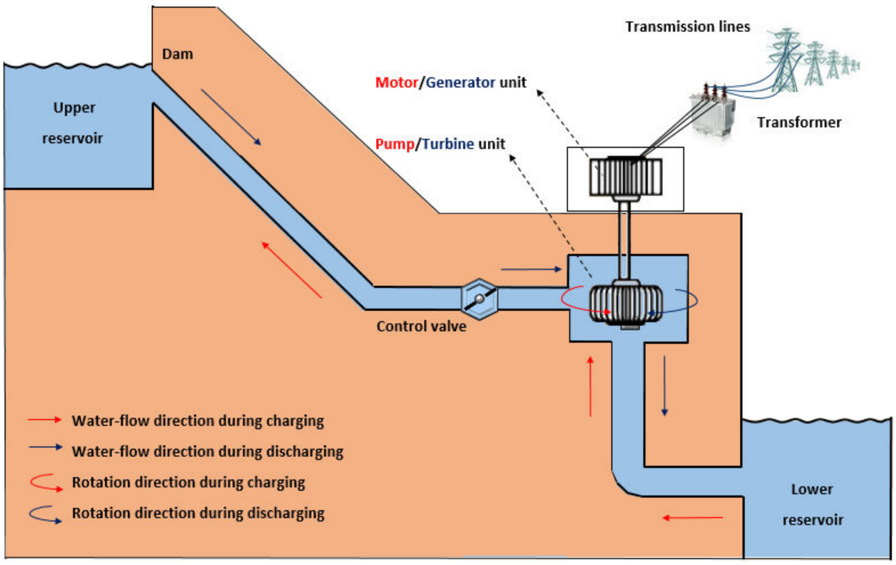
FACTSHEET – HYDROPOWER

BACKGROUND

The energy transition requires a massive increase in investments. According to the 'Net Zero Emissions by 2050' (NZE) scenario[1] of the International Energy Agency (IEA), which is the most referenced scenario with low or no overshoot and limited reliance on negative emissions technologies, yearly investments in the "clean" energy transition must more than double and reach US$4.2 trillion by 2030. Meanwhile investments in fossil fuels must decrease and any support to their expansion must be stopped immediately. However, the role of certain energy sources and technologies should be nuanced. Consideration is particularly required when development is uncertain or associated with damaging social, environmental and climate impacts or risks, or poses too great a threat to the 1.5°C objective and global biodiversity protection targets.

This document debates the potential of hydropower in the power sector transition. It is part of a series of factsheets that aim to guide the decisions of financial players wishing to contribute to a rapid and fair energy transition.



Schematic diagram of a pumped-storage hydropower plant (Pavlos Nikolaidis, www.researchgate.net)

Hydropower can refer to either reservoir-based hydropower, run-of-river hydropower or pumped-storage hydropower (PSH) and can take various forms. In terms of size, projects range from capacities of less than 1 megawatt (MW) to 22,500 MW, which is currently the largest[2].

[1] IEA, World Energy Outlook, 2023.
[2] Three Gorges Dam in Hubei Province, China.

- Reservoir-based hydropower, usually located in hilly or mountainous areas, takes advantage of the elevation loss along a river (potential energy).
- Run-of-river plants incorporate small impoundments of water relative to a river's volume of flow and are located along watercourses with high flow rates (kinetic energy).
- PSH plants are located between two lakes or reservoirs that are at different altitudes but close to each other, enabling water to be pumped from the lower to the upper reservoir when electricity is cheap and/or when there is a surplus on the power grid. As of 2021, PSH accounted for 85% of the world's storage capacity, making it the largest source of electricity storage today.[3]

KEY ELEMENTS – HYDROPOWER IN THE NZE

Hydropower production in the NZE doubles between 2022 and 2050, with installed capacity rising from 1,392 GW to 2,612 GW.[4] PSH constitutes a large part of this new capacity and will have increasing value due to its ability to balance the rapidly growing deployment of variable wind and solar.[5] For instance, when required to help meet peak electricity demand, a gas or coal plant can take several hours to start up whereas a hydropower plant can start relatively quick (2 to 20 minutes).[6] When there is a surplus of power production, PSH can also be engaged to use the excess power to pump water uphill for storage, and later to produce power when demand is high.[7]

Today, hydropower represents 15% of global power production, making it the third-largest power source after coal (36%), and fossil gas (22%), and by far the leading renewable power source ahead of wind (7%) and solar (4%).[8] However, the situation is rapidly evolving as the rate of deployment of wind or solar now far outstrips the growth of hydropower. In the NZE, wind and solar will respectively account for 41% and 31% of the global electricity mix by 2050, while hydropower will account for around 11%.

