Freshwater ecosystems could become the biggest losers of the Paris Agreement.

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Abstract

Securing access to energy for a growing population under the international commitment of reduction of greenhouse emissions requires increasing the contribution of renewable sources to the global share. Hydropower energy, which accounts for > 80% of green energy, is experiencing a boom fostered by international investment mainly in developing countries. This boom could be further accelerated by the recent climate agreement reached in Paris. Despite its flexibility, hydropower production entails social, economic and ecological risks that need to be carefully considered before investing in the development of potentially thousands of planned hydropower projects worldwide. This is especially relevant given the weak or non-existent legislation that regulates hydropower project approval and construction in many countries. I highlight the need for adequate policy to provide the Paris Agreement with new financial and planning mechanisms to avoid further and irreversible damage to freshwater ecosystem services and biodiversity.

Turning green: support for a more sustainable development.

The Paris Agreement reached at the COP21 in December 2015 represents the compromise of 195 countries, responsible for more than 94% of global greenhouse gas emissions, to limit global warming to well below 2°C above pre-industrial levels (UNFCCC 2015). Developed countries committed to support actions to reduce emissions and build resilience to climate change impacts in developing countries by mobilising USD 100 billion per year by 2020. This financial support is intended to help move global economies towards new pathways of low greenhouse gas emissions and climate-resilient development. Action should especially target energy production, a sector that dominates current greenhouse gas emission levels (35% of total; Edenhofer et al. 2014). There are other international initiatives working in the same direction, such as Rio+20 (UNEP 2012) or the 2030 Sustainable Development Goals promoted by United Nations (UN 2014), which encourages countries to meet their growing energy demand by investing in renewable alternatives.

Securing access to energy for a growing population under the international commitment to reducing greenhouse emissions requires increasing the contribution of renewable sources to the global share. At present, 20% of the total energy demand is covered by renewables such as solar, wind, geothermal, biomass and, especially, hydropower, which accounts for 80% of the total contribution from renewables (Zarfl et al. 2015). The contribution of hydropower has been achieved at the expense of constructing more than 8,600 large dams (>15 m high) and numerous other smaller infrastructures. After a period of deceleration of investment in hydropower over the past two decades, investment is currently increasing at an unprecedented rate. For example, investment in the period 2010-2012 increased more than six-fold compared to the average investment in the previous decade (Zarfl et al. 2015). The more than 3,700 large hydropower dams under construction or planned worldwide will boost hydroelectric production by 73%, mostly in developing countries (Zarfl et al. 2015), supported by international initiatives like Rio+20, UN programs and international investors (Winemiller et al. 2016) and possibly by the financial mechanisms made available through the Paris Agreement.

Is promoting hydropower the best option?

Hydropower has traditionally received more attention over other sources of renewable energy due to its reliability and flexibility, given that its production can be adapted to meet changes in demand if enough water resources are available. However, large hydropower dams (responsible for more than 90% of all hydropower production) are expensive to build and have a very low rate of return on investment. Economic studies have reported that 75% of large dams suffered cost overruns of nearly 96% of the initial budget projected prior its construction (Ansar et al. 2014). It is estimated that a global investment of USD 2 trillion would be needed to develop all the dams currently under construction or planned worldwide. This investment would, however, be insufficient to fill the gap in access to energy for more than 1.4 billion people worldwide that are currently without electricity or cover the increase in demand in the remaining areas (Zarfl et al. 2015). The high uncertainty of future climate and water resource availability makes development of hydropower infrastructure an extremely risky investment.

New hydropower dams are being developed or planned for the exploitation of freshwater resources in river systems that are already exhausted with infrastructures or that are highly sensitive from a social and ecological point of view. River regulation compromises crucial ecosystem services that sustain the livelihoods of people living downstream and causes the displacement of locals affected by the inundation of upstream lands. For example, more than 1 million tons of freshwater fish are caught annually in the floodplains of the Mekong River (Ziv et al. 2012) providing the main source of protein for millions of people. However, these freshwater fisheries could be seriously compromised if some of the dams projected for the mainstem of the Mekong River were developed (Gumbrine et al., 2012). Impacts on the productivity of fisheries and flood-recession agriculture are estimated to currently affect near 500 million people worldwide (Richter et al., 2010). Moreover, these hydropower dams cause drastic changes to the ecological functioning of aquatic ecosystems and the biodiversity they sustain, ranging from fragmentation, that constrains the movement of freshwater strict species, to significant modifications of flow (timing and magnitude), temperature regimes and sediment transport (Vörösmarty et al. 2010; Sánchez-Zapata et al. 2016). Freshwater ecosystems are among the most threatened worldwide (Vörösmarty et al. 2010; WWF, 2016) and this status could worsen in the near future due to hydropower expansion. Hydropower dams under construction or planned in the Amazon, Congo and Mekong basins alone could compromise the persistence of 1/3 of all freshwater fish species in the world (Winemiller et al. 2016). In addition, current and planned hydropower dams are also a major threat to protected areas in developing countries like Brazil and jeopardize international commitments to UN Conventions on Biological Diversity and Climate Change (Ferreira et al. 2014). Finally, most large catchments under the focus of current and future hydropower development (e.g., Amazon, Ganges-Brahmaputra, Mekong or Congo rivers) are transboundary systems, which coupled with the increasing uncertainty in future water availability (Palmer et al. 2008), make the development of new hydropower projects a geopolitically sensitive and risky issue.

