COMMENT

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The Katse dam on the Malibamat'so River in Lesotho was completed in 2009.

Dams have the power to slow climate change

Mitigate global warming and produce clean, cheap hydropower at the same time, urges **Mike Muller**.

Every few years, a cyclone hits Mozambique's Sofala province. The Pungwe River floods and severs road connections between Zimbabwe and coastal ports, sometimes for months. After a few weeks, the standing water starts to bubble as flooded vegetation decays. This 'marsh gas' is methane, a greenhouse gas that is some 20 times more potent than carbon dioxide.

Elsewhere in Mozambique, such devastation is a thing of the past. Since two hydropower dams started operating on the Zambezi River in the 1960s and 1970s, floods no longer kill hundreds of people and destroy thousands of hectares of crops. Although they were criticized for their environmental impacts (see go.nature.com/2wpjh4y), these dams generate 3,500 megawatts of clean electricity, supplying most of the needs of Mozambique, Zambia and Zimbabwe. Methane emissions from downstream floodplains have also been curbed, an effect that goes largely unnoticed.

Methane is responsible for one-fifth of the rise in average global temperatures over the past century. Approximately half of the roughly 600 million tonnes released every ▶

year comes from natural sources — mainly wetlands. In tropical regions such as the Amazon and Africa, fresh water releases almost as much carbon to the atmosphere as forests and agriculture mop up[1].

Because aquatic carbon sources and sinks are poorly understood and hard to measure, they are given limited attention in climate policies. Worse, because such policies address the impacts mainly of human activities, some researchers focus disproportionately on emissions from artificial lakes, and neglect those from other waters and wetlands. Many scientists maintain the view that 'natural' emissions are good and 'artificial' ones bad.

What really matters is how much carbon enters the atmosphere, not how it got there[2].

Politics is filling the void. Hydropower projects, already controversial for their social and environmental impacts, are now routinely opposed because they are said to add to greenhouse-gas emissions and aggravate global warming. Yet dams that are well planned, constructed and managed can deliver decades of clean, cheap energy and help to mitigate climate change (see 'Life-cycle emissions'). Hydropower dams account for 97% of electricity storage worldwide, and can reach full power in less than a minute. They thus help in the integration of other renewable sources, such as solar and wind, into supply grids[3].

These wider benefits are seldom acknowledged. And in a rapidly warming world, we cannot afford blind spots. Researchers need to take a systems approach to carbon emissions and sequestrations from fresh waters. And the roles of dams and other water-management interventions need to be reassessed from the perspective of climate change: in some places, they might help communities and the environment more than they damage them.

CARBON FLOWS

Rivers function as both pipes and reactors[4]. Carbon washed from river catchments is transported downstream. On the way, some organic material reacts to produce methane and CO_2, which escape to the atmosphere. Solids can settle along river banks, in lakes and on floodplains. The remainder reaches the sea, from which some is recycled into the atmosphere and the rest is locked in sediment and rocks.

The amounts vary from place to place. Earth scientists have mapped carbon flow in some rivers, but global estimates of freshwater emissions and sequestration are still too uncertain to produce the robust carbon budgets needed to guide mitigation strategies. Methane is especially hard to follow, because emissions can vary by factors of hundreds across regions and seasons[5].

It is therefore understandable that lakes are often used to provide a baseline — their areas are well defined and gases emitted from their surfaces are easy to measure. But studying a lake alone paints a partial picture. In my view, this has encouraged anti-dam campaigners to misrepresent the science.

> ***"The negative environmental effects of dams must thus be balanced against the positive contribution."***

Many early studies of reservoirs started with the premise that newly flooded vegetation would decay and emit methane. High levels of methane were then used to infer that hydroelectricity is not a carbon-free source of energy[6]. This argument was taken up by lobbyists who opposed dam construction.

However, other work reveals that most of the methane emanating from dam reservoirs actually comes from carbon sources elsewhere in the catchment. Damming a river blocks the flow of organic material that might otherwise have ended up on floodplains or in the oceans. As in a natural lake, that carbon is either stored in sediments or decomposes. But some methane would have been emitted anyway had the dam not been there.

To determine the impact of a dam on overall sequestration and emissions, the carbon balance of the whole catchment needs to be analysed. Yet some researchers persist in studying reservoirs in isolation. Excited reports of high methane emissions from tropical reservoirs still frequently neglect to mention that their main source is the carbon flowing in from upstream wetlands and forests.

So far, the Intergovernmental Panel on Climate Change (IPCC) has resisted calls to include reservoirs as a specific source of greenhouse-gas emissions and to downgrade hydropower from classification as a clean source of energy, citing a lack of evidence[7,8]. But the panel fails to address the overall dynamics of freshwater carbon and could be missing mitigation opportunities.

BLOCKS TO PROGRESS

Hydropower investment is floundering. Large hydropower projects can take a decade to build, and require large up-front investments (typically, around US$1 billion per 1,000 megawatts) before they can recoup costs by producing power. Many financial institutions are reluctant to lend money, citing reputational risks and delays likely to be caused by environmental objectors. From Brazil to Laos, grass-roots campaigns to stop hydropower projects now cite the facilities' negative effects on climate change. Brazil's ambitious hydropower programme is being opposed on the basis that emissions generated as a result of its 18 dams supposedly exceed those from electricity generation based on fossil fuels.

