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Hydropower and the Water-Energy-Nexus

Input for the Water and Energy Nexus Report by the UN Special Rapporteur on the rights to water and sanitation

In order to help inform the Special Rapporteur's report on "Water and Energy Nexus: the human right to safe drinking water and sanitation and access to energy for all," civil society organisations CounterCurrent, Waterkeeper Alliance and Ríos to Rivers would like to offer the following input and comments to assist the preparation of that report, with a specific focus on the connection between hydropower and the water-energy nexus. Hydropower plays a significant, multi-pronged role in the interplay between water and energy. Hydropower and water have a fundamentally counter-productive connection: hydropower is dependent on a steady and reliable supply of water to function, and the infrastructure needed for hydroelectric energy production directly interferes with the water cycle. In addition, hydropower developments are linked with major influences on the enjoyment of human rights and on the sustainability of ecosystems. Hence, it is very important for a report on the water and energy nexus from a human rights perspective to closely examine the role of hydropower.

In this submission, we outline different ways in which this nexus plays out in relation to hydropower. We also describe strategies for state and non-state actors to address challenges in the water-energy sector with regard to hydropower.

Direct impact of hydropower dams on water availability, accessibility and quality

Hydropower infrastructure directly impacts the availability, accessibility and quality of water in the river in multiple ways, leading to impacts on the human right to water for riverine communities.

- Evaporation: Depending on the local climate, and increasingly so in a warming world, slowing down the flow of water in a hydropower reservoir can lead to major water losses due to increased evaporation. For example, approximately 16% of the Zambezi's mean annual flow is evaporated from reservoirs, so hydropower is the largest single water consumer in the Zambezi basin, despite its frequent classification as a non-consumptive use of water.[1]

- Diversion: Often the original flow of a river is diverted in order to run hydropower turbines, especially in so-called “run-of-the-river” plants which operate without a dam and reservoir. Certain stretches of the river then carry significantly less water which can lead to accessibility issues for local communities. For example, after the construction of the Belo Monte dam in Brazil, water flow decreased by 80% in a 100km stretch of the river known as Volta Grande do Xingu.[2]
- Sedimentation and thermal stratification: In a reservoir, sediments and nutrients which would usually flow freely in the river are held back and no longer reach downstream areas. The deprivation of these sediments and nutrients negatively impacts coastal ecosystems and coastal erosion. Their accumulation behind the dam negatively impacts the lifespan of the dam which retains them. Today, many prospective mega-dam projects are proposed on high-sediment rivers, such as the Amazon, Congo, and Brahmaputra Rivers. The accumulation of nutrients and pollutants in stagnant reservoirs can lower water quality and create conditions where Harmful Algal Blooms (HABs) frequently occur. Moreover, thermal stratification occurs in reservoirs, negatively impacting the quality of the water in the reservoir and downstream.[3]
- Fragmentation: Fragmenting a river with a hydropower dam disrupts its natural flow, impacting water availability, accessibility, and quality. By altering seasonal flow patterns, dams can reduce downstream water availability, especially during dry seasons, affecting ecosystems and communities reliant on the river. Accessibility is compromised as natural pathways for fish, sediment, and nutrients are blocked, leading to habitat loss and declining fisheries that sustain local populations. Human access, both recreational and otherwise, is duly altered. Water quality deteriorates due to stagnant reservoirs that promote algal blooms, reduced oxygen levels, and increased pollutant accumulation, harming aquatic life and human health.

These direct impacts of hydroelectric plants on water have ripple effects on agriculture and fisheries and thereby on food security and sources of income, thus impacting not only the human right to water but also the human rights to food and to an adequate standard of living.

Climate change, water scarcity and its impact on hydropower

An increasing number of droughts due to climate change have led to an increasing number of failures of hydropower.