Stronger international policy urgently needed

The climate agreement reached in Paris could accelerate the new boom in hydropower development as an alternative to reduce greenhouse gas emissions and closing the energy gap in developing countries. Several proposed hydropower projects that could have remained undeveloped, may now progress with new impetus due to the increased international funding support. In fact, the recent acceleration observed in hydropower dam construction (Zarfl et al. 2015) could have already been fostered by the support of international initiatives like the UN Framework Convention on Climate Change (UNFCCC), Rio+20 and the 2030 Sustainable Development Goals (Pittock 2010a, Bunn 2016). In the absence of stronger international rules and coordination across different conventions and international organisations, there is a high risk of irreversible social, economic and ecological damage for a very low return in terms of energy production and climate change attenuation. For example, there is substantial conflict between the goals of climate change institutions, such as UNFCCC, and the sustainable management of freshwater ecosystems. These conflicts arise from the limited consideration of biodiversity agreements such as the CBD, and lack of obligation to mitigate the impact of climate change policies on other sectors (Pittock 2010b). In order to operationalise the implementation of the Paris Agreement, new policies and funding mechanisms to support a sustainable development agenda seem an urgent priority. This is important to give more specific content to the agreement, given that the COP decisions involve political compromises with no indication of priorities (Gerstetter et al. 2012). Furthermore, a stronger integration of sectoral environmental protection agreements to avoid perverse outcomes, such as support to development of hydropower projects that may cause severe social and ecological dmage, and realize positive synergies (Pittock 2010b) are urgently needed.

The uncertainties about the future availability of freshwater resources and the significant social, ecological and political conflicts of hydropower development highlight the need for robust international policies that mandate minimum impact assessment standards to ensure sustainability of future development of this sector. This is especially relevant given the lack of adequate legislation that regulates the concession of projects and construction of hydropower dams in some tropical developing countries (Ferreira et al. 2014; Winemiller et al. 2016), where most of this new boom is taking place, and the complete exemption of small projects (>10 MW) from any assessment process. There are two critical aspects that need to be considered when developing these common standards. Firstly, there is an urgent need for minimising externalities on rural populations and ecological impacts derived from the construction and operation of dams should be minimised. The losses of fisheries, fertile land and places of cultural significance or the complete reallocation of communities affected by dams are rarely compensated by new job opportunities, access to energy and new infrastructure, such as roads (Winemiller et al. 2016). Moreover, the large ecological impacts of hydropower infrastructures require careful consideration, not only from a biodiversity conservation point of view but also from the implications on key ecosystem services on which large numbers of people depend. In order to reduce potential conflicts, local populations should be given the opportunity to participate directly in decision-making processes, for which stronger participatory mechanisms to enhance public engagement in the process are required (Pittock 2010b). Second, it is critical to foster cumulative impact assessment at the whole catchment scale. The connected nature of river systems facilitates the propagation of impacts of hydropower dams in both upstream and downstream direction, and their accumulation along the river network. For example, the impact of climate change could compromise hydropower potential in distant downstream regions and the presence of dams may impede upstream migrations to key spawning and cause the collapse of entire freshwater fisheries. By accounting for these critical aspects, international financial support to hydropower projects should rely on proven socio-economic and ecological viability. The adequate assessment of socio-economic and ecological trade-offs of hydropower projects at whole catchment scale will require transboundary collaboration for many of the world's large river systems. There are examples of efforts in transboundary cooperation, like the Mekong River Commission (MRC), an intergovernmental organisation that was created to coordinate the development of water resources that gathers all countries in the catchment. This organisation aims to promote the sustainable development of the catchment, optimise benefits and minimise harmful effects derived from the use of water resources (MRC, 1995). This should facilitate the governance of water resources in the catchment and help reduce environmental problems derived from hydropower development. For example, the MRC commissioned a Strategic Environmental Assessment to assess the cumulative impacts, costs, and benefits of the major hydropower projects planned on the mainstem of the Mekong River (ICEM, 2010). However, despite the existence of this supranational organisation, compliance with national environmental regulations is not always enforced, protocols directed to the private-sector are only advisory, and non-binding. Moreover, most private hydropower investors have limited commitment to environmental assessment protocols, mitigation, or human livelihood safeguards (Grumbine et al., 2012).