➢ A shifting position in the power system

Two key reasons for this shift are the massive costs (including cost overruns) and the long timelines associated with the construction of major hydropower projects.[9] On the one hand, hydropower is a mature technology with little room for technological improvements and increasing project costs, as high-potential sites are often already exploited, particularly in Europe and North America. Additionally, existing dams are aging, requiring major investment for maintenance and repair in the years to come. On the other hand, technological improvements continue apace for wind and solar, and their costs continue to fall rapidly. Both wind power and solar photovoltaics (PV) already have a lower levelized cost of energy (LCOE) on average compared to hydropower.[10]

In terms of storage, battery costs and performance are improving rapidly and could surpass PSH for short-term storage. For long-term storage, PSH is likely to remain important, although other mechanical and thermal systems are becoming increasingly viable, as are demand-side management solutions.[11]

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[3] As of 2021, pumped-storage hydropower plants provided almost 85% of the world's total installed electricity storage capacity of 190 GW. IEA, Hydropower Special Market Report: Analysis and forecast to 2030, p.22, July 2021.

[4] Ibid.

[5] IEA, Net Zero by 2050: A Roadmap for the Global Energy Sector, p.178, 2021.

[6] Hydropower plants can start up in 2 to 20 minutes, which is similar to open-cycle gas turbines (OCGT) but significantly faster than combined-cycle gas turbines (CCGTs) and coal-fired facilities that require up to several hours to become fully operational from a cold start. IEA, Hydropower Special Market Report: Analysis and forecast to 2030, p.92, Table 4.2, July 2021.

[7] Today, hydropower plants account for almost 30% of the world's capacity for flexible electricity supply. Ibid, p.8.

[8] IEA, World Energy Outlook 2023, Annex A - Table A.3c: World electricity sector, p.279.

[9] For example, see: A. Ansar et al., 'Should We Build More Large Dams? The Actual Costs of Hydropower Megaproject Development', Energy Policy, March 2014.

[10] In 2022, the global weighted average LCOE of newly commissioned hydropower projects was US$0.061/kilowatt hour (kWh), versus US$0.049/kWh for utility-scale solar PV plants and US$0.033/kWh for onshore wind. IRENA, Renewable power generation costs in 2022, p.69, 89, 151, 2023.

[11] Reclaim Finance, Factsheet – Energy Storage, December 2023.

Finally, climate change and extreme weather events are already having severe impacts on hydroelectric production. Extreme precipitation events have led to dam breaches and other technical problems causing major damage downstream, while repeated droughts are reducing streamflow and hydropower output. In recent years, droughts have drastically reduced electricity production in some areas (for example, the US West and Brazil)[12] and have even led to large-scale power cuts and power rationing (for example, in Zambia, Zimbabwe, and the Sichuan province in China).[13] This effect has been recorded on a global scale.[14]

Areas of concern regarding reservoirs, run-of-river dams and PSH

The many negative social and environmental impacts of hydropower have often been neglected, leading to overestimations of the likely scope for development of new hydropower plants. Among these impacts are biodiversity losses, human rights abuses, and methane emissions produced by reservoirs.

➢ Biodiversity issues

Virtually all types of dams – even small ones – negatively impact freshwater ecosystems, downstream estuaries and coastal zones. They obstruct rivers and change the flows of water and sediments. Additionally, the migration of fish and other species is interrupted, habitats are fragmented and degraded, and the water flow regime is completely altered.[15]
Due to flooding, the creation of reservoirs also destroys ecosystems (riverbeds, wetlands, forests, grasslands) and agricultural lands. It can also lead to water quality problems (for example, due to stagnation or the chemical modification of water), resulting in the asphyxiation of aquatic biodiversity.[16]

➢ Human rights issues

By flooding areas that were potentially inhabited or used for farming, grazing, or the hunting and gathering of wild foods and other resources, reservoirs have displaced many tens of millions of people. Often these lands have been expropriated without due process.[17] Many more people have lost access to resources due to the impacts of dams on downstream areas,[18] and have been greatly impoverished by the process of displacement. Opponents of dams have frequently been subjected to repression and even extra-judicial killings.[19]

