—the dam industry's primary business association—as one that is over 15 meters tall. The ICOLD database used by the INPE researchers counts some 33,071 registered large dams. The actual number of large dams is likely to be closer to 50,000, mainly due to the large number of unregistered medium-sized (15-30m) dams in China.

How much methane is emitted from large dams in specific countries?

The INPE team have done the first estimates of dam methane emissions in Brazil, China and India. Their estimate for Chinese emissions is likely an underestimate, mainly because according to their methodology the many dams in sub-tropical southern China are treated as temperate dams when in reality their emissions are more likely to be on the scale of tropical dams.

Location	LD CH_4 emissions (Tg/yr) (1)	LD CO_2e emissions* (Tg/yr)	Total non-dam CO_2e emissions (Tg/yr) (8)**	LD CO_2e emissions as % of total emissions
World	104.0	2184	41,331	5
Brazil	21.8	545	2,221	20
China	2.7	67	4,916	1
India	19.2	480	1,849	21

Tg = teragrams = million tonnes
* CO_2e = CO_2 equivalent calculated using 100-year Global Warming Potentials from the IPCC's 1996 Second Assessment Report (SAR). The SAR 100-year GWP for CH_4 is 21 (the value used in the Kyoto Protocol). The IPCC's 2007 Fourth Assessment Report gives a 100-year GWP for CH_4 of 25.
** All data for year 2000. Includes land use, land use change, and forestry. Includes contribution of all 6 Kyoto Protocol gases (CO_2, CH_4, nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6)).

Sources:

1. Ivan B.T. Lima et al. (2007) "Methane Emissions from Large Dams as Renewable Energy Resources: A Developing Nation Perspective," *Mitigation and Adaptation Strategies for Global Change*, published on-line March 2007. http://tinyurl.com/2bzawj
2. International Energy Agency, Key World Energy Statistics 2006.
3. www.eia.doe.gov/oiaf/1605/ggrpt/carbon.html
4. International Energy Agency, Global CO_2 Emissions From Fuel Combustion 2005.
5. Carbon Dioxide Information Analysis Center, http://cdiac.ornl.gov/ftp/ndp030/global.1751_2003.ems
6. UK Department of Trade and Industry, Forecasts of CO2 emissions from civil aircraft for IPCC, November 2006
7. Climate Analysis Indicators Tool. cait.wri.org

For more information:

See the November 2006 report from International Rivers Network, "Fizzy Science: Loosening the Hydro Industry's Grip on Reservoir Emissions Research." Download the report at www.irn.org/pdf/greenhouse/FizzyScience2006.pdf