Whenever a project´s impacts (social, economic or ecological) are expected to exceed the benefits, alternative options based on other sources of renewable energy with less social, economic and ecological impacts should be considered priority for investment. If a hydropower dam was considered the most suitable alternative, more strategic planning from the early planning stages to the dam operation is required (Bunn 2016) to minimise the potential impacts. Only in this way can the long-pursued goal of sustainable development be achieved, capitalising on the window of opportunity opened by recent international agreements and financial support to the cause. If we fail in our attempt, we might miss a unique opportunity for a more sustainable future and future access to strategic resources and services provided by some of the world´s freshwater ecosystems.

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References

Ansar A, Flyvbjerg B, Budzier A, Lunn D. 2014. Should we build more large dams? The actual costs of hydropower megaproject development. *Energ. Policy* **69**: 43–56.

Bunn SE. 2016. Grand challenge for the future of freshwater ecosystems. *Front. Environ. Sci.* **4**:21. doi: 10.3389/fenvs.2016.00021

Edenhofer O, Pichs-Madruga R, Sokona Y, *et al*. 2014. Technical Summary. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer O, Pichs-Madruga R, Sokona Y, *et al.* (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Ferreira J, Aragão LEOC, Barlow J, *et al.* 2014. Brazil's environmental leadership at risk. Mining and dams threaten protected areas. *Science* **346**: 706-707.

Gerstetter C, Görlach B, Stoessel S, *et al.* 2012. Rio+20: Financial Resources for Improved International Environmental Governance. Ecologic Institute, Pfalzburger Str. 43/44, 10717 Berlin.

Grumbine RE, Dore J, Xu J. 2012. Mekong hydropower: drivers of change and governance challenges. *Front. Ecol. Environ*. **10**: 91-98.

ICEM. 2010, MRC Strategic Environmental Assessment (SEA) of hydropower on the Mekong mainstream, Hanoi, Viet Nam. Available at: http://icem.com.au/documents/envassessment/mrc_sea_hp/SEA_Final_Report_Oct_2010.pdf. Last accessed 2nd Feb 2017.

MRC. 2010. State of the basin report 2010. Vientiane, Laos.

Palmer MA, Reidy Liermann CA, Nilsson C, et al. 2008. Climate change and the world's river basins: anticipating management options. *Front. Ecol. Environ.* **6**: 81–9.

Pittock J. 2010a. Better management of hydropower in an era of climate change. Water Alternatives 3: 444-452.

Pittock J. 2010b. A pale reflection of political reality: Integration of global climate, wetland, and biodiversity agreements. Climate Law 1: 343-373.

Richter BD, Postel S, Revenga C, Scudder T, Lehner B, Churchill A and Chow M (2010). Lost in development's shadow: the downstream human consequences of dams. Water Alternatives, 3: 14–42

Sánchez-Zapata JA, Clavero M, Carrete M, et al. 2016. Effects of renewable energy production and infrastructure on wildlife. In: Current Trends in Wildlife Research (J.T. Garcia et al. eds.). Wildlife Research Monographs 1, Springer International Publishing Switzerland, DOI 10.1007/978-3-319-27912-1_5

UN. 2014. The Road to Dignity by 2030: Ending Poverty, Transforming All Lives and Protecting the Planet. Synthesis Report of the Secretary-General on the Post-2015 Agenda. New York December 2014.

UNEP. 2012. The Future We Want. Outcome Document of the United Nations Conference on Sustainable Development (Rio + 20). http://www.un.org/en/sustainablefuture. Last accessed 14th July 2015

UNFCCC. 2015. The Paris Agreement (FCCC/CP/2015/L.9/Rev.1); http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf.

Vörösmarty CJ, McIntyre PB, Gessner MO, *et al.* 2010. Global threats to human water security and river biodiversity. *Nature* **467**:555–561

Winemiller KO, McIntyre P, Castello L, *et al.* 2016. Balancing hydropower and biodiversity in the Amazon, Congo, and Mekong. *Science* **6269**: 128-129.

WWF. 2016. Living Planet Report 2016. Risk and resilience in a new era. WWF International, Gland, Switzerland.

Zarfl C, Lumsdon AE, Berlekamp J, Tydecks L, Tockner K. 2015. A global boom in hydropower dam construction. *Aquat. Sci.* **77**: 161-170.

Ziv G, Baran E, Nam S, Rodríguez-Iturbe I, Levin SA. 2012. Trading-off fish biodiversity, food security, and hydropower in the Mekong River Basin. *Proc. Natl. Acad. Sci.* **109**: 5609–5614.