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[12] L.A. Cuartas et al., 'Recent Hydrological Droughts in Brazil and Their Impact on Hydropower Generation', Water, February 2022; IEA Climate Impacts on Latin American Hydropower, January 2021.
[13] Reuters, Insight: Droughts shrink hydropower, pose risk to global push to clean energy, August 2021.
[14] W. Wan et al., Analyzing the Impact of Streamflow Drought on Hydroelectricity Production: A Global-Scale Study, April 2021.
[15] The World Commission on Dams, World Commission on Dams: A new framework for decision-making, November, 2000;
P. McCully, Silenced Rivers: The Social and Environmental Impacts of Large Dams, Zed Books/St Martin's Press, 2001;
C. Zarfli et al., 'Future large hydropower dams impact global freshwater megafauna', Scientific Reports 9, 2019;
A. Kuriqi et al., Ecological impacts of run-of-river hydropower plants—Current status and future prospects on the brink of energy transition, 2021.
[16] Emilio F. Moran et al., 'Sustainable hydropower in the 21st century', PNAS, 2018;
Soudeep Deb et al., Hydropower Construction and Deforestation: Linking Forest Cover to Changes in Water Balance, IIC Brazil Summer Policy Lab, 2021.
[17] The World Commission on Dams, World Commission on Dams: A new framework for decision-making, November, 2000;
P. McCully, Silenced Rivers: The Social and Environmental Impacts of Large Dams, Zed Books/St Martin's Press, 2001.
[18] "By substantially changing natural flow patterns and blocking movements of fish and other animals, large dams can severely disrupt natural riverine production systems – especially fisheries, flood-recession agriculture and dry-season grazing."
B. D. Richter et al., Lost in Development's Shadow: The Downstream Human Consequences of Dams, Water Alternatives, 2010.
[19] P. Arrojo et al., Joint statement on the human rights of people affected by dams and other water infrastructure, UN Human Rights Office of the High Commissioner, November 2021.

Consequently, any new hydropower project or existing plant expansion must respect the principles of free, prior, and informed consent (FPIC)[20] and comply with the recommendations of the World Commission on Dams (WCD).[21]

Greenhouse gas emissions issues

The climate impact of hydropower reservoirs has largely been underestimated. The decomposition of flooded vegetation and organic matter in stagnant water reservoirs emits carbon dioxide (CO_2) and, in particular, methane (CH_4) – a powerful greenhouse gas (GHG). This phenomenon is highly variable and depends on things like the location and size of the reservoir, but several factors accentuate it, including warm or tropical ambient temperatures, high soil carbon content, or the presence of numerous decomposing organic elements when flooding a previously wooded area. A study conducted on 1,500 dams worldwide estimates that hydropower emits on average 173 kg of CO_2 and 2.95 kg of CH_4 per MWh of electricity produced.[22]

RECLAIM FINANCE'S POSITION

Considering the significant risk of negative impacts on biodiversity, human rights, and climate, Reclaim Finance recommends conditioning the financing of new hydropower projects (greenfields and brownfields) to the strict application of robust standards.

Although some forms of hydropower may have a role to play in a rapid and just energy transition, its vulnerability to climate events like droughts and extreme rainfall – both growing in frequency and intensity with global warming – mean that it cannot be relied upon to a large degree. PSH is likely to remain an important storage source and grid stability factor, yet priority should be given to energy sources and technologies with fewer impacts and that are less exposed to climate change risks, such as wind and solar, and batteries for short-term storage.[23]

To reduce the need for new hydropower plants, priority in this sector should be given to the maintenance and rehabilitation of existing hydropower infrastructure and, where relevant, additions or increases of generating capacity at existing dams. In particular, no new hydropower should be developed in Europe, as most of hydropower potential has already been harnessed, with significant negative impacts on ecosystems and biodiversity and increasing hydropower capacity should exclusively rely on refitting and upgrading existing hydropower plants.

New hydropower projects must be examined on a case-by-case basis, should apply the recommendations and principles of the World Commission on Dams,[24] and should respect the consent of local populations with the FPIC principle[25] for Indigenous Peoples. For both new and existing hydropower plants, a project must not compromise any efforts to restore riverine and riparian ecosystems.

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[20] UN Human Rights Office of the High Commissioner, Free, Prior and Informed Consent of Indigenous Peoples, September 2013; United Nations Declaration on the Rights of Indigenous Peoples, Article 32.2.

[21] World Commission on Dams, Dams and Development: A New Framework for Decision-Making, November 2000.

[22] "This results in a combined average carbon footprint of 273 kg CO_2e/MWh when using the global warming potential over a time horizon of 100 years." L. Scherer and S. Pfister, 'Hydropower's Biogenic Carbon Footprint', PLoS ONE, 2016. Relative to CO_2, methane has a very strong greenhouse gas effect in the first few years after its release into the atmosphere and then rapidly degrades. As such, it is particularly dangerous in terms of short-term warming and pushing the world past points of no return for biodiversity loss in particular.

[23] Reclaim Finance, Factsheet – Energy Storage, December 2023.

[24] The World Commission on Dams, Dams and Development: A New Framework for Decision-Making, November 2000.

[25] UN Human Rights Office of the High Commissioner, Free, Prior and Informed Consent of Indigenous Peoples, September 2013; United Nations Declaration on the Rights of Indigenous Peoples, Article 32.2.