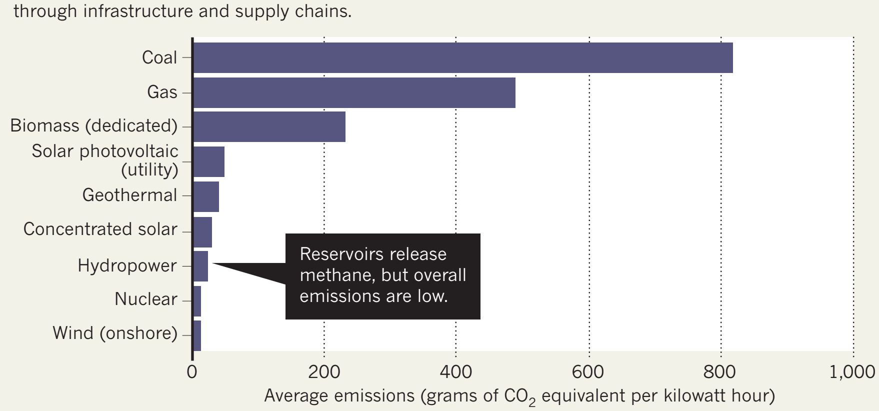
Environmental groups have lobbied to restrict finance for hydropower projects under the United Nations Framework Convention on Climate Change (UNFCCC) Clean Development Mechanism (see go.nature.com/2ernyhc). In 2017, a coalition of 282 organizations wrote to the Green Climate Fund and its advisers to express concern about methane emissions from hydropower projects. The Climate Bonds Initiative, which encourages financiers to lend billions of dollars to activities that mitigate climate change (and which I advise), has found it difficult to define science-based sustainability standards for hydropower that will be both practical for developers and acceptable to environmentalists.

This matters, particularly for poorer countries. Once in place, hydropower dams produce affordable electricity for many decades, as experience from numerous countries attests. Hydropower helps Brazil to balance power from seasonal electricity production from biofuels, and Norway's surplus keeps the lights on in Germany and Denmark on days when their wind-power supply falls.

And hydropower's contribution goes beyond the energy sector, whether it be China's Three Gorges Dam on the Yangtze River reducing flooding and improving inland navigation (reducing fuel

LIFE-CYCLE EMISSIONS

Over their working lives, electricity sources emit carbon emissions both directly and through infrastructure and supply chains.



SOURCE: IPCC, AVAILABLE AT GO.NATURE.COM/2E7XFP3

Wetlands, such as this one in South Sudan, are often neglected in emissions models.

MADS NISSEN/POLITIKEN/PANOS

consumption) or new livelihoods from fish farming on the Zambezi dams in southern Africa. Human activity will always have environmental impacts. But it is land-use change — urbanization, intensification of agriculture — that drives the need for energy and environmental change, rather than the dams themselves.

The negative environmental effects of dams must thus be balanced against the positive contribution that the facilities can make. After all, climate change is the greatest present threat to aquatic ecosystems. Reservoirs should be viewed as potential places to store carbon, a role that continues to be discounted[2]. And, if they reduce the extent of wetlands, the resulting fall in emissions should be credited to the dam when making decisions — global warming is the biggest threat to the world's wetlands.

A useful model could be the more enlightened approach towards land use. It is recognized, for instance, that although plantations of exotic trees might be bad for biodiversity, they are better for the climate than is clearing land to accommodate herds of methane-belching cattle.

STRATEGIC RETHINK

The IPCC must engage more strategically with these debates. Its next assessment report, due in 2022, should review the state of knowledge about the freshwater carbon cycle and consider to what extent hydropower and other water-management activities could reduce greenhouse-gas emissions.

Water managers should consider how dams and other infrastructure can be designed and operated to mitigate the emissions from freshwater systems generally, as well as from their own operations. Given the controversies about geoengineering, public discussions will be needed around the implications of such interventions, including the benefits of emissions reductions and impacts on local biodiversity.

Policymakers should re-examine hydropower's strategic value as a long-term source of clean energy and as a tool for integrating renewable energy sources. And although wetlands are sacrosanct in much environmental legislation, a more nuanced approach to their management should be considered. For example, in many cases, their methane emissions and size could be reduced without significantly affecting wildlife; artificial wetlands can provide new focuses for biodiversity and valuable services, such as treating wastewater.

Finally, financiers should fund hydropower to help mitigate climate change. Standard-setting organizations need to develop and promote evidence-based standards that recognize hydropower's potential contribution to emissions reduction. Certainly, hydropower should be on the table on 5 March, when 500 global financiers meet in London to discuss investing in climate-friendly infrastructure through the Climate Bonds Initiative. ■

Mike Muller *is a visiting adjunct professor at the University of Witwatersrand School of Governance in Johannesburg, South Africa. He is a member of the Climate Bonds Initiative's Hydropower Technical Working Group and adviser to Mozambique's Hidroelectrica Cahora Bassa company. He previously held senior positions in South African water and planning agencies and was responsible for water management in Mozambique's Sofala province in the early 1980s.*
e-mail: mike.muller@wits.ac.za

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