THE EXCHANGES BETWEEN FEARNSIDE AND ROSA CONCERNING THE GREENHOUSE GAS EMISSIONS FROM HYDRO-ELECTRIC POWER DAMS

An Editorial Comment

The rather heated exchange between Philip Fearnside and Luiz Pinguelli Rosa and co-authors in this issue of *Climatic Change* is a continuation of an earlier exchange in the pages of this journal (Fearnside, 2004; Rosa et al., 2004). These exchanges center around the question of the net impact of hydro-electric dams on the emissions of greenhouse gases and their radiative forcing over some time horizon approaching the lifespan of the project. Rather than take sides in this argument (I can find points of disagreement with both sides), I would like to make some brief points pertaining to the context of this debate, pertaining to the areas where Fearnside and Rosa agree and the need for further research concerning the impact of hydro-electric dams, and pertaining to energy and climate policy more generally.

The over-arching context is the United Nations Framework Convention on Climate Change (UNFCCC), ratified by over 180 countries, which declares as its ultimate goal the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". The UNFCCC does not state the levels at which GHG concentrations should be stabilized, but one of the conditions that the chosen stabilization levels must satisfy under the UNFCCC is that they must be such that natural ecosystems can adapt naturally to whatever climate change is associated with the chosen stabilization levels. Many groups, including the Parliamentary Commission of the European Union, have suggested a maximum allowable global average warming of 2 K, although one can make the argument that even 2 K is too large a warming. For example, 1–2 K warming may be sufficient to provoke widespread massive mortality of coral reef ecosystems, as witnessed in 1998, when a global average temperature only 0.9 K above the 1870–1900 mean was associated with widespread mortality due to bleaching (Wellington et al., 2001); or to provoke the melting of the Greenland Ice cap or collapse of the West Antarctic ice sheet (Hansen, 2005). A comprehensive assessment by 19 ecologists based in Europe, North and South America, Africa, and Australia shows that, for a scenario with a global mean warming of 2 K by 2050, between 15–37% of terrestrial animal species will be committed to extinction (Thomas et al., 2004). This is a staggering impact. Given that there is a non-negligible risk that the climate sensitivity *might* be as large as 4 K or more (as found by Harvey and Kaufmann (2002), Murphy et al. (2004), and many others) for a CO_2 doubling (which produces a forcing of about 4 W/m^2), and that the goal of the UNFCCC is to avoid the *risk* of dangerous interference, it follows that the current GHG radiative forcing (2.5 ± 0.5 W/m^2) already violates the UNFCCC.

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It is therefore of the utmost urgency that emissions of all GHGs be reduced as rapidly as possible with minimal delay so as to minimize the risk of disruptive climatic change, and to minimize the damage to critical ecosystems (and to major food-producing regions). At the same time, developing countries such as Brazil have the legitimate need to improve the material well-being of their people through greater provision of energy services. Minimization of climate damage and development can be reconciled only through a major acceleration in the rate of improvement of energy efficiency combined with a massive deployment of carbon-free energy sources. The daunting nature of this challenge is illustrated in Hoffert et al. (1998) and in the introduction to Harvey (2006).

Hydro-electric power would appear to qualify as a carbon-free power source, but both Fearnside and Rosa agree that hydro-electric power is not entirely blameless. Where they disagree concerns the extent to which GHG emissions are associated with hydro-electric power. The emissions involve both CO_2 and CH_4, the latter produced by the anaerobic decomposition of organic matter in lands flooded by the reservoir. The terms that need to be taken into account (and about which both sides seem to agree) are as follows:

1. Pre-dam emissions of CH_4 from the river and from periodically-flooded wetlands.
2. Emissions of CH_4 from the reservoir itself.
3. Emissions of CH_4 from the water as at flows through the turbines and spillways (relative losses to the atmosphere likely being different for the two).
4. Emissions of CO_2 from organic matter that decomposes as a result of the flooding that created the reservoir behind the dam.

The difficulties lie in the computation of these terms. For present reservoirs, there generally are no measurements of pre-dam CH_4 emissions. Emissions from the reservoir itself are highly variable in space and time, so a comprehensive, long-term monitoring program would be needed. To measure the loss of CH_4 from the water as it flows through the turbines and spillways, one needs site-specific measurements of the methane concentration in water entering the spillways and turbines, and some distance downstream. The methane concentration in entering water depends on the depth from which the water is drawn, and the vertical profile of methane concentration in the reservoir, something that will vary from reservoir to reservoir and also over time (there being both a seasonal cycle and long-term trends). Not all the emission of CO_2 from the reservoir should be counted as an impact of the reservoir; some of the emission will be from decomposition of organic matter swept into the reservoir from elsewhere within the watershed, and some will be from the respiration of organic matter produced by photosynthetic organisms within the reservoir. Needless to say, these processes pose difficult accounting and measurement problems that are compounded by legitimate disagreements concerning how to combine CO_2 and CH_4 emissions into a single index such as the

Global Warming Potential (GWP). Nevertheless, there is no disputing the value of longterm measurements to collect as much of the needed data as possible, in order to form as complete and accurate a picture as possible of the impact on GHG emissions of hydro-electric dams. The ongoing exchange between Fearnside and Rosa underlines the point that there is no “free-lunch” when it comes to renewable energy.

I would like to close with some brief comments on the demand side of the electricity supply-demand equation. Much of the electricity used in industrialized or industrializing countries is used in buildings, and much of that is used to provide services that can be largely supplied through the direct use of solar energy, without generating electricity as an intermediate step. Furthermore, the required solar energy can be provided by the building fabric itself. The major uses of electricity in buildings include lighting (much of which can be supplied through various daylighting systems during daytime), ventilation (much of which can be supplied passively by exploiting indoor-outdoor temperature differentials and by enhancing the available wind forcing), and air conditioning. The need for the latter can be significantly reduced through building designs that minimize externally-generated cooling loads and that exploit passive cooling techniques whenever this is viable. Remaining cooling requirements can be supplied through low-temperature solar thermal energy, such as can be provided from building-integrated solar-thermal collectors, which can drive desiccant-evaporative cooling systems that are applicable even in hot-humid climates. Once these uses of electricity are largely stripped from the building energy loads, the remaining loads are often small enough that they can be largely satisfied through building-integrated PV (photovoltaic) power. These and other options (including passive and active solar space and hot water heating) are comprehensively discussed in a book that I have written (Harvey, 2006) – directed towards architects and engineers – that will be published at about the time these comments are published. The main point that I wish to make here is that the conventional, large-scale, stand-alone renewable energy systems – whether hydro-electric dams, PV arrays in the desert, biomass plantations, or large wind farms – are not the only C-free, renewable-energy options available. Largely overlooked is the enormous potential to transform the built environment itself into the collector and transformer of solar energy, directly supplying our major energy needs in buildings – lighting, ventilation, cooling, heating, and plug loads – by matching the available solar energy as closely as possible to the end use needs. Backup power sources that can be readily ramped up or down as needed, such as hydro-electric power, provide an ideal complement to buildings as power plants.

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