For example, severe droughts have caused a major electricity crisis in Ecuador in late 2024. People faced daily power cuts of up to 14 hours for weeks. These cuts have heavily disrupted all

[1] https://www.mdpi.com/2073-4441/14/5/721/pdf
[2] https://www.mdpi.com/1660-4601/21/2/155
[3] https://bg.copernicus.org/articles/16/1657/2019/bg-16-1657-2019.html

aspects of daily life, including access to running water for households.[4] A similar crisis unfolded in Zambia, also in 2024.[5] In 2023, despite a global increase of hydropower capacity by 20GW, electricity production by hydropower saw a record decline due to droughts.[6]

According to a 2022 paper in the Journal *Water,* "Approximately 26% of existing hydropower dams and 23% of projected dams are within river basins that currently have medium to very high risk of water scarcity; 32% and 20% of the existing and projected dams, respectively, are projected to have increased risk by 2050 due to climate change".[7]

Thus, when states rely on hydropower to create access to energy, the impacts of climate change on water availability do not only threaten the right to water, but also energy access. As a result, for the increasing number of areas prone to drought in a changing climate, hydropower is not a reliable energy source.

Additional impacts

Beyond the direct nexus to water explained above, hydroelectric facilities have a multitude of impacts on the enjoyment of other human rights. When considering potential solutions, a siloed approach to these intersecting issues is not useful. Instead, it is necessary to design solutions that address the whole range of impacts in a holistic manner. Examples of these impacts include:

- Loss of livelihood and impact on food security: these impacts occur because of the changes in water flow and the disruption of the river ecosystem, but also because of land previously used directly or indirectly for food production being inundated for reservoirs.
- Displacement: in many cases, communities are evicted from their land to create reservoirs, often without proper compensation. A 2017 study estimates that 80 million people have been displaced by dam projects worldwide.[8]
- Climate impacts: in hydropower reservoirs, especially in tropical climates, organic matter decompositions without oxygen, leading to the emission of methane gas.[9] Methane is a very potent greenhouse gas with a global warming potential more than eighty times higher than carbon dioxide in the first twenty years.[10] Thus, hydropower contributes to all the human rights impacts of climate change.
- Dangers to life and livelihoods through dam collapse: climate change brings not only droughts but also an increase in heavy precipitation. Increasingly, dams cannot

[4] https://www.theguardian.com/global-development/2024/nov/11/ecuador-energy-generation-power-sources-cuts-blackouts-drought-reliance-hydropower-adapt-diversify-protests
[5] https://www.euronews.com/green/2024/10/14/ongoing-african-drought-has-plunged-zambia-into-daily-blackouts-as-hydroelectric-dam-unabl
[6] https://www.iea.org/reports/co2-emissions-in-2023/weather-and-continued-covid-19-reopening-effects-played-an-important-role-in-the-emissions-increase
[7] https://www.mdpi.com/2073-4441/14/5/721/pdf
[8] https://www.internal-displacement.org/publications/case-study-series-dam-displacement/
[9] https://academic.oup.com/bioscience/article/66/11/949/2754271
[10] https://ghgprotocol.org/sites/default/files/2024-08/Global-Warming-Potential-Values%20%28August%202024%29.pdf

withstand the force of flash floods, leading to dam bursts with catastrophic consequences.[11]

- Contribution to conflict: It is well documented that due to the control afforded by dams over water resources, these projects have often led to increased diplomatic tension between states. Analysts fear that as water scarcity worsens, these tensions may turn into armed conflict.[12]
- Fiscal consequences: large hydropower projects are expensive and often not profitable. In many cases, states take out loans to finance these projects, leading to an increased debt burden and less availability of resources for the realization of human rights and sustainable development goals.[13]
- Ecosystem services: Dams disrupt the natural flow of rivers, reducing essential ecosystem services such as sediment transport, which sustains fertile floodplains and deltas. They block fish migration routes, leading to population declines that impact fisheries and biodiversity, reducing food and livelihood resources for local communities. Additionally, altered water flow and temperature disrupt wetland and riparian ecosystems, decreasing water purification, groundwater recharge, and climate regulation services.[14]

When weighing these impacts against the potential for an increase in energy availability, one should also consider that dams often make only a questionable contribution to the availability of electricity for communities and households. In many cases, the electricity produced is used for large industries, e.g. for mining, with their own set of human rights and ecological impacts.[15] The possible contribution by hydropower to access to energy for all is further limited by increasing climate change-driven water scarcity which is threatening the reliability of that energy source.

Strategies to address challenges in the water-energy sector with regard to hydropower

To ensure sustainable water and energy management and address the challenges described above, the development of hydropower dams should be critically reassessed due to their significant and interconnected environmental and social impacts, including impacts on the right to water. We recommend that governments, policy-makers and relevant non-state actors such as business enterprises in the energy sector adhere to the following:

1. Avoid dam construction where possible, particularly in protected areas and biodiversity hotspots, as over 500 new dams are currently planned in ecologically sensitive zones, threatening freshwater ecosystems and species migration pathways and adding to the

[11] https://www.preventionweb.net/news/dams-increasing-danger-collapse-due-climate-change-and-conflict
[12] https://fpif.org/waters-of-conflict/
[13] https://www.tandfonline.com/doi/full/10.1080/09692290.2018.1511449#d1e2220
[14] https://www.researchgate.net/profile/Matthew-Mccartney-3/publication/45165880_Ecosystem_Impacts_of_Large_Dams/links/0deec538c8d836760c000000/Ecosystem-Impacts-of-Large-Dams.pdf
[15] E.g. https://news.mongabay.com/2017/06/unexamined-synergies-dam-building-and-mining-go-together-in-the-amazon/

more than 1,200 large dams already existing within these ecologically sensitive zones.[16][17] Additionally, The high sediment loads of many proposed dam sites make them inefficient for long-term energy production, as sedimentation reduces reservoir capacity and operational lifespan, leading to increased maintenance costs and environmental degradation[18]

2. Prioritize the protection of free-flowing rivers, which play a critical role in climate change mitigation by regulating temperatures, maintaining wetlands, and ensuring sediment transport—services that are lost when rivers are fragmented by dams.[19] Implement policies that protect free-flowing rivers for water security, climate resilience, and biodiversity conservation.

3. Prioritize lower-impact alternatives such as wind and solar energy over hydropower, aiming for a "nature-positive" transition[20]

4. Reduce overall energy demand by assessing all options to improve energy efficiency and limit luxury consumption.

5. Prioritize the expansion of off-grid, small-scale, decentralized, and community-based energy to provide electricity to households, as recommended by the UNFCCC Katowice Committee of Experts on the Impacts of the Implementation of Response Measures[21]

6. Engage local communities and Indigenous peoples in the planning of new energy projects from the outset and under all circumstances, respect Indigenous peoples' right to free, prior, and informed consent

7. Address the existing impacts of hydropower on the human right to water and other human rights by considering dam removal and the restoration of free-flowing rivers, as exemplified by the Klamath Dam Removal[22]

8. If after careful evaluation of the socio-economic impacts and all alternatives, new hydropower developments are still under consideration, such consideration must take into account the most recent models on water availability over changing climate conditions to determine whether there will be sufficient water to support both energy production through hydropower and the water needs of the local population.

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[16] worldwildlife.org
[17] inhabitat.com
[18] insights.globalspec.com
[19] insights.globalspec.com
[20] See also https://files.worldwildlife.org/wwfcmsprod/files/Publication/file/56sr3qndka_Nature_Friendly_Energy_Report.pdf
[21] https://unfccc.int/sites/default/files/resource/KCI%20Technical%20Paper%20-%20impacts%20of%20response%20measures%20on%20people%20in%20vulnerable%20situations_publication.pdf?download
[22] https://www.sustainablenorthwest.org/

Achieving a sustainable water-energy future requires a fundamental shift in how hydropower is assessed and implemented. By prioritizing the protection of free-flowing rivers, investing in lower-impact renewable alternatives, and engaging local and Indigenous communities in decision-making, policymakers can ensure energy development does not come at the expense of critical ecosystems and human rights when it comes to **water availability, accessibility and quality**. The negative environmental and social consequences of large-scale dams—such as biodiversity loss, sedimentation, and disruptions to freshwater access—underscore the need for a more holistic approach to energy planning that integrates water security and climate resilience. As demonstrated by successful dam removals like the Klamath River restoration, restoring natural river systems can yield long-term ecological and cultural benefits. To build a truly just and sustainable water-energy system, governments must critically evaluate hydropower projects, invest in decentralized and community-led solutions, and commit to a nature-positive transition that safeguards both people and the planet.